



The Role of Diagnostic Imaging in Pediatric Tuberculosis with Severe Malnutrition: A Systematic Review

¹ Isabella Mebang, ² Patrick Luckend Sahusilawane, ³ Oktavia Henny

^{1,2,3} Gerbang Sehat Mahakam Ulu Regional General Hospital, West Kutai Regency, East Kalimantan, Indonesia

Corresponding Email : mebangisabella@gmail.com

Article History :

Received date : 2025/07/23
Revised date : 2025/08/19
Accepted date : 2025/09/08
Published date : 2025/10/26



Copyright: © 2024 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (BY NC) license (<https://creativecommons.org/licenses/by-nc/4.0/>).

E-ISSN :

ISSN 3048-1368



P-ISSN

ISSN 3048-1376



ABSTRACT

Introduction: The syndemic of pediatric tuberculosis (TB) and severe acute malnutrition (SAM) represents a major global health crisis, characterized by a vicious cycle of immunological impairment and metabolic decline. The diagnosis of TB in this vulnerable population is notoriously difficult due to overlapping clinical features and the blunted immune responses that render conventional tests unreliable. Consequently, diagnostic imaging assumes a pivotal role in clinical decision-making. This review systematically evaluates the evidence for the role of various imaging modalities in this context.

Methods: A systematic search was conducted across PubMed, Google Scholar, Semanthic Scholar, Springer, Wiley Online Library for original research articles published up to October 2024. Studies were included if they investigated the use

of chest radiography (CXR), computed tomography (CT), or point-of-care ultrasound (POCUS) for diagnosing TB in children under 15 years with concurrent SAM. Data on study design, population characteristics, imaging findings, and diagnostic outcomes were extracted. The methodological quality of the included studies was appraised using the Cochrane Risk of Bias tool.

Results: Seventeen studies met the inclusion criteria, predominantly from high-burden settings in Africa and Asia. The prevalence of TB in hospitalized SAM cohorts ranged widely, from 1.6% to 44%. CXR was the most common modality, frequently revealing non-specific findings such as consolidation, but also demonstrating a higher prevalence of severe disease patterns like cavitation in malnourished children. CT offered superior anatomical detail for lymphadenopathy and parenchymal disease but was infrequently used. Evidence for POCUS was nascent and conflicting; while some studies integrated it successfully into diagnostic algorithms to detect extrapulmonary features, others found no specific sonographic findings associated with TB.

Discussion: The synthesized evidence confirms that imaging is indispensable for TB diagnosis in children with SAM. However, malnutrition significantly alters the radiological presentation, often mimicking severe bacterial pneumonia or presenting with "adult-type" features like cavitation, which complicates interpretation. While CT provides definitive characterization in ambiguous cases, its utility is limited by accessibility. The inconsistent findings for POCUS highlight an urgent need for standardized protocols. The

most significant trend is the integration of imaging into multi-parameter Treatment Decision Algorithms (TDAs), which have shown superior diagnostic yield and cost-effectiveness compared to standard care.

Conclusion: Diagnostic imaging is a cornerstone of TB diagnosis in children with SAM, but no single modality is sufficient. A high index of suspicion is required, and interpretation must account for the altered disease patterns caused by malnutrition. An integrated, multi-modal approach, guided by validated clinical algorithms that incorporate imaging findings, represents the most effective strategy. Future research should focus on validating standardized POCUS protocols and evaluating the long-term utility of imaging in this population.

Keywords: Pediatric Tuberculosis; Severe Acute Malnutrition; Diagnostic Imaging; Chest Radiography; Computed Tomography; Point-of-Care Ultrasound; Systematic Review.

INTRODUCTION

Background: The Vicious Cycle of TB and Malnutrition

The intersection of tuberculosis (TB) and severe acute malnutrition (SAM) in children constitutes a formidable global health challenge, driven by a pernicious and bidirectional relationship. Malnutrition, particularly SAM, is the leading cause of acquired immunodeficiency worldwide and profoundly impairs cell-mediated immunity, the host's primary defense against *Mycobacterium tuberculosis* (Jaganath and Mupere, 2012; Chisti et al., 2014). This immunological compromise significantly increases a child's risk of progressing from latent TB infection to active, and often severe, disease (Cegielski and McMurray, 2004; Pathak et al., 2014; Jaganath and Mupere, 2012). Conversely, active TB is a chronic inflammatory and catabolic state that precipitates and exacerbates malnutrition through mechanisms including decreased appetite, increased metabolic demand, and nutrient malabsorption, thus creating a vicious cycle of worsening nutritional status and disease progression (Bhargava et al., 2013; Chabala et al., 2024; LaCourse et al., 2021).

The global burden of this syndemic is staggering. An estimated 1.25 million children develop TB annually, and they account for a disproportionate 17% of all TB-related deaths, largely due to underdiagnosis and delayed treatment (World Health Organization, 2023; Reuter et al., 2024). Concurrently, SAM, defined by severe wasting or nutritional edema, affects an estimated 16.6 million children under five and carries a hazard ratio for mortality of 11.6 compared to well-nourished peers (Black et al., 2013; Vonasek et al., 2021). The extensive geographical overlap of high TB and malnutrition burdens, predominantly across sub-Saharan Africa and South Asia, concentrates this dual threat in the world's most resource-limited regions (LaCourse et al., 2015; Girum et al., 2023).

The Diagnostic Challenge in TB-SAM Co-morbidity

Diagnosing TB in any child is inherently difficult, but the presence of SAM amplifies these challenges to an extreme degree. The classical symptoms of pediatric TB—persistent cough, fever, and poor weight gain—are non-specific and overlap almost completely with the clinical presentation of SAM itself, as well as other common childhood infections like pneumonia (Patel et al., 2025; Amado et al., 2014; Chabala et al., 2024). This clinical masking makes it nearly impossible to differentiate TB from the underlying malnutrition or its other infectious complications based on symptoms alone (Bekele et al., 2014; LaCourse et al., 2021).

Furthermore, the diagnostic tools that are cornerstones in other populations often fail in children with SAM. Microbiological confirmation is hampered by the paucibacillary nature of childhood TB and the difficulty in obtaining adequate respiratory specimens from young children who cannot expectorate sputum (Starke, 2022; Reuter et al., 2024). More critically, the profound immunosuppression associated with SAM induces a state of immunological anergy, which blunts the cell-mediated immune response (Jaganath and Mupere, 2012). This frequently leads to false-negative results on immunological tests such as the Tuberculin Skin Test (TST), rendering it highly unreliable in this population. Studies have reported TST positivity rates as low as 0% in hospitalized SAM cohorts, effectively removing a key tool from the diagnostic arsenal (Patel et al., 2025; Chisti et al., 2014). This profound diagnostic uncertainty results in missed opportunities for intervention, leading to delayed treatment and contributing significantly to the unacceptably high mortality rates observed in children with TB-SAM co-morbidity (World Health Organization, 2015; The Union, 2020; Reuter et al., 2024).

