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Spirometry after treatment completion for pulmonary tuberculosis – a necessity?

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Abstract

Pulmonary tuberculosis often results in permanent lung damage, such as fibrosis, bronchiectasis, and emphysema, despite a successful microbiological cure. These structural changes lead to post-tuberculosis lung disease (PTLD), which is characterized by chronic respiratory symptoms and impaired lung function. This study aimed to evaluate functional and radiological impairments in patients after completion of anti-tubercular therapy to understand the long-term impact of tuberculosis on respiratory health. This prospective study evaluated 175 adults within 1 year of completing anti-tubercular therapy to assess the prevalence of PTLD. Results revealed spirometric abnormalities in 57.1% of participants, predominantly restrictive patterns (30.3%), followed by obstructive defects (16.6%) and Preserved Ratio Impaired Spirometry or PRISm (10.3%). Sputum smear positive status at diagnosis strongly predicted obstructive disease and severe structural damage. Notably, this impairment affected a young, non-smoking cohort and was largely irreversible. The study concludes that microbiological cure does not equate to respiratory health, highlighting the necessity of integrating assessment of comprehensive respiratory system evaluation and routine spirometry at treatment completion to manage long-term morbidity.

Key words: pulmonary tuberculosis, post-tuberculosis lung disease, spirometry, airflow obstruction, restrictive spirometry pattern, pulmonary rehabilitation.

Introduction

Pulmonary Tuberculosis (PTB), caused by *Mycobacterium tuberculosis*, remains one of the most formidable global health challenges. The incidence for 2022 was 199 per lakh population, with 16% decline as compared to 2015 (237 per lakh population). The TB mortality was 23 per lakh population, with 18% decline as compared to 2015 [1]. For decades, the primary metric of success in TB programmes has been microbiological conversion of sputum from positive to negative and the completion of anti-tubercular therapy (ATT). However, the end of treatment may not often be the end of the disease for the patient.

PTB is characterised by chronic inflammatory processes with the histopathological hallmark being granulomatous caseous necrosis [2]. Even after the bacilli are eradicated, patients are left with various radiological sequelae including fibrosis, bronchiectasis, and emphysema. These changes manifest clinically as Post-Tuberculosis Lung Disease (PTLD), a condition that significantly impairs respiratory function and quality of life [3,4]. The GOLD 2026 Report, has formally recognised the infectious etiotypes under the classification COPD-I [5]. This shifts the paradigm from viewing post-TB breathlessness as a mere complication to treating it as a distinct chronic pathology requiring specific management. Despite this, routine functional assessment following treatment completion is not yet standard practice in many high-burden settings including India.

This study was designed to bridge this gap by evaluating the functional and radiological status of PTB patients within the first year of treatment completion. By focusing on this critical window, we aimed to identify the early onset of PTLD and determine the clinical predictors that correlate with functional impairment.

Materials and Methods

This prospective observational study was conducted at a tertiary respiratory care centre in Western Maharashtra, India. We enrolled 175 adults who had successfully completed a course of ATT within the preceding 12 months. The study was approved by the Institutional Ethics Committee, and all participants provided informed written consent.

AIM - To assess lung function using spirometry in pulmonary tuberculosis patients after completion of therapy at a Tertiary Respiratory Care Centre in Maharashtra.

Screening: All patients attending the OPD or admitted to the IPD with a documented history of PTB, confirmed by medical records, were screened for eligibility.

Inclusion Criteria:

- Age 18 years.
- History of PTB with completion of ATT within 1 year prior to enrolment.

Exclusion Criteria:

- Sputum smear positive TB at the time of enrolment or relapse.
- Pre-existing obstructive airway disease (OAD) diagnosed before the TB episode.
- Extrapulmonary TB cases without pulmonary involvement.
- History of irregular ATT or loss to follow-up during treatment.
- Contraindications to spirometry, such as recent myocardial infarction, uncontrolled hypertension, recent thoracic/abdominal surgery, or active hemoptysis.

A comprehensive clinical history including symptoms, duration and sputum smear status at time of diagnosis was recorded for each participant. Patients were classified into the following subsets -

Sputum smear positive pulmonary TB - Sputum smear positive on ZN stain

Sputum smear negative pulmonary TB – Sputum smear negative on ZN stain but microbiologically confirmed pulmonary TB on cartridge based nucleic acid amplification test (CBNAAT) using MTB GeneXpert or MTB GeneXpert ultra on sputum sample or bronchoalveolar lavage.

