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Role of HRCT in Early Diagnosis and Management of Pulmonary Tuberculosis

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ABSTRACT

Pulmonary tuberculosis (TB) is a major global health issue, especially in low-and middle-income countries. Early diagnosis is crucial to control TB and reduce morbidity and mortality. High-Resolution Computed Tomography (HRCT) has emerged as a superior imaging tool compared to chest radiography, offering detailed visualization of lung abnormalities, such as cavitation, consolidation and the "tree-in-bud" pattern. This study evaluates the role of HRCT in the early diagnosis and management of pulmonary TB. A prospective observational study was conducted on 40 patients with suspected pulmonary TB at Sree Mookambika Institute of Medical Sciences between November 2023 and April 2024. HRCT scans were performed on all patients after suggestive or inconclusive chest radiographs. Patients with previous TB history were excluded. Key HRCT findings, including consolidation, cavitation, tree-in-bud appearance and fibrosis, were analyzed. Clinical data, sputum results and treatment decisions based on HRCT findings were recorded. Disease status (active or inactive TB) was classified based on HRCT. The majority of patients (37.5%) were between 31-50 years of age, with males accounting for 67.5%. HRCT revealed the tree-in-bud appearance in 65% of cases, followed by consolidation (50%) and cavitation (45%). Active TB was diagnosed in 75% of cases based on HRCT findings, leading to the initiation of anti-TB therapy. HRCT influenced treatment modifications in 30% of patients and guided surgical referrals in 7.5%. Clinical improvement was noted in 80% of patients following HRCT-guided management. HRCT plays a crucial role in the early diagnosis and management of pulmonary TB. It is particularly useful in detecting subtle lung changes, differentiating between active and inactive TB and guiding treatment decisions. Its use can improve clinical outcomes, especially in resource-limited settings where accurate diagnosis is essential for timely intervention.

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Key Words

Pulmonary tuberculosis, high -resolution computed tomography (HRCT), early diagnosis, tree-in-bud appearance, cavitation, bronchogenic spread, disease management, active vs inactive TB, radiological findings, tertiary care settings

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INTRODUCTION

Pulmonary tuberculosis (TB) remains a significant public health concern worldwide, particularly in low- and middle-income countries. It is caused by Mycobacterium tuberculosis, which primarily affects the lungs, leading to a wide range of clinical manifestations. Despite advances in diagnostic tools and treatment strategies, TB continues to pose challenges due to its complex clinical presentation, increasing drug resistance and its association with comorbidities such as HIV and diabetes mellitus. Early and accurate diagnosis is crucial for controlling the spread of TB and improving patient outcomes[1]. High-Resolution Computed Tomography (HRCT) has emerged as a pivotal imaging modality in the evaluation of pulmonary TB. HRCT provides detailed visualization of lung parenchyma changes and has shown higher sensitivity compared to traditional chest radiography in detecting early and subtle findings, such as cavitation, consolidation and the characteristic "tree-in-bud" pattern, which signifies bronchogenic spread. HRCT also helps in assessing disease severity, guiding management decisions and predicting patient outcomes[2]. Globally, an estimated 10.6 million people were diagnosed with TB in 2021, with approximately 1.6 million deaths, making it one of the top infectious causes of death worldwide .Burden of TB is seen in countries such as India, China, Indonesia and South Africa . India united for 26% of the global TB cases in 2021[3]. While the World Health Organization (WHO) has set a target to eliminate TB by 2030 under the Sustainable Development Goals (SDGs), the emergence of drug-resistant TB strains and the COVID-19 pandemic have exacerbated the global TB control efforts[4,5]. Several studies have investigated the role of HRCT in diagnosing and managing pulmonary TB. According to a study by Sharma[6], HRCT is superior to chest radiography in identifying early TB lesions, particularly in immunocompromised patients. Furthermore, a Mizuki[7] demonstrated that HRCT findings, such as cavitation and "tree-in-bud" appearance, strongly correlate with disease severity and the extent of pulmonary involvement. Another study by Arun[8] revealed HRCT could detect subclinical TB cases that might be missed on sputum smear microscopy and radiographs, particularly in patients with negative sputum tests . HRCT has thus become an indispensable tool in the diagnosis of TB, particularly in challenging cases, such as smear-negative or extra pulmonary TB.