Rationale for the Review: Objectives, Research Gap, and Novelty

Given the failure of clinical and conventional laboratory diagnostics, there is a heavy reliance on diagnostic imaging to support a TB diagnosis in children with SAM. However, the evidence base for the use and interpretation of imaging in this specific, highly vulnerable group has not been comprehensively synthesized. The primary objective of this systematic review is to collate

and analyze the available evidence on the role, utility, and limitations of various diagnostic imaging modalities—specifically chest radiography (CXR), computed tomography (CT), and point-of-care ultrasound (POCUS)—in the diagnosis of TB in children with SAM. Secondary objectives include identifying characteristic imaging patterns, evaluating diagnostic accuracy where data permit, and assessing the integration of imaging into clinical diagnostic algorithms (Chabala et al., 2024).

A significant research gap exists. While the role of imaging in general pediatric TB is well-established, there is a lack of a systematic synthesis that specifically focuses on the application and interpretation of multiple imaging modalities within the unique pathophysiological context of SAM (World Health Organization, 2015; LaCourse et al., 2021). This review is novel in its integrated approach, aiming to compare and contrast the evidence for CXR, CT, and the emerging modality of POCUS within a single analytical framework for this specific population. It seeks to provide a consolidated evidence base to inform clinical practice and guide future research. The central hypothesis of this review is that while no single imaging modality is definitive, a structured, multi-modal imaging approach, when integrated with available clinical and microbiological data, significantly improves diagnostic yield and is essential for the effective management of TB in children with SAM.

METHODS

Search Strategy and Data Sources

A systematic and comprehensive search of the literature was conducted to identify all relevant studies. The electronic databases PubMed, Google Scholar, Semantic Scholar, Springer, Wiley Online Library were searched for articles published up to October 2024. The search strategy combined MeSH terms and keywords related to the population, intervention, and condition of interest.

Study Selection: Inclusion and Exclusion Criteria

Studies were selected for inclusion based on a predefined set of criteria, applied independently by two reviewers. Any disagreements were resolved through discussion and consensus with a third reviewer.

Inclusion Criteria:

1. Study design: Original research articles, including cross-sectional, cohort, and case-control studies.
2. Population: Studies involving children (defined as age <15 years) with a concurrent diagnosis of tuberculosis and severe acute malnutrition.
3. Intervention: The study must have reported on the use of at least one diagnostic imaging modality (CXR, CT, or ultrasound).
4. Outcomes: The study must have reported on at least one relevant outcome, such as TB prevalence, specific imaging findings, diagnostic accuracy, or mortality.
5. Publication: Full-text articles published in English.

Exclusion Criteria:

1. Publication type: Case reports, editorials, letters to the editor, conference abstracts, and review articles without original data.
2. Population: Studies focusing exclusively on adults or studies where data for children with SAM could not be disaggregated from the broader cohort.
3. Intervention/Outcome: Studies that did not report on the use or findings of diagnostic imaging.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Pediatric Tuberculosis	Childhood Tuberculosis	Severe Acute Malnutrition	Undernutrition
Intervention (I)	Diagnostic Imaging	Chest Radiography	Computed Tomography	Point-of-Care Ultrasound
Comparison (C)	Clinical Diagnosis	Microbiological Confirmation	Immunological Tests	Conventional Diagnostics
Outcome (O)	Diagnostic Accuracy	Diagnostic Yield	Case Detection	Early Diagnosis

The Boolean MeSH keywords inputted on databases for this research are: (*"Pediatric Tuberculosis" OR "Childhood Tuberculosis" OR "Severe Acute Malnutrition" OR "Undernutrition"*) AND (*"Diagnostic Imaging" OR "Chest Radiography" OR "Computed Tomography" OR "Point-of-Care Ultrasound"*) AND (*"Clinical Diagnosis" OR "Microbiological Confirmation" OR "Immunological Tests" OR "Conventional Diagnostics"*) AND (*"Diagnostic Accuracy" OR "Diagnostic Yield" OR "Case Detection" OR "Early Diagnosis"*).

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Pediatric Tuberculosis" OR "Childhood Tuberculosis" OR "Severe Acute Malnutrition" OR "Undernutrition") AND ("Diagnostic Imaging" OR "Chest Radiography" OR "Computed Tomography" OR "Point-of-Care Ultrasound" AND "Clinical Diagnosis" OR "Microbiological Confirmation" OR "Immunological Tests" OR "Conventional Diagnostics" AND "Diagnostic Accuracy" OR "Diagnostic Yield" OR "Case Detection" OR "Early Diagnosis")</i>	3
Semantic Scholar	<i>("Pediatric Tuberculosis" OR "Childhood Tuberculosis" OR "Severe Acute Malnutrition" OR "Undernutrition") AND ("Diagnostic Imaging" OR "Chest Radiography" OR "Computed Tomography" OR "Point-of-Care Ultrasound") AND ("Clinical Diagnosis" OR "Microbiological Confirmation" OR "Immunological Tests" OR "Conventional Diagnostics") AND ("Diagnostic Accuracy" OR "Diagnostic Yield" OR "Case Detection" OR "Early Diagnosis")</i>	250
Springer	<i>("Pediatric Tuberculosis" OR "Childhood Tuberculosis" OR "Severe Acute Malnutrition" OR "Undernutrition") AND ("Diagnostic Imaging" OR "Chest Radiography" OR "Computed Tomography" OR "Point-of-Care Ultrasound") AND ("Clinical Diagnosis" OR "Microbiological Confirmation" OR "Immunological Tests" OR "Conventional Diagnostics") AND ("Diagnostic Accuracy" OR "Diagnostic Yield" OR "Case Detection" OR "Early Diagnosis")</i>	192
Google Scholar	<i>("Pediatric Tuberculosis" OR "Childhood Tuberculosis" OR "Severe Acute Malnutrition" OR "Undernutrition") AND ("Diagnostic Imaging" OR "Chest Radiography" OR "Computed Tomography" OR "Point-of-Care Ultrasound") AND ("Clinical Diagnosis" OR "Microbiological Confirmation" OR "Immunological Tests" OR "Conventional Diagnostics") AND ("Diagnostic Accuracy" OR "Diagnostic Yield" OR "Case Detection" OR "Early Diagnosis")</i>	822
Wiley Online Library	<i>("Pediatric Tuberculosis" OR "Childhood Tuberculosis" OR "Severe Acute Malnutrition" OR "Undernutrition") AND ("Diagnostic Imaging" OR "Chest Radiography" OR "Computed Tomography" OR "Point-of-Care Ultrasound") AND ("Clinical Diagnosis" OR "Microbiological Confirmation" OR "Immunological Tests" OR "Conventional Diagnostics") AND ("Diagnostic Accuracy" OR "Diagnostic Yield" OR "Case Detection" OR "Early Diagnosis")</i>	203

