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Original Article

Radiology Section

Spectrum of Radiological Findings in Pulmonary Tuberculosis- A Tertiary Care Hospital-based Retrospective Descriptive Study

GV VISHNUPRIYASRIEE[1], RAVIPATI CHAKRADHAR[2], MURALIDHARAN YUVARAJ[3], RAMAKRISHNAN KARTHIK KRISHNA[4], PITCHANDI MUTHIAH[5]

ABSTRACT

Introduction: Tuberculosis is a worldwide public health problem associated with high morbidity and mortality. Tuberculosis can manifest in active and latent forms. Improving the diagnosis, treatment, and screening of tuberculosis is crucial for effective tuberculosis control. Chest X-ray and Computed Tomography chest play a vital role in diagnosing and screening for tuberculosis.

Aim: To analyse the spectrum of radiological findings in pulmonary tuberculosis.

Materials and Methods: The present retrospective descriptive study was conducted at a teritary care hospital in the Department of Radiodiagnosis, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India. The data of 160 patients diagnosed with pulmonary tuberculosis between January 2019 and December 2020 were accessed and analysed. The recorded variables included forms of pulmonary tuberculosis, age/gender distribution, co-morbidities, Acid-fast Bacillus (AFB) smear status, and radiological findings and distribution. Descriptive statistics are presented in frequency and percentage.

Results: Among the 160 cases of pulmonary tuberculosis, 30 (18.75%) cases were active primary tuberculosis, 105 (65.63%) cases were active post-primary tuberculosis, and 25 (15.62%) cases were inactive tuberculosis. Among the 30 cases of active primary tuberculosis, 14 (46.67%) cases had consolidation with air bronchogram, and 6 (20%) cases had consolidation without air bronchogram. Among the 105 cases of active post-primary tuberculosis, 65 (61.9%) cases had consolidation, 50 (47.62%) cases had cavities, and 56 (81.9%) cases had centrilobular nodules with a tree-in-bud appearance. Among the 25 cases of inactive tuberculosis, 18 (72%) cases had fibrosis with bronchiectasis, while 4 (16%) cases had fibrosis without bronchiectasis, and 3 (12%) cases had calcified granulomas.

Conclusion: The study conclusively demonstrates the diverse radiological manifestations of pulmonary tuberculosis in different patient demographics. It highlights a higher incidence of active post-primary tuberculosis, especially in patients above 45 years, with varying radiological findings such as consolidation, cavitation, and fibrosis.

Keywords: Bronchiectasis, Cavity, Consolidation, Fibrosis, Granuloma, Pleural effusion

INTRODUCTION

India has the world's highest number of tuberculosis cases reported, with an incidence of 26.9 lakh cases reported in the year 2019 [1]. Mycobacterium tuberculosis complex is the causative agent of tuberculosis, with mycobacterium tuberculosis being the most common cause. Despite the discovery of the causal bacterium over a century ago and the availability of potent medications for treatment, tuberculosis remains a major public health problem even today [2].

Tuberculosis is an airborne disease spread via droplet transmission, involving alveolar macrophages being infected by the inhaled bacilli droplets in the terminal air spaces of the lungs [2]. The virulence of the bacterium and the individual's immunological response influence the likelihood of infection and clinical Tuberculosis (TB) [2]. Specific populations are predisposed to the disease mainly due to poor living conditions, debility, and malnutrition.

Sputum analysis, which includes smear, culture, and nucleic acid amplification testing, is the primary method of detecting active tuberculosis. Radiology also plays a major role in the diagnosis and screening of tuberculosis. Radiologically, tuberculosis mainly manifests in two forms: active and latent forms [3]. Based on the presence or absence of prior infection and acquired specific immunity, active pulmonary tuberculosis can be categorised into primary and post-primary tuberculosis [4]. Primary tuberculosis develops shortly after infection and is most common in children and immunocompromised patients. It mainly manifests with lymphadenopathy, miliary disease, atelectasis, pulmonary consolidation, and pleural effusion [5]. Post-primary tuberculosis develops after an extended period of latent infection and may be evident with cavities, consolidations, and centrilobular nodules [3]. A cavity is the hallmark of post-primary tuberculosis and is suggestive of active disease. Cavities are most common in areas of consolidation and have thick irregular walls with or without air-fluid levels. This may progress or heal with fibrosis resulting in volume loss or tractional bronchiectasis [4-6]. Previous tuberculosis, which is now inactive, manifests as fibronodular opacities in the apical and upper lung zones. Latent tuberculosis is an asymptomatic infection that can progress to post-primary tuberculosis. Chest radiographs can be used to detect asymptomatic active disease and to stratify risk. Clinical diagnosis, laboratory diagnosis, and chest radiography aid in the diagnosis and management of tuberculosis [3].

