High-Resolution Computed Tomography (HRCT) Chest Findings in Active Pulmonary Tuberculosis

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ABSTRACT

Background: Tuberculosis (TB) is an airborne infection caused by the acid-fast bacillus Mycobacterium tuberculosis. It is estimated that about 10.8 million people fell ill with tuberculosis worldwide, and about 1.25 million of them died in 2023. In Nepal, nearly half of the population are estimated to harbor latent TB. Early diagnosis and effective treatment are the mainstay of the control of tuberculosis.

Objective: This study aimed to evaluate the diagnostic utility of high-resolution computed tomography (HRCT) of the chest in detecting active pulmonary tuberculosis (PTB).

Methods: It is a case-control study done in the Department of Radiodiagnosis at Chitwan Medical College, Teaching Hospital from August 2022 to January 2023. Adult patients with presumptive pulmonary TB who underwent both microbiological testing for Mycobacterium tuberculosis, and High-Resolution CT (HRCT) chest imaging were included. Patient's demographics, clinical features, sputum microscopy for acid-fast bacilli (AFB), GeneXpert for MTB, and relevant HRCT chest findings were recorded in a predesigned proforma. Data were entered into Microsoft Excel and analyzed using IBM SPSS version 20.0.

Results: Data from 72 patients with active pulmonary TB were analyzed. Of these, 46 patients (63.9%) had Mycobacterium tuberculosis identified via AFB staining, while the remaining 26 (36.1%) were diagnosed using GeneXpert. The control group included 35 sputum-negative cases where bacteria could not be isolated using GeneXpert. The mean age of patients was 56 years, and the majority were male (68.1%). The most frequent HRCT findings in active TB cases included tree-in-bud appearance (69.4%), enlarged mediastinal lymph nodes (65.3%), and consolidation (56.9%). The tree-in-bud pattern was significantly more common in TB-positive patients compared to controls.

Conclusion: Common HRCT chest findings in pulmonary tuberculosis were tree-in-bud appearance, mediastinal lymphadenopathy, and consolidation. Tree-in-bud appearance in HRCT was significantly associated with bacteriologically confirmed pulmonary tuberculosis. When microbiological confirmation is delayed or negative, HRCT chest findings can support early initiation of treatment in suspected cases, thereby reducing community transmission and improving patient outcomes.

Keywords: HRCT Chest, Pulmonary tuberculosis (PTB), Tree in bud, Mycobacterium tuberculosis

INTRODUCTION

Tuberculosis is an infection caused by the acid-fast bacillus Mycobacterium tuberculosis is an airborne disease that remains the top infectious disease in the world. WHO estimated that 10.8 million new cases of tuberculosis with 1.25 million deaths due to tuberculosis in 2023[1]. The risk of developing active tuberculosis is greatly dependent upon the infectiousness of the tuberculosis source, the environment and duration of exposure, and importantly the immune status of the exposed individual. Hence, people with extremes of age, malnutrition, cancer, HIV infection, end-stage renal disease, diabetes, and immunosuppressive therapy have a higher risk of developing the disease. In a developing country like Nepal, poverty, malnutrition, rapid urbanization, high density population, along with factors affecting lung health

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like escalating tobacco use, occupational lung disease, and indoor/outdoor air pollution, make favorable conditions for tuberculosis to flourish[2]. In Nepal, nearly two-thirds of the cases were pulmonary tuberculosis, of which 80% were bacteriologically confirmed, either by microscopy or GeneXpert MTB[3].

