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SPECTRUM OF HIGH-RESOLUTION COMPUTED TOMOGRAPHY FINDINGS IN POST-TUBERCULAR LUNG DISEASE: A CROSS-SECTIONAL STUDY FROM A TERTIARY CARE HOSPITAL IN NORTH INDIA

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ABSTRACT

Background: Pulmonary tuberculosis remains a major public health problem in India. Although successful anti-tubercular therapy achieves microbiological cure in most patients, many continue to experience chronic respiratory symptoms due to residual structural lung damage, collectively termed post-tubercular lung disease (PTLD). High-resolution computed tomography (HRCT) is a sensitive imaging modality for detecting and characterizing these residual pulmonary abnormalities.

Objectives: To evaluate the spectrum and frequency of HRCT findings in patients with post-tubercular lung disease attending a tertiary care hospital in North India.

Methods: A hospital-based observational cross-sectional study was conducted in the Department of Radiodiagnosis of a tertiary care hospital in North India from September 2022 to December 2022. Thirty adult patients with a documented history of treated pulmonary tuberculosis who underwent HRCT chest evaluation for post-tubercular sequelae were included using consecutive sampling. Demographic and clinical data were collected using a predesigned case record form. HRCT scans were assessed for residual pulmonary abnormalities including fibrosis, bronchiectasis, volume loss, pleural thickening, calcified granulomas, residual cavities, emphysematous changes, and bullae. Data were analyzed using SPSS version 25.0. A p-value <0.05 was considered statistically significant.

Results: Among the 30 study participants, males constituted 60.0% of the cohort, and the majority belonged to the 31–45-year age group. Cough (66.7%) and dyspnea (60.0%) were the most common presenting symptoms. HRCT revealed parenchymal fibrosis in 73.3% of patients, bronchiectasis in 60.0%, volume loss in 53.3%, pleural thickening in 40.0%, and calcified granulomas in 33.3%. Residual cavities and emphysematous changes were observed in 26.7% and 23.3% of patients, respectively. Bilateral pulmonary involvement was present in 63.3% of cases, while upper lobe predominance was noted in 63.3%. A statistically significant association was observed between smoking status and emphysematous changes on HRCT ($p=0.040$).

Conclusion: HRCT demonstrates a wide range of residual pulmonary abnormalities in post-tubercular lung disease, with fibrosis and bronchiectasis being the most common findings. Bilateral and upper lobe involvement predominate. HRCT serves as an important tool for identifying structural sequelae responsible for persistent respiratory symptoms and can guide long-term management strategies in treated tuberculosis patients.

Keywords: Post-tubercular lung disease; High-resolution computed tomography; Pulmonary tuberculosis; Bronchiectasis; Pulmonary fibrosis; Tuberculosis sequelae; HRCT

INTRODUCTION

Tuberculosis (TB) remains one of the leading infectious diseases worldwide and continues to pose a major public health challenge, particularly in low- and middle-income countries. Despite substantial advances in diagnosis and treatment, TB is associated with significant morbidity and mortality. According to the World Health Organization (WHO), millions of new cases of TB are reported annually, with a substantial proportion occurring in high-burden countries such as India [1]. While successful completion of anti-tubercular therapy results in microbiological cure in most patients, many individuals continue to experience persistent respiratory symptoms and long-term pulmonary impairment due to structural damage caused by the disease [2].

Post-tubercular lung disease (PTLD) has emerged as an important clinical entity encompassing chronic respiratory abnormalities attributable, at least in part, to previous pulmonary tuberculosis. PTLD may manifest as airflow limitation, restrictive ventilatory defects, impaired gas exchange, recurrent respiratory infections, hemoptysis, and reduced quality of life [3]. The pathological sequelae of pulmonary TB include fibrosis, bronchiectasis, cavitary destruction, emphysematous changes, pleural thickening, parenchymal scarring, and vascular alterations, which may persist long after microbiological cure has been achieved [4].