Justification: Despite the wealth of data supporting the role of HRCT in diagnosing pulmonary TB, there is a need for more region-specific studies to evaluate its utility in different populations, given the variable clinical and radiological presentations of TB across demographic groups. In settings like India, where the burden of TB is particularly high, it is crucial to understand the radiological patterns seen on HRCT and their impact on clinical decision-making and outcomes. This study seeks to assess the HRCT findings in a cohort of patients with pulmonary TB in a tertiary care setting and to analyze the influence of these findings on disease management and outcomes. By doing so, it will contribute to the growing body of evidence that supports the use of HRCT as a key diagnostic and prognostic tool in TB management, particularly in resource-limited settings.

Aims and Objectives:

Aim of the Study:

- To evaluate the role of High- Resolution Computed Tomography (HRCT) in diagnosing pulmonary tuberculosis, distinguishing between active and inactive disease and assessing its impact on disease management.

Objectives:

- To assess the characteristic HRCT findings in patients with pulmonary tuberculosis, including consolidation, cavitation, tree-in-bud appearance and bronchogenic spread.
- To evaluate the ability of HRCT to differentiate between active and inactive pulmonary tuberculosis for early diagnosis and treatment initiation.
- To determine the impact of HRCT findings on clinical management decisions, such as initiating anti-TB therapy, modifying treatment regimens and planning surgical interventions.

MATERIALS AND METHODS

Study Design: This was a prospective observational study conducted in the Department of Radiology and Pulmonary Medicine at Sree Mookambika Institute of Medical Sciences from November 2023 to April 2024. The study aimed to evaluate the role of high-resolution computed tomography (HRCT) in diagnosing pulmonary tuberculosis (TB), differentiating between active and inactive disease and its impact on clinical management decisions.

Study Population: A total of 40 patients, aged 18 and above, presenting with clinical suspicion of pulmonary tuberculosis (e.g., chronic cough, fever, weight loss, hemoptysis) were included in the study. The patients were referred for HRCT following inconclusive or suggestive chest radiography findings. Patients with a prior history of treated pulmonary TB were excluded.

Inclusion Criteria:

- Patients with clinical symptoms suggestive of pulmonary TB.
- Patients with abnormal or inconclusive chest X-ray findings.
- Patients with a positive sputum smear or culture for Mycobacterium tuberculosis (where available).

Exclusion Criteria:

- Patients with a known history of previously treated pulmonary TB.
- Patients with other known lung diseases (e.g., lung cancer, interstitial lung disease).
- Patients who were unable to undergo HRCT due to clinical instability or contraindications (e.g., pregnancy).

Imaging Modality: HRCT scans were performed using a SIEMENS gotop 384 multidetector computed tomography (MDCT) scanner. The following technical parameters were used for image acquisition:

- **Slice Thickness:** 1mm.
- **Reconstruction Interval:** 1mm.
- **Scan Parameters**: 120 kVp, 160 mAs
- **Patient Position**: Supine.
- **Breath-Hold Technique:** Used for all scans to minimize respiratory motion artifacts.

Images were reconstructed using a high-resolution algorithm and multi planar reconstructions were performed in the coronal and sagittal planes for a detailed assessment.

HRCT Interpretation: All HRCT scans were independently reviewed by two experienced radiologists, each with <10 years of experience in thoracic imaging. Discrepancies between interpretations were resolved by consensus. The following features were specifically assessed and recorded:

Presence and extent of lung consolidation.

- Cavitary lesions.
- Tree-in-bud appearance (centrilobular nodules).
- Bronchogenic spread.
- Miliary nodules.
- Lymphadenopathy (mediastinal, hilar).
- Fibrosis or scarring indicative of previous infection.
- Pleural effusion and other complications such as pneumothorax.

Based on HRCT findings, the disease was classified into:

- Active TB (suggesting ongoing infection).
- Inactive TB (fibrotic or scarring changes without signs of active infection).
- Indeterminate (requiring further testing).

Data Collection: Clinical data, including age, sex, symptoms, comorbidities (such as diabetes, HIV status) and sputum smear results, were collected. The HRCT findings were correlated with clinical data and microbiological confirmation (where available). The management decisions were recorded based on HRCT findings, including initiation of anti-TB therapy, modification of treatment regimens, and surgical referrals.