Presumption of tuberculosis is done in a patient presenting with low grade fever, cough ≥2 for two weeks, hemoptysis, chest pain, unintentional weight loss, and night sweats, or has any chest X-ray changes[3]. Microbiological confirmation is done by conventional light microscopy or GeneXpert MTB/Rif. Culture is the most sensitive tool, but the delay in yielding organisms precludes its use as a first-line test for diagnosis[4,5]. In a recent study carried out in Nepal by Chaudhary et al, it was found that molecular diagnostic modality like Xpert MTB/RIF were comparable with culture diagnosis of both pulmonary and extrapulmonary tuberculosis cases with high sensitivity and specificity[6,7]. Chest radiography is the first-line radiological technique in evaluating pulmonary tuberculosis cases and remains unsurpassed in the amount of information yielded in relation to its cost, radiation dose, availability, and ease of performance. However, chest X-ray-based diagnosis is correct in only 34% and 59% cases of primary pulmonary TB and post-primary pulmonary TB, respectively[8]. High -resolution computed tomography (HRCT) is more sensitive than chest X-ray in identifying and assessing the disease activity in pulmonary TB. The apical and posterior segments of the upper lobes and the superior segment of the lower lobes are the most affected segments[6,9]. Patchy heterogeneous consolidation involving the typical sites described are the most common radiographic manifestation, along with poorly defined nodules and linear opacities. Cavities are seen in 20-45% cases and are considered the hallmark of active disease[10,11]. Tree-in-bud pattern, patchy or lobular areas of consolidation and cavitation are the most common findings in reactivation of pulmonary TB. Less common findings are enlarged mediastinal lymph nodes (5-10%) and pleural effusion, usually unilateral (15-20%)[10,12].

Many international studies have described the characteristic HRCT findings in pulmonary tuberculosis; however, the data from local patients remains non-existent. The recognition of HRCT pattern in our setting, in combination with respective clinical findings, can significantly aid in the diagnosis of dilemma cases[13]. In this study, we investigated the different HRCT chest findings in bacteriologically confirmed pulmonary tuberculosis and patients with presumptive tuberculosis cases and identify a combination of these findings that were significantly associated with an increased probability of having active PTB.

METHODS

This case control series was conducted in the Chitwan Medical College, Teaching Hospital (CMCTH) in the Departments of Radiodiagnosis and Pulmonology from August 2022 to January 2023. Ethical approval was taken from the Institutional Review Committee of CMCTH, CMC-IRC (079/080-44). All adult patients with suspected pulmonary tuberculosis who had undergone microbiological testing (sputum smear examination and GeneXpert for MTB/Rif) and HRCT chest study were enrolled in the study. A total of 107 patients aged 16-88 years of both genders with newly diagnosed pulmonary tuberculosis were included in our study, out of which the tuberculosis bacilli were isolated in 72 patients, and in the remaining 35 cases were sputum-negative cases, which constituted our control group. Relapse and default cases, and tuberculosis in pregnant women and pediatric cases were excluded from our study.

The HRCT chest was done with the Siemens Somatom CT scanner using the following protocol. Serial thin section slices were taken in the supine position with the breath held in inspiration, with 2 mm collimation at 10 mm intervals from the apices to the hemidiaphragm. All images were reconstructed in a high-resolution bone algorithm without targeting. The scans were photographed with both mediastinal (window width [WW] 250-400 Hounsfield units; window length [WL], -10 to 50 Hounsfield Units (HU)), and lung (WW 1000; WL 700 HU) windows. Intravenous non-ionic contrast was administered manually as a bolus dose of 1.5 ml/kg of iodinated contrast with a concentration of 300 mg iodine/ml in cases with associated lymphadenopathy to look for areas of low attenuation. Two consultant radiologists independently assessed the HRCT chest findings.

The pattern, extent, and severity of the HRCT findings were recorded. The patterns included micronodules (≤ 6 mm in diameter), nodules (>6 mm to ≤ 30 mm in diameter), masses (> 3 cm in diameter), lobular consolidation (an area of increased opacity with obscuration of underlying bronchovascular markings), ground glass attenuation (an area of increased opacity without obscuration of underlying bronchovascular markings), and irregular lines. Based on size and distribution, micronodules are further divided into: a) centrilobular: well-defined lesion 2-4 mm in size, related to a terminal or respiratory bronchiole in the secondary pulmonary lobule 2 mm from the pleural surface or interlobular septa; while tree-in-bud appearance is branching, linear structure with more than one contiguous branching site; b) acinar: 6-10 mm in diameter and poorly defined, and c) miliary: 1-2 mm symmetric and bilateral randomly distributed nodules. Lymphadenopathy was considered significant when the short-axis diameter was greater than 10 mm[14].

