ORIGINAL RESEARCH

Study on the Long-term Pulmonary Pathological Changes in Patients with Chest Tuberculosis

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ABSTRACT

Aim: This study aimed to evaluate the long-term pulmonary pathological changes in patients who have completed treatment for chest tuberculosis (TB) and to assess the recovery and complications that arise post-treatment. **Materials and Methods:** A total of 100 patients with a confirmed diagnosis of pulmonary TB were enrolled in this prospective, observational study at a tertiary care hospital. The follow-up period lasted for 3 years, during which patients underwent regular clinical evaluations, chest X-rays, high-resolution computed tomography (HRCT), spirometry, and sputum analysis. Histopathological assessments were performed on patients with persistent abnormalities. Statistical analysis was conducted using descriptive statistics and appropriate tests to evaluate the data. **Results:** At the end of the study, 45% of the patients showed fibrotic changes, 35% had resolved disease, and 12% exhibited bronchiectasis. Significant improvements were observed in pulmonary function, with Forced Expiratory Volume in 1 second (FEV1) increasing from 2.6 ± 0.5 liters at baseline to 3.0 ± 0.5 liters by the end of the study ($p=0.03$). Radiological findings revealed fibrotic lesions in 55% of patients, and histopathological findings identified tuberculous granulomas in 4% and pulmonary fibrosis in 5% of cases. **Conclusion:** This study confirms that fibrotic changes and bronchiectasis are common long-term pulmonary sequelae following TB treatment, though most patients show gradual improvement in lung function over time. Continuous monitoring is essential to manage post-TB pulmonary complications and promote long-term lung health.

Keywords: Chest tuberculosis, long-term pulmonary sequelae, fibrotic changes, lung function, bronchiectasis.

INTRODUCTION

Tuberculosis (TB) remains one of the most significant global public health challenges, with an estimated 10 million new cases and 1.5 million deaths reported annually worldwide. While TB primarily affects the lungs, its effects extend beyond acute infection, influencing pulmonary structure and function long after the initial infection has been treated. This phenomenon is particularly important when considering chest tuberculosis, a severe form of the disease that involves pleural or parenchymal involvement. Understanding the long-term consequences of chest TB is critical for improving the management of patients and mitigating ongoing health burdens that extend beyond the acute infection phase.[1]Chest tuberculosis, a common manifestation of pulmonary TB, often leads to significant lung pathology, including cavitary lesions, fibrosis, and scarring. These pathological changes can cause irreversible damage to lung architecture and function. While current medical advancements have significantly reduced the mortality associated with TB, the long-term pulmonary consequences in those who survive the infection remain inadequately studied. The cumulative evidence suggests that even after successful treatment, individuals who have experienced chest TB may face ongoing respiratory impairment, diminished quality of life, and increased susceptibility to further respiratory complications.[2,3]The pulmonary pathological changes induced by chest TB can persist well into the recovery phase and may continue to progress over time. These changes are not always immediately apparent, often manifesting as subclinical symptoms or slow declines in lung function. In some cases, they may be exacerbated by secondary infections, environmental factors, or comorbidities such as smoking and other pre-existing lung diseases. Therefore, identifying these long-term changes early is crucial for optimizing patient care and preventing additional complications.[4]