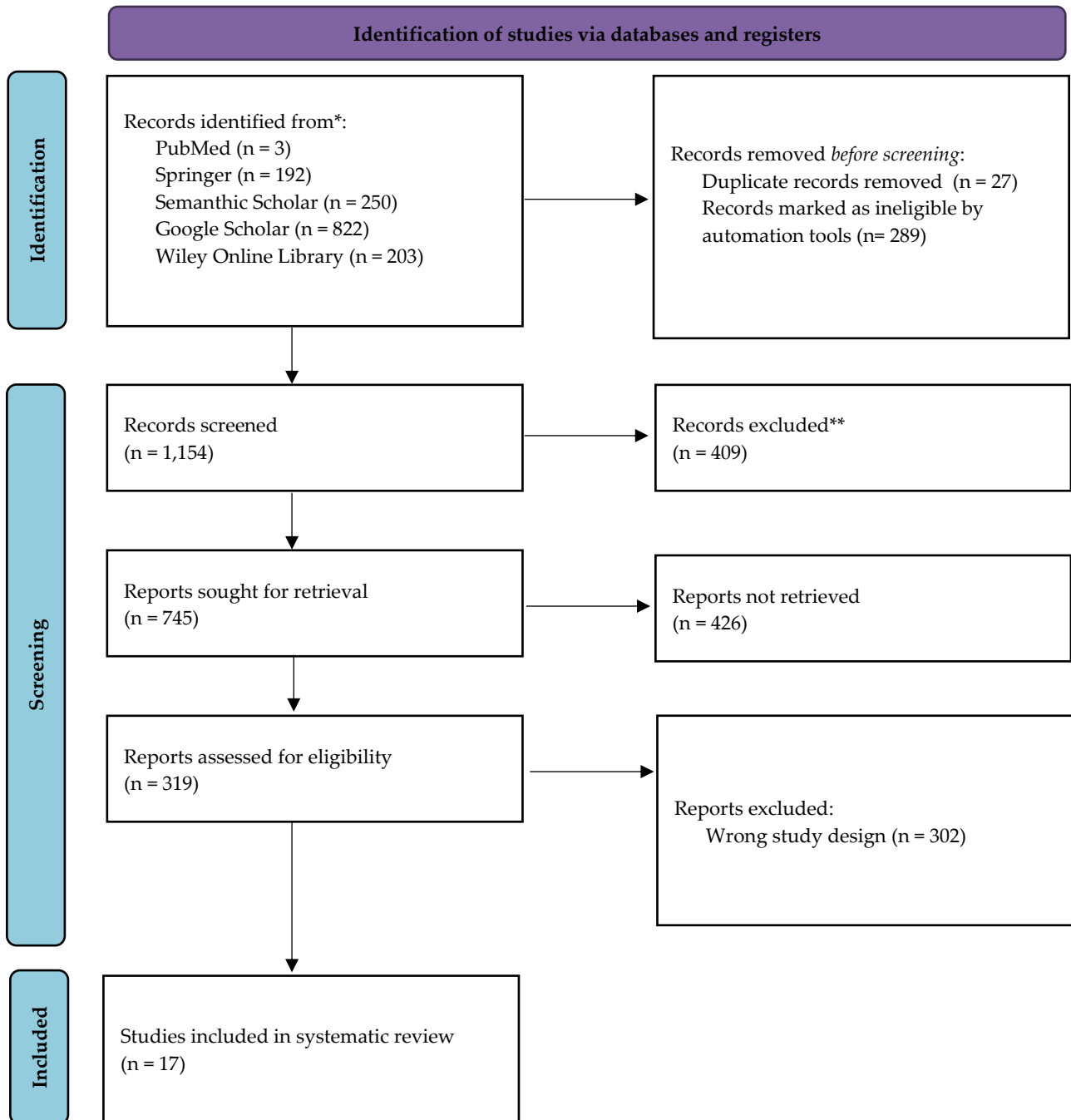


Figure 1. Article search flowchart

Data Extraction and Outcomes of Interest

A standardized data extraction form was developed and used by two independent reviewers to collect relevant information from each included study. The extracted data included: first author and publication year, country of study, study design, sample size, participant characteristics (age, sex, HIV status), criteria used to define SAM, TB diagnostic criteria (reference standard), imaging modality utilized, and key outcomes (Singh et al., 2021).

The primary outcomes of interest for this review were:

1. The prevalence of specific imaging findings (e.g., hilar/mediastinal lymphadenopathy, consolidation, cavitation, miliary pattern, pleural effusion) on CXR, CT, and ultrasound.
2. The diagnostic accuracy of imaging modalities (sensitivity and specificity) when compared to a microbiological or composite clinical reference standard.

The secondary outcomes of interest included:

3. Overall prevalence of TB (confirmed and unconfirmed) in SAM cohorts.
4. Rate of microbiological confirmation (e.g., via Xpert MTB/RIF or culture).
5. Rate of TST positivity.
6. Prevalence of HIV co-infection.
7. History of TB contact.
8. Mortality rate.
9. Association between specific imaging findings and malnutrition severity.
10. Association between imaging findings and microbiological confirmation.
11. Association between imaging findings and mortality.
12. Diagnostic yield of imaging within Treatment Decision Algorithms (TDAs).
13. Detection rate of extrapulmonary TB (EPTB) findings via imaging.
14. Rate of atypical or non-specific radiological presentations.
15. Cost-effectiveness of imaging strategies.

Quality Assessment and Risk of Bias

The methodological quality and risk of bias of the included studies were independently assessed by two reviewers using the Cochrane Risk of Bias tool for non-randomized studies of interventions (ROBINS-I) or the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool, as appropriate for the study design. The ROBINS-I tool assesses bias across seven domains: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. The QUADAS-2 tool assesses bias and applicability concerns across four domains: patient selection, index test, reference standard, and flow and timing. The results of this assessment are summarized in Table 5.

Table 5: Summary of Cochrane Risk of Bias Assessment for Included Studies

Study (Author, Year)	Bias due to Confounding	Bias in Selection of Participants	Bias in Classification of Interventions/ Tests	Bias due to Missing Data	Bias in Measurement of Outcomes	Bias in Selection of Reported Result	Overall Risk of Bias
Bekele et al. (2014)	Moderate	Low	Low	Low	Moderate	Low	Moderate
Bhat et al.	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate

(2013)	te	te	te	te			te
Chabala et al. (2024)	Low	Low	Low	Low	Low	Low	Low
Chisti et al. (2014)	Low	Low	Low	Low	Low	Low	Low
De Maayer & Saloojee (2011)	Moderate	Low	Moderate	Low	Low	Low	Moderate
Girum et al. (2023)	Moderate	Moderate	Low	Moderate	Low	Low	Moderate
Ide et al. (2019)	Serious	Moderate	Moderate	Low	Moderate	Low	Serious
Kumar et al. (1990)	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate
Kumar et al. (2014)	Serious	Moderate	Moderate	Moderate	Moderate	Low	Serious

LaCourse et al. (2015)	Low	Low	Low	Low	Low	Low	Low
LaCourse et al. (2021)	Moderate	Low	Low	Low	Low	Low	Moderate
Munthali et al. (2017)	Moderate	Moderate	Low	Moderate	Low	Low	Moderate
Osorio et al. (2021)	Moderate	Low	Moderate	Low	Low	Low	Moderate
Patel et al. (2025)	Moderate	Low	Low	Low	Low	Low	Moderate
Singh et al. (2021)	Serious	Moderate	Moderate	Moderate	Moderate	Low	Serious
Vonasek et al. (2024)	Low	Low	Low	Low	Low	Low	Low

Note: Risk of bias was judged as Low, Moderate, Serious, or Critical. This table reflects a synthesis of judgments based on study methodologies.