Radiological sequelae were assessed via chest X-rays, which were reviewed by an experienced radiologist to identify patterns of fibrosis, bronchiectasis, pleural thickening, and the extent of lung zone involvement (graded from 0 to 6).

Spirometry was the cornerstone of our functional evaluation, performed using a calibrated digital spirometer in accordance with ATS/ERS 2019 guidelines. We measured Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and the FEV1/FVC ratio. Obstructive Pattern was defined as post bronchodilator FEV1/FVC < 0.7 and further classified into mild (FEV1>80%), moderate (FEV1 – 50-80%), severe (FEV1 – 30-50%) and very severe (FEV1<30%). Restrictive pattern was defined as FVC < 80% of the predicted value with a preserved FEV1/FVC ratio. It was further classified into mild (FVC 60-80%), moderate (FVC 40-60%) and severe (FVC<40%). PRISm (Preserved Ratio Impaired Spirometry) was defined by a normal FEV1/FVC ratio (0.7) but a reduced FEV1 (< 80% predicted) based on GOLD 2026 guidelines(5). Post-bronchodilator testing was performed 15 minutes after the administration of 400 mcg of salbutamol to assess the reversibility (Post BDR) of any identified obstruction, defined as a change of more than 12% or 200 ml in FEV1 or FVC.

Statistical analysis

Data were analysed using SPSS version 24. We employed Chi-square and Fisher's exact tests to evaluate associations between microbiological history (sputum status) and functional outcomes. A p-value of <0.05 was considered statistically significant.

Results

The study cohort was notably young, with a mean age of 32.5 years (SD 11.0, Table 1). There was a strong male predominance (86.3%), largely reflecting the patient base of the tertiary military hospital where the study was conducted. 93.7% of the patients were non-smokers, 5% had smoking index of less than 100 and 1% having a smoking index between 101-200, suggesting that the identified lung impairments were directly attributable to TB rather than tobacco exposure.

Cough was the most common symptom during initial presentation (n=148, 84.6%), followed by weight loss (76.0%), fever and expectoration (73.1% each), and anorexia (68.6%). Breathlessness was noted in 68 participants (38.9%), while chest pain was present in 60 (34.3%). Hemoptysis was the least commonly reported symptom (Table 2). 105 individuals (60.0%) were initially sputum smear negative at onset of treatment, while 70 individuals (40.0%) were sputum smear positive at onset of treatment. All patients had been declared cured within the past 12 months. Only 22 patients (12.5%) were symptomatic post completion of treatment with breathlessness being most common (n=12, 54.5%), followed by chest pain (n=10, 45.5%), cough (n=8, 36.4%), expectoration (n=5, 22.7%) and wheeze (n=2, 9%).

Spirometric abnormalities were identified in 57.1% of the participants within just one year of completing ATT (Figure 1).

- Restrictive spirometry patterns were the most common defect, found in 30.3% of the cohort.
- Obstructive patterns were seen in 16.6%.
- PRISm was identified in 10.3%.

Patients who were sputum smear positive at the time of their TB diagnosis were significantly more likely to develop an obstructive pattern (32.9%) compared to those who were sputum smear negative (5.7%; $p < 0.001$). Furthermore, the obstructive defects were functionally more severe than the restrictive ones; 79.3% of obstructive cases were moderate-to-severe, whereas 71.7% of restrictive spirometry patterns were mild ($p < 0.001$).

Figure 2a outlines the initial radiological findings observed among the study subjects at time of diagnosis which included reticulonodular opacities, consolidation, cavity and pleural effusion. Figure 2b outlines the radiological sequelae observed among the study subjects. Fibrosis was the most common complication, seen in 45% followed by pleural thickening (31.6%), bronchiectasis (12.2%). Less common complications included lung collapse in 2 individuals (2.0%), fibrosis combined with collapse in 1 subject (1.0%), and fibrosis with pleural thickening in 7 subjects (7.1%). A single case (1.0%) showed a unilateral destroyed lung and had severe obstruction on spirometry. These findings indicate that post-tuberculosis pulmonary complications were relatively common, with fibrosis being the predominant feature.

