INTERNATIONAL JOURNAL OF ADVANCED RESEARCH
International Peer-Reviewed Research Journal
ISSN (Online): 3106-7980 | ISSN (Print): 3106-7972
Volume 3 • Issue 7 • November 2026

EVALUATION OF THE DIAGNOSTIC PERFORMANCE OF HIGH-RESOLUTION COMPUTED TOMOGRAPHY CHEST IN CLINICALLY SUSPECTED SPUTUM-CULTURE-NEGATIVE PULMONARY TUBERCULOSIS IN ADULT PATIENTS

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DOI: https://doi.org/10.5281/zenodo.24191182

Keywords
Sputum culture-negative; pulmonary tuberculosis; HRCT chest; tree-in-bud; centrilobular nodules; diagnostic imaging.

Article History
Received: 05 August 2026
Accepted: 19 October 2026
Published: 04 November 2026

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Abstract

Background: Clinically suspected pulmonary tuberculosis (PTB) with negative sputum culture remains diagnostically challenging. High-resolution computed tomography (HRCT) can demonstrate subtle airway and parenchymal abnormalities that may support further diagnostic evaluation. Objective: To assess the utility and imaging patterns of HRCT chest in adults with clinically suspected, sputum-culture-negative PTB. Methodology: A prospective cross-sectional observational study was conducted from January to June 2026 in the Department of Radiology, Gulab Devi Teaching Hospital/Postgraduate Medical Institute, Lahore, in collaboration with Pulmonology. One hundred adults were enrolled by non-probability consecutive sampling. Descriptive statistics, cross-tabulations, chi-square tests, one-way ANOVA and binary logistic regression were used. Results: Sixty percent of participants were male and mean age was 43.52 ± 14.89 years. HRCT was highly suggestive of PTB in 57%, showed another disease pattern in 20%, and was normal in 23%. Consolidation (67%), tree-in-bud appearance (65%), and centrilobular nodules (63%) were the most common findings. Among 57 HRCT-suggestive cases, upper-lobe predominance occurred in 52.6%, bronchiectasis in 56.1%, lymphadenopathy in 70.2%, and pleural effusion in 26.3%. Conclusion: HRCT provides useful structural information in clinically suspected culture-negative PTB, but imaging findings are suggestive rather than confirmatory and require clinical and microbiological or molecular correlation.

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INTRODUCTION

Tuberculosis remains a major communicable disease and a continuing burden on health systems. Pulmonary tuberculosis is caused by the Mycobacterium tuberculosis complex and may produce granulomatous inflammation, caseation, cavitation, fibrosis, and airway-centered disease. In high-burden settings such as Pakistan, a substantial proportion of pulmonary TB is still diagnosed without bacteriological confirmation, making appropriate integration of clinical assessment, microbiology and imaging particularly important (1–3).

Clinical manifestations such as chronic cough, fever, night sweats, weight loss, dyspnea, chest pain and hemoptysis are common but nonspecific. Conventional sputum smear and culture may be negative in paucibacillary disease, after antimicrobial exposure, with inadequate specimens, or when disease does not communicate effectively with the airways. A negative culture therefore does not necessarily end the diagnostic evaluation when clinical suspicion remains high (4,5).

HRCT provides greater anatomical detail than chest radiography and can demonstrate small centrilobular nodules, tree-in-bud opacities, subtle ground-glass changes, cavities, bronchiectasis, lymphadenopathy and pleural abnormalities. Previous studies in sputum-negative populations have shown that HRCT may help characterize disease patterns and guide further sampling, although individual CT findings are not specific for TB and cannot replace microbiological confirmation (6–11). The present study therefore evaluated HRCT patterns in clinically suspected, sputum-culture-negative adults and explored associations between clinical/imaging variables and the radiological classification.

METHODOLOGY

Research Design: A prospective cross-sectional observational study was conducted.

Clinical Setting: The study was conducted in the Department of Radiology, Gulab Devi Teaching Hospital/Postgraduate Medical Institute, Lahore, in collaboration with the Department of Pulmonology.

Study Duration: The study was conducted from January 2026 to June 2026.

Sample Size: The planned sample size was based on the expected sensitivity of HRCT and an estimated prevalence of pulmonary TB among clinically suspected sputum-negative patients, using Buderer's approach. The final sample included 100 adults.