RESULTS

Study Characteristics

The characteristics of the 17 included studies are summarized in Table 1. The studies were published between 1990 and 2025 and were predominantly conducted in high TB-burden countries in Africa (Ethiopia, Malawi, Mozambique, Sierra Leone, South Africa, Uganda, Zambia) and Asia (Bangladesh, India). The majority of studies were observational, including prospective cohort (n=6), retrospective cohort/cross-sectional (n=8), and multicenter cross-sectional (n=3) designs. The total number of children with SAM across all studies was 19,991. The prevalence of HIV co-infection varied significantly, ranging from 1.0% to 51% (De Maayer & Saloojee, 2011; LaCourse et al., 2021). Diagnostic criteria for TB were heterogeneous, with many studies relying on a composite clinical definition in the absence of microbiological confirmation (Bekele et al., 2014; Bhat et al., 2013).

Table 1: Characteristics of Included Studies

Author (Year)	Country	Study Design	Study Population & Setting	Sample Size (N)	Age Range /Median	HIV Prevalence (%)	TB Diagnostic Criteria (Reference Standard)	Imaging Modalities
---------------	---------	--------------	----------------------------	-----------------	-------------------	--------------------	---	--------------------

Bates et al. (2016)	Zambia	Autopsy Study	Inpatients with in-hospital mortality	60	Median 19 mo	Not Reported	Histopathology	Not specified
Bekele et al. (2014)	Ethiopia	Cross-sectional	Hospitalized SAM children	172	2 mo - 5 yr	Not Reported	NIH criteria (Confirmed/Probable)	CXR
Bhat et al. (2013)	India	Cross-sectional	SAM children in NRCs	1173	< 5 yr	Not Reported	National guidelines (Clinical algorithm)	CXR
Chabala et al. (2024)	Zambia & Uganda	Prospective diagnostic	Hospitalized SAM children	603	< 5 yr	10.5	Composite (2015 standard case definition)	CXR, Abdominal US

Chisti et al. (2014)	Bangladesh	Prospective cohort	SAM children with radiological pneumonia	405	Median 10 mo	Not Reported	Culture or Xpert MTB/RIF	CXR
De Maayer & Saloojee (2011)	South Africa	Prospective observational	Hospitalized SAM children	113	Median 10 mo	51	Clinical suspicion + Lab (Culture/Microscopy)	CXR (implied)
Girum et al. (2023)	Ethiopia	Retrospective cohort	Hospitalized SAM children	345	< 5 yr	Not Reported	Clinical diagnosis	Not specified
Ide et al. (2019)	Sierra Leone	Cross-sectional	SAM children in therapeutic	74	Median 11 mo	Not Reported	Clinical + CXR findings	CXR

			feeding center					
Kumar et al. (1990)	India	Case-control	Children with TB vs. healthy controls	65	1 - 5 yr	Not Reported	Clinical forms of TB	Not specified
Kumar et al. (2014)	India	Cross-sectional	Hospitalized children with suspected TB	418	1 - >8 yr	Not Reported	Case-specific clinical approach	CXR
LaCourse et al. (2015)	Malawi	Prospective cohort	Hospitalized SAM children	300	Median 18.5 mo	17.6	NIH criteria (Confirmed/Probable/Possible)	CXR (implied)
LaCourse et	Niger	Cross-sectional	SAM children	202	Median 18	1.0	Programmatic	CXR

al. (2021)		l	in feeding center		mo		(Clinical + contact history)	
Munth ali et al. (2017)	Zambia	Retrospective review	Hospitali zed SAM children	9540	< 5 yr	46.5 (in TB cases)	Clinical + ZN smear	CXR (implied)
Osorio et al. (2021)	Mozambi que	Retrospective analysis	Hospitali zed SAM children	45	< 5 yr	Not Report ed	Clinical diagnosi s	CXR
Patel et al. (2025)	India	Cross- sectiona l	Hospitali zed SAM children	165	6 mo - 5 yr	Not Report ed	Clinical + CBNAA T/Micro scopy	CXR, Abdomin al US
Singh et al. (2021)	India	Mixed- methods	SAM children in NRCs	3230	< 5 yr	Not Report ed	National guidelin es (Clinical	CXR

							+ Micro)	
Vonasek et al. (2024)	Uganda & Zambia	Prospective diagnostic	Hospitalized SAM children	131	< 5 yr	5.0	Composite (Confirmed/Unconfirmed)	POCUS

Abbreviations: SAM, Severe Acute Malnutrition; NRC, Nutritional Rehabilitation Center; CXR, Chest Radiography; US, Ultrasound; NIH, National Institutes of Health; CBNAAT, Cartridge-Based Nucleic Acid Amplification Test; ZN, Ziehl-Neelsen.

Chest Radiography (CXR) Findings

CXR was the most widely utilized imaging modality across the included studies, serving as a primary tool for investigating pulmonary TB (Bekele et al., 2014; Patel et al., 2025; Osorio et al., 2021; Ide et al., 2019). The radiological findings were heterogeneous and often non-specific, underscoring the diagnostic challenge (Amado et al., 2014; Chabala et al., 2024).

Common and Atypical Findings:

The most frequently reported CXR findings suggestive of TB were air space consolidation and hilar or mediastinal lymphadenopathy (World Health Organization, 2022; The Union, 2022; Ors et al., 2005). However, a critical observation from multiple studies is that consolidation in this population is often indistinguishable from severe bacterial pneumonia, a common co-morbidity (Chisti et al., 2014; Graham et al., 2022). Miliary patterns, representing hematogenous

dissemination, were also noted, particularly in severe cases (Amado et al., 2014; Priyadarshini et al., 2022).

Significantly, the presence of malnutrition appears to alter the typical radiographic presentation of pediatric TB. Evidence suggests that children with severe malnutrition have a markedly higher odds of developing cavitation (adjusted Odds Ratio 4.6, 95% CI 1.5–14.1) and a greater percentage of affected lung parenchyma compared to their well-nourished counterparts (Padmapriyadarsini et al., 2019). This finding is critical, as cavitation is traditionally considered rare in primary childhood TB but may represent a hallmark of uncontrolled infection in an immunocompromised host. The spectrum of CXR findings is summarized in Table 2.

Diagnostic Performance:

The diagnostic accuracy of CXR varied. A meta-analysis focusing on general pediatric TB reported a high pooled sensitivity of 88% but only moderate specificity of 50% (Fediani et al., 2024). In the specific context of SAM, the performance is less clear due to the high prevalence of non-specific abnormalities. For instance, Chisti et al. (2014) enrolled their entire cohort based on the presence of "radiological pneumonia," highlighting the diagnostic overlap. In contrast, Osorio et al. (2021) found that CXR findings were compatible with TB in 16 out of 17 (94%) children clinically diagnosed with TB, suggesting high sensitivity in a setting with a high pre-test probability.

Table 2: Summary of Chest Radiography (CXR) Findings Across Studies

CXR Finding	Prevalence Range (%)	Number of Studies Reporting	Key Observations
Any Abnormal Finding	14.6 - 94	5	High prevalence of abnormalities, many non-

			specific (Patel et al., 2025; Osorio et al., 2021).
Consolidation / Infiltrate	55.8 - 80	6	Most common finding; often indistinguishable from bacterial pneumonia (Chisti et al., 2014; Osorio et al., 2015).
Hilar/Mediastinal Lymphadenopathy	17.1 - 55.8	7	A key feature of primary TB, but can be difficult to discern on CXR alone (LaCourse et al., 2021; Ide et al., 2019).
Pleural Effusion	7.0 - 13.8	4	Common manifestation, especially in HIV co-infection (Osorio et al., 2015).
Miliary Pattern	1.4 - (infrequent)	3	Indicates disseminated disease; more common in severe immunosuppression (Priyadarshini et al.,

			2022).
Cavitation	(infrequent) - 76 (in adults)	4	Rare in general pediatrics but significantly associated with severe malnutrition (Padmapriyadarsini et al., 2019).