Existing studies on pulmonary Tuberculosis (TB) in India have extensively documented the high incidence rate, the microbiological characteristics of the mycobacterium tuberculosis complex, and the various modes of transmission and population predispositions to the disease [1]. The clinical management and diagnostic protocols, including sputum analysis and radiological assessments, are well established and pivotal in the detection and treatment of TB.

However, there is a gap in the comprehensive analysis of radiological findings specific to the Indian demographic, which experiences a unique set of environmental and genetic factors that may influence the presentation of tuberculosis. Radiological findings can vary greatly from patient to patient, and understanding these variations within the context of a high-incidence population can provide crucial insights into disease patterns.

The study aimed to address these gaps by conducting a detailed analysis of the spectrum of radiological findings in patients with pulmonary tuberculosis in India. The novelty of present study lies in its focused examination of radiological data within the Indian context, which has not been explored to this extent previously.

MATERIALS AND METHODS

A hospital-based retrospective descriptive study was conducted for a period of two years from January 2019 to December 2020 in the Department of Radiodiagnosis at Saveetha Medical College and Hospital, Chennai, Tamil Nadu, India. Data analysis and interpretation were performed over a period of one month. The proposal for the study was submitted to the Institution's Ethics Committee, and approval was obtained (IEC Approval No. SMC/IEC/2018/12/037).

Inclusion criteria: Patients diagnosed with pulmonary tuberculosis by clinical or laboratory investigations and on anti-tuberculosis therapy, patients previously treated for tuberculosis and presenting with respiratory infections as a post-tuberculosis sequelae, were included in the study.

Exclusion criteria: Patients aged <15 years, patients with known malignancy, pregnant women, and patients with extrapulmonary tuberculosis were excluded from the study.

Study Procedure

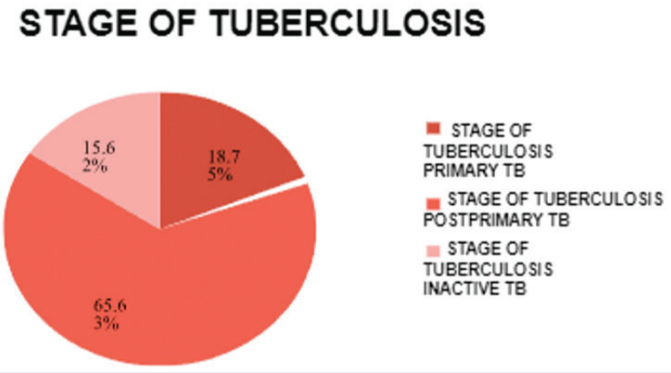
The data of 160 patients diagnosed with pulmonary tuberculosis and its sequelae who underwent chest radiography/CT chest were accessed from the manual and digital records in the Radiology Department and medical records division of the hospital and analysed. The recorded variables included forms of pulmonary tuberculosis, age/gender distribution, co-morbidities, AFB smear status, and radiological findings and distribution.

STATISTICAL ANALYSIS

All details regarding the patients were kept confidential. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 17.0 for Microsoft windows. Descriptive statistics were presented in frequency tables and graphs.

RESULTS

Among the 160 cases, 30 (18.75%) cases were active primary tuberculosis, 105 (65.63%) cases were active post-primary tuberculosis, and 25 (15.62%) cases were inactive or previous tuberculosis, as shown in [Table/Fig-1].



[Table/Fig-1]: Distribution of form of pulmonary tuberculosis in the study population.

In a series of 160 cases, 97 (60.62%) cases were above the age of 45 years. Among the 160 cases, 119 (74.37%) cases were male, while 41 (25.63%) cases were female [Table/Fig-2].

