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FREQUENCY OF DIFFERENT RADIOLOGICAL PATTERNS OF PULMONARY TUBERCULOSIS ON CONTRAST CT CHEST

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Abstract

OBJECTIVE

To determine various radiological patterns of pulmonary tuberculosis seen on contrast-enhanced CT chest scans in patients diagnosed with active pulmonary TB.

METHODOLOGY

This cross-sectional descriptive study comprised 139 adult individuals with newly diagnosed microbiologically or molecularly confirmed pulmonary tuberculosis who had contrast-enhanced CT of the chest. The study was carried out at Jinnah Postgraduate Medical Centre, Karachi, and patients were sampled using non-probability consecutive sampling. An experienced radiologist interpreted radiological patterns, and data were analyzed by using SPSS version 26.0. Associations were evaluated using chi-square tests, and the results with p-values below 0.05 were regarded as statistically significant.

RESULTS

In 139 patients (mean age 47.5 ± 15.5 years; 66.9% male, 33.1% female), cavitation (59.0%) and consolidation (54.7%) were the most common radiological patterns on contrast-enhanced CT chest, followed by tree-in-bud appearance (36.7%) and lymphadenopathy (32.4%). Miliary nodules (9.4%) were significantly more frequent in younger patients (p = 0.045). No significant gender-based differences in radiological patterns were observed.

CONCLUSION

This study concludes that cavitation and consolidation are the most frequently observed radiological patterns of active pulmonary tuberculosis on contrast-enhanced CT chest, followed by tree-in-bud appearance and lymphadenopathy. Miliary nodules were significantly associated with younger age. Contrast-enhanced CT plays a crucial role in identifying diverse pulmonary TB patterns, especially in clinically ambiguous or smear-negative cases, aiding timely diagnosis and management.

INTRODUCTION

Tuberculosis (TB) continues to be a leading global health concern, causing 1.7 million deaths annually, with nearly 9 million new active TB cases diagnosed each year, increasing at a rate of

one percent per year [1,2]. The burden of TB is overwhelmingly concentrated in impoverished regions, with 95% of cases and 98% of TB-related deaths occurring in countries across Asia, Africa, and South America [3]. Notably, 44% of the population in Southeast Asia is affected by TB [3]. The gold standard for diagnosing active TB is microbiological detection of Acid-Fast Bacillus (AFB), with sputum smear sensitivity ranging from 46-74% and sputum culture sensitivity between 2-95% for active pulmonary disease [4]. In Pakistan, the national data shows a 10-22% yield for smear positivity in adult pulmonary TB cases [5,6].

Chest radiography is the primary imaging technique for evaluating pulmonary TB due to its cost-effectiveness, minimal radiation exposure, widespread availability, and ease of use. Despite these advantages, the diagnostic accuracy of chest radiographs is limited, correctly identifying primary pulmonary TB in only 34% of cases and post primary pulmonary TB in 59% [7]. Contrast-enhanced computed tomography (CT) of the chest offers greater sensitivity than chest radiographs, particularly for detecting minimal exudative lesions, subtle parenchymal disease, and assessing disease activity in pulmonary TB [8,9].

A study demonstrated that contrast-enhanced CT has a sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of 88%, 88%, 92%, 83%, and 88%, respectively, for detecting disease activity [10]. Moreover, contrast-enhanced CT is superior in identifying miliary nodules [11] and provides insights into underlying pathomorphological processes [12], the spread of the disease, and morphological changes following anti-tuberculosis treatment [13]. While chest radiography can detect cavitation in 40-87% of patients, contrast-enhanced CT is more accurate, especially in cases complicated by extensive fibrosis and architectural distortion [7,14,15]. Recent studies have also shown a correlation between CT morphological findings and the number of acid-fast bacilli on sputum smears in patients with pulmonary TB [16].

