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The Analysis Study of Diagnostic Imaging Performance and Accuracy of Tuberculosis: A Systematic Review

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ABSTRACT

Background: Tuberculosis (TB) remains a major global health challenge, with its variable clinical presentations often complicating timely and accurate diagnosis. Diagnostic imaging modalities such as chest X-ray, computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography/computed tomography (PET/CT) provide varying degrees of sensitivity and specificity depending on disease location and progression. However, diagnostic accuracy may be influenced by interobserver variability, regional disease prevalence, and coexisting conditions. This systematic review aims to critically evaluate and compare the diagnostic performance and accuracy of various imaging techniques in TB to support evidence-based clinical decision-making. **Methods:** This review adhered strictly to the PRISMA 2020 guidelines, incorporating only full-text, peer-reviewed articles published in English between 2015 and 2025. To ensure the credibility and traceability of sources, editorial pieces and review articles lacking a Digital Object Identifier (DOI) were excluded. A comprehensive search strategy was implemented across three major academic databases—ScienceDirect, PubMed, and SAGE Publications—to identify studies directly relevant to the research objectives. **Result:** The initial database search yielded over 100 potentially relevant studies. Through a structured three-phase screening and selection process, eight studies fulfilled the predefined inclusion criteria and were selected for detailed analysis. These studies were rigorously appraised for methodological quality and relevance, ensuring that the final synthesis was based on robust and high-quality evidence. The findings provide critical insight into the strengths and limitations of each imaging modality in the context of TB diagnosis. **Conclusion:** Diagnostic imaging is a cornerstone in the evaluation of tuberculosis, with each modality offering distinct advantages depending on the clinical scenario. CT thorax demonstrates the highest accuracy for detecting pulmonary TB, while MRI is superior for assessing extrapulmonary manifestations, particularly in the central nervous system and spine. Ultrasonography (USG) serves as a valuable adjunct in evaluating abdominal and pleural involvement. A tailored, context-specific imaging strategy is essential to enhance diagnostic precision and optimize patient management.

Keywords: Tuberculosis, Diagnostic Imaging, CT Thorax, MRI, Imaging Accuracy

INTRODUCTION

Tuberculosis (TB) remains one of the leading infectious causes of morbidity and mortality worldwide, posing a significant public health challenge, particularly in low- and middle-income countries.[1] The clinical presentation of TB can be nonspecific, especially in extrapulmonary or latent forms, which necessitates the use of diagnostic imaging as a key adjunct to microbiological and molecular methods. Imaging plays a critical role not only in the initial detection and localization of TB but also in guiding biopsies, monitoring therapeutic response, and identifying complications.[2] Given the heterogeneous manifestations of TB across various organ systems, a systematic evaluation of the diagnostic imaging modalities is essential to ensure timely and accurate diagnosis.[3]

Radiological modalities such as chest X-ray, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound offer varying degrees of sensitivity and specificity in detecting TB-related changes. Chest X-ray, often used as a first-line tool, provides a rapid and cost-effective overview but has limited specificity due to overlapping features with other pulmonary diseases.[4] CT imaging, with its superior spatial resolution, enhances the detection of subtle parenchymal, nodal, and extrapulmonary lesions, particularly in early or atypical presentations.[5] MRI, although less frequently utilized for pulmonary TB, demonstrates excellent soft-tissue contrast, making it invaluable in assessing central nervous system and musculoskeletal involvement.[6] Recent advancements, including positron emission tomography (PET) combined with CT, offer functional insights that could complement anatomical imaging, especially in complex or treatment-refractory cases.[7]

Despite the widespread use of imaging, discrepancies persist in diagnostic performance due to interobserver variability, regional differences in disease prevalence, and lack of standardized imaging criteria. The accuracy of imaging is also influenced by the skill of the interpreting radiologist, the stage of disease progression, and coexisting conditions such as HIV infection.[8,9] Therefore, a systematic review of the diagnostic performance and accuracy of various imaging

modalities in TB is crucial. Such an analysis would provide evidence-based insights into optimal imaging strategies, inform clinical decision-making, and potentially contribute to developing standardized diagnostic algorithms tailored to diverse clinical settings.