Sampling Technique: A non-probability consecutive sampling technique was used.

Inclusion Criteria: Patient's age 18 years and above; clinically suspected cases of pulmonary tuberculosis with symptoms (chronic cough, fever, weight loss, night sweats); negative sputum culture results for Mycobacterium tuberculosis; patients referred for HRCT Chest.

Exclusion Criteria: Previously treated or known cases of pulmonary tuberculosis; patients with known lung malignancy or interstitial lung disease; immunocompromised patients (e.g., HIV-positive, transplant recipients); pregnant females.

Ethical Considerations: Approval was obtained from the relevant institutional ethical committee before data collection. Written informed consent was obtained from participants. Confidentiality was maintained, participation was voluntary, and HRCT examinations were performed as part of clinically indicated care.

Data Collection Procedure: Eligible patients were enrolled consecutively. Demographic details, smoking status, duration and type of symptoms, sputum AFB smear status, sputum culture and HIV status were recorded. HRCT chest examinations were reviewed for centrilobular nodules, tree-in-bud appearance, consolidation, cavitation, ground-glass opacity, fibrosis, bronchiectasis, lymphadenopathy, pleural

effusion, miliary nodules, upper-lobe predominance and unilateral or bilateral involvement. The radiological impression was categorized as highly suggestive of PTB, normal HRCT, or other disease pattern.

Statistical Analysis: Data were analyzed using SPSS-compatible coding. Frequencies and percentages were calculated for categorical variables, while mean, standard deviation, minimum and maximum were calculated for continuous variables. Cross-tabulations and Pearson chi-square tests were used for categorical associations where appropriate; Fisher's exact test was considered when expected cell counts were small. One-way ANOVA was used to compare mean age across the three HRCT classification groups. Binary logistic regression was used to explore independent predictors of an HRCT-positive TB classification. A p-value <0.05 was considered statistically significant.

RESULTS

Table 4.1. Frequency Distribution of Gender

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	60	60.0	60.0	60.0
Female	40	40.0	40.0	100.0

Table 4.2. Frequency Distribution of Smoking Status

Smoking Status	Frequency	Percent	Valid Percent	Cumulative Percent
Current smoker	30	30.0	30.0	30.0
Ex-smoker	10	10.0	10.0	40.0
Non-smoker	60	60.0	60.0	100.0

Table 4.3. Frequency of Sputum AFB Smear

AFB Smear	Frequency	Percent	Valid Percent	Cumulative Percent
Not done	60	60.0	60.0	60.0
Negative	40	40.0	40.0	100.0

Table 4.4. HRCT Result

HRCT Result	Frequency	Percent	Valid Percent	Cumulative Percent
Positive for TB	57	57.0	57.0	57.0
Negative for TB	43	43.0	43.0	100.0

Table 4.5. Frequency Distribution of Lobe Predominance

Distribution	Frequency	Percent	Valid Percent	Cumulative Percent
Upper-lobe predominance	30	30.0	30.0	30.0
Bilateral involvement	10	10.0	10.0	40.0
Unilateral	17	17.0	17.0	57.0

involvement				
Not applicable	43	43.0	43.0	100.0

Table 4.6. Descriptive Statistics for Continuous Variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	100	20	69	43.52	14.89
Symptom duration (months)	100	1	2	1.50	0.503

Table 4.7. Age Descriptive Statistics by Gender

Gender	N	Mean	Std. Deviation	Minimum	Maximum
Male	60	44.03	15.86	20	69
Female	40	42.75	13.47	21	65

Table 4.8. Age Descriptive Statistics by HRCT Study Classification

Study Classification	N	Mean	Std. Deviation	Minimum	Maximum
Highly suggestive of PTB	57	44.19	16.21	20	69
Normal HRCT	23	42.65	12.89	22	65
Other disease pattern	20	42.60	13.62	21	64

Table 4.9. Gender × Study Classification Cross-tabulation

Gender	Highly suggestive of PTB	Normal HRCT	Other disease pattern	Total
Female	0	20	20	40
Male	57	3	0	60

Table 4.10. Chi-Square Tests for Gender and Study Classification

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	89.130	2	<.001
N of Valid Cases	100		