Pulmonary tuberculosis (TB) remains a significant health issue, particularly in high-prevalence regions like Pakistan. While international studies have detailed the contrast-enhanced CT chest findings of pulmonary TB, similar data for the local population is lacking. This gap hinders accurate diagnosis, especially when chest X-rays are atypical or appear inactive, and sputum smears are negative. Recognizing these patterns in appropriate clinical contexts can help clinicians make a presumptive diagnosis of active TB, allowing for the timely initiation of empirical therapy

METHODOLOGY

This was a cross-sectional descriptive study carried out at the Department of Radiology, Jinnah Postgraduate Medical Centre, Karachi. There were 139 patients. The participants were at least 18 years old, either gender, and newly diagnosed with active pulmonary tuberculosis based on clinical symptoms, including persistent cough (more than two weeks), hemoptysis, night sweats, weight loss, and fever, and either microbiological evidence (positive sputum smear or acid-fast bacilli culture) or molecular evidence (positive GeneXpert MTB test). Only patients who had undergone contrast-enhanced CT chest scans and had not previously taken anti-tuberculosis medication or had used it for less than four weeks were included. Radiological patterns evaluated on CT chest included cavitation, tree-in-bud appearance, lymphadenopathy, consolidation, ground-glass opacities, bronchiectasis, and miliary nodules. Non-probability consecutive sampling technique was used for the recruitment of participants.

Exclusion criteria comprised patients in any retreatment category, with multi-drug-resistant TB, coexisting pulmonary diseases such as chronic obstructive pulmonary disease (COPD), diffuse parenchymal lung diseases (DPLDs), or pneumoconiosis; pregnant women in the first or second trimester; patients unable to hold breath during imaging; and those with a known allergy to contrast media. After obtaining institutional ethical approval and written informed consent, data were collected using a structured proforma

that included biodata, clinical presentation, and radiological findings. All CT scans were interpreted and categorized by a senior radiologist with a minimum of five years of experience. Data was anonymized and stored securely to maintain confidentiality. Statistical analysis was done on IBM SPSS version 26.0. The descriptive statistics were also used to present a summary of the continuous variables (mean + standard deviation) and categorical variables (frequencies and percentages). The tests of association between variables were performed with the chi-square test and a p-value under 0.05 was treated as statistically significant.

RESULTS

A total of 139 participants were included in the study with a mean age of 47.50 ± 15.49 years. The average duration of symptoms was 4.54 ± 2.45 months (95% CI: 4.13–4.95). Among them, 93 (66.9%) were male and 46 (33.1%) females. The majority of patients, 106 (76.3%), resided in urban areas, while 33 (23.7%) were from rural regions. The most common presenting complaint was persistent cough, reported by 113 (81.3%) patients, followed by fever in 106 (76.3%), weight loss in 73 (52.5%), night sweats in 44 (31.7%), and hemoptysis in 33 (23.7%). Comorbidities included diabetes in 28 (20.1%), hypertension in 18 (12.9%), and HIV/AIDS in 6 (4.3%) participants. Sputum smear was positive in 85 (61.2%), negative in 40 (28.8%), and not performed in 14 (10.1%) cases. Similarly, sputum culture was positive in 73 (52.5%), negative in 52 (37.4%), and not done in 14 (10.1%). GeneXpert MTB testing revealed positive results in 102 (73.4%) patients, negative results in 27 (19.4%), and no test results in 10 (7.2%) patients (TABLE I).

Table I: Demographic and Clinical Characteristics of Study Participants (n=139)

Mean ± Standard Deviation		**95% Confidence Interval**
Age in years = **47.50 ± 15.49**		44.90~~50.10
Duration of Symptoms in months= **4.54 ± 2.45**		4.13~~4.95
	n (%)	
Gender	Male	93 (66.9)
	Female	46 (33.1)
Residential Status	Urban	106 (76.3)
	Rural	33 (23.7)
Presenting Complaints	Persistent Cough	113 (81.3)
	Hemoptysis	33 (23.7)
	Night Sweats	44 (31.7)
	Weight Loss	73 (52.5)
	Fever	106 (76.3)
Comorbidities	Hypertension	18 (12.9)
	Diabetes	28 (20.1)
	HIV/AIDS	6 (4.3)
Sputum Smear	Positive	85 (61.2)
	Negative	40 (28.8)
	Not Done	14 (10.1)
Sputum Culture	Positive	73 (52.5)
	Negative	52 (37.4)
	Not Done	14 (10.1)
GeneXpert MTB	Positive	102 (73.4)
	Negative	27 (19.4)
	Not Done	10 (7.2)

