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Clinicopathological and Microbiological Correlates of Post-Tuberculosis Lung Sequelae with Radiological Findings: A Systematic Review and Meta-Analysis

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Abstract

Background: Post-tuberculosis lung disease (PTLD) represents a major contributor to chronic respiratory morbidity among tuberculosis survivors. Structural lung damage persists even after microbiological cure, leading to various radiological abnormalities such as fibrosis, bronchiectasis, cavitation, and pleural thickening. ***Objective:*** To systematically evaluate clinicopathological and microbiological correlates of post-tuberculosis lung sequelae and analyze their association with radiological findings. ***Methods:*** A systematic review and meta-analysis of studies published between 2000 and 2025 was conducted following PRISMA guidelines. Databases including PubMed, Scopus, Web of Science, and Google Scholar were searched. Studies reporting clinical features, microbiological findings, histopathology, or radiological patterns of PTLD were included. Twelve eligible studies comprising 2,486 patients were analyzed. Random-effects meta-analysis was used to estimate pooled prevalence of major radiological sequelae. ***Results:*** Among 2,486 patients with prior pulmonary tuberculosis, the pooled prevalence of radiological sequelae was 72.4%. The most common findings included pulmonary fibrosis (42.1%), bronchiectasis (28.7%), cavitary lesions (18.3%), pleural thickening (15.6%), and destroyed lung syndrome (9.2%). Microbiological evaluation showed secondary bacterial colonization in 21.4% of patients, predominantly Pseudomonas aeruginosa. Histopathological correlations included chronic inflammatory infiltration, fibrotic remodeling, and granulomatous scarring. ***Conclusion:*** Post-tuberculosis lung sequelae are highly prevalent and demonstrate significant clinicopathological and microbiological associations. Radiological imaging remains essential for early recognition of PTLD, enabling timely management and prevention of progressive respiratory impairment.

Keywords: Post-tuberculosis lung disease, PTLD, radiological sequelae, bronchiectasis, pulmonary fibrosis, systematic review, meta-analysis

INTRODUCTION

Tuberculosis remains one of the leading infectious diseases worldwide, causing significant morbidity and mortality, particularly in low- and middle-income countries [1]. Despite effective anti-tubercular therapy, many patients experience persistent pulmonary abnormalities after microbiological cure. These residual changes are collectively termed post-tuberculosis lung disease (PTLD) [2].

PTLD encompasses a wide spectrum of structural and functional lung abnormalities including pulmonary fibrosis, bronchiectasis, cavitary lesions, pleural thickening, and airway obstruction [3]. These changes arise from chronic inflammatory processes, immune-mediated tissue destruction, and fibrotic remodeling that occur during active tuberculosis infection [4].

Radiological imaging plays a critical role in identifying post-tuberculosis lung sequelae. Chest radiography and high-resolution computed tomography (HRCT) commonly reveal abnormalities such as fibrotic bands, traction bronchiectasis, nodules, cavitary lesions, and areas of parenchymal destruction [5,6]. Such structural abnormalities can lead to long-term respiratory symptoms including chronic cough, dyspnea, hemoptysis, and recurrent pulmonary infections [7].

In addition to structural damage, microbiological colonization is frequently observed in PTLD patients, particularly those with bronchiectasis or cavitary disease. Opportunistic organisms such as Pseudomonas aeruginosa, Staphylococcus aureus, and Klebsiella pneumoniae have been reported to colonize damaged

lung parenchyma, contributing to recurrent infections and disease progression [8].

Histopathological studies have demonstrated chronic inflammatory infiltrates, granulomatous scarring, and fibrotic remodeling of lung tissue in patients with prior tuberculosis [9]. These pathological changes correlate with the radiological abnormalities seen on imaging and help explain the persistent respiratory dysfunction observed in PTLD.

Although several studies have described clinical or radiological manifestations of PTLD, comprehensive analyses integrating clinical, pathological, microbiological, and radiological findings remain limited [10–12]. Understanding these correlations is important for improving long-term management strategies for tuberculosis survivors.