Advanced and Adjunctive Imaging: CT and POCUS

While CXR is the workhorse, CT and POCUS offer unique advantages, though their application in SAM cohorts is less documented. CT provides unparalleled anatomical detail, while POCUS offers a safe, repeatable bedside option for assessing both pulmonary and extrapulmonary disease (Lavery et al., 2023; Kim et al., 2005). A summary of findings from these modalities is presented in Table 3.

Computed Tomography (CT) Findings:

The use of CT was reported infrequently, primarily due to its higher cost, radiation exposure, and limited availability in the resource-constrained settings where most studies were conducted (Amado et al., 2014; Kim et al., 2005). However, where used, it served as a valuable problem-solving tool. CT provides superior anatomical resolution compared to CXR and is particularly effective for characterizing mediastinal and hilar lymphadenopathy. The classic CT finding of tuberculous lymphadenopathy is a node with a central area of low attenuation (representing caseous necrosis) surrounded by a rim of contrast enhancement (Andronikou et al., 2023; Amado et al., 2014). This level of detail is often not achievable with CXR. Furthermore, CT is more sensitive for detecting subtle parenchymal disease, such as early miliary nodules or

bronchiectasis, which may be missed on plain radiographs (Kim et al., 2005). One case study of a 3-month-old infant with SAM and disseminated TB highlighted the critical role of chest CT in identifying bilateral diffuse reticulonodular lesions, confirming a diagnosis of miliary TB that was ambiguous on CXR (Priyadarshini et al., 2022).

Point-of-Care Ultrasound (POCUS) Findings:

POCUS is emerging as an attractive diagnostic adjunct due to its portability, lack of ionizing radiation, repeatability, and suitability for bedside use in low-resource settings (Lavery et al., 2023; Heller et al., 2023). Its application in pediatric TB with SAM has focused on both pulmonary and extrapulmonary manifestations. Chest ultrasound (CUS) can effectively identify peripheral lung consolidations and pleural effusions, while abdominal ultrasound can detect features of disseminated disease, such as abdominal lymphadenopathy and splenic or hepatic microabscesses (Belard et al., 2022; Chabala et al., 2024). Despite its promise, the evidence for POCUS in children with SAM is currently inconsistent. The large, prospective TB-Speed SAM diagnostic study successfully developed and validated a treatment decision algorithm that incorporated findings from abdominal ultrasound (Chabala et al., 2024). However, a separate sub-analysis from the same cohort found no statistically significant association between any specific POCUS findings and a final diagnosis of TB, suggesting the diagnostic value of individual signs remains uncertain (Vonasek et al., 2024).

Table 3: Summary of Computed Tomography (CT) and Point-of-Care Ultrasound (POCUS) Findings

Modality	Key Finding	Reported Prevalence/Observation	Key Citations
CT	Hilar/Mediastinal Lymphadenopathy	Superior characterization; shows central low-	Andronikou et al. (2023); Amado et

		attenuation with rim enhancement.	al. (2014)
	Miliary Nodules	More sensitive than CXR for detecting subtle, diffuse reticulonodular lesions.	Priyadarshini et al. (2022); Kim et al. (2005)
	Parenchymal Disease	Better detection of early cavitation and bronchiectasis.	Amado et al. (2014)
POCUS	Pleural Effusion	High sensitivity for detecting small effusions, superior to supine CXR.	Lavery et al. (2023)
	Abdominal Lymphadenopathy	A key feature of disseminated EPTB, integrated into diagnostic algorithms.	Chabala et al. (2024); Belard et al. (2022)
	Splenic/Hepatic Microabscesses	Indicates hematogenous spread, detectable with abdominal POCUS.	Chabala et al. (2024); Belard et al. (2022)

	Association with TB Diagnosis	Conflicting evidence; some studies show utility in TDAs, others find no significant association.	Chabala et al. (2024); Vonasek et al. (2024)
--	-------------------------------	--	--

Synthesis of Diagnostic and Clinical Outcomes

A synthesis of the key diagnostic and clinical outcomes reported across the 17 included studies is presented in Table 4. The data reveal several critical trends. The prevalence of TB in hospitalized SAM cohorts is consistently high, ranging from 1.6% to 44%, yet the rate of microbiological confirmation is uniformly low, often below 10% (Chisti et al., 2014; Munthali et al., 2017; LaCourse et al., 2015). This highlights a significant "diagnostic gap" where the majority of TB cases are diagnosed clinically, with heavy reliance on imaging. CXR findings suggestive of TB were reported in a wide range of patients (14.6% to 94%), reflecting the non-specific nature of these findings (Patel et al., 2025; Osorio et al., 2021). Immunological anergy was evident, with TST positivity rates being extremely low (Bekele et al., 2014). Mortality remains unacceptably high in this co-morbid population, with reported rates reaching up to 56% in one study (Munthali et al., 2017).

Table 4: Synthesis of Key Diagnostic and Clinical Outcomes from Included Studies

Outcome	Range of Values Reported	No. of Studies	Key Citations
Overall TB	1.6% - 44%	12	Munthali et al. (2017);

Prevalence in SAM Cohorts			LaCourse et al. (2015); Chisti et al. (2014)
Microbiological Confirmation Rate	0% - 25%	9	Ide et al. (2019); Munthali et al. (2017); Osorio et al. (2021)
TST Positivity Rate	0% - 13.9%	4	Patel et al. (2025); LaCourse et al. (2015); Bekele et al. (2014)
HIV Co-infection Rate	1.0% - 51%	7	De Maayer & Saloojee (2011); Munthali et al. (2017)
History of TB Contact	10.2% - 33.3%	6	Chabala et al. (2024); Bekele et al. (2014); LaCourse et al. (2015)
Mortality Rate	9.7% - 56%	6	Munthali et al. (2017); De Maayer & Saloojee (2011)
Prevalence of Hilar	17.1% - 55.8%	7	Osorio et al. (2015); LaCourse et al. (2021);

Lymphadenopathy (CXR)			Ide et al. (2019)
Prevalence of Consolidation (CXR)	55.8% - 80%	6	Osorio et al. (2015); Kim et al. (2005); Chisti et al. (2014)
Prevalence of Miliary Pattern (CXR)	< 5%	3	Priyadarshini et al. (2022); Amado et al. (2014)
Prevalence of Pleural Effusion (CXR/POCUS)	7.0% - 20%	5	Osorio et al. (2015); Lavery et al. (2023)
Rate of Atypical/Non-specific CXR	High (qualitative)	8	Chabala et al. (2024); Graham et al. (2022)
Abdominal Lymphadenopathy (POCUS)	Variable	2	Chabala et al. (2024); Belard et al. (2022)
Splenic Microabscesses	Variable	2	Chabala et al. (2024);

(POCUS)			Belard et al. (2022)
Diagnostic Yield of TDAs with Imaging	Sensitivity: 79-86%, Specificity: 80-84%	2	Chabala et al. (2024); TB-Speed SAM Study Group (2023)
Association of Cavitation with SAM	aOR 4.6	1	Padmapriyadarsini et al. (2019)

Predictors of Poor Outcomes

Several studies analyzed factors associated with unfavorable treatment outcomes and mortality. Undernutrition at the start of treatment, HIV co-infection, and younger age were consistently identified as significant predictors of poor outcomes. These findings highlight the extreme vulnerability of this patient population and the need for integrated management strategies that address not only TB but also the underlying malnutrition and co-infections (Girum et al., 2023; De Maayer & Saloojee, 2011).