Among the active primary tuberculosis cases (30 cases), 19 (63.33%) cases were unilateral, while 11 (36.67%) cases were bilateral. Out of the 252 cases of inactive pulmonary tuberculosis, 7 (28%) cases were unilateral, while 18 (72%) cases were bilateral [Table/Fig-3].

Characteristics	Stage of tuberculosis						Total N=160
	Active				Inactive		
	Primary		Post-primary				
	n=30	%	n=105	%	n=25	%	
1. Age (years)							
<45	28	93.33	27	25.71	8	32	63 (39.38)
>45	2	6.67	78	74.29	17	68	97 (60.62)
2. Gender							
Male	18	60	67	63.81	14	56	99 (61.87)
Female	12	40	38	36.19	11	44	61 (38.13)
3. Social habits							
Smoker	6	20	31	29.52	5	20	42 (26.25)
Alcoholic	3	10	6	5.71	2	8	11 (6.87)
Smoker and alcoholic	5	16.67	25	23.81	9	36	39 (24.38)
Non smoker and non alcoholic	16	53.33	43	40.96	9	36	68 (42.5)
4. Co-morbid illness							
Illness present	8	26.67	65	61.9	16	64	89 (55.63)
Illness absent	22	73.33	40	38.1	9	36	71 (44.37)
5. AFB smear							
Positive	21	70	77	73.33	0	0	98 (61.25)
Negative	9	30	28	26.67	25	100	62 (38.75)

[Table/Fig-2]: Demographic characteristics of study population.

Among the 30 cases of active primary tuberculosis, 19 (63.33%) cases mainly involved the upper and middle zones of the lung in the chest radiography, while the remaining 11 (36.67%) cases affected the lower zone of the lung as shown in [Table/Fig-4].

Out of the 105 cases of active post-primary tuberculosis, 90 (85.71%) cases involved the upper and middle zones of the lung, while 15 (14.29%) cases involved the lower zone of the lung in chest radiography, as shown in [Table/Fig-5].

Among the 25 cases of inactive pulmonary tuberculosis, 60% (15 cases) involved the upper and middle zones of the lung, while 40% (10 cases) involved the lower zone of the lung in chest radiography, as shown in [Table/Fig-6].

Consolidation was the most common radiological finding. It was seen with air bronchogram in 14 patients with primary TB (46.67%), 47 patients with post-primary TB (44.76%), and three patients with inactive TB (12%), making a total of 64 patients (40%). Without air bronchogram, it was observed in 6 patients with primary TB (20%), 18 patients with post-primary TB (17.14%), and 1 patient with inactive TB (4%), making a total of 25 (15.63%).

Cavity with a fungal ball was seen in zero patients with primary TB, 4 patients with post-primary TB (3.81%), and 1 patient with inactive TB (4%), making a total of 5 (3.13%). Without a fungal ball, it was observed in 14 patients with primary TB (46.67%), 46 patients with post-primary TB (43.81%), and 5 patients with inactive TB (20%), making a total of 65 (40.63%) [Table/Fig-7].

Chest radiograph [Table/Fig-8] of a 65-year-old male patient shows right upper zone consolidation.

Chest radiograph [Table/Fig-9a,b] of a 54-year-old female shows a cavity in the right upper zone, marked by a solid yellow arrow.

High Resolution Computed Tomography (HRCT) chest (lung window) [Table/Fig-10a,b] of a 56-year-old female shows a thin-walled cavity and bronchiectatic changes in the left lung.

HRCT chest (lung window) [Table/Fig-11] of a 20-year-old female shows centrilobular nodules with a tree-in-bud appearance (solid yellow arrow).

Laterality	Primary TB		Post-primary TB		Inactive TB		Total	
	Frequency (n=30)	%	Frequency (n=105)	%	Frequency (n=25)	%	N=160	%
Unilateral								
Right	11	36.67	40	38.1	3	12	54	33.75
Left	8	26.66	6	5.71	4	16	18	11.25
Bilateral	11	36.67	59	56.19	18	72	88	55

[Table/Fig-3]: Laterality of pulmonary tuberculosis in the study population.

Site	Unilateral (right)		Unilateral (left)		Bilateral		Total	
	Frequency (n=11)	%	Frequency (n=8)	%	Frequency (n=11)	%	Frequency (n=30)	%
Upper zone+middle zone	9	81.82	3	37.5	7	63.64	19	63.33
Lower zone	2	18.18	5	62.5	4	36.36	11	36.67

[Table/Fig-4]: Radiological distribution of pulmonary tuberculosis.