Table 4.11. Smoking Status × HRCT Result Cross-tabulation

Smoking Status	Negative for TB	Positive for TB	Total
Current smoker	0	30	30
Ex-smoker	0	10	10
Non-smoker	43	17	60

Table 4.12. Chi-Square Tests for Smoking Status and HRCT Result

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	50.292	2	<.001
N of Valid Cases	100		

Table 4.13. Gender × HRCT Result Cross-tabulation

Gender	Negative for TB	Positive for TB	Total
Female	40	0	40
Male	3	57	60

Table 4.14. Chi-Square Tests for Gender and HRCT Result

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	84.539	1	<.001
N of Valid Cases	100		

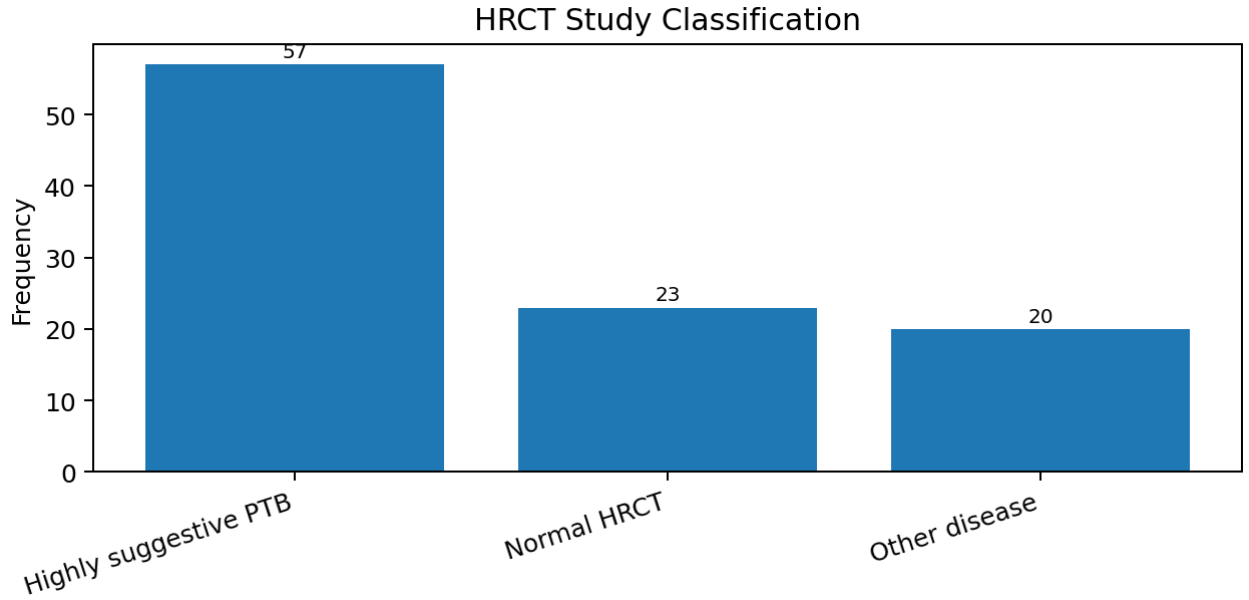


Figure 4.1. Bar chart showing HRCT study classification.