Table 3 shows the spirometry grades among the 82 study subjects with abnormal spirometry results. Among the 53 subjects with a restrictive spirometry pattern, 38 (71.7%) were classified as mild, 12 (22.6%) as moderate, and 3 (5.7%) as severe. In contrast, among the 29 subjects with an obstructive pattern, 2 (6.9%) were mild, 23 (79.3%) were moderate, and 4 (13.8%) were severe. The p-value of <0.001 indicates a statistically significant difference in the distribution of spirometry grades between restrictive and obstructive patterns, suggesting that restrictive impairments in post-TB patients are predominantly mild, likely due to fibrotic changes limiting lung expansion, while obstructive impairments, potentially linked to bronchiectasis or airway remodelling, are more commonly moderate to severe. The mean FEV_1 was slightly higher in sputum smear negative subjects (mean ± SD: 3.0 ± 0.8 L; median: 3.1 L) compared to sputum smear positive subjects (mean ± SD: 2.8 ± 0.9 L; median: 3.0 L), though this difference was not statistically significant ($p = 0.175$). The FEV_1% predicted showed a significant difference, with sputum smear negative patients having a higher value (mean: 79.5 ± 17.5%; median: 80.0%) compared to sputum smear positive patients (mean: 73.9 ± 17.3%; median: 73.5%) ($p = 0.033$), suggesting better preserved lung function in the sputum smear negative group. The FVC values were almost identical in both groups, with means of 3.6 L and medians of 3.7 L, showing no significant difference ($p = 0.982$). Similarly, FVC% was nearly the same between the groups (mean: 80.7 ± 14.4%; median: 82.0% in sputum smear negative vs. mean: 81.2 ± 14.4%; median: 82.0% in sputum smear positive), with $p = 0.956$. A significant difference was observed in the FEV_1/FVC ratio, which was higher in sputum smear negative subjects (mean: 83.1 ± 7.2%; median: 83.7%) compared to sputum smear positive subjects (mean: 75.5 ± 13.2%; median: 81.1%), with a p-value of 0.001. Table 4 shows the comparison of sputum report with spirometry findings. Among the 105 subjects with sputum smear negative TB, 52 (49.5%) had normal lung function, 10 (9.5%) exhibited PRISm pattern, 37 (35.2%) had a restrictive pattern, and 6 (5.7%) had an obstructive pattern. In contrast, among the 70 subjects with sputum smear positive TB, 23 (32.9%) had normal lung function, 8 (11.4%) had PRISm, 16 (22.9%) had restriction, and 23 (32.9%) had obstruction. The p-value of <0.001 indicates a statistically significant difference in lung function distribution between sputum-negative and sputum-positive cases. This suggests that sputum smear positive PTB patients are more likely to develop obstructive lung disease, potentially due to greater airway damage from higher bacillary load, while sputum smear negative patients more frequently exhibit restrictive patterns, possibly linked to fibrotic sequelae or thickening.

Sputum smear positive status was again a major predictor of structural damage, correlating strongly with bilateral lung involvement (27.1% vs 6.7% in sputum smear negative; $p < 0.001$)

and extensive fibrosis (40% vs 16.2%; $p < 0.001$). In the group with sputum positivity lasting more than 2 months, obstruction was the most prevalent lung condition (38.7%), followed by normal function (32.3%), restriction (19.4%), and PRISm (9.7%). The distribution suggests a trend toward a higher proportion of obstructive lung impairment in those with prolonged sputum positivity, though this difference was not statistically significant ($p = 0.774$).
A key finding for clinical management was the predominantly fixed nature of the obstruction. Only 8.6% of participants showed a significant bronchodilator response (Table 5). However, none of the patients had any prior history of atopy or asthma. This suggests that the airflow limitation in PTLD is probably due to structural remodelling and bronchoconstriction.