Outcome Measures: The primary outcome was the classification of disease status (active vs. inactive) based on HRCT findings. Secondary outcomes included:

- The correlation of HRCT findings with microbiological and clinical diagnosis.
- The impact of HRCT findings on patient management, including treatment modifications and referral for surgical intervention.
- Patient outcomes following HRCT-guided management, including clinical improvement, treatment failure, or relapse.

Statistical Analysis: Descriptive statistics were used to summarize patient demographics and HRCT findings. Categorical variables were expressed as frequencies and percentages, while continuous variables were expressed as means±standard deviation. The association between HRCT findings and microbiological confirmation was analyzed using the chi-square test or Fisher's exact test. A p-value of <0.05 was considered statistically significant. All analyses were performed using SPSS software version 25.0 (IBM Corp, Armonk, NY, USA).

RESULTS AND DISCUSSIONS

Table 1: Patient Demographics and Clinical Characteristics

Characteristic	Number of Patients (n = 40)	Percentage (%)
Age Group (years)		
18-30	7	17.5
31-50	15	37.5
51-70	11	27.5
>70	7	17.5
Gender		
Male	27	67.5
Female	13	32.5
Comorbidities		
Diabetes Mellitus	8	20.0
HIV Infection	5	12.5
Chronic Obstructive Pulmonary		
Disease (COPD)	3	7.5
Clinical Presentation		
Cough	30	75.0
Fever	23	57.5
Weight Loss	20	50.0
Hemoptysis	7	17.5

This table outlines the demographic and clinical characteristics of 40 patients with pulmonary tuberculosis. Most patients (37.5%) were in the 31-50 years age group and males (67.5%) were more affected

than females. Diabetes mellitus (20%) was the most common comorbidity, followed by HIV infection (12.5%). The predominant clinical symptoms included cough (75%), fever (57.5%) and weight loss (50%).

Table 2: HRCT Findings in Pulmonary Tuberculosis

HRCT Feature	Number of Patients (n=40)	Percentage (%)
Consolidation	20	50.0
Cavitation	18	45.0
Tree-in-bud appearance	26	65.0
Miliary pattern	10	25.0
Bronchogenic spread	13	32.5
Pleural effusion	8	20.0
Lymphadenopathy	12	30.0
Fibrosis/Scarring	17	42.5

(Table 2) illustrates the HRCT findings in 40 patients. The "tree-in-bud" appearance was the most common HRCT feature (65%), followed by consolidation (50%) and cavitation (45%). Bronchogenic spread was observed in 32.5% of cases, while miliary pattern was noted in 25%. Pleural effusion and lymphadenopathy were present in 20% and 30% of patients, respectively, with fibrosis/scarring occurring in 42.5% of cases.

Table 3: Disease Severity Based on HRCT Findings

HRCT Severity Grade	Number of Patients (n = 40)	Percentage (%)
Mild (localized disease)	12	30.0
Moderate (multifocal disease)	20	50.0
Severe (extensive disease)	8	20.0
Presence of complications		
Pneumothorax	3	7.5
Bronchopleural fistula	1	2.5

This table shows the disease severity based on HRCT findings. Half of the patients (50%) had moderate, multi focal disease, while 20% had severe, extensive disease. Mild or localized disease was noted in 30% of patients. Pneumothorax and bronchopleural fistula were rare complications, observed in 7.5% and 2.5% of cases, respectively.

Table 4: Impact of HRCT Findings on Management Decisions

Management Decision	Number of Patients (n=40)	Percentage (%)
Initiation of Anti-TB Therapy		
Confirmed TB Diagnosis (active)	30	75.0
Suspected TB (requiring further testing)	6	15.0
No Active TB (inactive disease)	4	10.0
Changes in Treatment Based on HRCT		
Drug regimen modification	12	30.0
Extended duration of therapy	8	20.0
Referral for surgical intervention	3	7.5
Outcomes After HRCT-Based Intervention		
Improved after treatment	32	80.0
No improvement (drug-resistant TB)	3	7.5
Relapse	5	12.5

(Table 4) outlines the impact of HRCT on treatment decisions and outcomes. HRCT confirmed the diagnosis of active TB in 75% of patients, leading to the initiation of anti-tuberculosis therapy. In 30% of cases, HRCT findings led to drug regimen modifications. Clinical improvement was noted in 80% of patients following HRCT-guided treatment, while 7.5% had no improvement due to drug-resistant TB. Relapse occurred in 12.5% of patients. The present study provides valuable insights into the HRCT findings and their impact on the clinical management of pulmonary tuberculosis (TB) in a cohort of 40 patients. These results highlight key radiological features and their relevance in guiding treatment decisions, consistent with previous research, while also identifying some unique trends.