Site	Unilateral (right)		Unilateral (left)		Bilateral		Total	
	Frequency (n=40)	%	Frequency (n=6)	%	Frequency (n=59)	%	Frequency (n=105)	%
Upper zone+middle zone	35	87.5	4	66.67	51	86.44	90	85.71
Lower zone	5	12.5	2	33.33	8	13.56	15	14.29

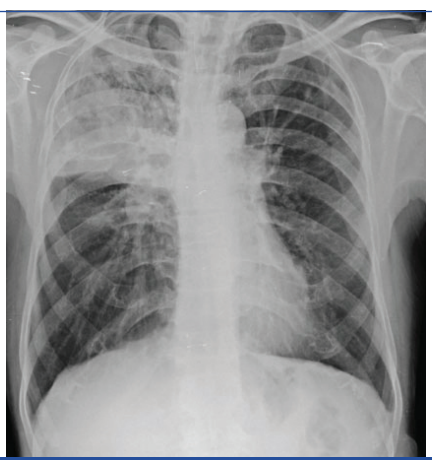
[Table/Fig-5]: Radiological distribution of pulmonary tuberculosis in post-primary tuberculosis type in the study population.

Site	Unilateral (right)		Unilaterl (left)		Bilateral		Total	
	Frequency (n=3)	%	Frequency (n=4)	%	Frequency (n=18)	%	Frequency (n=25)	%
Upper zone+Middle zone	2	66.67	2	50	11	61.11	15	60
Lower zone	1	33.33	2	50	7	38.89	10	40

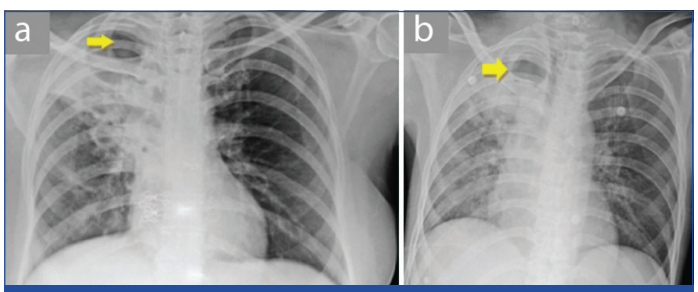
[Table/Fig-6]: Radiological distribution of pulmonary tuberculosis in inactive tuberculosis type in the study population.

Radiological findings		Number of patients with primary tuberculosis		Number of patients with post-primary tuberculosis		Number of patients with inactive tuberculosis		Total	
		n=30	%	n=105	%	n=25	%	N=160	%
1. Consolidation	With air bronchogram	14	46.67	47	44.76	3	12	64	40
	Without air bronchogram	6	20	18	17.14	1	4	25	15.63
2. Cavity	With fungal ball	0	0	4	3.81	1	4	5	3.13
	Without fungal ball	14	46.67	46	43.81	5	20	65	40.63
3. Centrilobular nodules with tree in bud appearance		12	40	86	81.9	7	28	105	65.63
4. Pleural effusion		8	26.67	19	18.1	1	4	28	17.5
5.Fibrosis	With bronchiectasis	7	23.33	57	54.29	18	72	82	51.25
	Without bronchiectasis	5	16.67	3	2.86	4	16	12	7.5
6. Miliary nodules		3	10	6	5.71	0	0	9	5.63
7. Calcified granuloma		0	0	19	18.09	3	12	22	13.75
8. Collapse		10	33.33	11	10.48	3	12	24	15
9. Volume loss	With mediastinal shift	6	20	14	13.33	2	8	22	13.75
	Without mediastinal shift	3	10	16	15.24	3	12	22	13.75
10. Bronchopleural fistula		0	0	4	3.81	1	4	5	3.13
11.Bullae		2	6.67	9	8.57	10	40	21	13.12

[Table/Fig-7]: Spectrum of radiological findings of pulmonary tuberculosis in the study population.