The burden of PTLD is increasingly recognized globally. Studies have demonstrated that a significant proportion of patients successfully treated for pulmonary TB develop chronic respiratory symptoms and radiological abnormalities that contribute to long-term disability [5]. The extent and pattern of residual pulmonary damage are influenced by several factors, including disease severity at presentation, delay in diagnosis, treatment adherence, host immune response, and presence of comorbidities [6]. Consequently, evaluation of structural lung abnormalities following TB treatment has become an important component of patient management and follow-up.

High-resolution computed tomography (HRCT) has become the imaging modality of choice for detailed assessment of pulmonary parenchymal and airway abnormalities. Compared with conventional chest radiography, HRCT provides superior visualization of bronchiectasis, fibrosis, cavitary lesions, emphysema, small airway disease, and pleural abnormalities [7]. The technique allows accurate characterization of the distribution, extent, and severity of residual lesions, thereby facilitating clinical decision-making and prognostication [8]. Furthermore, HRCT findings often correlate with pulmonary function impairment and symptom burden, emphasizing its role in comprehensive evaluation of PTLD [9].

India accounts for the highest number of TB cases globally and bears a disproportionate share of the disease burden [1]. Consequently, the population at risk for developing PTLD is substantial. In northern India, tertiary care centers frequently encounter patients with persistent respiratory symptoms after completion of anti-tubercular therapy. However, available literature from this region regarding the spectrum of HRCT findings in post-tubercular lung disease remains limited. Most studies have focused on active pulmonary TB, while fewer investigations have systematically evaluated the radiological sequelae following treatment completion [10].

A better understanding of HRCT manifestations in PTLD is essential for early recognition of chronic complications, optimization of long-term management strategies, and prevention of further respiratory deterioration. Identification of common imaging patterns may also aid clinicians in differentiating post-infectious sequelae from disease reactivation and other chronic pulmonary disorders. Therefore, the present study was undertaken in a tertiary care hospital in North India to evaluate the spectrum and frequency of HRCT findings among patients with post-tubercular lung disease. The objective of the study was to describe the various residual pulmonary abnormalities detected on HRCT and assess their distribution among patients with a documented history of treated pulmonary tuberculosis.

METHODOLOGY

Study Design: This was a hospital-based observational cross-sectional study conducted to evaluate high-resolution computed tomography (HRCT) findings in patients with post-tubercular lung disease attending a tertiary care hospital in North India. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Study Setting: The study was conducted in the Department of Radiodiagnosis in collaboration with the Departments of Pulmonary Medicine and General Medicine at a tertiary care teaching hospital in North India. Patients with a documented history of treated pulmonary tuberculosis who were referred for HRCT chest evaluation during the study period were considered for inclusion.

Study Duration: The study was conducted from September 2022 to December 2022.

Study Population: The study population comprised adult patients with a previous history of pulmonary tuberculosis who had completed anti-tubercular treatment and subsequently underwent HRCT chest evaluation for persistent respiratory symptoms, follow-up assessment, or radiological evaluation of residual pulmonary abnormalities.

Inclusion Criteria

Patients aged ≥18 years.
Documented history of treated pulmonary tuberculosis with completion of anti-tubercular therapy.
Patients undergoing HRCT chest for evaluation of post-tubercular sequelae.
Patients willing to participate and providing written informed consent.

Exclusion Criteria

Patients with active pulmonary tuberculosis at the time of evaluation.
Patients with known interstitial lung disease unrelated to tuberculosis.
Patients with primary lung malignancy or metastatic pulmonary disease.
Patients with significant occupational lung disease or pneumoconiosis.
Patients with incomplete clinical records or poor-quality HRCT images.
Patients unwilling to provide informed consent.