Discussion

Previous literature consistently demonstrates that pulmonary tuberculosis leads to persistent and clinically significant lung function impairment, even after microbiological cure. Across diverse populations, PTLD is highly prevalent, with abnormal spirometry reported in 54–91% of treated patients [3,4,6-8]. Obstructive ventilatory defects are the most common abnormality, though restrictive and mixed patterns are also frequently observed [8-11]. PLATINO study was a large population based, multicentre study in Latin America which showed a strong association between a PTB and airflow obstruction [12]. However, most of the studies have been done in symptomatic individuals [10,11] or the spirometry has been performed after more than a year from completion of treatment [6,13,14]. Our study was unique in the way that only 22 subjects had reported with symptoms and spirometry was performed within 1 year of completion of treatment for early diagnosis of functional defect which can help in early initiation of treatment and prevent further complications and permanent disability.
The results of this study underscore a critical public health reality: the successful completion of ATT is merely the end of the infectious phase and often the beginning of a chronic respiratory journey. Our finding that over half (57.1%) of cured TB patients have lung function abnormalities within one year is particularly alarming given the young age of our cohort.
The most significant finding in our data is the powerful association between sputum smear positive PTB and obstructive lung disease. This suggests that an initial higher bacillary load at diagnosis may act as a catalyst for greater airway inflammation and subsequent airway remodelling. This may allow clinicians to use the initial sputum smear status as a simple risk-stratification tool to identify which patients require the most aggressive follow-up.
The identification of PRISm in 10.3% of our patients is a vital "early warning" result. In the context of the GOLD 2026 guidelines, PRISm is a known precursor to airway obstruction as well as increased cardiovascular mortality [5]. Identifying these patients early provides a golden opportunity for early intervention and disability limitation. Since the damage is largely

irreversible (as shown by the 8.6% BDR response), the focus must shift from relieving the obstruction to optimizing the remaining lung function through pulmonary rehabilitation and the targeted use of long-acting bronchodilators. To the best of our knowledge this is the first study showing the prevalence of PRISm in this subset of patients.

The younger age of our participants (mean 32.5 years) carries profound socioeconomic implications. These are individuals in their prime working years. If over half have impaired lung function, the economic burden of cured PTB extends far beyond the cost of the initial 6-month therapy.

Our study suggests that the National Tuberculosis Elimination Programme (NTEP) must evolve. Microbiological cure should not be the exit point for patient care. Instead, we propose the integration of functional evaluation within one year of careful and correct documentation of treatment cure in microbiologically confirmed cases.

The limitations of the study were that it was conducted at a single tertiary care center, potentially introducing selection bias toward severe cases and limiting generalizability to primary care or community settings, and resulted in a predominantly male cohort. The study lacked pre-ATT baseline spirometry/radiological data, limiting causal inferences. Environmental factors like biomass fuel exposure, which may influence PTLD outcomes, were also not assessed. However, since the study was conducted in an army hospital, the patients can be followed up yearly to look at subsequent symptom development and progression of spirometric defects.

Conclusions

This study highlights that microbiological cure of pulmonary tuberculosis does not equate to restoration of pulmonary health. More than half of the patients in our cohort demonstrated abnormal spirometry within one year of completing anti-tubercular therapy, despite the majority being young, non-smokers, and largely asymptomatic at follow-up. These findings underscore the substantial and often silent burden of PTLD that emerges early after treatment completion. The predominantly fixed nature of airflow limitation, with minimal bronchodilator reversibility, indicates that structural remodelling rather than reversible bronchoconstriction is the principal mechanism of impairment. This has important therapeutic implications, shifting emphasis toward early detection, pulmonary rehabilitation, risk-factor modification, and long-term functional optimisation rather than symptom-driven reactive care.

From a public health perspective, these results challenge the traditional endpoint of tuberculosis programmes. In a country with a high TB burden and a predominantly young affected population, failure to address post-treatment functional impairment risks substantial long-term morbidity and socioeconomic loss. Routine spirometric evaluation at treatment completion, should therefore be integrated into standard TB care pathways. Such an approach would enable early identification of PTLD, facilitate timely interventions, and ultimately redefine "cure" in tuberculosis as not only microbiological eradication but also preservation of long-term respiratory health.

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Table 1. Age distribution of cohort with a mean of 32.5 years and SD of 11.0.

Age group	Frequency	Percentage
<25 years	55	31.4
26-50 years	104	59.4
>50 years	16	9.1
Range	18-75	
Mean	32.5	
Standard deviation	11.0	

Table 2. Initial clinical features at time of diagnosis of pulmonary tuberculosis.

Clinical features	Frequency	Percentage
Cough	148	84.6
Weight loss	133	76.0
Fever	128	73.1
Expectoration	128	73.1
Anorexia	120	68.6
Breathlessness	68	38.9
Chest pain	60	34.3
Hemoptysis	45	25.7

Table 3. Spirometry severity grading of restrictive and obstructive patterns. Note PRISm has not been included in this table as there is no grading criteria for the same.