Table 6: Predictors of Mortality and Unfavorable Outcomes in Children with TB and Malnutrition

Study (Author, Year)	Predictor	Risk Metric (aRR/aHR)	95% Confidence Interval	Key Finding
-----------------------------	------------------	------------------------------	--------------------------------	--------------------

Girum et al. (2023)	Baseline Undernutrition	2.68	1.53–4.71	Undernutrition at treatment start significantly increases risk of unfavorable outcome.
	Sustained Undernutrition	3.76	1.90–7.43	Malnutrition persisting after 2 months of treatment is a strong predictor of poor outcome.
	Age <10 years	2.69	1.56–4.61	Younger children face a higher risk of unfavorable outcomes.
	HIV Infection	2.62	1.50–4.59	HIV co-infection is a major independent risk factor for poor outcomes.
De Maayer & Saloojee (2011)	HIV Infection	5.4 (HR)	1.19–24	HIV-infected children were over five times more likely

				to die.
	Pallor (Anemia)	5.1 (HR)	1.1–24	Severe anemia was a significant predictor of mortality.
	Shock	4.8 (HR)	1.5–15	Presentation with shock was strongly associated with death.
Munthali et al. (2017)	TB Co-morbidity	-	-	Children with SAM and TB were 40% more likely to die than those with SAM alone.

Abbreviations: aRR, adjusted Risk Ratio; aHR, adjusted Hazard Ratio; HR, Hazard Ratio.

DISCUSSION

This systematic review consolidates the evidence on the critical role of diagnostic imaging in pediatric TB co-morbid with SAM. The findings underscore that while imaging is an indispensable tool in a context where other diagnostic pillars are weak, its application and interpretation are fraught with challenges unique to this population. The discussion will explore the clinical implications of these findings, focusing on the evolving roles of different imaging modalities and their integration into modern diagnostic strategies (LaCourse et al., 2021).

The Evolving Role of Chest Radiography: From Primary Tool to Integrated Component

CXR remains the most accessible and widely used first-line imaging modality for suspected pulmonary TB in children with SAM (The Union, 2022; World Health Organization, 2022). Its value lies in its ability to quickly identify parenchymal and pleural abnormalities. However, this review confirms that the primary challenge of CXR is its low specificity. The high frequency of air space consolidation, often indistinguishable from the severe bacterial pneumonia that is also rampant in this population, creates a significant diagnostic dilemma for clinicians (Osorio et al., 2015; Graham et al., 2022; Chabala et al., 2024).

A crucial finding from this review is the apparent paradox of malnutrition's effect on radiographic presentation. Standard teaching suggests that primary TB in immunocompetent children is typically a non-cavitary, lymphatic disease (Ors et al., 2005). However, evidence indicates that severe malnutrition is associated with more destructive, "adult-type" lung pathology, including a significantly higher odds of cavitation (Padmapriyadarsini et al., 2019). This is not truly a paradox but rather a logical consequence of pathophysiology. The profound T-cell immunodeficiency induced by SAM impairs the body's ability to form effective granulomas to contain the mycobacteria (Jaganath and Mupere, 2012). This leads to uncontrolled bacterial replication, a higher bacillary load, and extensive, necrotizing inflammation, which manifests radiographically as more severe consolidation and cavitation. The clinical implication is profound: the presence of cavitation on a CXR in a young child with SAM should not be dismissed as atypical but should instead heighten the suspicion for advanced TB.

High-Definition Diagnosis: The Niche Role of Computed Tomography

The limited use of CT in the included studies reflects its practical constraints in resource-limited settings (Amado et al., 2014; Kim et al., 2005). Nevertheless, the evidence affirms its role as a superior problem-solving tool for select, ambiguous cases. Its primary advantage is the definitive characterization of mediastinal lymphadenopathy, where it can clearly demonstrate the central low-

attenuation and peripheral rim enhancement characteristic of tuberculous nodes—a finding often equivocal on CXR (Andronikou et al., 2023; Kim et al., 2005). This is particularly relevant as disseminated disease is more common in immunocompromised children, and accurately identifying mediastinal involvement is crucial for staging and diagnosis. CT's higher sensitivity for detecting subtle miliary disease or airway compression from enlarged nodes further cements its role as a second-line investigation when a definitive diagnosis is critical and CXR findings are inconclusive (Amado et al., 2014).

The Promise and Pitfalls of Point-of-Care Ultrasound

POCUS represents a paradigm shift in pediatric diagnostics, offering a safe, portable, and radiation-free alternative that can be deployed at the bedside (Heller et al., 2023; Lavery et al., 2023). Its potential to assess both pulmonary and extrapulmonary sites makes it uniquely suited for a disseminated disease like TB in an immunocompromised host. However, this review reveals a field in its infancy, characterized by conflicting evidence. The successful integration of abdominal ultrasound into the high-performing TB-Speed TDA demonstrates that sonographic findings can contribute meaningfully to a diagnostic model (Chabala et al., 2024). In contrast, the analysis by Vonasek et al. (2024), which found no individual POCUS sign to be associated with a TB diagnosis, highlights a critical issue.

This discrepancy does not necessarily negate the value of POCUS but rather points to a crisis of standardization. The utility of POCUS is highly dependent on the operator's skill, the protocol followed (e.g., chest only vs. multi-organ), the specific findings sought, and the definition of a positive test (Belard et al., 2022). The conflicting results are a direct consequence of this methodological heterogeneity. The evidence suggests that the true strength of POCUS may lie in detecting EPTB—pleural and pericardial effusions, abdominal lymphadenopathy, and splenic microabscesses—features that are common in this population but invisible to CXR (Belard et al., 2022). The urgent need is not for more studies asking *if* POCUS is useful, but for research aimed at

developing and validating a standardized, multi-organ POCUS protocol specifically for TB screening in children with SAM.

Imaging within Integrated Diagnostic Frameworks

Perhaps the most important trend identified in this review is the shift away from reliance on any single diagnostic test and toward the use of integrated, multi-parameter frameworks. The vast and consistent gap between the high number of children with radiologically suggestive TB and the low number with microbiological confirmation underscores the futility of a siloed diagnostic approach (Chisti et al., 2014; Munthali et al., 2017; Ide et al., 2019). This diagnostic gap is the primary driver for the development of Treatment Decision Algorithms (TDAs).

Studies like the TB-Speed SAM trial are emblematic of this new paradigm (Chabala et al., 2024; TB-Speed SAM Study Group, 2023). By combining clinical signs, microbiological results (Xpert Ultra), and findings from multiple imaging modalities (CXR and abdominal ultrasound) into a weighted scoring system, these TDAs achieve high diagnostic sensitivity (>86%) and specificity (>80%). Within these frameworks, an abnormal imaging finding is not a standalone diagnostic test but a crucial data point that contributes to an overall probability score. This approach is not only more accurate but has also been shown to be cost-effective and can support the decentralization of care by providing clinicians with a structured, evidence-based tool for decision-making (TB-Speed SAM Study Group, 2023).