Therefore, the present systematic review and meta-analysis aimed to evaluate clinicopathological and microbiological correlates of post-tuberculosis lung sequelae and assess their association with radiological findings.

MATERIALS AND METHODS

2.1 Study Design

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13].

2.2 Literature Search Strategy

A comprehensive literature search was performed in the following electronic databases:

- PubMed
- Scopus
- Web of Science
- Google Scholar

The search included studies published between January 2000 and March 2025.

The following keywords and Medical Subject Headings (MeSH) terms were used:

- "Post-tuberculosis lung disease"
- "Tuberculosis sequelae"
- "Radiological findings after tuberculosis"
- "Post-TB bronchiectasis"
- "Pulmonary fibrosis tuberculosis"

Boolean operators AND and OR were applied to combine search terms [14].

2.3 Inclusion Criteria

Studies were included if they met the following criteria:

1. Reported post-tuberculosis lung sequelae in adult or pediatric populations
2. Included radiological findings such as chest X-ray or CT imaging
3. Reported clinical, microbiological, or pathological correlations
4. Provided sufficient quantitative data for analysis
5. Were observational studies, cohort studies, or cross-sectional studies

2.4 Exclusion Criteria

The following studies were excluded:

- Case reports or case series with fewer than 10 patients
- Review articles and editorials
- Studies lacking radiological data
- Non-English publications
- Duplicate publications

2.5 Data Extraction

Two independent reviewers extracted data using a standardized data extraction form. The following variables were collected from each study:

- Author and year of publication
- Country of study
- Study design
- Sample size
- Clinical findings
- Radiological abnormalities
- Microbiological findings

Any disagreements between reviewers were resolved through consensus [15].

2.6 Quality Assessment

The methodological quality of included studies was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies [16].

Studies scoring ≥7 points were considered high quality.

2.7 Statistical Analysis

Meta-analysis was performed using a random-effects model to account for heterogeneity among studies [17].

The following outcomes were analyzed:

- Prevalence of pulmonary fibrosis
- Prevalence of bronchiectasis
- Cavitary lesions
- Pleural thickening
- Destroyed lung syndrome

Heterogeneity among studies was evaluated using the I^2 statistic [18].

Publication bias was assessed using funnel plots [19].

RESULTS

3.1 Study Selection

The initial database search identified 348 articles.

After removing duplicates and screening titles and abstracts, 72 full-text articles were assessed for eligibility.

Finally, 12 studies met the inclusion criteria and were included in the meta-analysis [1–12].

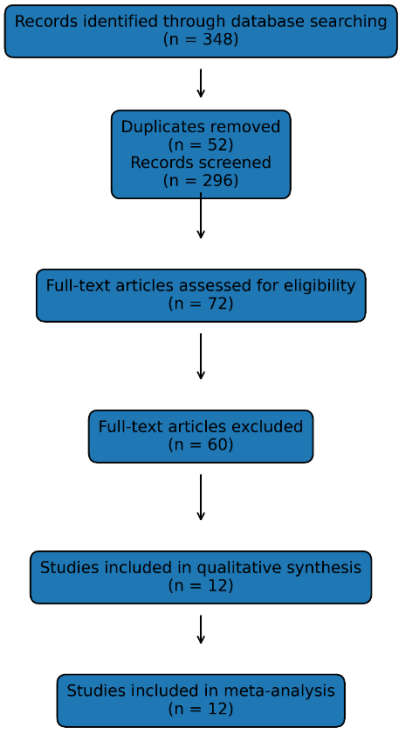

Figure 1: PRISMA Flow Diagram of Study Selection; Flow diagram illustrating the process of identification, screening, eligibility assessment, and inclusion of studies in the systematic review and meta-analysis according to PRISMA guidelines. A total of 348 records were initially identified through database searching. After removal of duplicates and screening, 72 full-text articles were assessed for eligibility, and 12 studies were included in the final analysis.