Informed consent was obtained from all participants of the study. Demographics, microbiological report on acid-fast bacilli, and HRCT chest findings were recorded in a proforma, and data were processed using SPSS version 20 for statistical analysis.

Descriptive statistics were expressed using the mean, standard deviation, and median. Distribution and prevalence were expressed as a percentage. To assess the association between the Xpert MTB/RIF result and clinical findings, as well as between the Xpert MTB/RIF result and various HRCT findings, the Miller Fisher test was used. A significant p-value was taken as $p<0.05$

RESULTS

In total, 72 patients with pulmonary bacteriologically confirmed (PCB) TB cases in whom HRCT chest was performed were included in the study. Thirty-five clinically diagnosed pulmonary clinically diagnosed (PCD) cases were taken as controls.

The mean age of the patients with PBC was 56.0± 20.8 years (Range: 16 - 88 years). Majority (49, 68.1%) of the patients were males. The predominant presenting symptoms were cough (83.3%) and fever (69.4%). The patients were diagnosed as active pulmonary TB based on AFB in sputum smear in 46 (63.9%), whereas the remaining 36.1% had a positive GeneXpert (Table 1).

Table 1: Baseline patient characteristics with active pulmonary TB (cases) and controls.

Characteristics	Cases (n = 72)	Controls (n = 35)
Age (years), mean ± SD	56.0 ± 20.8	54.0 ± 20.4
Gender, n (%) Male Female	 49 (68.1) 23 (31.9)	 16 (45.7) 19 (54.3)
Presenting symptom, n (%) Cough Fever Chest pain Weight loss Shortness of breath	 60 (83.3) 50 (69.4) 49 (68.1) 46 (63.9) 44 (61.1)	 30 (85.7) 22 (62.9) 22 (62.9) 4 (11.4) 25 (71.4)
Positive diagnostic test, n (%) AFB NAAT	 46 (63.9) 26 (36.1)	-

Centrilobular nodules in tree-in-bud appearance was the most common HRCT finding (69.4%) among the cases, followed by enlarged mediastinal lymph nodes (65.3%) and consolidation (56.9%). The right lobe was more frequently involved than the left lobe in terms of the major HRCT findings (Table 2). When compared with the controls, the occurrence of centrilobular nodules in tree-in-bud appearance and cavity was significantly higher in the cases ($P<0.05$). There was no statistically significant difference between other HRCT findings.

Table 2: Comparison of major HRCT findings between active pulmonary cases and control.

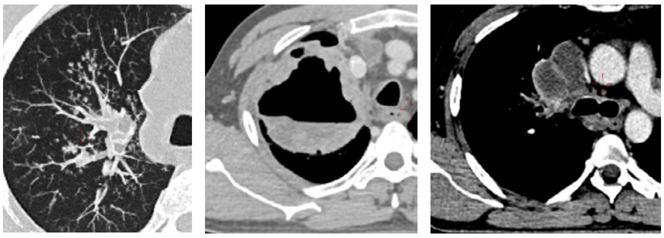
HRCT Morphology	Cases (N = 72)	Controls (N = 35)	P-value
Tree-in-bud appearance, n (%) Right Left	50 (69.4) 43 (59.7) 29 (40.3)	13 (37.1) 11 (31.4) 10 (28.6)	0.02
Enlarged mediastinal lymph nodes, n (%)	47 (65.3)	22 (62.9)	0.78
Consolidation, n (%) Right Left	41 (56.9) 35 (48.6) 26 (36.1)	18 (51.4) 15 (42.9) 12 (34.3)	0.66
Cavity Right Left	30 (41.7) 22 (30.6) 21 (29.2)	7 (20.0) 5 (14.3) 4 (11.4)	0.03
Bronchiectasis, n (%)	17 (23.6)	13 (37.1)	0.32
Macronodules, n (%)	15 (20.8)	4 (11.4)	0.5

Tree-in-bud appearance was more commonly observed in the S6 segment compared to controls. Cavities were more frequent in the S1 segment than in the controls. Consolidations were more common in S1 and S2 segments (Table 3).