METHODS

Protocol

This review was meticulously designed following the PRISMA 2020 framework to maintain methodological accuracy and ensure the integrity of the research process. By adhering to these established standards, the study achieved greater transparency, consistency, and scientific rigor. Every stage—from extensive literature identification to careful data extraction and synthesis—was conducted with an emphasis on reducing potential bias and enhancing the reliability of the outcomes. This structured approach reinforces the credibility of the findings and contributes meaningful evidence to the broader scientific discourse.

Criteria for Eligibility

This systematic review is designed to critically assess the performance and diagnostic accuracy of imaging techniques in tuberculosis by synthesizing evidence from a diverse array of relevant studies. Through the identification of common patterns, emerging trends, and existing research gaps, the review aims to offer valuable insights that can enhance clinical practice. Its central goal is to deepen the current understanding of how imaging contributes to tuberculosis diagnosis and to build a stronger foundation of evidence that supports improved diagnostic strategies and informed medical decision-making.

To ensure methodological rigor, the review employed well-defined inclusion and exclusion criteria. Only peer-reviewed, full-text articles published in English between 2015 and 2025 were considered, with each source verified via a valid Digital Object Identifier (DOI). Non-primary literature—including editorials, reviews without DOI verification, and duplicate records—was excluded to maintain

a clear focus on original, high-quality research. This selective process reinforces the reliability and scientific value of the review's conclusions.

By adopting a structured and methodical research framework, this study grounds its analysis in credible, data-driven evidence. The findings aim to refine diagnostic imaging approaches in tuberculosis, promote more accurate clinical assessments, and ultimately contribute to better patient outcomes. Through its commitment to evidence-based evaluation, the review supports the ongoing advancement of diagnostic standards and best practices in tuberculosis care.

Search Strategy

An extensive and methodical search strategy was implemented to identify pertinent studies for this review, incorporating targeted keywords such as “diagnostic imaging,” “performance,” “accuracy,” and “tuberculosis.” To capture a comprehensive and representative selection of scholarly literature, searches were carried out across three leading academic databases: PubMed, SAGE Publications, and ScienceDirect. This approach ensured access to a broad spectrum of peer-reviewed articles, enhancing both the depth and diversity of the evidence gathered. The systematic and academically rigorous search process reinforces the credibility of the review’s outcomes and supports a more detailed and accurate assessment of imaging effectiveness in tuberculosis diagnosis.

Table 1. Search Strategy

Database	**Search Strategy**	***Hits***
Pubmed	*("diagnostic imaging" AND "performance" AND "accuracy" AND “tuberculosis”)*	118
Science Direct	*("diagnostic imaging" AND "performance" AND "accuracy" AND “tuberculosis”)*	667
Sagepub	*("diagnostic imaging" AND "performance" AND "accuracy" AND “tuberculosis”)*	179

Data retrieval

The authors implemented a thorough and methodical initial screening process by closely reviewing the titles and abstracts of all retrieved studies to determine their relevance to the review's objectives. Only those studies that clearly met the predefined inclusion criteria and were closely aligned with the review's scope were selected for full-text evaluation. This structured approach enabled the identification of recurring themes and critical insights across the literature, ensuring that the synthesis remained focused and directly addressed the primary research question. Through a transparent and systematic selection method, the review effectively distilled high-quality evidence to support its findings.

To promote consistency and ensure reliable comparisons, only full-text studies published in English were considered for inclusion. A strict screening protocol was applied to confirm that each selected article met all eligibility criteria and contributed meaningfully to the review's core aims. Studies that fell short of these requirements were excluded, resulting in a carefully curated collection of relevant and credible sources. This rigorous filtering process minimized the potential for bias and enhanced the overall validity and trustworthiness of the conclusions drawn.