The challenges associated with studying long-term pulmonary changes in chest tuberculosis patients are multifaceted. First, chest TB manifests with variable clinical presentations, ranging from mild symptoms to severe forms that require extensive medical intervention. Furthermore, the variability in treatment regimens, the presence of multidrug-resistant strains, and the comorbid conditions of individual patients make it difficult to generalize findings. However, over the years, advances in diagnostic imaging, pulmonary function testing, and histopathological examinations have enabled researchers to gain a clearer understanding of the long-term effects of chest tuberculosis on pulmonary health.[5] One of the most profound impacts of chest tuberculosis is the development of pulmonary fibrosis. This occurs when the lung tissue heals after the TB infection, but in the process, it becomes stiff and scarred. Pulmonary fibrosis can severely impair the ability of the lungs to expand and contract, limiting oxygen intake and leading to persistent shortness of breath. Additionally, the formation of fibrotic tissue may restrict the movement of the chest wall, further complicating respiratory function. The degree of fibrosis varies among patients, with some experiencing only mild restriction, while others may suffer from severe disability due to widespread scarring of the lung parenchyma.[6] Another major issue is the risk of recurrent respiratory infections, which are a common long-term complication of chest TB. Patients who have previously had chest TB may have an altered immune response and a compromised pulmonary defense system, leaving them more susceptible to reinfection or secondary bacterial infections. Moreover, chronic obstructive pulmonary disease (COPD) is increasingly recognized as a comorbidity in individuals who have had chest TB, further complicating the respiratory profile of such patients. The co-occurrence of TB-induced lung damage and COPD can significantly increase morbidity and mortality in these individuals, as both conditions can result in progressive respiratory failure.[7,8] Furthermore, the psychological and social impacts of chest tuberculosis should not be overlooked. Survivors of TB often experience long-lasting psychological effects, including anxiety, depression, and fear of relapse. The social stigma associated with tuberculosis, particularly in regions where the disease is still prevalent, can exacerbate feelings of isolation and hopelessness. These psychosocial factors, in turn, may hinder adherence to follow-up care and rehabilitation, which is critical for managing long-term pulmonary changes and improving overall health outcomes.

MATERIALS AND METHODS

This study is a prospective, observational investigation aimed at evaluating the long-term pulmonary pathological changes in patients who have undergone treatment for chest tuberculosis (TB). The study included a total of 100 patients diagnosed with pulmonary TB, admitted and treated at tertiary care hospital. The follow-up period lasted for 3 years, and all participants provided informed consent for inclusion in the study.

Inclusion and Exclusion Criteria

- **Inclusion Criteria:**
  - Patients aged 18 to 65 years.
  - Confirmed diagnosis of pulmonary TB by microbiological or radiological criteria.
  - Completion of a full course of anti-tubercular therapy (ATT) as per standard treatment guidelines.
  - No active smoking history or smoking cessation for at least 12 months prior to recruitment.
  - Ability to provide informed consent.
- **Exclusion Criteria:**
  - Active non-tuberculous lung infections.
  - Severe comorbidities (e.g., chronic obstructive pulmonary disease, carcinoma).
  - Inability to participate in follow-up visits.
  - Pregnancy or lactation.

Methodology

A total of 100 patients who met the inclusion criteria were enrolled in the study. Baseline demographic data were collected, which included information such as age, gender, smoking history, comorbidities, duration of tuberculosis (TB) treatment, and any prior history of pulmonary disease. Clinical examination, chest X-rays, sputum microscopy, and sputum culture for *Mycobacterium tuberculosis* were conducted at the time of recruitment to confirm the diagnosis and assess the extent of the disease.

The patients were followed up at six-month intervals over a designated follow-up period. During each visit, several procedures were performed to monitor the progression or resolution of pulmonary abnormalities. Clinical evaluations included symptom assessments for cough, hemoptysis, dyspnea, and chest pain, along with a thorough physical examination that involved lung auscultation and palpation. Radiological investigations were conducted with chest X-rays at baseline and during each follow-up visit to assess any pulmonary changes, and high-resolution computed tomography (HRCT) was performed at baseline and at the end of the study to evaluate detailed pulmonary alterations, such as fibrotic lesions, bronchiectasis, or other structural abnormalities. Pulmonary function tests, including spirometry (measuring Forced Expiratory Volume in 1 second [FEV1], Forced Vital Capacity [FVC], and FEV1/FVC ratio), were carried out at baseline and again at 1 year, 2 years, and at the study's conclusion to assess lung function. The Diffusion Capacity of the Lungs for Carbon Monoxide (DLCO) was also measured at baseline and at the end of the study to evaluate gas exchange capacity. Sputum samples were collected at regular intervals to check for the presence of acid-fast bacilli

(AFB) and for cultures to rule out active *Mycobacterium tuberculosis* infection.

Patients were classified into various categories based on the findings from their clinical and radiological assessments. These categories included resolved disease, in which no radiological abnormalities or only minimal scarring were observed following treatment completion; fibrotic changes, characterized by lung fibrosis or consolidation evident on chest X-ray or CT scans; bronchiectasis, identified by dilated bronchi, mucus accumulation, and scarring on CT images; and other abnormalities, including pleural thickening, cavitary lesions, or granulomatous formations. In cases where persistent pulmonary abnormalities were noted, histopathological samples were obtained, if clinically indicated, through bronchoscopy or surgery. These samples were processed and evaluated for tuberculous granulomas, fibrosis, or other pathological findings.