Grade	Interpretation		p-value
	Restriction	Obstruction	
Mild	38	2	<0.001
	71.7%	6.9%	
Moderate	12	23	
	22.6%	79.3%	
Severe	3	4	
	5.7%	13.8%	
Total	53	29	
	100.0%	100.0%	

Table 4. Comparison of sputum report and spirometry findings among study subjects.

Interpretation	Diagnosis		p-value
	Sputum negative pulmonary tuberculosis	Sputum positive pulmonary tuberculosis	
Normal	52	23	<0.001
	49.5%	32.9%	
PRISm	10	8	
	9.5%	11.4%	
Restriction	37	16	
	35.2%	22.9%	
Obstruction	6	23	
	5.7%	32.9%	
Total	105	70	
	100.0%	100.0%	

Table 5. FEV1, FVC and post BDR amongst study subjects.

Parameters	Diagnosis		p-value
	Sputum negative pulmonary tuberculosis	Sputum positive pulmonary tuberculosis	
FEV1 (in liters)			
Mean	3.0	2.8	0.175
Median	3.1	3.0	
Standard Deviation	0.8	0.9	
FEV1%			
Mean	79.5	73.9	0.033
Median	80.0	73.5	
Standard Deviation	17.5	17.3	
FVC (in liters)			
Mean	3.6	3.6	0.982
Median	3.7	3.7	
Standard Deviation	0.9	0.8	
FVC%			
Mean	80.7	81.2	0.956
Median	82.0	82.0	
Standard Deviation	14.4	14.4	
FEV1/FVC			
Mean	83.1	75.5	0.001
Median	83.7	81.1	
Standard Deviation	7.2	13.2	
Significant post BDR changes	**Frequency**	**Percentage**	
No	160	91.4	
Yes	15	8.6	
Total	**175**	**100.0**	

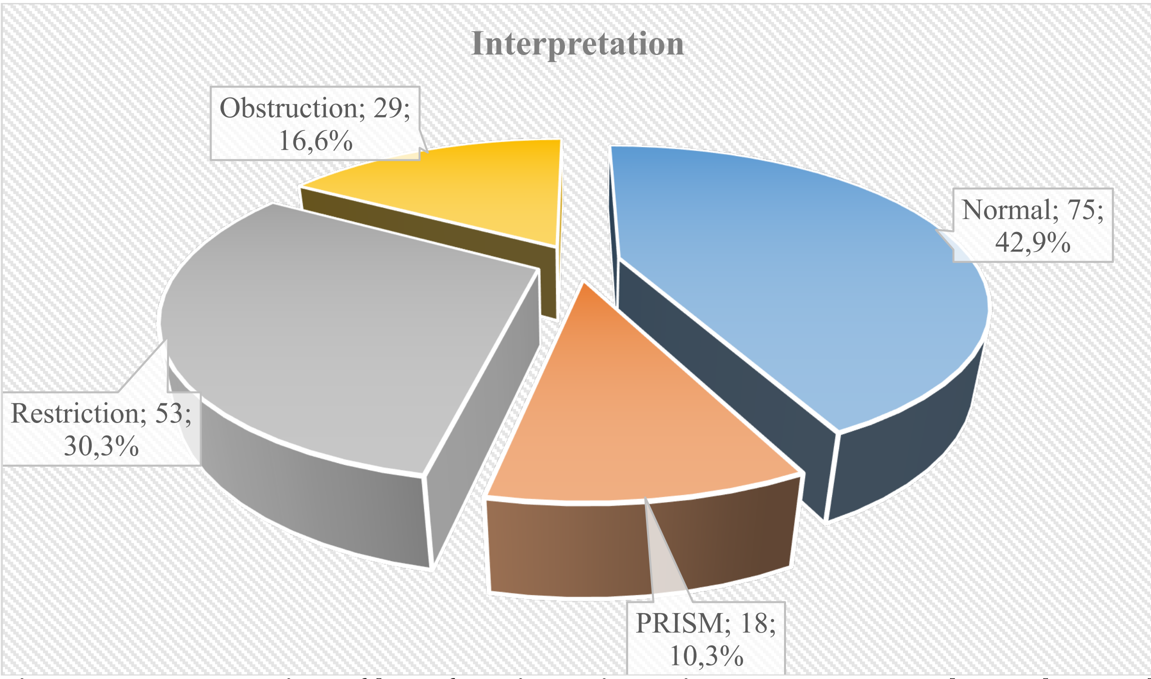

Figure 1. Interpretation of lung function using spirometry amongst the study population.