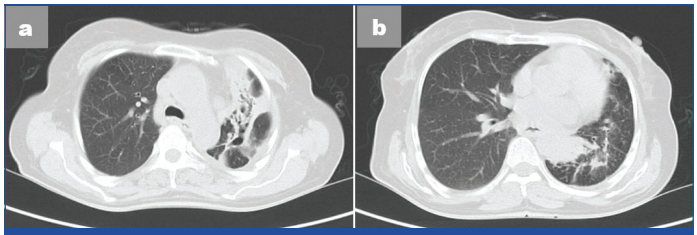
[Table/Fig-8]: Consolidation.



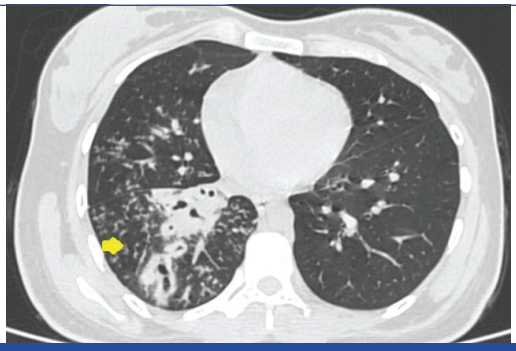
[Table/Fig-9a,b]: Cavity.

Chest radiograph [Table/Fig-12] of a 68-year-old female shows a massive right pleural effusion.

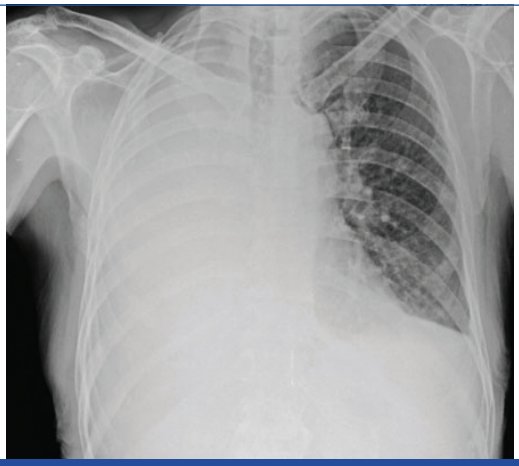
Chest radiograph [Table/Fig-13a] and HRCT chest (mediastinal window) [Table/Fig-13b] of a 27-year-old female show hilar lymphadenopathy with calcifications (solid yellow arrow).



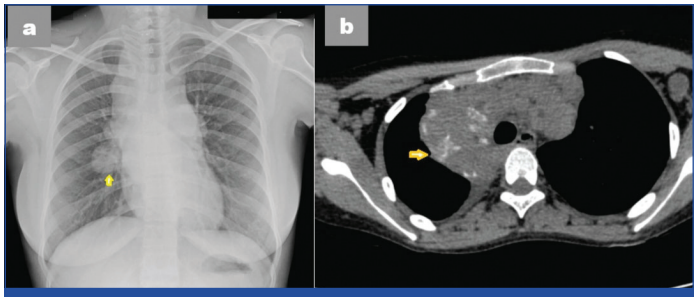
[Table/Fig-10a,b]: HRCT Chest (lung window) of a 56-year-old female showing thin walled cavity and bronchiectatic changes in left lung.



[Table/Fig-11]: Centrilobular nodules with tree in bud appearance.



[Table/Fig-12]: Pleural effusion.



[Table/Fig-13a,b]: Hilar lymphadenopathy.

Chest radiograph [Table/Fig-14] of a 61-year-old male shows volume loss with fibro-cavity and minimal pleural effusion on the left side.

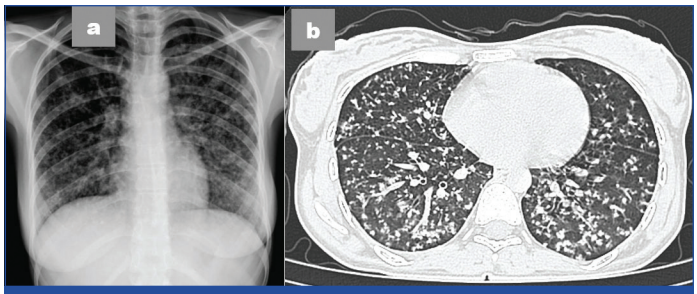
Chest radiograph [Table/Fig-15a] of a 38-year-old female shows multiple tiny nodular infiltrates noted diffusely distributed in bilateral lung fields. HRCT chest (lung window) [Table/Fig-15b] of the same patient shows multiple tiny nodular densities scattered diffusely and equally in bilateral lungs.