Furthermore, the selection process included an in-depth evaluation of critical study attributes such as authorship, publication year, geographical context, and research design. This comprehensive assessment helped ensure that only methodologically sound and contextually relevant studies were incorporated into the final analysis. By adopting this detailed and systematic approach, the review was able to establish a solid foundation for generating insightful conclusions, thereby advancing the clinical understanding of the performance and accuracy of diagnostic imaging in tuberculosis.

Quality Assessment and Data Synthesis

A disciplined and well-organized screening strategy was adopted by the authors, beginning with a detailed evaluation of study titles and abstracts to pinpoint research that aligned with established relevance and quality benchmarks. Studies advancing to full-text analysis were those that not only aligned closely with the review's core objectives but also exhibited methodological soundness and academic rigor. This focused approach allowed for the inclusion of only the most relevant and reliable studies, thereby enriching the analytical depth and scholarly value of the review. By prioritizing trustworthy and context-specific sources, the authors enhanced the accuracy, consistency, and credibility of their synthesis, reinforcing both the validity and academic merit of the findings.

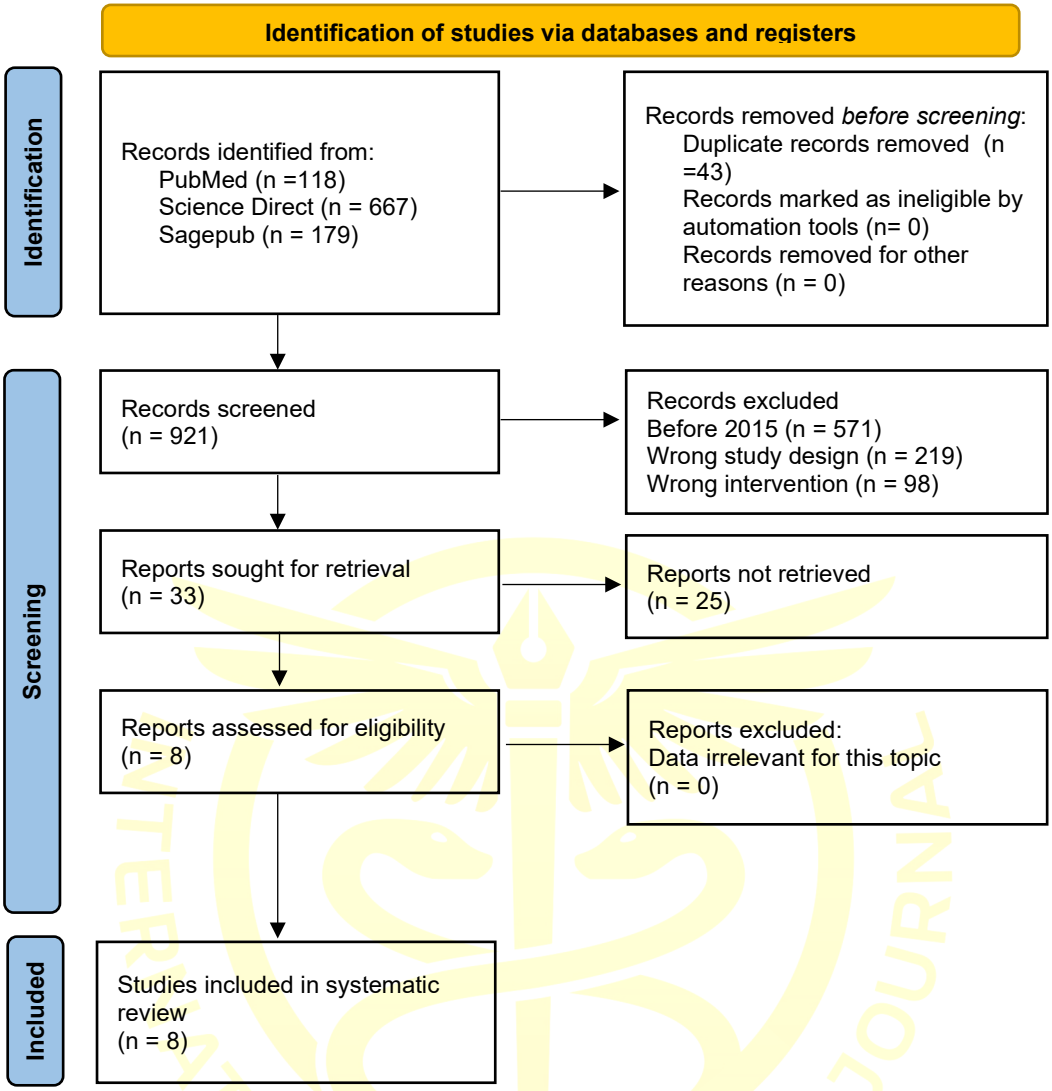

Figure 1. Article search flow chart

Table 2. Critical appraisal of Study

Parameters	(Ahmad et al., 2020)	(Yan et al., 2021)	(Fentress et al., 2022)	(Chen et al., 2023)	(Erem et al., 2023)	(El-Ghany et al., 2024)	(Macpherson et al., 2025)	(Zhang et al., 2025)
1. Bias related to temporal precedence								
Is it clear in the study what is the "cause" and what is the "effect" (ie, there is no confusion about which variable comes first)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Bias related to selection and allocation								
Was there a control group?	No	No	No	No	No	No	No	No
3. Bias related to confounding factors								
Were participants included in any comparisons similar?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
4. Bias related to administration of intervention/exposure								
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Yes.	Yes.	Yes.	Yes.	No.	Yes.	No.	Yes.
5. Bias related to assessment, detection, and measurement of the outcome								
Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	No	No	No	No	No	No	No	No
Were the outcomes of participants included in any comparisons measured in the same way?	No	No	Yes	No	No	No	No	No
Were outcomes measured in a reliable way?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
6. Bias related to participant retention								
Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Yes	No	No	Yes	Yes	Yes	No	Yes
7. Statistical conclusion validity								