Statistical Analysis

Data were entered into a statistical software package (e.g., SPSS 21.0) for analysis. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize baseline characteristics, radiological findings, and pulmonary function parameters. Changes in pulmonary function over time were analyzed using paired t-tests or repeated measures analysis, as appropriate. The relationship between demographic variables and the presence of long-term pulmonary pathological changes was evaluated using chi-square tests and logistic regression models. A p-value of <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic and Baseline Characteristics of the Study Population

The study included 100 patients who met the inclusion criteria. The demographic distribution of the participants showed a range of ages, with the majority being between 31 -60 years. Specifically, 40% of the patients were aged between 46 and 60 years, while 35% were aged between 31 - 45 years, 15% were in the 18-30 year age group, and 10% were between 61 - 65 years. The p-value for age was 0.32, indicating no significant difference between the age groups in relation to the study variables.

In terms of gender, 60% of the patients were male, while 40% were female. The p-value for gender was 0.16, suggesting no significant gender differences in the study population. Smoking history also revealed that 30% of the participants were smokers, while 70% were non-smokers. A significant p-value of 0.05 suggests that smoking history might have some impact on the pulmonary outcomes in this cohort.

Regarding comorbidities, 12% of the patients had diabetes mellitus, 18% had hypertension, and 5% had chronic respiratory disease. The p-values for these conditions were 0.06, 0.10, and 0.09, respectively, indicating no significant impact of comorbidities on the pulmonary outcomes in this cohort.

The duration of tuberculosis treatment varied, with 10% of patients receiving less than six months of treatment, 50% completing 6 to 12 months of treatment, and 40% undergoing treatment for more than 12 months. The p-values for duration of TB treatment ranged from 0.04 to 0.12, with the variation in treatment duration not showing a significant relationship to pulmonary changes.

Table 2: Radiological and Clinical Findings at Baseline

At baseline, radiological and clinical findings were assessed. A significant portion of patients exhibited fibrotic changes on chest X-ray, with 50% showing these changes, while 30% had normal or minimal scarring, and 15% presented with cavitary lesions. Only 5% showed pleural thickening on their chest X-rays. The p-value for the chest X-ray findings was 0.32, indicating no significant correlation between radiological findings and the study variables.

On CT scans, fibrotic lesions were observed in 55% of patients, bronchiectasis in 20%, pleural thickening in 5%, and granulomatous changes in 10%. The p-value of 0.05 for the fibrotic lesions on CT scans indicates a statistically significant presence of fibrotic changes in the patients, which may indicate long-term consequences of TB treatment. Other abnormalities such as bronchiectasis and granulomatous changes were seen in a smaller portion of the patients, with p-values of 0.08 and 0.11, respectively, suggesting that these findings may not be significant in the long-term pulmonary changes.

Table 3: Pulmonary Function Test Results (Baseline and Follow-up)

The pulmonary function tests showed significant improvements in lung function over the 3-year follow-up period. At baseline, the average Forced Expiratory Volume in 1 second (FEV1) was 2.6 ± 0.5 liters. After one year, this increased to 2.8 ± 0.6 liters, reaching 2.9 ± 0.5 liters at two years, and 3.0 ± 0.5 liters at the end of the study. The p-value for FEV1 was 0.03, indicating a significant improvement in lung function over time.

Similarly, Forced Vital Capacity (FVC) showed a positive trend, increasing from 3.2 ± 0.6 liters at baseline to 3.6 ± 0.6 liters by the end of the study. The p-value of 0.02 further supports the significance of the improvement in lung capacity. The FEV1/FVC ratio also improved, from $81.3 \pm 7.1\%$ at baseline to $85.0 \pm 6.3\%$ at 3 years, with a p-value of 0.04, suggesting an overall improvement in pulmonary function.

Diffusion capacity (DLCO), which measures the efficiency of gas exchange in the lungs, also showed significant improvement. The baseline value was $70 \pm 10\%$, and it improved to $78 \pm 7\%$ by the end of the study, with a p-value of 0.01, indicating a significant

recovery in the lung's ability to exchange gases after treatment for TB.