Chest radiograph [Table/Fig-16a] and HRCT chest (lung window) [Table/Fig-16b] of a 43-year-old male show calcified granulomas in bilateral upper and mid zones, marked by solid yellow arrows.

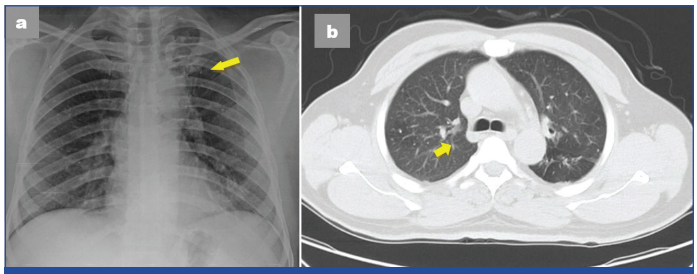
Chest radiograph [Table/Fig-17a] and HRCT chest (lung window) [Table/Fig-17b-d] of a 42-year-old female show cystic bronchiectasis changes with complete collapse of the left lung.

Chest radiograph [Table/Fig-18] of a 47-year-old patient shows volume loss of the left lung with mediastinal shift.

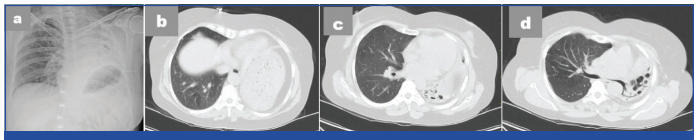
[Table/Fig-14]: Fibrosis.



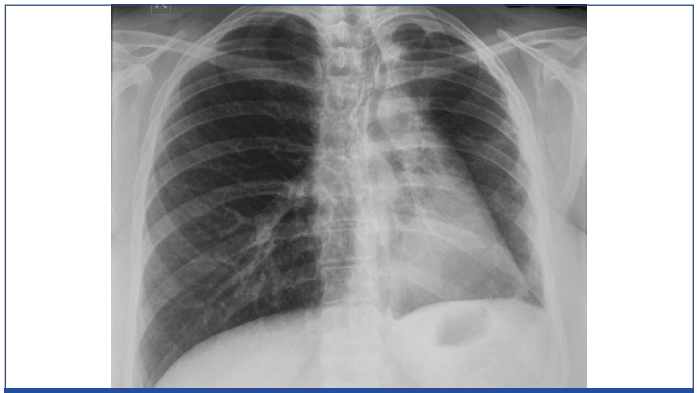
[Table/Fig-15a,b]: Miliary nodules.



[Table/Fig-16a,b]: Calcified granuloma.



[Table/Fig-17a-d]: Collapse.

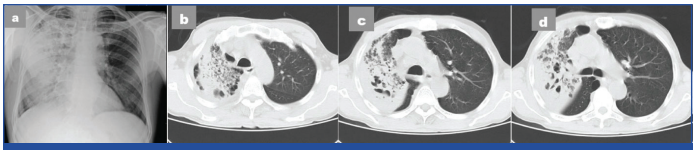


[Table/Fig-18]: Volume loss.

Chest radiograph [Table/Fig-19a] and HRCT chest (lung window) [Table/Fig-19b-d] of a 57-year-old male show dense consolidation with air bronchogram, minimal pleural effusion, and emphysematous changes in the visualised right hemithorax.

HRCT chest (lung window) [Table/Fig-20] of a 45-year-old male shows a broncho-pleural fistula of the right lung with right hydropneumothorax (solid black arrow).

About 4 (3.81%) cases of active post-primary tuberculosis (105 cases) and 1 (4%) case of inactive tuberculosis (25 cases) had a broncho-pleural fistula.