Table 3: Involvement of different lung segments in HRCT findings between cases and controls who had positive findings.

HRCT Morphology	Lung segment (% involvement)					
	S1(apical)		S2 (posterior)		S6 (superior)	
	Cases	Controls	Cases	Controls	Cases	Controls
Tree-in-bud appearance	76.0	76.9	62.0	76.9	48.0	38.5
Cavity	86.7	71.4	56.7	57.1	30.0	28.6
Consolidation	73.2	33.3	68.3	44.4	36.6	33.3

The three most common HRCT findings are presented in the pictures below (figure 1).



(a) (b) (c)

Figure 1: HRCT findings. a). Multiple centrilobular, branching nodular opacities with a "tree-in-bud" appearance b) Thick-walled cavity a right upper lobe with an air-fluid level. c) Enlarged necrotic hilar lymph node.

Furthermore, the cases were divided into two groups based on the microbiological modality of sputum positivity i.e., AFB smear positive and GeneXpert positive. It was found that the tree-in-bud pattern was the most common feature in both the groups {AFB positive: n=34 (73.9%); GeneXpert positive: n=16 (61.5%)}. In the AFB positive group, consolidation was the most common HRCT finding (n=30, 65.2%), followed by mediastinal lymphadenopathy (n=29, 63%). In contrast, among GeneXpert positive patients, mediastinal lymphadenopathy (n=18, 69.2%) was the most frequent, followed by pleural effusion and consolidation, each observed in 11 cases (42.3%), as shown in descending order in Table 4. When comparing the data of AFB positive cases with GeneXpert positive cases, it was seen that consolidation and bronchiectasis were found to be significantly associated more in AFB positive cases than in the nucleic acid amplification test (NAAT) positive cases, with a p-value<0.05.

Table 4: Comparison of HRCT chest findings between AFB positive and GeneXpert positive cases

S.N.	HRCT finding	AFB positive	NAAT positive	P value
1	Centrilobular nodules in tree in bud pattern	34 (73.9%)	16 (61.5%)	0.298
2	Other Micro-nodules	6 (13%)	6 (23.1%)	0.33
3	Macronodules	7 (15.2%)	8 (30.8%)	0.14
4	Consolidation	30 (65.2%)	11 (42.3%)	0.083**
5	GGO	6(13%)	6(23.1%)	0.33
6	Cavity	21(45.7%)	9(34.6%)	0.458
7	Mass	2(4.3%)	1(3.8%)	1
8	Bronchiectasis	14(30.4%)	3(11.5%)	0.088**
9	Effusion	15(32.6%)	11(42.3%)	0.451
10	Lymphadenop-athy	29(63%)	18(69.2%)	

*** denotes significant association (by applying Miller fisher test at 5.00%level of significance)*

DISCUSSION

The early diagnosis of PTB is very crucial for TB control. Chest X-ray is used in the screening, diagnosis, and to see the treatment response in patients with TB, but it has a few limitations- detecting hilar and mediastinal lymph node enlargement, identifying subtle parenchymal abnormalities, and small cavities, nodules, or scarring[8].

HRCT chest is a more sensitive radiological tool that can detect and characterize parenchymal disease in addition to delineating mediastinal lymphadenopathy and is usually recommended in the context of normal or inconclusive chest X-ray findings with clinical suspicion of PTB, for confirming the diagnosis and determining the disease activity[15,16]. Several studies have been carried out to study the HRCT findings of pulmonary tuberculosis and the role of HRCT in predicting activity of PTB[15,17,18].