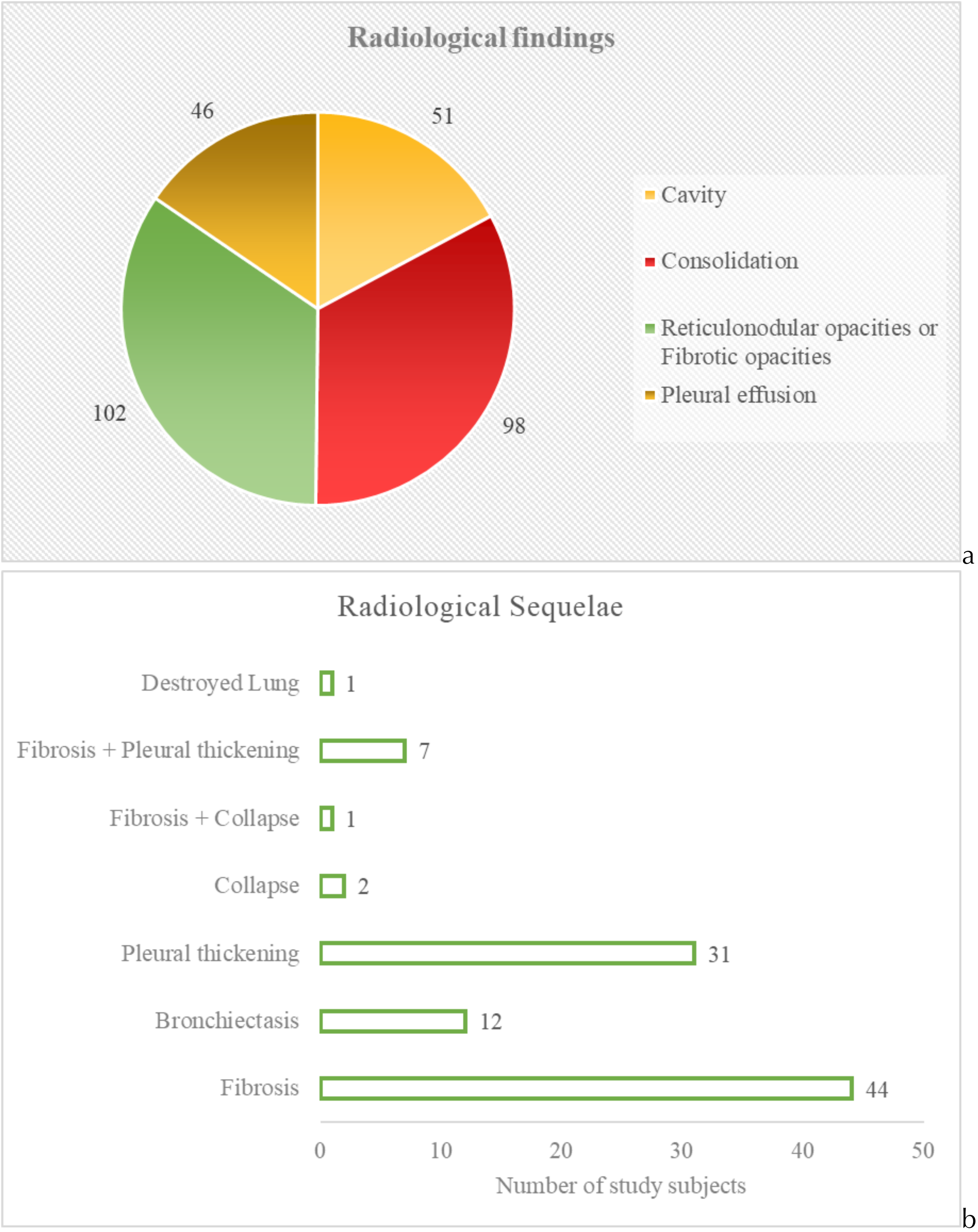

Figure 2. a) Initial radiological findings during diagnosis of pulmonary tuberculosis; b) radiological sequelae observed among study subjects.