Table 4: Pulmonary Pathological Changes at the End of Study (3 Years)

At the conclusion of the study, the patients were categorized based on the pulmonary pathological changes observed over the three-year period. The majority (45%) of patients showed fibrotic changes, which were the most common long-term consequence of TB treatment. This was followed by 35% of patients who had resolved disease, showing minimal to no radiological abnormalities. A small proportion of patients (12%) exhibited bronchiectasis, and 5% had pleural thickening. The p-value of 0.05 for resolved disease and 0.03 for fibrotic changes suggests that these two conditions were statistically significant long-term pulmonary outcomes for patients who had completed TB treatment. Other abnormalities, including granulomas and cavitary lesions, were found in only 3% of the patients, with a p-value of 0.08, indicating these changes were not as commonly observed.

Table 5: Histopathological Findings from Bronchoscopy/Surgery (if applicable)

In cases where persistent pulmonary abnormalities were noted, histopathological findings were obtained through bronchoscopy or surgery. Of the patients who underwent these procedures, 4% had tuberculous granulomas, and 5% exhibited pulmonary fibrosis. A majority of patients (91%) had no pathological findings. The p-values for tuberculous granulomas (0.02) and pulmonary fibrosis (0.03) were statistically significant, suggesting these findings were meaningful for understanding the long-term pulmonary consequences of TB. The absence of pathological findings in 91% of the patients reflects the resolution of the disease in the majority of the study participants.

Table 1: Demographic and Baseline Characteristics of the Study Population

Characteristic	Number of Patients	Percentage (%)	p-value
Total Number of Patients	100	100%	-
Age			
18-30 years	15	15%	0.32
31-45 years	35	35%	
46-60 years	40	40%	
61-65 years	10	10%	
Gender			
Male	60	60%	0.16
Female	40	40%	
Smoking History			
Smoker	30	30%	0.05
Non-smoker	70	70%	
Comorbidities			
Diabetes Mellitus	12	12%	0.06
Hypertension	18	18%	0.10
Chronic Respiratory Disease	5	5%	0.09
Duration of TB Treatment			
Less than 6 months	10	10%	0.04
6-12 months	50	50%	0.12
More than 12 months	40	40%	0.07

Table 2: Radiological and Clinical Findings at Baseline

Finding	Number of Patients	Percentage (%)	p-value
Chest X-ray			
Normal or Minimal Scarring	30	30%	0.32
Fibrotic Changes	50	50%	
Cavitary Lesions	15	15%	
Pleural Thickening	5	5%	
CT Scan			
Fibrotic Lesions	55	55%	0.05
Bronchiectasis	20	20%	
Pleural Thickening	5	5%	
Granulomatous Changes	10	10%	

Table 3: Pulmonary Function Test Results (Baseline and Follow-up)

Test	Baseline (n=100)	1 Year (n=100)	2 Years (n=100)	3 Years (n=100)	p-value
Forced Expiratory Volume (FEV1) (L)	2.6 ± 0.5	2.8 ± 0.6	2.9 ± 0.5	3.0 ± 0.5	0.03
Forced Vital Capacity (FVC) (L)	3.2 ± 0.6	3.4 ± 0.7	3.5 ± 0.6	3.6 ± 0.6	0.02
FEV1/FVC Ratio (%)	81.3 ± 7.1	83.2 ± 6.5	84.1 ± 6.2	85.0 ± 6.3	0.04
Diffusion Capacity (DLCO) (%)	70 ± 10	75 ± 9	77 ± 8	78 ± 7	0.01

Table 4: Pulmonary Pathological Changes at the End of Study (3 Years)

Pathological Change	Number of Patients	Percentage (%)	p-value
Resolved Disease	35	35%	0.05
Fibrotic Changes	45	45%	0.03
Bronchiectasis	12	12%	0.12
Pleural Thickening	5	5%	0.14
Other Abnormalities (Granulomas, Cavitary Lesions)	3	3%	0.08

Table 5: Histopathological Findings from Bronchoscopy/Surgery (if applicable)

Finding	Number of Patients	Percentage (%)	p-value
Tuberculous Granulomas	4	4%	0.02
Pulmonary Fibrosis	5	5%	0.03
No Pathological Findings	91	91%	-

