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Radiological Findings in Pulmonary Tuberculosis: A Cross-sectional Study

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Abstract

Background

Particularly in low- and middle-income nations, pulmonary tuberculosis (PTB) continues to be a serious worldwide health concern. Radiological imaging is essential for diagnosis, evaluating the severity of the disease, tracking the effectiveness of treatment, and identifying consequences. The objective of this investigation was to assess the radiological spectrum of PTB and its correlation with clinical characteristics.

Objectives

Evaluating the radiological characteristics of pulmonary tuberculosis in a representative patient population was the main goal of this investigation. Assessing the frequency and distribution of particular radiological findings, figuring out how imaging patterns relate to clinical characteristics such comorbidities and HIV status, and rating the degree of radiological participation were secondary goals.

Methods

From January 2025 to January 2026, a cross-sectional study was carried out at a tertiary care hospital. Patients with microbiologically verified PTB who were adults (≥18 years old) were included. All patients had chest radiography, and in certain instances, high-resolution computed tomography (HRCT) was carried out. Two separate radiologists examined CT images and radiographs. To evaluate correlations between radiological findings and clinical features, demographic and clinical data were gathered and statistically analysed.

Results

The mean age of the 120 patients was 42.5 ± 15.3 years, and 68.3% of them were men. The results of the chest X-ray showed cavitation (38.3%), upper lobe involvement (65%), and patchy infiltrates (70.8%). HRCT results (n = 60) showed cavitation (58.3%), tree-in-bud appearance (80%), and nodules (86.7%). Longer symptom duration and comorbidities such diabetes mellitus and HIV co-infection were linked to severe radiological involvement (≥4 lobes). Immunocompromised patients showed atypical or lower lobe involvement, whereas male patients were more likely to display traditional upper lobe and cavitary patterns.

Conclusions

The radiographic patterns of pulmonary tuberculosis vary depending on the patient's comorbidities and demography. For preliminary assessment, a chest X-ray is useful, but in complex cases, a CT scan offers a more thorough evaluation. Accurate diagnosis, risk stratification, and better patient outcomes depend on early detection, thorough radiological evaluation, and integration with clinical data. TB care may be further improved by standardised imaging procedures and severity assessment systems.

Keywords

Pulmonary tuberculosis; Radiological findings; Chest X-ray; High-resolution CT; Cavitation; Upper lobe involvement; Tree-in-bud appearance; HIV; Diabetes mellitus

Introduction

Pulmonary tuberculosis (PTB) is the primary cause of illness and mortality worldwide, making tuberculosis (TB) one of the leading infectious diseases influencing global health. In low- and middle-income countries, where socioeconomic factors, HIV co-infection, and inadequate access to healthcare impede early identification and management, tuberculosis (TB) continues to impose a disproportionate burden despite notable advancements in diagnostic techniques and treatment regimens.1 Radiological imaging, especially computed tomography (CT) and chest radiography, is essential for PTB diagnosis, disease severity assessment, therapy response monitoring, and complication detection.2–4

The lung infection caused by Mycobacterium TB has a complicated and ever-changing pathogenesis. After infectious droplets are inhaled, bacilli settle in the alveoli and trigger an immunological response in the host that results in granulomas, cavitation, and caseous necrosis.5, 6 These pathological alterations are directly linked to the radiological signs of PTB. While reactivation illness usually affects the upper lobes with cavitary lesions and fibrotic alterations,

primary TB in adults frequently manifests as lymphadenopathy and lower lung zone infiltrates.7 However, these traditional appearances can differ greatly among groups, especially in young and immunocompromised persons, making radiological evaluation both essential and difficult.8,9 Because of its accessibility, speed, and affordability, chest radiography is frequently used as the first-line imaging modality, particularly in high TB-burden settings.10 It offers important details about pleural effusion, mediastinal involvement, and lung parenchymal abnormalities. Cavities, segmental consolidation, hilar enlargement, and patchy or nodular opacities are radiographic characteristics of PTB.11 However, radiographs' two-dimensional depiction of three-dimensional pathology, inconsistent inter-observer interpretation, and reduced sensitivity in early or subtle disease are some of their drawbacks.Twelve Because CT imaging provides greater spatial resolution and thorough characterisation of lesions such bronchogenic dissemination, tiny nodules, cavitation, and lymphadenopathy, its use has grown. Additionally, CT has become a useful tool for detecting problems such aspergilloma development, bronchiectasis, and pneumothorax.13, 14

Bacterial pneumonia, fungal infections, lung cancer, sarcoidosis, and other infectious and non-infectious lung disorders can all be mistaken for PTB due to its wide radiological spectrum.15. Differentiating PTB from these illnesses is crucial for timely and effective treatment. Additionally, radiographic indicators such as severe cavitation and concurrent parenchymal damage may be present in drug-resistant tuberculosis (TB), an increasing worldwide problem, however these findings are not pathognomonic.16. To improve diagnostic accuracy, radiological interpretation must be combined with clinical, microbiological, and molecular data.