Was appropriate statistical analysis used?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

RESULT

The research commenced with a thorough literature search across reputable academic platforms such as ScienceDirect, PubMed, and SAGE Publications to locate studies aligned with the review's aims. A meticulous three-phase screening procedure was employed to refine the initial pool of results, leading to the selection of eight studies that satisfied all inclusion criteria. These chosen articles were then subjected to in-depth analysis, enabling the identification and assessment of key themes and significant insights. For improved clarity and comparability, the synthesized findings are systematically presented in Table 3, providing a well-organized summary that facilitates effective cross-study evaluation.

Table 3. The literature included in this study

Author	Origin	Method	Sample	Result
Ahmad et al.[10] (2020)	Pakistan	Cross Sectional	147 participants	The study found that magnetic resonance imaging is the non-invasive modality with high diagnostic accuracy in diagnosing spinal tuberculosis, with sensitivity, specificity, positive predictive value, negative predictive value, and 89.12%, taking histopathology findings as gold standard.
Yan et al.[11] (2021)	China	Retrospective Study	526 participants	CT scans of 526 participants revealed a lung lesion detection subsystem with a mean average precision of 0.68. The AI model-quantified TB score and radiologist-estimated CT score showed a moderate to strong correlation, enabling early detection and optimal clinical management of pulmonary TB.
Fentress et al.[12] (2022)	United Kingdom	Cross Sectional	92 participants	Ultrasound tests were used to detect radiologic tuberculosis in 92 patients,

				with 91% sensitivity and 46% specificity for bacteriologically-confirmed tuberculosis and 86% for both bacteriologically-confirmed and radiologic tuberculosis. The specificity of these tests was comparable to those for bacteriologically-confirmed tuberculosis.
Chen et al.[13] (2023)	China	Review	-	Tuberculous meningitis requires early and accurate diagnosis to prevent neurological deficits and reduce mortality rates. MRI has emerged as a crucial diagnostic modality, with advancements in AI and deep learning algorithms improving diagnostic precision and efficiency in this specialized area.
Erem et al.[14] (2023)	Uganda	Cross Sectional	80 participants	A study involving 80 children with presumptive TB found that CUS and CXR were used independently for screening. The sensitivity of CUS was 64%, while its specificity was 42.7%. Both CUS and CXR identified 29 children with TB likelihood and 27 children unlikely, meeting WHO TPP's sensitivity target and having a sensitivity and specificity comparable to CXR.
El-Ghany et al.[15] (2024)	Saudii Arabia	Review	-	The superior performance of our CAD model, yielding exceptional metrics such as average precision of 99.90%, recall