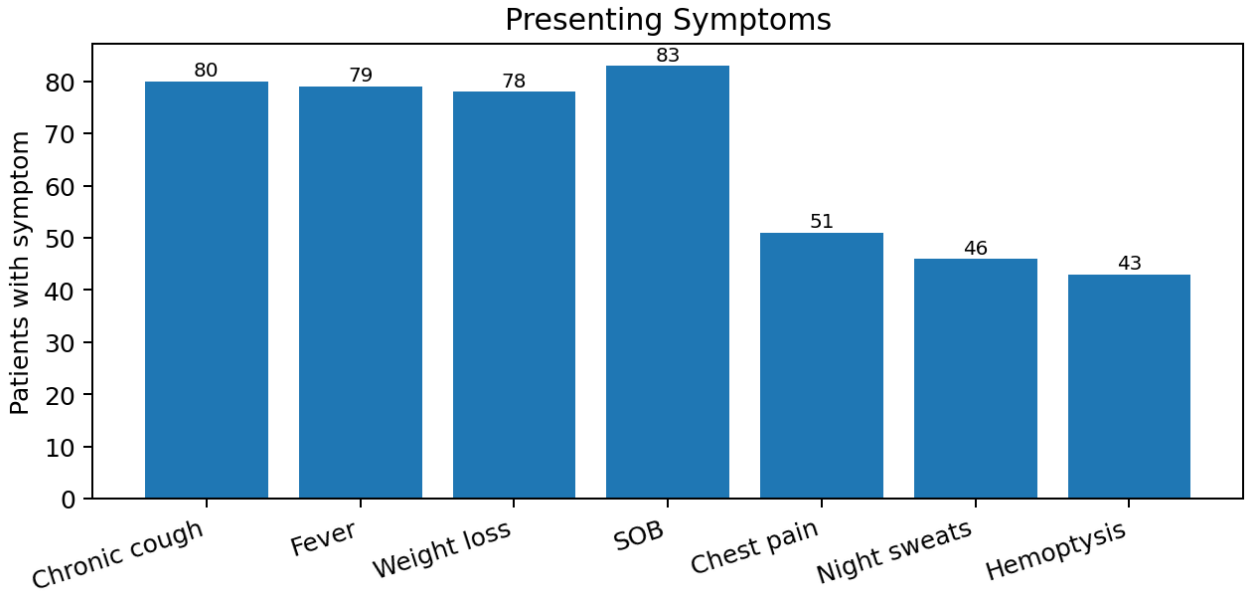


Figure 4.2. Bar chart showing presenting symptoms.

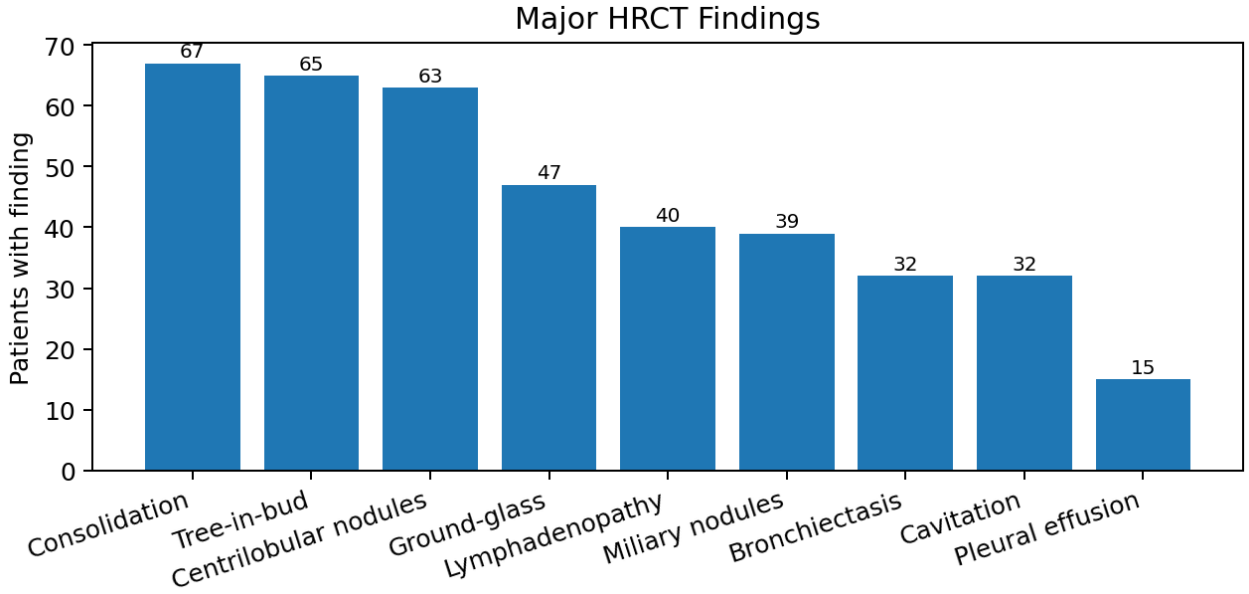


Figure 4.3. Bar chart showing major HRCT findings.