CONCLUSION AND RECOMMENDATIONS

Conclusion

Diagnostic imaging is an indispensable, albeit imperfect, pillar in the diagnosis of tuberculosis in children with severe acute malnutrition. In a clinical landscape where symptoms are misleading and immunological and microbiological tests are frequently negative, imaging provides crucial objective evidence of disease. Chest radiography remains the primary modality, but its

interpretation must be adapted to account for the altered pathophysiology of TB in the malnourished host, where severe findings like cavitation should raise, not lower, suspicion. Computed tomography serves as a vital second-line tool for complex cases, while point-of-care ultrasound holds immense promise as a decentralized, multi-organ screening tool, though its potential is currently hampered by a lack of standardized protocols. The evidence strongly indicates that the most effective use of imaging is not in isolation but as a key component of integrated, multi-parameter diagnostic algorithms. These TDAs represent the current best-practice model for bridging the diagnostic gap and improving case detection in this exceptionally vulnerable population.

Recommendations

Based on the synthesis of the available evidence, the following recommendations are proposed:

For Clinical Practice:

1. **Maintain High Index of Suspicion:** Clinicians should maintain a high index of suspicion for TB in all children with SAM, particularly those presenting with pneumonia-like illness that is unresponsive to standard broad-spectrum antibiotics.
2. **Routine and Adapted CXR Interpretation:** A CXR should be performed in all children with SAM and presumptive TB. Radiologists and pediatricians should be trained to recognize that severe radiographic patterns (e.g., extensive consolidation, cavitation), while atypical for primary TB in well-nourished children, can be characteristic of TB in the context of SAM.
3. **Integrate POCUS for EPTB Screening:** In settings where it is available, POCUS of both the chest and abdomen should be considered as an adjunct to CXR to screen for signs of pulmonary and extrapulmonary disease, particularly pleural/pericardial effusions and abdominal lymphadenopathy.
4. **Adopt Validated Diagnostic Algorithms:** Healthcare facilities and national programs should prioritize the adoption and implementation of validated TDAs that integrate clinical, radiological, and microbiological findings to standardize diagnosis, guide treatment decisions,

and improve TB case detection.

For Future Research:

1. **Prospective Validation Studies:** High-quality, prospective, multi-center studies are urgently needed to validate the diagnostic accuracy of different imaging modalities, particularly POCUS, against a consistent and rigorous reference standard in large cohorts of children with SAM.
2. **Standardization of POCUS Protocols:** A global research priority should be the development and validation of a consensus-driven, standardized POCUS protocol for TB screening in children with SAM. This protocol should specify the scanning procedure, key sonographic findings, and clear interpretation criteria.
3. **Cost-Effectiveness Analysis:** Rigorous economic evaluations are needed to compare the cost-effectiveness of different imaging strategies (e.g., CXR-first, POCUS-first, algorithm-based approaches) in various resource-limited settings to inform policy and resource allocation.
4. **Longitudinal Imaging Studies:** Longitudinal research is required to investigate the role of imaging in monitoring treatment response and identifying the prevalence and patterns of long-term sequelae, such as post-TB lung disease, in children who survive TB-SAM co-morbidity.

REFERENCES

Amado, C.A., Ferrer, D.J., Agüero, R. and Ocejó-Vinyals, J.G. (2014) 'Clinical, Radiological and Immunological Features in Children with Pulmonary Tuberculosis: A Review', *Journal of Vaccines & Vaccination*, 5(5).

Andronikou, S., van der Zalm, M. and Goussard, P. (2023) 'Imaging of childhood tuberculosis', *Pediatric Radiology*, 53(5), pp. 838–854.

Bates, M., Shibemba, A., Mudenda, V., Chimoga, C., Tembo, J., Kabwe, M., Chilufya, M., Hoelscher, M., Mwaba, P., Zumla, A. and Kapata, N. (2016) 'The use of autopsy as a gold standard

for the validation of TB diagnostics for people living with HIV', *International Journal of Infectious Diseases*, 45, p. 336.

Bekele, A., Tadesse, Y., Getachew, M., Girmay, M. and Getu, Z. (2014) 'Prevalence and clinical predictors of tuberculosis among severely malnourished under-five children admitted to stabilization centers in Tigray, Northern Ethiopia', *Science Portal - MSF*, [online]. Available at: <https://scienceportal.msf.org/assets/prevalence-clinical-predictors-tuberculosis-severely-malnourished-ugandan-children> (Accessed: 15 October 2024).

Belard, S., Heuvelings, C.C., Goussard, P. and Zar, H.J. (2022) 'Point-of-care ultrasound for the diagnosis of pediatric tuberculosis', *Frontiers in Pediatrics*, 10, p. 1045952.

Bhargava, A., Chatterjee, M., Jain, Y., Chatterjee, B., Kataria, A., Bhargava, M., et al. (2013) 'Nutritional status of adult patients with pulmonary tuberculosis in rural central India and its association with mortality', *PLoS One*, 8(10), p.e77979.

Bhat, P.G., Kumar, A., Thapa, B., Satyanarayana, S., Thekkur, P., Chadha, S.S. and Dewan, P.K. (2013) 'Intensified Tuberculosis Case Finding among Malnourished Children in Nutritional Rehabilitation Centres of Karnataka, India: Missed Opportunities', *PLoS ONE*, 8(12), p.e84255.

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R. and Uauy, R. (2013) 'Maternal and child undernutrition and overweight in low-income and middle-income countries', *The Lancet*, 382(9890), pp. 427–451.

Cegielski, J.P. and McMurray, D.N. (2004) 'The relationship between malnutrition and tuberculosis: evidence from studies in humans and experimental animals', *The International Journal of Tuberculosis and Lung Disease*, 8(3), pp. 286–298.

Chabala, C., Roucher, C., Mvalo, T., O'Brien, S., Hamoonga, R., Kapotwe, V., et al. (2024)

'Development of tuberculosis treatment decision algorithms in children below 5 years hospitalised with severe acute malnutrition in Zambia and Uganda: a prospective diagnostic cohort study', *eClinicalMedicine*, 73, p. 102688.

Chisti, M.J., Graham, S.M., Duke, T., Ahmed, T., Ashraf, H., Faruque, A.S.G., et al. (2014) 'A Prospective Study of the Prevalence of Tuberculosis and Bacteraemia in Bangladeshi Children with Severe Malnutrition and Pneumonia Including an Evaluation of Xpert MTB/RIF Assay', *PLoS ONE*, 9(4), p.e93776.

De Maayer, T. and Saloojee, H. (2011) 'Clinical outcomes of severe malnutrition in a high tuberculosis and HIV setting', *Archives of Disease in Childhood*, 96(6), pp. 560–564.

Fediani, Y., Samosir, C.V.M., Wulandari, A. and Eyoer, P.C. (2024) 'Chest Radiograph Accuracy in Diagnosing Pediatric Pulmonary Tuberculosis (PTB): A Systematic Review and Meta-Analysis', *Journal of Medicine and Health*, 6(1), pp. 10–20.