				of 99.52%, F1-score of 99.71%, accuracy of 99.84%, false negative rate of 0.48%, and negative predictive value of 99.90%, is noteworthy.
Macpherson et al.[16] (2025)	United Kingdom	Prospective Study	483 participants	The performance of CAD-CXR screening for TB was found to be superior to blood testing, with over 30% of participants with a negative routine confirmatory sputum score above recommended thresholds being diagnosed. However, the potential of CAD-CXR screening for TB is not maximized, as a high proportion of those above current thresholds may benefit intervention.
Zhang et al.[17] (2025)	China	Systematic Review	7 studies	The review highlights the success of Deep Learning (DL) in CT-based PTB diagnosis, but challenges such as data scarcity, model generalization, interpretability, and ethical concerns need to be addressed for improved patient outcomes.

DISCUSSION

The accurate and timely diagnosis of tuberculosis (TB) is essential to effective disease control, particularly given TB's status as one of the leading infectious causes of mortality worldwide. Diagnostic imaging plays a critical complementary role to microbiological and molecular testing, especially in cases where direct pathogen detection is challenging, such as in extrapulmonary TB or paucibacillary forms. This systematic review evaluated and synthesized existing evidence on the diagnostic performance and accuracy of four widely used imaging modalities—chest X-ray (CXR), computed tomography (CT) of the thorax, magnetic resonance imaging (MRI), and ultrasonography (USG)—to identify their relative strengths, limitations, and suitability across various clinical scenarios.

Chest X-Ray (CXR): Strengths and Limitations

Chest X-ray remains the most accessible and frequently utilized imaging tool for initial TB screening, particularly in high-burden and resource-limited settings. Its wide availability, low cost, and ease of use make it an indispensable first-line diagnostic method.[9,18] CXR can reveal hallmark features of pulmonary TB such as upper lobe infiltrates, cavitary lesions, nodular opacities, and hilar or mediastinal lymphadenopathy. However, the interpretation of chest radiographs is highly subjective and influenced by the reader's expertise, resulting in considerable interobserver variability.[9] Moreover, its sensitivity and specificity are moderate, with significant overlap in radiographic findings between TB and other respiratory conditions such as pneumonia, lung cancer, or chronic obstructive pulmonary disease (COPD).[19] This limitation is especially pronounced in immunocompromised patients or those with atypical presentations, where early-stage TB may be radiographically occult. Consequently, while CXR is valuable as an initial screening modality, it is insufficient on its own for definitive diagnosis or disease staging.

Computed Tomography (CT) of the Thorax: The Emerging Gold Standard in Pulmonary TB

Thoracic CT imaging offers superior anatomical resolution and cross-sectional imaging capability, allowing for enhanced visualization of parenchymal, pleural, and mediastinal structures.[9] CT is particularly adept at detecting early and subtle TB lesions that may be missed on CXR, such as tree-in-bud opacities, bronchiectasis, ground-glass attenuation, and miliary nodules. It is also invaluable in evaluating the extent of the disease, monitoring treatment response, and detecting complications such as bronchopleural fistula or post-TB fibrotic changes.[9,20] Studies consistently demonstrate that CT has higher sensitivity (up to 95%) and specificity compared to CXR in pulmonary TB diagnosis. It also aids in differentiating active from inactive TB, a critical distinction in both public health and clinical management.[21] However, the limitations of CT include higher costs, exposure to ionizing radiation, and limited accessibility in low-income regions. Despite these constraints, CT thorax is widely considered the radiologic gold standard for pulmonary TB, especially when microbiological confirmation is unavailable or inconclusive.[22]