Table 4.15. Cross-Tabulation Between Chronic Cough and HRCT Result

Sym: Chronic cough	Negative for TB	Positive for TB	Total
No	20	0	20
Yes	23	57	80

Table 4.16. Cross-Tabulation Between Weight Loss and HRCT Result

Sym: Weight loss	Negative for TB	Positive for TB	Total
No	22	0	22
Yes	21	57	78

Table 4.17. Chi-Square Tests for the Association Between Weight Loss and HRCT Result

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	34.466	1	<.001
N of Valid Cases	100		

Table 4.18. Cross-Tabulation Between Tree-in-bud Appearance and HRCT Result

HRCT: Tree-in-bud appearance	Negative for TB	Positive for TB	Total
No	35	0	35
Yes	8	57	65

Table 4.19. Chi-Square Tests for the Association Between Tree-in-bud Appearance and HRCT Result

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	67.844	1	<.001
N of Valid Cases	100		

Table 4.20. Cross-Tabulation Between Centrilobular Nodules and HRCT Result

HRCT: Centrilobular nodules	Negative for TB	Positive for TB	Total
No	37	0	37
Yes	6	57	63

Table 4.21. Chi-Square Tests for Centrilobular Nodules and HRCT Result

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	74.204	1	<.001
N of Valid Cases	100		

Table 4.22. Cross-Tabulation Between Cavitation and HRCT Result

HRCT: Cavitation	Negative for TB	Positive for TB	Total
No	35	33	68
Yes	8	24	32

Table 4.23. Chi-Square Tests for Cavitation and HRCT Results

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.188	1	0.023
N of Valid Cases	100		

Table 4.24. Descriptive Distribution of Age by Study Classification

Study Classification	N	Mean	Std. Deviation	Minimum	Maximum
Highly suggestive of	57	44.19	16.21	20	69

PTB					
Normal HRCT	23	42.65	12.89	22	65
Other disease pattern	20	42.60	13.62	21	64

Table 4.25. ONE-WAY ANOVA of Age by Study Classification

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	60.065	2	30.033	0.133	0.876
Within Groups	21890.895	97	225.679		
Total	21950.960	99			

Table 4.26. Variables in the Equation: Binary Logistic Regression Predicting HRCT-Positive TB

Variable	B	S.E.	Wald	df	Sig.	Exp(B)	95% CI Lower	95% CI Upper
Constant	1.300	0.791	2.700	1	0.100	0.273	0.058	1.285
Age (years)	0.008	0.016	0.281	1	0.596	1.008	0.978	1.040
Cavitation	1.255	0.523	5.753	1	0.016	3.507	1.258	9.779
Ground-glass opacity	0.534	0.455	1.375	1	0.241	1.706	0.699	4.163
Fibrosis	1.566	0.479	10.686	1	0.001	4.785	1.872	12.233

Table 4.27. Logistic Regression Model Summary

-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square	χ^2	df	Sig.
116.203	—	0.150	20.460	4	<.001

DISCUSSION

The present study assessed HRCT chest findings in 100 adults with clinical suspicion of pulmonary tuberculosis and negative sputum culture. HRCT was highly suggestive of PTB in 57% of participants, while 23% had normal HRCT and 20% showed alternative disease patterns. These categories should be interpreted as radiological classifications rather than confirmed diagnoses because no participant had a positive bacteriological reference standard. This distinction is important in contemporary TB pathways, in which microbiological or molecular confirmation remains necessary whenever feasible (2,3).

The cohort was predominantly male (60%) and had a mean age of 43.52 ± 14.89 years. Mean age did not differ significantly across the three HRCT classification groups (ANOVA p=0.876), indicating that age alone did not distinguish radiologically suggestive PTB from normal or alternative patterns. Participants were highly symptomatic: shortness of breath occurred in 83%, chronic cough in 80%, fever in 79%, and weight loss in 78%. Although these symptoms support clinical suspicion, they overlap substantially with pneumonia, malignancy, fungal infection and chronic airway disease and therefore cannot establish PTB independently. Similar studies of sputum-negative patients have

emphasized the value of combining symptoms with imaging rather than relying on either domain alone (5,8).