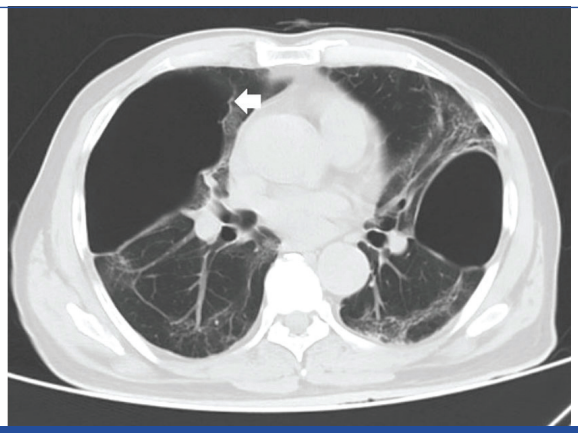


[Table/Fig-19a-d]: Consolidation.

[Table/Fig-20]: Broncho-pleural fistula.

Chest radiograph [Table/Fig-21] of a 55-year-old male patient shows multiple thin-walled air-containing bullae (solid white arrow).

9 (8.57%) cases of active post-primary tuberculosis (105 cases) and 10 (40%) cases of inactive tuberculosis (25 cases) had bullae.



[Table/Fig-21]: Bullae.

DISCUSSION

Tuberculosis is a multi-system disease that clinically manifests as pulmonary tuberculosis and extra-pulmonary tuberculosis. Pulmonary tuberculosis is the most common manifestation. Any bacteriologically confirmed or clinically diagnosed case of tuberculosis involving lung parenchyma or the tracheo-bronchial tree is known as pulmonary tuberculosis [7]. Chest X-ray and CT chest play a vital role in making treatment decisions and thereby preventing the spread of the disease, which is a major health concern. The optimal method of tuberculosis screening is concurrent symptom inquiry and chest radiography/CT chest [8].

In present study, it was found that among 160 cases of pulmonary tuberculosis, 99 (61.87%) cases were male, and 61 (38.13%) cases were female. It is noted that pulmonary tuberculosis is more common in the male population than in the female population. Similar results were obtained in a study conducted by Devi RKJ and Singh KHM, where the incidence of pulmonary tuberculosis in males was 58%, and the incidence in females was 42% [9].

Active primary pulmonary tuberculosis is common in infancy and young adults who have not been previously exposed to mycobacterium Tuberculosis bacilli. It mainly manifests as consolidation, pleural effusion, mediastinal lymphadenopathy, and military opacities. The presence of a cavity in active primary pulmonary tuberculosis indicates progressive primary disease [10,11].

Active post-primary pulmonary tuberculosis (TB reactivation or secondary TB) is a disease that affects adults who have previously been exposed to mycobacterium tuberculosis bacilli. It mainly manifests as consolidation, cavity, and centrilobular nodules with a tree-in-bud appearance. Cavity is the hallmark of active post-primary tuberculosis [11,12]. Consolidation is an area of increased lung attenuation with obscuration of pulmonary vessels [13].

In present study, out of 160 cases, 135 cases were classified as active primary (30 cases) and active post-primary tuberculosis (105 cases). Among the active tuberculosis cases (135 cases), lung consolidation was found in 85 (62.96%) cases, which is similar to the study conducted by Drusty K et al., where 68% of active pulmonary tuberculosis cases had lung consolidation [14]. Among the 30 cases of active primary tuberculosis, 20 (66.7%) cases had lung consolidation. Similar results were found in the study conducted by Hua and Pu-Xuan L [15], where lung consolidations were found in 70% of primary tuberculosis cases.

A cavity is defined as a lucency with a diameter of more than 1cm, surrounded by a complete wall of 3 mm or more in thickness [13]. Among the 135 cases of active pulmonary tuberculosis, 64 (47.41%) cases had lung cavitation on chest radiography, which is similar to the findings reported by Drusty K et al., [14], where 40.9% of active pulmonary tuberculosis cases had lung cavities. Cavitation is a common finding in post-primary tuberculosis, observed in 20%-45% of patients on chest radiographs [3], compared to 50 (47.62%) cases in present study.

Pleural effusion appears as an arcuate area of homogeneous density paralleling the chest wall on chest radiography, and it is a common complication in tuberculosis, mostly exudative and commonly unilateral [16]. It is seen in approximately 25% of adult primary tuberculosis cases [17]. In present study, among the 30 cases of active primary tuberculosis, 8 (26.67%) cases had pleural effusion on chest radiography.