Sample Size: The sample size was calculated using the formula for estimation of a proportion:
$n = Z^2 \times p \times q / d^2$
Where:

n = required sample size
Z = 1.96 at 95% confidence level
p = expected prevalence of the most common HRCT abnormality among post-tubercular patients (assumed as 50% in the absence of precise local data)
$q = 1 - p = 50\%$

d = allowable error of 18%

Substituting the values:

$n = (1.96)^2 \times 50 \times 50 / (18)^2$

$n \approx 29.3$

The calculated minimum sample size was approximately 30 patients. Therefore, a total of 30 eligible patients were included in the study.

Sampling Technique: A consecutive sampling technique was employed. All eligible patients meeting the inclusion criteria and presenting during the study period were recruited until the required sample size of 30 participants was achieved.

Data Collection Tools and Procedure: After obtaining informed consent, demographic and clinical information including age, sex, smoking history, duration since completion of anti-tubercular therapy, presenting symptoms, and relevant medical history were recorded using a predesigned case record form. HRCT examinations were performed using a multidetector computed tomography scanner with thin-section acquisition. Images were obtained during full inspiration and reconstructed using a high-spatial-resolution algorithm. The scans were reviewed independently by experienced radiologists. HRCT findings including fibrosis, bronchiectasis, cavitary lesions, emphysematous changes, calcified granulomas, pleural thickening, volume loss, bullae, and other residual abnormalities were documented. Distribution of lesions according to lobar involvement and laterality was also recorded.

Study Variables: Independent variables included age, sex, smoking status, duration since completion of anti-tubercular therapy, and clinical presentation. Dependent variables consisted of HRCT findings suggestive of post-tubercular lung disease, including fibrosis, bronchiectasis, cavities, emphysema, calcifications, pleural abnormalities, volume loss, and extent of pulmonary involvement. Associations between selected demographic and clinical variables and HRCT findings were evaluated.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ±standard deviation (SD) or median with interquartile range, depending on data distribution. Categorical variables were expressed as frequencies and percentages. The Chi-square test or Fisher's exact test was used to assess associations between categorical variables. Independent sample t-test was applied for comparison of continuous variables where appropriate. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: Written informed consent was obtained from all participants before enrollment. Confidentiality and anonymity of patient information were maintained throughout the study. Participation was entirely voluntary, and participants were free to withdraw from the study at any stage without affecting their medical care. The study adhered to the ethical principles outlined in the Declaration of Helsinki and its subsequent amendments concerning research involving human participants.

RESULTS

A total of 30 patients with post-tubercular lung disease were included in the study. The majority of participants belonged to the 31–45 years age group, and males constituted a higher proportion of the study population (Table 1).

Table 1. Demographic Characteristics of Study Participants (N = 30)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	18–30	5	16.7
	31–45	10	33.3
	46–60	9	30.0
	>60	6	20.0
Sex	Male	18	60.0
	Female	12	40.0
Smoking Status	Smoker/Ex-smoker	11	36.7
	Non-smoker	19	63.3

Persistent respiratory symptoms were common following completion of anti-tubercular therapy, with cough and dyspnea being the most frequently reported complaints. Nearly half of the participants had completed treatment between one and three years before presentation (Table 2)

Table 2. Clinical Profile of Patients with Post-Tubercular Lung Disease (N = 30)

Variable	Category	Frequency (n)	Percentage (%)
Duration since completion of ATT	<1 year	8	26.7
	1–3 years	14	46.7
	>3 years	8	26.7
Presenting Symptoms*	Cough	20	66.7
	Dyspnea	18	60.0
	Sputum production	13	43.3
	Hemoptysis	5	16.7
	Chest pain	4	13.3

*Multiple responses possible.

HRCT demonstrated a wide spectrum of residual pulmonary abnormalities. Fibrotic parenchymal changes were the most common finding, followed by bronchiectasis and volume loss. Pleural thickening, calcified granulomas, residual cavities, and emphysematous changes were also observed in a substantial proportion of patients (Table 3).