Demographics and Clinical Characteristics: In our study, the majority of patients (37.5%) were in the 31-50 years age group and a male predominance (67.5%) was observed. This is in line with the findings from Palani[9], who reported a similar age distribution and male preponderance in their study on pulmonary TB patients. Males are generally more affected due to higher exposure to risk factors like smoking, outdoor occupations and delayed health-seeking behaviors. Regarding comorbidities, diabetes mellitus was the most prevalent (20.0%), followed by HIV infection (12.5%). Similar findings were reported by Baker[10], who emphasized that diabetes increases susceptibility to TB by impairing immune response and HIV significantly increases the risk of active TB . Chronic obstructive pulmonary disease (COPD) was also present in a minority of patients (7.5%), consistent with other studies highlighting the higher risk of TB among COPD patients due to compromised lung function.

HRCT Findings: The most common HRCT finding in our study was the "tree-in-bud" appearance (65%), followed by consolidation (50%) and cavitation (45%). This is comparable to the study by Sara *et al.* (2017), where the "tree-in-bud" pattern was a frequent observation, indicating endobronchial spread, particularly in active pulmonary TB cases . Cavitation is a hallmark of advanced disease and our findings are consistent with previous studies that highlight cavitation as a marker of bacterial load and transmission risk[11]. Other HRCT features such as bronchogenic spread (32.5%) and pleural effusion (20.0%) were observed at similar rates in studies by Fatih[12], further validating the role of HRCT in identifying both early and advanced stages of TB . The presence of fibrosis/scarring (42.5%) indicates the chronicity of disease in a substantial proportion of our patients, which has also been reported in other cohorts[13].

Disease Severity and Complications: The distribution of disease severity in our study showed that 50% of patients had moderate disease (multi focal involvement) and 20% had severe disease (extensive

involvement with complications). These findings are comparable to those of Gaetano[14], who reported a similar pattern of disease severity, with moderate to severe disease in over half of their patients. Complications such as pneumothorax (7.5%) and bronchopleural fistula (2.5%) were less common but still significant, reflecting the advanced disease stages in some patients, consistent with previous studies[15].

Impact of HRCT on Management: HRCT played a crucial role in the management of TB in our study, with 75% of patients diagnosed with active TB based on HRCT findings, leading to the initiation of anti-TB therapy. These results are comparable to the findings of Vandna[16], who demonstrated that HRCT substantially aids in confirming TB diagnosis in patients with equivocal clinical and microbiological findings. Moreover, HRCT findings led to modifications in drug regimens in 30% of patients, consistent with its role in influencing treatment strategies in previous studies. The clinical outcomes after HRCT-guided intervention were favorable in 80% of cases, with significant improvement observed post-treatment. However, 7.5% of patients showed no improvement, likely due to drug-resistant TB, a phenomenon well-documented in the literature. Relapse rates (12.5%) in our study underscore the chronic nature of TB, which aligns with global trends reported in studies such as that by Dheda[17].

CONCLUSION

High-Resolution Computed Tomography (HRCT) is a crucial tool for early detection and assessment of pulmonary tuberculosis (TB). It distinguishes between active and inactive TB, identifying features like consolidation, cavitation, tree-in-bud appearance and bronchogenic spread. HRCT's findings significantly influence clinical decision-making, leading to early anti-TB therapy initiation and treatment adjustments. It's especially useful in cases where chest radiographs are inconclusive, offering superior resolution for subtle pulmonary changes. Men are more affected than women, with a higher proportion of patients presenting with comorbidities like diabetes and HIV. HRCT guides management, preventing TB spread and improving patient outcomes.

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