Centrilobular nodules with a tree-in-bud appearance indicate endobronchial spread of tuberculosis, resulting from communication between active tuberculosis and the bronchial tree. These nodules appear as 2-4 mm ill-defined centrilobular nodules in a branching pattern, with linear thickened branching opacities around the terminal and respiratory bronchioles on CT chest [4]. Among the cases of active pulmonary tuberculosis (135 cases), 98 (72.59%) cases had centrilobular nodules with a tree-in-bud appearance. Similar results were obtained in the study conducted by Drusty K et al., where 77% had centrilobular nodules with a tree-in-bud appearance on chest radiography and CT chest [14].

Miliary nodules present as small nodules with a diameter of 1-3mm, randomly distributed in both lungs on chest radiography and CT. Miliary disease can occur in primary or post-primary tuberculosis. It spreads through haematogenous seeding and can occur in 2-6% of cases of primary tuberculosis [18,19]. In present study, among the 30 cases of active primary tuberculosis, 3 (10%) cases had miliary nodules on chest radiography/CT.

Chest X-ray/CT findings of inactive tuberculosis include fibrosis, persistent nodal calcification (Ranke's complex), and a tuberculoma [10,11]. HRCT findings in patients with post-tuberculosis suggestive of past infection include deranged bronchovascular structures, bronchiectasis, emphysema, and fibrotic bands [20]. Bronchiectasis develops in 30%-60% of active post-primary TB cases and 71%-86% of inactive TB cases on HRCT [14].

In present study, 57 (54.29%) cases of active post-primary tuberculosis and 18 (72%) cases of inactive tuberculosis had bronchiectasis.

The strengths of present study lie in its substantial sample size and its focus on a demographic with a high incidence of pulmonary tuberculosis. A significant strength is the detailed analysis of radiological patterns, which are pivotal for timely intervention and could assist clinicians in the early identification of active TB, particularly in an endemic area like India.

For future studies, authors recommend a prospective design to corroborate these findings and explore the longitudinal outcomes associated with different radiological presentations. Long-term follow-up could provide insight into the prognostic significance of the radiological features identified. Additionally, expanding the research to include molecular and genetic studies could elucidate the psychophysiological correlations with radiological findings.

From a clinical relevance standpoint, the findings of present study could enable healthcare providers to make more informed decisions regarding TB treatment and management. It may also contribute to the development of region-specific diagnostic algorithms that consider the unique radiological presentations observed in Indian patients. This approach can potentially lead to earlier detection of active TB cases, better risk stratification for latent TB infections, and more effective monitoring of treatment response.

Limitation(s)

The retrospective design, while informative, limits the ability to establish causality. Additionally, there may be an inherent selection bias given the tertiary care setting, which might not be representative of the general population. Furthermore, the lack of correlation with microbiological data and patient outcomes is a significant gap that future research should address.

CONCLUSION(S)

Tuberculosis is more common in males than females. Active primary tuberculosis is more common among younger age groups, while active post-primary and inactive tuberculosis are more common in the elderly. Consolidation, pleural effusion, and mediastinal lymphadenopathy are common radiological findings in active primary tuberculosis. Consolidation, cavity, and centrilobular nodules with a tree-in-bud appearance are common findings in active post-primary tuberculosis, while fibrosis, bronchiectasis, and calcified granuloma are common findings in the post-tuberculosis or inactive form of tuberculosis. Chest radiography/CT chest, in addition to clinical and laboratory investigations, can help in the prompt diagnosis and management of the disease. Future studies should aim to include a broader spectrum of patients and link radiological data with microbiological and clinical outcomes. It would also be beneficial to compare the trends observed in sampled south Indian cohort with those of other populations to assess the generalisability of these findings.

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PARTICULARS OF CONTRIBUTORS:

1. Undergraduate Student, Department of Radiodiagnosis, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.
2. Postgraduate Resident, Department of Radiodiagnosis, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.
3. Associate Professor, Department of Radiodiagnosis, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.
4. Associate Professor, Department of Radiodiagnosis, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.
5. Professor, Department of Radiodiagnosis, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Ramakrishnan Karthik Krishna,
Department of Radiodiagnosis, Saveetha Medical College and Hospital,
Saveetha Institute of Medical and Technical Sciences, Saveetha University,
No. 1, Saveetha Nagar, Thandalam, Chennai-602105, Tamil Nadu, India.
E-mail: kkdrkrradio@gmail.com

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