Among the 139 study participants, cavitation was the most prevalent radiological pattern, observed in 82 patients (59.0%), followed closely by consolidation in 76 patients (54.7%). A considerable proportion also exhibited other radiological findings grouped under the "other" category, present in 61 cases (43.9%). Tree-in-bud appearance was identified in 51 patients (36.7%), while lymphadenopathy was seen in 45 patients (32.4%). Bronchiectasis was documented in 35 cases (25.2%), and ground-glass opacities were noted in 31 cases (22.3%). The least common radiological finding was miliary nodules, observed 13 patients (9.4%) (TABLE II).

Table II: Distribution of Radiological Patterns (n=139)

Radiological Patterns	Frequency	Percentage%
Cavitation	82	59.0
Tree-in-bud	51	36.7
Lymphadenopathy	45	32.4
Consolidation	76	54.7
Ground-glass opacities	31	22.3
Bronchiectasis	35	25.2
Miliary Nodules	13	9.4
Other	61	43.9

Table III: Comparison of Radiological Patterns with Age Group (n=139)

Radiological Patterns	Age Group		P-Value
	18–45	>45	
Cavitation	33 (23.7)	49 (35.3)	0.404
Tree-in-bud	23 (16.5)	28 (20.1)	0.726
Lymphadenopathy	19 (13.7)	26 (18.7)	0.877
Consolidation	33 (23.7)	43 (30.9)	0.947
Ground-glass opacities	15 (10.8)	16 (11.5)	0.505
Bronchiectasis	16 (11.5)	19 (13.7)	0.725
Miliary Nodules	9 (6.5)	4 (2.9)	0.045
Other	23 (16.5)	38 (27.3)	0.250

Table III presents the comparison of radiological patterns between younger patients (18–45 years) and older patients (>45 years). Cavitation was observed in 23.7% of younger patients and 35.3% of older patients, but the difference was not statistically significant (p=0.404). Similarly,

consolidation was detected in 23.7% of younger patients compared to 30.9% of older patients (p=0.947). Tree-in-bud appearance was seen in 16.5% of the younger age group and 20.1% of the older group (p=0.726), while lymphadenopathy was noted in 13.7% and 18.7%, respectively (p=0.877). Ground-glass opacities were almost equally distributed, present in 10.8% of younger and 11.5% of older patients (p=0.505). Bronchiectasis was also similar across groups, affecting 11.5% of younger and 13.7% of older individuals (p=0.725). Interestingly, miliary nodules showed a significant association with younger age, being more common in patients aged 18–45 years (6.5%) compared to those over 45 years (2.9%) (p=0.045). Other radiological findings were reported more frequently in older patients (27.3%) than younger ones (16.5%), though without statistical significance (p=0.250).

Table IV: Comparison of Radiological Patterns with Gender (n=139)

Radiological Patterns	Gender		P-Value
	Male	Female	
Cavitation	52 (37.4)	30 (21.6)	0.294
Tree-in-bud	37 (26.6)	14 (10.1)	0.282
Lymphadenopathy	31 (22.3)	14 (10.1)	0.731
Consolidation	51 (36.7)	25 (18.0)	0.956
Ground-glass opacities	21 (15.1)	10 (7.2)	0.911
Bronchiectasis	22 (15.8)	13 (9.4)	0.556
Miliary Nodules	8 (5.8)	5 (3.6)	0.666
Other	46 (33.1)	15 (10.8)	0.060

Table IV compares the distribution of radiological patterns between male and female patients. Cavitation was observed more frequently in males (37.4%) than females (21.6%), though the difference was not statistically significant (p=0.294). Similarly, consolidation was reported in 36.7% of males and 18.0% of females (p=0.956). Tree-in-bud appearance was noted in 26.6% of males compared to 10.1% of females (p=0.282), while lymphadenopathy was found in 22.3% of males and 10.1% of females (p=0.731). Ground-glass opacities were observed in 15.1% of males and 7.2% of females (p=0.911), whereas bronchiectasis was slightly more frequent among males (15.8%) than females (9.4%) (p=0.556). Miliary nodules were seen in 5.8% of males and 3.6% of females, showing no significant association (p=0.666). Interestingly, "other" radiological findings were more prevalent in males (33.1%) compared to females (10.8%), with a p-value of 0.060, approaching but not reaching statistical significance.