Table 3. Spectrum of HRCT Findings in Post-Tubercular Lung Disease (N = 30)

HRCT Finding	Frequency (n)	Percentage (%)
Fibrotic bands/parenchymal fibrosis	22	73.3
Bronchiectasis	18	60.0
Volume loss	16	53.3

Pleural thickening	12	40.0
Calcified granuloma/nodule	10	33.3
Residual cavity	8	26.7
Emphysematous changes	7	23.3
Bullae	4	13.3

Most patients showed bilateral pulmonary involvement, and upper lobe predominance was the characteristic distribution pattern of post-tubercular sequelae (Table 4).

Table 4. Distribution of Pulmonary Involvement on HRCT (N = 30)

Variable	Category	Frequency (n)	Percentage (%)
Laterality	Unilateral	11	36.7
	Bilateral	19	63.3
Predominant Zone Involvement	Upper lobes	19	63.3
	Middle lobe/lingula	3	10.0
	Lower lobes	8	26.7

A statistically significant association was observed between smoking status and emphysematous changes on HRCT, with smokers and ex-smokers demonstrating a higher frequency of emphysema compared with non-smokers (p=0.040) (Table 5).

Table 5. Association Between Smoking Status and Emphysematous Changes on HRCT

Smoking Status	Emphysematous Changes Present n (%)	Emphysematous Changes Absent n (%)	Total	p-value
Smoker/Ex-smoker (n=11)	5 (45.5)	6 (54.5)	11	0.040*
Non-smoker (n=19)	2 (10.5)	17 (89.5)	19	
Total (N=30)	7 (23.3)	23 (76.7)	30	

*Statistically significant (Chi-square test, $p<0.05$).

DISCUSSION

The present study evaluated the spectrum of HRCT findings in patients with post-tubercular lung disease attending a tertiary care hospital in North India. The study demonstrated that fibrotic parenchymal changes, bronchiectasis, and volume loss were the most frequent residual abnormalities. Bilateral involvement and upper lobe predominance were commonly observed, while emphysematous changes showed a significant association with smoking status. These findings highlight the substantial burden of structural lung damage that may persist even after successful completion of anti-tubercular therapy.

Pulmonary tuberculosis is well recognized for causing chronic architectural distortion of the lungs despite microbiological cure. In the current study, fibrosis was the most common HRCT finding,

observed in nearly three-fourths of patients. Similar observations have been reported in previous studies evaluating post-tuberculous sequelae, where fibrotic scarring represented the predominant residual abnormality following treatment completion [3,6]. The development of fibrosis is attributed to tissue destruction, prolonged inflammatory response, and subsequent reparative processes leading to permanent parenchymal remodeling. Such structural changes may contribute to chronic respiratory symptoms and long-term functional impairment.[11-12]

Bronchiectasis was identified in a substantial proportion of patients and represented the second most frequent HRCT abnormality. This finding is consistent with earlier studies that have documented post-infectious bronchiectasis as a major consequence of pulmonary tuberculosis [3,9]. Tuberculous inflammation involving the bronchial wall can result in irreversible airway dilatation through destruction of supporting elastic and muscular components. Persistent bronchiectasis increases susceptibility to recurrent respiratory infections, chronic sputum production, and progressive decline in pulmonary function. The high prevalence observed in the present study emphasizes the importance of long-term surveillance and appropriate management of affected individuals.

Volume loss and upper lobe predominance observed in this study are characteristic features of healed pulmonary tuberculosis. Previous radiological investigations have similarly demonstrated preferential involvement of the apical and posterior segments of the upper lobes because of higher oxygen tension favoring mycobacterial proliferation [7,8]. Residual volume loss results from fibrosis, cicatrization, and parenchymal destruction, leading to distortion of normal pulmonary anatomy. Recognition of these patterns is clinically relevant because they help distinguish healed disease from alternative pulmonary pathologies.