DISCUSSION

The results of this study showed that the majority of patients (40%) were between the ages of 46 and 60 years, with 60% male participants. These findings align with those of [Choi et al. (2017)], who found that TB primarily affects middle-aged adults, with a higher incidence in males. Their study also reported a male-to-female ratio of 60:40, similar to our findings. However, unlike our cohort, they reported a slightly higher prevalence of smoking among TB patients, with 40% of their patients being smokers, compared to our study where 30% were smokers. This difference in smoking history might be attributed to regional variations in tobacco use or the study's inclusion criteria, as smoking history can contribute to the severity of pulmonary disease post-TB (Choi et al., 2017).[9] In contrast, comorbidities like diabetes and hypertension were observed in a smaller proportion in our study (12% and 18%, respectively), which is consistent with findings by [Kumar et al. (2016)], who also reported that comorbidities did not significantly influence the long-term pulmonary outcomes of TB patients.[10]

Regarding the radiological and clinical findings at baseline, our study showed that 50% of the patients had fibrotic changes, 30% had minimal scarring, and 15% had cavitary lesions on chest X-ray. This is in line with the results from [Tan et al. (2015)], who reported that approximately 50% of patients had fibrotic changes post-TB treatment. Tan et al. (2015) also observed that chest X-rays revealed minimal scarring in a similar proportion (28%) of their study population, which is consistent with our finding of 30%. However, they noted a slightly higher rate of pleural thickening (7%) compared to our study's 5%. This variation could be due to differences in the methods of radiological interpretation or the follow-up duration.[11] Similarly, our CT findings showed that 55% of patients had fibrotic lesions, while bronchiectasis and granulomatous changes were less prevalent. These results corroborate the findings of [Hassan et al. (2017)], who identified fibrotic lesions in 52% of TB survivors in their study, further highlighting the prevalence of long-term fibrotic changes after TB treatment.[12]

In terms of pulmonary function, this study observed significant improvements in FEV1, FVC, and DLCO over the 3-year follow-up period. FEV1 increased from 2.6 ± 0.5 liters at baseline to 3.0 ± 0.5 liters by the end of the study (p=0.03), which is comparable to findings from [Patel et al. (2016)]. In Patel et al.'s (2016) study, FEV1 improved from 2.7 liters at baseline to 3.2 liters after two years of follow-up, indicating that TB treatment leads to substantial recovery in lung function. The improvement in DLCO in our study (from 70% to 78%) is also consistent with Patel et al.'s results, where DLCO was reported to improve by approximately 7% over two years. This improvement in gas exchange capacity suggests that TB treatment allows for some recovery of lung function, although the complete return to normal levels may not always be achieved.[13]

The findings regarding long-term pulmonary pathological changes also supported the presence of fibrotic changes as a common outcome, with 45% of our cohort showing fibrotic changes at the 3-year follow-up. [Araujo et al. (2014)] similarly found that fibrotic changes were the most frequent long-term

complication post-TB treatment, affecting 48% of their study participants. Araujo et al. (2014) also reported that 12% of their patients developed bronchiectasis, which is similar to the 12% observed in our study. However, unlike our study, they found that pleural thickening was more prevalent (12%), suggesting potential differences in TB severity or treatment strategies between the two studies. [14]

Histopathological findings in our study indicated that tuberculous granulomas and pulmonary fibrosis were present in 4% and 5% of cases, respectively. This is consistent with [Araujo et al. (2014) who reported granulomas in 6% of their post-TB cohort. Araujo et al. (2014) also found pulmonary fibrosis in 7% of patients, suggesting that these histopathological changes may reflect ongoing inflammatory processes or inadequate healing in certain individuals. [14]

CONCLUSION

In conclusion, this study highlights the significant long-term pulmonary sequelae observed in patients who have completed treatment for tuberculosis. While many patients show substantial recovery in lung function, fibrotic changes and bronchiectasis remain common complications. Radiological and histopathological findings further suggest that a considerable portion of patients experience persistent lung abnormalities even years after TB treatment. Despite these challenges, the majority of individuals demonstrate a gradual improvement in pulmonary function, emphasizing the importance of continuous monitoring and management of post-TB lung health.

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