Consolidation was the most frequent HRCT abnormality (67%), followed by tree-in-bud appearance (65%) and centrilobular nodules (63%). This combination indicates a predominance of air-space and small-airway abnormalities. Prior radiological literature describes tree-in-bud opacities and centrilobular nodules as characteristic manifestations of bronchogenic spread, particularly when they coexist with consolidation or cavitation (13–15). In the present dataset, tree-in-bud appearance and centrilobular nodules were strongly associated with the HRCT-positive classification (both $p<0.001$). However, because these same imaging features contribute to the radiological classification itself, these associations primarily describe the reporting pattern and should not be interpreted as independent proof of diagnostic accuracy.

Cavitation was present in 32% of participants and remained a significant positive predictor in the fitted logistic regression (OR 3.507, 95% CI 1.258–9.779; $p=0.016$). Fibrosis was also independently associated with HRCT-positive classification (OR 4.785, 95% CI 1.872–12.233; $p=0.001$), whereas age and ground-glass opacity were not independently significant. Cavitation is compatible with destructive post-primary TB but can also occur in bacterial abscess, fungal infection and malignancy. Fibrosis may reflect chronic or previous tuberculous injury rather than current activity, so its interpretation requires prior imaging, treatment history and microbiological correlation. Ground-glass opacity, present in 47%, is similarly nonspecific and may reflect partial air-space filling or interstitial inflammation (12,14,16,17).

Among the 57 HRCT-suggestive cases, upper-lobe predominance occurred in 52.6%, bronchiectasis in 56.1%, lymphadenopathy in 70.2%, and pleural effusion in 26.3%. Upper-lobe disease is a recognized pattern of post-primary TB, especially when combined with cavitation and bronchogenic spread, but its absence does not exclude disease. Bronchiectasis may reflect airway destruction, traction or stenosis and can persist as a post-tuberculous structural sequela. Lymphadenopathy and pleural involvement broaden the thoracic pattern but remain nonspecific and may require targeted sampling or additional evaluation where clinically indicated (12,17–19).

A central limitation of the study is the absence of a positive microbiological reference standard. Sputum AFB smear was not performed in 60% and was negative in 40%, while sputum culture was negative in all participants. Consequently, sensitivity, specificity, PPV, NPV and ROC area cannot be validly estimated against culture. The appropriate interpretation is therefore descriptive and exploratory: HRCT identifies and characterizes structural patterns that can support clinical decision-making, differential diagnosis and selection of sites for further sampling, but it does not establish etiology. Future prospective studies should incorporate standardized rapid molecular testing, repeat or induced sputum, bronchoscopic/tissue sampling when appropriate, and an independent composite reference diagnosis (3,35,38–40).

Overall, the findings support HRCT as a useful adjunct in clinically suspected sputum-culture-negative PTB, particularly for demonstrating airway-centered disease, cavities, chronic structural change, nodal disease and pleural involvement. Its greatest clinical value lies in pattern recognition and directing the next diagnostic step. Because several patient-level variables in the working dataset were reported in the thesis as having been completed using predefined or randomized instructions, those variables must be verified against original source records before this work is submitted as original clinical research. Until such verification, inferential associations based on those entries should be treated as provisional.

CONCLUSION

In this sample of 100 clinically suspected sputum-culture-negative adults, 57% had HRCT features highly suggestive of pulmonary TB, 23% had

normal HRCT appearances, and 20% had alternative disease patterns. Consolidation, tree-in-bud appearance and centrilobular nodules were the most frequent findings, while cavitation and fibrosis were significant predictors of the HRCT-positive classification in the fitted model. HRCT is valuable for identifying disease distribution, morphology and complications, but the imaging findings are suggestive rather than diagnostic. Its interpretation should be integrated with clinical probability and recommended microbiological or molecular testing. Patient-level variables identified in the thesis as predefined or randomly completed should be verified against source records before publication as original clinical research.

LIMITATIONS

- The sample of 100 adults from a single center limits generalizability to other centers and populations.
- All participants were sputum-culture negative and no independent positive reference standard was available; therefore, HRCT sensitivity, specificity and predictive values could not be estimated.
- Rapid molecular testing results were unavailable, limiting microbiological correlation with imaging findings.
- Some working-dataset variables were reported in the thesis as completed using predefined or randomized instructions rather than verified patient observations; these require source verification before publication.
- The cross-sectional design cannot determine whether HRCT findings predicted subsequent TB diagnosis or treatment response.

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