Pleural thickening and calcified granulomas were also commonly encountered. These findings reflect chronic healing processes following infection and have been reported in several studies evaluating radiological sequelae of pulmonary tuberculosis [4,10]. Calcified nodules and granulomas generally indicate inactive disease, whereas pleural thickening may contribute to restrictive ventilatory defects in some patients. Although these abnormalities are often asymptomatic, their presence provides valuable information regarding the extent of prior pulmonary involvement.

Residual cavitary lesions were observed in approximately one-fourth of patients. Persistent cavities have important clinical implications because they may serve as sites for secondary bacterial colonization, fungal infection, or hemoptysis. Previous studies have similarly documented residual cavities among treated tuberculosis patients and emphasized the need for continued follow-up in selected cases [5,6]. HRCT offers superior sensitivity in detecting such lesions compared with conventional radiography and may assist in identifying complications at an early stage.[13-15]

An important finding of the present study was the association between smoking and emphysematous changes. Smokers demonstrated a significantly greater frequency of emphysema than non-smokers. This observation is biologically plausible because both tobacco smoke exposure and prior tuberculous lung injury contribute to airway inflammation and destruction of alveolar architecture. Similar interactions between smoking and post-tubercular structural lung damage have been described in previous investigations of chronic respiratory impairment after tuberculosis [4,5]. The finding reinforces the importance of smoking cessation counseling in patients with a history of pulmonary tuberculosis.

The results of the present study have important clinical implications. Persistent respiratory symptoms in previously treated tuberculosis patients should not automatically be attributed to recurrent infection. HRCT can identify underlying structural abnormalities responsible for symptom persistence and facilitate appropriate management strategies, including pulmonary rehabilitation, bronchodilator therapy, airway clearance techniques, and monitoring for complications. Given India's

substantial tuberculosis burden, systematic evaluation of post-tubercular lung disease may help reduce long-term respiratory morbidity and improve quality of life.

The strengths of the study include the use of HRCT, which provides detailed assessment of pulmonary parenchymal and airway abnormalities, and the inclusion of clinically relevant imaging patterns encountered in routine practice. The study also contributes regional data from North India, where evidence regarding HRCT manifestations of post-tubercular lung disease remains relatively limited.

However, certain limitations should be acknowledged. The study was conducted at a single tertiary care center with a relatively small sample size of 30 patients, which may limit generalizability. The cross-sectional design precluded assessment of temporal progression of radiological abnormalities. Pulmonary function testing and quality-of-life assessment were not incorporated, preventing correlation of imaging findings with functional outcomes. Larger multicentric studies with longitudinal follow-up are warranted to better characterize the natural history and clinical impact of post-tubercular lung disease.

CONCLUSION

Post-tubercular lung disease represents a significant cause of chronic respiratory morbidity among patients who have successfully completed treatment for pulmonary tuberculosis. In the present study, HRCT demonstrated a broad spectrum of residual pulmonary abnormalities, with parenchymal fibrosis, bronchiectasis, and volume loss being the most frequently encountered findings. Bilateral involvement and upper lobe predominance were characteristic imaging patterns. Residual cavities, pleural thickening, calcified granulomas, and emphysematous changes were also identified in a considerable proportion of patients. Smoking was significantly associated with emphysematous changes, highlighting the additive impact of tobacco exposure on post-tubercular structural lung damage.The findings underscore the value of HRCT in the comprehensive evaluation of patients with persistent respiratory symptoms following completion of anti-tubercular therapy. Early identification of residual pulmonary sequelae may facilitate timely intervention, optimize long-term management, and improve patient outcomes. Routine clinical follow-up of treated tuberculosis patients should include assessment for post-tubercular lung disease. Further multicentric studies with larger sample sizes and functional correlation are recommended to better define the long-term burden and clinical implications of these radiological abnormalities.

DECLARATIONS

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Conflict of Interest: The authors declare that there is no conflict of interest.
Informed Consent: Written informed consent was obtained from all participants before enrollment in the study.
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