Magnetic Resonance Imaging (MRI): A Cornerstone in Extrapulmonary TB Diagnosis

While MRI is not typically used for evaluating pulmonary TB, it plays an indispensable role in diagnosing extrapulmonary TB (EPTB), particularly when the central nervous system (CNS), spine, musculoskeletal system, or abdominal organs are involved. Its superior contrast resolution and multiplanar capabilities enable detailed soft tissue evaluation without the risks associated with ionizing radiation.[23] In cases of tuberculous meningitis, spinal TB (Pott's disease), or musculoskeletal involvement, MRI has shown excellent sensitivity and specificity. It allows for early detection of marrow edema, abscesses, and vertebral body destruction, often before clinical symptoms manifest.[23,24] Furthermore, MRI is particularly advantageous in pediatric populations and during pregnancy due to its favorable safety profile.[25] Nonetheless, challenges such as high cost, longer imaging times,

and limited availability in rural or under-resourced areas may hinder its widespread use. In the context of extrapulmonary TB, MRI is the preferred imaging modality and is often regarded as the diagnostic gold standard for CNS and spinal involvement.[23]

Ultrasonography (USG): Versatile but Limited

Ultrasonography is a portable, non-invasive, and cost-effective imaging technique widely used in TB-endemic regions. Although its role in pulmonary TB is minimal due to its limited ability to penetrate lung parenchyma, USG excels in identifying extrapulmonary manifestations such as pleural effusion, pericardial involvement, abdominal TB, lymphadenopathy, and genitourinary TB.[26,27] It is particularly useful in screening for abdominal TB in HIV-positive patients and can guide aspiration or biopsy of suspicious lesions. The modality is highly sensitive in detecting fluid collections and enlarged lymph nodes; however, its diagnostic accuracy is heavily dependent on operator skill and experience.[28] Moreover, USG has limited specificity and cannot replace cross-sectional imaging in complex or deep-seated cases. Despite these limitations, USG remains a valuable adjunct tool in the TB diagnostic arsenal, especially in settings where advanced imaging is not readily accessible.

Defining the Gold Standard: A Contextual Approach

Identifying a single gold standard among imaging modalities for TB is complex due to the heterogeneity of the disease, which can involve multiple organ systems and present with variable clinical features.[29] Nonetheless, CT thorax currently represents the most accurate and reliable imaging modality for pulmonary TB, given its high diagnostic yield and ability to detect early lesions and subtle anatomical changes.[20,21] For extrapulmonary TB, particularly involving the CNS or spine, MRI stands out as the gold standard due to its superior soft tissue contrast and detailed visualization of neural structures.[23] While CXR and USG remain valuable for initial evaluation and resource-limited settings, their diagnostic

accuracy is inherently lower and often necessitates confirmation through more advanced imaging or microbiological methods.

Implications for Clinical Practice and Future Research

The findings of this review underscore the importance of a tailored, patient-centered approach in TB imaging, where the selection of modality is guided by the suspected site of infection, clinical presentation, and available resources. In high-burden or resource-constrained regions, strengthening access to CT and MRI could significantly improve diagnostic outcomes. Furthermore, integrating artificial intelligence (AI) and machine learning algorithms into radiological assessment holds promise in enhancing interpretation accuracy, particularly for CXR and CT scans. Future studies should focus on validating standardized radiologic criteria, evaluating imaging performance in pediatric and immunocompromised populations, and comparing imaging modalities head-to-head in diverse clinical scenarios.

CONCLUSION

Diagnostic imaging plays a vital role in the detection and evaluation of tuberculosis, with each modality offering unique strengths depending on the clinical context. Chest X-ray remains a useful initial screening tool, while CT thorax demonstrates the highest sensitivity and diagnostic accuracy for pulmonary TB, making it the current gold standard in radiologic evaluation. MRI is superior for diagnosing extrapulmonary TB, particularly in the central nervous system and spine, whereas USG serves as a valuable adjunct in detecting pleural, abdominal, and peripheral lymph node involvement. An integrated, context-specific imaging approach—guided by patient presentation and resource availability—is essential for improving diagnostic precision and optimizing TB management.

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