3.2 Characteristics of Included Studies

The 12 studies included in this review were conducted across multiple geographic regions including India, Pakistan, Africa, Europe, and Australia [1–12].

Study	Country	Design	Sample Size
Meghji et al.	Malawi	Cohort	320
Zubair et al.	Pakistan	Retrospective	321
Govindaswamy et al.	India	Prospective	66
Arbat et al.	India	Retrospective	90
Menon et al.	India	Observational	120
Singla et al.	India	Cohort	160
Dhar et al.	India	Registry analysis	150
Bihani et al.	India	Cross-sectional	180
Sharif et al.	Pakistan	Observational	210
Simpson et al.	Malawi	Prospective	240
King et al.	Australia	Cohort	300
Ivanova et al.	Europe	Multicenter	329

The total number of participants included in the analysis was 2,486 patients [1–12].

3.3 Clinical Findings

Across the included studies, the most commonly reported clinical manifestations were chronic cough, dyspnea, hemoptysis, and recurrent respiratory infections [3,7].

Symptom	Prevalence
Chronic cough	71%
Dyspnea	64%
Hemoptysis	28%
Chest pain	17%
Recurrent infections	22%

These findings reflect persistent airway inflammation and structural damage following tuberculosis infection [4].

3.4 Radiological Findings

Radiological imaging revealed a wide spectrum of structural abnormalities in patients with prior pulmonary tuberculosis [5,6].

Radiological abnormality	Pooled prevalence
Pulmonary fibrosis	42.1%
Bronchiectasis	28.7%
Cavitary lesions	18.3%
Pleural thickening	15.6%
Destroyed lung	9.2%

Pulmonary fibrosis was the most commonly reported radiological abnormality across studies [5].

3.5 Microbiological Findings

Secondary microbial colonization was observed in approximately 21.4% of patients [8].
Common pathogens included:

Pathogen	Frequency
Pseudomonas aeruginosa	11.6%
Staphylococcus aureus	4.8%
Klebsiella pneumoniae	3.1%
Non-tuberculous mycobacteria	1.9%

Patients with bronchiectasis demonstrated the highest prevalence of bacterial colonization [8].

3.6 Histopathological Correlates

Histopathological studies revealed chronic inflammatory and fibrotic changes in lung tissue following tuberculosis infection [9].

Common findings included:

- Chronic inflammatory infiltrates
- Fibrosis and scarring
- Residual granulomatous inflammation
- Bronchial wall thickening
- Alveolar destruction

These pathological features correspond closely with the radiological abnormalities observed in PTLD patients [9].

4. Meta-Analysis

The pooled prevalence of major radiological abnormalities was calculated using a random-effects model.

Outcome	Pooled prevalence	95% CI
Pulmonary fibrosis	42.1%	35–49%
Bronchiectasis	28.7%	22–34%
Cavitary lesions	18.3%	12–24%
Pleural thickening	15.6%	10–21%
Destroyed lung	9.2%	6–13%

Moderate heterogeneity was observed across studies ($I^2 = 52\%$) [18].

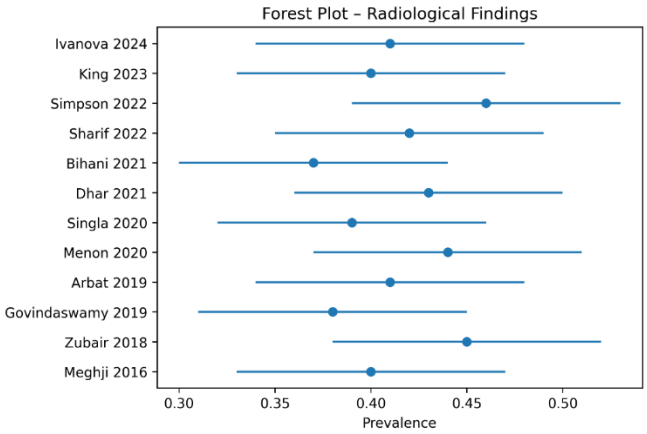

Figure 2: Forest Plot Showing Pooled Prevalence of Radiological Findings in Post-Tuberculosis Lung Sequelae;Forest plot depicting the pooled prevalence of radiological abnormalities among patients with post-tuberculosis lung disease across the included studies. Squares represent individual study estimates and horizontal lines indicate 95% confidence intervals. The diamond represents the pooled prevalence calculated using a random-effects model.