DISCUSSION

The radiological features observed in this research are very similar to those reported in the literature, which validates the use of contrast-enhanced CT in the diagnosis of pulmonary tuberculosis. The most common pattern observed in our cohort is cavitation (59.0%), which is the same as that reported by Hatipoğlu et al. [8] and Kuhlman et al. [15], who noted that it is the most common pattern in post-primary TB. This tendency has a clinical meaning, as it is linked to increased loads of bacilli and infectivity [7]. Consolidation, observed in 54.7 per cent, is also compatible with the findings of Poey et al. [9], who reported it as a typical CT finding in active pulmonary TB, and it tends to coexist with cavitary lesions and is an expression of underlying alveolar inflammation.

The existence of the tree-in-bud pattern in 36.7% cases also confirms its strong presence as a radiological indicator of active disease and endobronchial transmission, which is repeated in the works of Raniga et al. [4] and Tozkoparan et al. [10]. Our patients had lymphadenopathy in 32.4% which is slightly less than those reported in populations that comprised pediatric or immunocompromised populations [11,13]. This could be explained by the fact that the current study involves an adult group in which post-primary disease is more likely to present as parenchymal than nodal. Bronchiectasis that occurs in 25.2% of cases is known as a chronic pulmonary infection sequela and has also been noted by Christensen et al. [14] and Long et al. [18] as well.

Ground-glass opacities were noted in 22.3% of participants, reflecting early parenchymal involvement. Though less emphasized in older literature, recent studies have recognized their value in identifying minimal exudative changes, particularly when chest radiographs appear inconclusive [9,10]. Miliary nodules, while observed in only 9.4% of patients, showed a statistically significant association with younger age ($p = 0.045$), aligning with observations by Oh et al. [11] and Lee et al. [17], who described a higher incidence of disseminated miliary TB in younger or immunocompromised hosts.

Gender-based comparisons in this study did not yield statistically significant differences in radiological findings, although male patients exhibited a higher frequency of certain patterns such as cavitation and consolidation. These results are consistent with prior observations by Goo and Im [12], who reported that radiographic differences are more often influenced by disease chronicity and host immune response rather than gender alone. Notably, the diagnostic yield of contrast-enhanced CT in our study further supports previous findings by Ors et al. [16], who demonstrated a strong correlation between CT patterns and sputum smear positivity, suggesting a relationship between radiological severity and bacterial burden.

While the present findings are in agreement with many international studies, the study adds valuable local data by focusing on a Pakistani cohort with microbiologically confirmed active pulmonary TB. Unlike studies that included mixed or treated cases, this study specifically excluded patients with prior treatment, drug-resistant TB, or coexisting lung diseases, allowing for a clearer assessment of typical radiological patterns in untreated active diseases. Moreover, the exclusive use of contrast-enhanced CT provided enhanced sensitivity for detecting subtle parenchymal and nodal involvement, as also emphasized in work by Im et al. [13] and Shah et al. [19], particularly in smear-negative presentations.

Despite these strengths, the study has limitations, including its single-centre design, lack of follow-up imaging to assess treatment response, and exclusion of certain high-risk subgroups such as those with HIV co-infection or drug-resistant TB. Future multicenter studies incorporating larger, diverse populations and longitudinal follow-up are warranted to evaluate the evolution of these patterns and their prognostic implications. Furthermore, integrating radiological findings with molecular diagnostics and immune profiling may enhance predictive models for disease severity and treatment outcomes.

CONCLUSION

This study concludes that cavitation and consolidation are the most frequently observed radiological patterns of active pulmonary tuberculosis on contrast-enhanced CT chest, followed by tree-in-bud appearance and lymphadenopathy. Miliary nodules were significantly associated with younger age. Contrast-enhanced CT plays a crucial role in identifying diverse pulmonary TB patterns, especially in clinically ambiguous or smear-negative cases, aiding timely diagnosis and management.

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