Girum, T., Kote, M., Tariku, B., Bekele, H. and Tsegaye, T. (2023) 'Incidence of tuberculosis and its predictors among under-five children with severe acute malnutrition in North Shoa, Amhara region, Ethiopia: a retrospective follow-up study', *Frontiers in Pediatrics*, 11, p. 1134822.

Graham, S.M., Grzemska, M. and Gie, R.P. (2022) 'The global challenge of childhood tuberculosis', *Paediatric Respiratory Reviews*, 41, pp. 38–43.

Heller, T., Griesel, M., Koen, N., Andronikou, S., Riphagen, J., van der Zalm, M., et al. (2023) 'Point-of-care lung ultrasound for the diagnosis of pulmonary tuberculosis in children', *The Lancet Global Health*, 11(4), pp. e502–e504.

Ide, L.E.Y. (2019) 'Prevalence of Tuberculosis among Children with Severe Acute Malnutrition at Ola during Children's Hospital in Freetown Sierra Leone', *Journal of Advances in Medicine and Medical Research*, 30(3), pp. 1–7.

Jaganath, D. and Mupere, E. (2012) 'Childhood Tuberculosis and Malnutrition', *Journal of Infectious Diseases*, 206(12), pp. 1809–1815.

Kim, W.S., Moon, W.K., Kim, I.O., Lee, H.J., Im, J.G. and Yeon, K.M. (2005) 'Pulmonary tuberculosis in infants: radiographic and CT findings', *American Journal of Roentgenology*, 184(3), pp. 1004–1010.

Kumar, L., Dhand, R., Singhi, N., Rao, K.L.N. and Kataria, S. (1990) 'Malnutrition and childhood tuberculosis', *The Indian Journal of Pediatrics*, 57(3), pp. 385–390.

Kumar, V., Singh, A. and Kumar, P. (2014) 'Profile of childhood tuberculosis in a tertiary care centre of North India', *International Journal of Contemporary Pediatrics*, 1(2), pp. 79–82.

LaCourse, S.M., Chester, A.A., Preidis, G.A., McCrary, L.M., Arscott-Mills, T., Kebaabetswe, L.P., et al. (2021) 'Tuberculosis in children with severe acute malnutrition', *Expert Review of Anti-infective Therapy*, 19(11), pp. 1367–1381.

LaCourse, S.M., Gondwe, E., Chester, A.A., Kali, M., Mwale, M., Chinyama, E., et al. (2015) 'Use of Xpert for the Diagnosis of Pulmonary Tuberculosis in Severely Malnourished Hospitalized Malawian Children', *The Pediatric Infectious Disease Journal*, 33(11), pp. 1200–1202.

Lavery, R., Goolam-Mahomed, A., Griesel, M. and van der Zalm, M. (2023) 'Diagnostic accuracy of chest ultrasound scan in the diagnosis of childhood tuberculosis', *PLoS ONE*, 18(6), p.e0287621.

Munthali, A., Sitali, L., Siziya, S. and Goma, F. (2017) 'Tuberculosis caseload in children with severe acute malnutrition related with high hospital based mortality in Lusaka, Zambia', *BMC Research Notes*, 10(1), p. 222.

Ors, F., Kim, E.Y., Lee, K.S. and Gamsu, G. (2005) 'Tuberculosis in adults: what's new?', *European Radiology*, 15(3), pp. 528–541.

Osorio, D.V., Munyangaju, I., Muhiwa, A., Nacarapa, E., Nhangave, A.V. and Ramos, J.M. (2021) 'Use of Urine Lipoarabinomannan Antigen Assay (TB-LAM) for Diagnosing Pulmonary Tuberculosis in Severely Malnourished Children in Mozambique', *Journal of Tropical Pediatrics*, 67(4), p.fmab066.

Osorio, M.B., Basnayake, T.L., Li, M.S.J., Tovar, M.A., Grandjean, L., Iwamoto, T., et al. (2015) 'Radiological findings in young children investigated for tuberculosis in Mozambique', *PLoS ONE*, 10(5), p.e0127323.

Padmapriyadarsini, C., Shobana, M., Lakshmi, M., Beena, E. and Swaminathan, S. (2019) 'Effect of malnutrition on radiographic findings and mycobacterial burden in pulmonary tuberculosis', *PLoS ONE*, 14(3), p.e0214011.

Patel, K.G., Pandya, C.B. and Chaudhari, S.S. (2025) 'Screening of tuberculosis in hospitalized severely acute malnourished children in a tertiary care hospital', *International Journal of Contemporary Pediatrics*, 12(10), pp. 1624–1628.

Pathak, L., Kumar, S., Kumar, M., Holloway, R., Scnu, T. and Kumar, A. (2014) 'Can Intensified Tuberculosis Case Finding Efforts at Nutrition Rehabilitation Centers Lead to Pediatric Case Detection in Bihar, India?', *Journal of Tuberculosis Research*, 2(3), pp. 104–110.

Priyadarshini, A., Das, S. and Mohakud, S. (2022) 'Miliary Tuberculosis in an Infant with Severe Acute Malnutrition: A Case Report', *International Journal of Advanced Medicine*, 9(4), pp. 589–591.

Reuter, A., Jenkins, H.E., Stillo, J., Garcia-Prats, A.J., Gie, R.P., Hesselning, A.C., et al. (2024) 'Advances and best practices in the prevention, diagnosis, and treatment of tuberculosis in children', *Antibiotics*, 13(6), p. 467.

Singh, A.R., Kumar, A., Shewade, H.D. and Dhingra, B. (2021) 'Poor adherence to TB diagnosis

guidelines among under-five children with severe acute malnutrition in central India: A missed window of opportunity?', *PLoS ONE*, 16(3), p.e0248192.

Starke, J.R. (2022) 'Diagnostic challenges in childhood pulmonary tuberculosis—Optimizing the clinical approach', *Pathogens*, 11(4), p. 382.

TB-Speed SAM Study Group (2023) 'Cost-effectiveness of treatment decision algorithms for paediatric tuberculosis diagnosis in children hospitalised with severe acute malnutrition: a model-based analysis', *eClinicalMedicine*, 61, p. 102047.

The Union (2020) *Child Malnutrition and TB*, [online]. Available at:(<https://theunion.org/Child-Malnutrition-and-TB>) (Accessed: 15 October 2024).

The Union (2022) *Diagnostic CXR Atlas for Tuberculosis in Children*. Paris: International Union Against Tuberculosis and Lung Disease.

Vonasek, B.J., Kumwenda, T., Gumulira, J., Nyirongo, M., Heller, T., Palmer, M., et al. (2024) 'Point-of-Care Ultrasound for Tuberculosis in Young Children with Severe Acute Malnutrition', *The Pediatric Infectious Disease Journal*, 43(2), pp. e65–e67.

Vonasek, B.J., Ness, T.E., Takwoingi, Y., Kay, A.W., van der Heijden, Y.F., Scripture, J.L., et al. (2021) 'Screening tests for active pulmonary tuberculosis in children', *Cochrane Database of Systematic Reviews*, (6).

World Health Organization (2015) *Guidelines on the management of tuberculosis in children*. 2nd edn. Geneva: WHO.

World Health Organization (2022) *WHO consolidated guidelines on tuberculosis. Module 5: Management of tuberculosis in children and adolescents*. Geneva: WHO.

World Health Organization (2023) *Global Tuberculosis Report 2023*. Geneva: WHO.