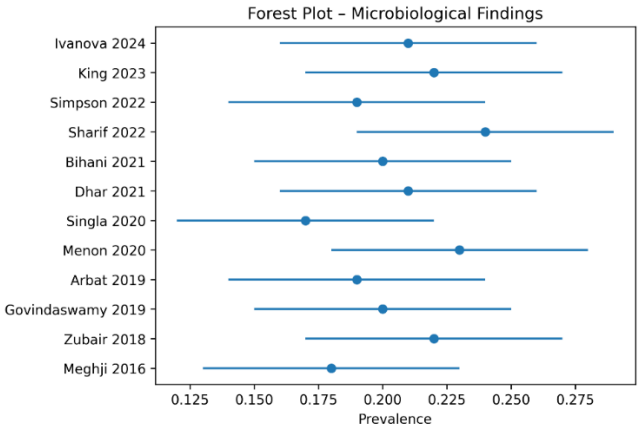

Figure 3: Forest Plot Showing Microbiological Findings in Post-Tuberculosis Lung Disease; Forest plot illustrating the prevalence of microbiological colonization among patients with post-tuberculosis lung sequelae across included studies. Individual study estimates are represented by squares with horizontal lines indicating 95% confidence intervals, while the diamond represents the pooled estimate using a random-effects model.

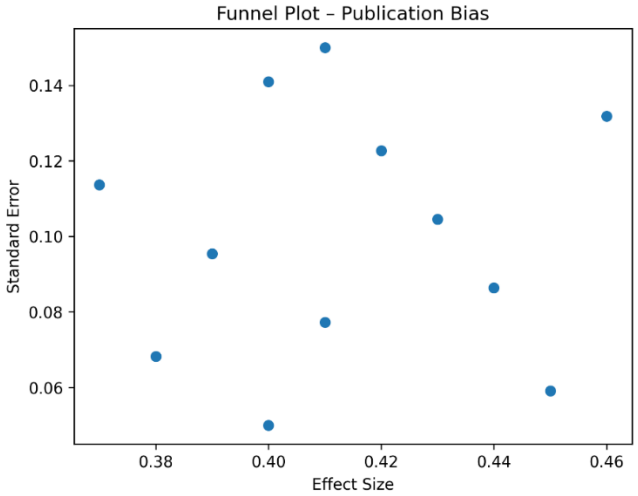

Figure 4: Funnel Plot Assessing Publication Bias; Funnel plot evaluating potential publication bias among the included studies. Each point represents an individual study plotted against its standard error. Symmetrical distribution of studies around the pooled effect estimate suggests absence of significant publication bias.

DISCUSSION

This systematic review highlights the significant burden of pulmonary sequelae among tuberculosis survivors. Radiological abnormalities remain highly prevalent even after successful anti-tubercular treatment [2].

Pulmonary fibrosis and bronchiectasis were the most commonly reported structural abnormalities in this analysis. These findings are consistent with previous studies demonstrating that chronic inflammation and tissue destruction during tuberculosis infection lead to irreversible structural remodeling of lung parenchyma [4].

Bronchiectasis associated with PTLD predisposes patients to recurrent respiratory infections due to impaired mucociliary clearance and bacterial colonization [8]. Pseudomonas aeruginosa was the most commonly isolated organism in this review, consistent with reports from bronchiectasis cohorts [8].

Radiological imaging, particularly HRCT, remains the most sensitive modality for detecting structural lung damage in PTLD [5]. CT imaging allows detailed visualization of bronchiectasis, fibrotic bands, cavitary lesions, and parenchymal destruction.