In our study, the most commonly observed HRCT findings among all patients had the tree-in-bud pattern (69.4%), mediastinal lymphadenopathy (65.3%), and consolidation (56.9%). Apart from these specific features, the segmental distribution of the tree in bud pattern in either the apical segment (S1), posterior segment (S2) or superior segment (S6) was also observed. Tree-in-bud pattern was observed more commonly in S6 segment compared to the control. Cavity was frequently noted in S1 segment, and consolidations were more common in S1 and S2 segments than in the controls, respectively. Centrilobular nodules in a tree-in-bud pattern was the most common HRCT finding in overall smear-positive cases, and it was also seen that their occurrence was significantly higher in cases compared to the control. In a study by Raniga et al, it was reported that the tree-in-bud pattern, which represents the endobronchial spread of disease and hence active disease, was the most common HRCT finding[18]. In a study by Im JG et al, common HRCT findings were centrilobular nodules (95%), bronchial wall thickening (73%), poorly defined nodules (61%), cavitation (51%), and lobular consolidation (41%) in active pulmonary tuberculosis[19]. A study by Lee et al., also showed similar results with the presence of centrilobular nodules (92%) being the most common HRCT finding[20]. Similarly, a study by Naseem et al., the HRCT pattern in adults with pulmonary tuberculosis, showed centrilobular nodule (92%) to be the most common finding, followed by lobular consolidation (84%), cavitation (76%), and tree in bud pattern nodules (68%), respectively. A study by Naseem A et al. in newly diagnosed pulmonary tuberculosis, common findings were centrilobular nodules and lobar consolidations (80%), centrilobular nodules with cavitation (72%), and centrilobular nodules with tree-in-bud appearance (68%)[13].

The smaller affected volume containing less AFB-rich exudate and necrotic material along with longer distance from central airway may be the reason contributing to the relatively less percentage of centrilobular nodules occurrence in our study.

Cavitation has a significant relationship with mycobacterial load and is considered an independent predictive factor of smear-positive sputum results. The cavity wall thickness and distance of cavity from nearest airway plays an important role in sputum positivity[22]. The presence of cavity was found to be significantly more in cases than in controls, with most cavities noted in apical segment of upper lobes.

The presence of individual HRCT findings, although being sensitive, is very non-specific. The constellation of 2 or more common HRCT findings is considered a pattern that might further aid in diagnosing cases that pose a dilemma. Findings of centrilobular nodules in tree-in-bud patterns were the most characteristic HRCT chest feature in active pulmonary tuberculosis.[15-18] However, in this study, the centrilobular nodules arranged in a tree-in-bud pattern and mediastinal lymphadenopathy were found to be common.

The study with a smaller sample size done in a single center is the limitation of the study.

CONCLUSION

The most common HRCT findings in active pulmonary tuberculosis are tree-in-bud pattern, enlarged mediastinal lymphadenopathy, and consolidation. The tree-in-bud pattern was seen to be significantly higher in bacteriologically confirmed cases. HRCT of the chest with appropriate interpretation can help to diagnose and treat pulmonary tuberculosis early, which can contribute to decrease the spread of tuberculosis and improve patient outcomes.

AUTHORS CONTRIBUTION

Consent and Design – Deepak Adhikari, and Shital Adhikari, Literature Review - All, Data Collection and Analysis - All, Draft - All, Revision - All; Final Manuscript and Accountability - All authors have read and agreed to the final version of the manuscript.

FUNDING

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

DATA AVAILABILITY STATEMENT

The data and supplementary materials that support the findings of this study are available from the corresponding author upon reasonable request.

ACKNOWLEDGEMENTS

We would like to acknowledge the patients and technical staff of Department of Radiodiagnosis and Respiratory Medicine for their support in regards to this study.

CONFLICT OF STATEMENT

The authors declare no conflict of interest.

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