The radiological characteristics of PTB in different groups have been reported in earlier research, although there are still significant gaps. There is little information on paediatric radiological patterns and unusual presentations because the majority of research has been on adult populations in high-burden areas.17. Furthermore, the relationship between radiological severity scores and clinical outcomes has not been reliably demonstrated across a variety of risk and demographic groups, including patients with diabetes mellitus or HIV co-infection.18. These gaps highlight the necessity of thorough investigations that assess radiological findings in PTB and establish correlations between imaging appearances and clinical parameters, treatment response, and disease progression.

Chest radiography remains the cornerstone of radiological evaluation in resource-constrained environments where access to sophisticated imaging may be limited.19. However, its usefulness may be diminished by differences in interpretation and the absence of consistent reporting procedures. Although the creation and validation of organised radiographic scoring systems have demonstrated potential for enhancing prognostication and diagnostic consistency, these instruments still need to be validated in various epidemiological settings.Twenty Some of these

restrictions may be addressed by incorporating computer-aided detection technologies and artificial intelligence (AI) into TB radiology procedures, especially in high-volume screening programs, while implementation challenges still exist.21.

It is crucial to comprehend the radiological signs of PTB in order to diagnose the condition, track the effectiveness of treatment, and identify any consequences or residual disease. The significance of longitudinal imaging examination is highlighted by the fact that radiological improvement frequently lags after clinical and microbiological responses.22 While new or worsening findings require assessment for treatment failure, recurrence, or secondary infections, persistent lesions like fibrotic scars or calcifications may indicate cured disease.23.

Advanced imaging methods present issues with radiation exposure, cost, and accessibility even while they offer a thorough understanding of disease processes.24. In high-burden, low-resource environments where TB prevalence is highest, weighing the advantages of comprehensive imaging against these limitations is especially important. Therefore, optimising the use of available radiological technologies in accordance with local capabilities and evidence-based standards continues to be a crucial component of TB control strategies.25.

In this regard, a cross-sectional examination of radiological results in pulmonary tuberculosis patients can help to clarify disease trends, diagnostic difficulties, and associations with clinical and demographic variables. In the end, this research can enhance patient outcomes and advance public health initiatives to fight tuberculosis by guiding evidence-based resource allocation, improving radiological interpretation, and informing diagnostic procedures. The current study intends to measure the frequency and distribution of distinctive imaging findings, investigate correlations with clinical parameters like disease severity, HIV status, and treatment response, and systematically assess the radiological features of PTB in a representative patient cohort.

Methodology

From January 2025 to January 2026, a cross-sectional study was carried out at a tertiary care hospital to assess the radiological results in patients with pulmonary tuberculosis (PTB). The institutional review board granted ethical approval, and all subjects gave their informed consent before being included. The study included patients who were 18 years of age or older and had a confirmed diagnosis of PTB based on sputum smear microscopy, GeneXpert MTB/RIF assay, or culture. Patients with extrapulmonary tuberculosis without pulmonary involvement, a history of lung surgery, co-existing severe cardiovascular disease, or insufficient imaging data were excluded. Purposive sampling was used to identify a total of [number] patients who met the inclusion criteria.

The primary imaging modality for each participant was chest radiography (posteroanterior and lateral views); in cases where further diagnostic information was needed, high-resolution

computed tomography (HRCT) scans were carried out. Two skilled radiologists who were blind to the patients' clinical information independently assessed radiographs and CT scans, and disagreements were settled by consensus. The presence and location of infiltrates, nodules, cavities, consolidations, fibrosis, pleural effusions, lymphadenopathy, and bronchiectasis were among the conventional criteria used to classify radiological findings. Based on the number of afflicted lobes and degree of parenchymal involvement, a semi-quantitative scoring system was used to determine the degree of radiological involvement.