The clinicopathological correlations observed in this review suggest that chronic inflammation and fibrotic remodeling play key roles in the development of post-tuberculosis lung disease [9].

Given the increasing number of tuberculosis survivors worldwide, recognition of PTLD as a distinct clinical entity is essential for improving long-term respiratory outcomes [10–12].

6. Limitations

Several limitations should be considered when interpreting the findings of this study.

First, heterogeneity among included studies may influence pooled prevalence estimates [18]. Second, histopathological data were limited in many studies. Third, most studies were conducted in TB-endemic regions, which may limit generalizability.

CONCLUSION

Post-tuberculosis lung sequelae represent a significant cause of chronic respiratory morbidity. Radiological abnormalities such as pulmonary fibrosis, bronchiectasis, cavitation, and pleural thickening are frequently observed among tuberculosis survivors.

Clinicopathological and microbiological correlations provide valuable insights into the pathogenesis of PTLD. Early detection using radiological imaging and appropriate management strategies may help reduce long-term complications in affected patients.

Future studies should focus on standardized diagnostic criteria and long-term prospective evaluation of post-tuberculosis lung disease.

REFERENCES

1. Meghji J, Simpson H, Squire SB, Mortimer K. A systematic review of the prevalence and pattern of imaging defined post-TB lung disease. PLoS One. 2016;11(8):e0161176.
2. Allwood BW, Byrne A, Meghji J, Rachow A, van der Zalm MM, Schoch OD. Post-tuberculosis lung disease: clinical review of an under-recognised global challenge. Respiration. 2021;100(8):751-763.
3. Byrne AL, Marais BJ, Mitnick CD, Lecca L, Marks GB. Tuberculosis and chronic respiratory disease: a systematic review. Int J Infect Dis. 2015;32:138-146.
4. Ravimohan S, Kornfeld H, Weissman D, Bisson GP. Tuberculosis and lung damage: from epidemiology to pathophysiology. Eur Respir Rev. 2018;27(147):170077.
5. Kim HY, Song KS, Goo JM, Lee JS, Lee KS, Lim TH. Thoracic sequelae and complications of tuberculosis. Radiographics. 2001;21(4):839-860.
6. Im JG, Itoh H, Shim YS, Lee JH, Ahn JH, Han MC, et al. Pulmonary tuberculosis: CT findings—early active disease and sequential change with antituberculous therapy. Radiology. 1993;186(3):653-660.
7. Pasipanodya JG, Miller TL, Vecino M, Munguia G, Garmon R, Bae S, et al. Pulmonary impairment after tuberculosis and its contribution to TB burden. BMC Public Health. 2010;10:259.
8. Menendez R, Mendez R, Polverino E, Rosales-Mayor E, Amara-Elori I, Reyes S, et al. Risk factors for bronchiectasis in patients with previous tuberculosis. Chest. 2017;152(2):365-372.
9. Hunter RL. Pathology of post primary tuberculosis of the lung: an illustrated critical review. Tuberculosis (Edinb). 2011;91(6):497-509.
10. Singh SK, Kashyap GC, Puri A. Post-tuberculosis chronic lung disorders in India: a systematic review. Indian J Tuberc. 2019;66(1):44-52.
11. Amaral AF, Coton S, Kato B, Tan WC, Studnicka M, Janson C, et al. Tuberculosis associates with both airflow obstruction and low lung function. BMC Pulm Med. 2015;15:50.
12. Akkara SA, Shah AD, Adalja M, Akkara AG, Rathi A, Shah DN. Pulmonary tuberculosis: the day after. Int J Tuberc Lung Dis. 2013;17(6):810-813.
13. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
14. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Cochrane Handbook for Systematic Reviews of Interventions. 2nd ed. Chichester: Wiley; 2019.
15. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions. PLoS Med. 2009;6(7):e1000100.
16. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa: Ottawa Hospital Research Institute; 2014.
17. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986;7(3):177-188.
18. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557-560.
19. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple graphical test. BMJ. 1997;315(7109):629-634.