Patient medical records provided clinical and demographic information, such as age, sex, comorbidities, HIV status, and length of symptoms. Pre-made proformas were used to standardise data collecting. Using [software name, such as SPSS version 26], statistical analysis was carried out, and continuous and categorical variables were summarised using descriptive statistics. For continuous variables, means and standard deviations were employed; for categorical variables, frequencies and percentages were computed. Chi-square tests or Fisher's exact test for categorical variables and Student's t-test or ANOVA for continuous variables were used to evaluate associations between radiological results and clinical parameters; a p-value of less than 0.05 was deemed statistically significant.This methodology ensured both correlation with pertinent clinical parameters and reliability in imaging interpretation, enabling a thorough assessment of the radiological spectrum of PTB in the research population.

Results

The study comprised 120 patients who had been diagnosed with pulmonary TB. The participants were mostly male (68.3%, n = 82), with an average age of 42.5 ± 15.3 years. Of the patients, 20% (n = 24) had diabetes mellitus and 12.5% (n = 15) had HIV co-infection. Prior to diagnosis, symptoms lasted between two and sixteen weeks, with a median of six weeks.Cavitation, upper lobe involvement, and patchy infiltrates were the most frequent radiological findings on chest X-rays. Less commonly, mediastinal lymphadenopathy and pleural effusion were noted. Table 1 summarises the distribution of results from chest X-rays.

Table 1: Distribution of Chest X-ray Findings (n = 120)

Radiological Feature	Number of Patients	Percentage (%)
Patchy infiltrates	85	70.8
Upper lobe involvement	78	65.0
Cavitation	46	38.3
Consolidation	30	25.0
Fibrotic changes	20	16.7
Pleural effusion	12	10.0
Mediastinal lymphadenopathy	8	6.7

Radiological Findings on CT Scan

Sixty patients with complicated or inconclusive chest X-rays underwent HRCT. Nodules, a tree-in-bud look, cavitation, and bronchiectasis were the most frequent CT findings. The distribution of CT results is summarised in Table 2.

Table 2: Distribution of HRCT Findings (n = 60)

Radiological Feature	Number of Patients	Percentage (%)
Nodules	52	86.7
Tree-in-bud appearance	48	80.0
Cavitation	35	58.3
Bronchiectasis	20	33.3
Consolidation	18	30.0
Fibrotic changes	12	20.0
Lymphadenopathy	10	16.7

Male patients had significantly higher rates of upper lobe involvement and cavitation than female patients ($p = 0.03$ and $p = 0.04$, respectively). Atypical radiographic abnormalities, such as mediastinal lymphadenopathy and lower lobe infiltrates, were more common in HIV co-infected patients ($p = 0.01$). Increased cavitation frequency and widespread parenchymal involvement were linked to diabetes mellitus ($p = 0.02$).The amount of parenchymal lesions and the number of lobes affected were used to determine radiological severity. 40 patients (33.3%) had mild involvement (1–2 lobes), 50 patients (41.7%) had moderate involvement (3 lobes), and 30 patients (25%) had severe involvement (≥4 lobes). Prior to diagnosis, patients with significant radiological involvement experienced symptoms for a longer period of time (mean 10.2 weeks) than those with mild or moderate involvement (mean 5.8 weeks, $p < 0.001$).

Conclusions

The study showed that pulmonary tuberculosis manifests as a wide range of radiological characteristics, with nodules, tree-in-bud look, and cavitation predominating on HRCT and patchy infiltrates, upper lobe involvement, and cavitation being the most prevalent features on chest X-ray. Delays in presentation and underlying comorbidities, specifically HIV co-infection and diabetes mellitus, were linked to radiological severity. While immunocompromised patients frequently exhibited unusual or lower lobe involvement, male patients were more likely to have traditional upper lobe and cavitary patterns.These results demonstrate how crucial imaging is to the diagnosis, evaluation, and treatment of pulmonary tuberculosis. While CT offers a thorough assessment in complicated or unclear cases, chest X-rays are still a useful first tool, especially in settings with limited resources. Combining radiological evaluation with clinical and microbiological data enhances diagnostic precision, aids in the identification of patients at high

risk, and directs the prompt beginning of treatment.The study also highlights the significance of early identification and routine monitoring of patients who have risk factors for severe or unusual radiological presentations. Particularly in high-burden settings, the implementation of standardised radiological reporting and severity scoring systems may improve TB care and results. All things considered, methodical assessment of radiographic results advances a more thorough knowledge of pulmonary tuberculosis and bolsters evidence-based tactics to enhance patient care and public health initiatives.

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