Section: Respiratory Medicine

Original Research Article

CORRELATION BETWEEN CBNAAT AND RADIOLOGICAL ACTIVITY ON CT THORAX IN CASES OF PRESUMPTIVE PULMONARY TUBERCULOSIS IN A TERTIARY CARE CENTRE

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ABSTRACT

Aim of the study is to address this gap by evaluating the correlation between the molecular detection of MTB using CBNAAT and specific radiological findings on CT thorax in presumptive PTB cases. Patients were included if they exhibited symptoms suggestive of PTB, such as a persistent cough lasting more than 2 weeks, fever exceeding 4 weeks, significant weight loss, hemoptysis, or any abnormalities identified on a chest radiograph Presumptive TB patients who took HRCT thorax were categorised into 4 radiological categories. Later their CBNAAT results were reviewed and the data was analysed. majority of patients (37.7%) fall within the 51–60 years. 39 (73.6%) were male. CT grading shows Definite active (45.3%), Probably active (26.4%), Indeterminate active (9.4%), and probably inactive (18.9%) groups. The overall CBNAAT results revealed that 75.5% (40 out of 53) of the patients tested positive for Mycobacterium tuberculosis, while 24.5% (13 out of 53) were negative. A significant association ($p < 0.001$) between CBNAAT results and the CT grading categories of pulmonary tuberculosis.

Key-words: Pulmonary tuberculosis, Cartridge Based Nucleic Acid Amplification Test, chest computed tomography.

INTRODUCTION

Chest radiographs serve as the initial radiological tool for diagnosing pulmonary tuberculosis (PTB), but their interpretation can vary significantly among clinicians. In contrast, chest computed tomography (CT) provides greater diagnostic accuracy and is pivotal in identifying early signs of PTB and differentiating it from other lung conditions. CT thorax can detect characteristic radiological features such as cavitation, consolidation, and the "tree-in-bud" pattern, often accompanied by pleural effusion.[1-5] These features are strongly associated with PTB and have been explored in relation to bacteriological data like sputum smear grades and Mycobacterium tuberculosis (MTB) culture yields.[6-8]
Cartridge Based Nucleic Acid Amplification Test (CBNAAT) has emerged as a rapid molecular diagnostic test for tuberculosis, providing results in approximately two hours. Its speed and accuracy have made it a cornerstone in early TB diagnosis and treatment, particularly within the framework of the National Tuberculosis Elimination Program (NTEP). Despite its widespread use, few studies have examined the correlation between CBNAAT results and radiological findings, especially in patients with presumptive TB—those showing symptoms or signs suggestive of TB but requiring further diagnostic confirmation.
This study aims to address this gap by evaluating the correlation between the molecular detection of MTB using CBNAAT and specific radiological findings on CT thorax in presumptive PTB cases. In doing so, it seeks to determine the relative frequency of CBNAAT positivity across different radiological categories and to assess how the severity of radiological activity correlates with PTB diagnosis.

MATERIALS AND METHODS

This observational study was conducted over a period of four months at a tertiary care hospital in Kerala. The study protocol was approved by the institutional human ethics committee, and informed consent was obtained from all participants. Throughout the study, data confidentiality and participant anonymity were rigorously maintained.

The study population comprised presumptive PTB patients who presented to the Emergency Medicine Department and/or the Respiratory Medicine outpatient department. Patients were included if they exhibited symptoms suggestive of PTB, such as a persistent cough lasting more than two weeks, fever exceeding two weeks, significant weight loss, hemoptysis, or any abnormalities identified on a chest radiograph. Additionally, patients who were willing to undergo a high-resolution computed tomography (HRCT) of the thorax were included.

Exclusion criteria encompassed patients with severe comorbidities, including acute myocardial infarction, significant hemoptysis, bronchogenic carcinoma, or those who were critically ill.

Presumptive TB patients who took HRCT thorax were categorised into 4 radiological categories based on a previously published criterion.[5-7,9]

i) Definitely Active: Cavitary lesion
ii) Probably Active: Tree-in-bud/non-calcified poorly circumscribed nodules without cavity or consolidation
iii) Indeterminate: Non-calcified well-circumscribed nodules
iv) Probably Inactive: calcified nodules or fibrotic bands

Later their CBNAAT results were reviewed and the data was analysed.

RESULTS

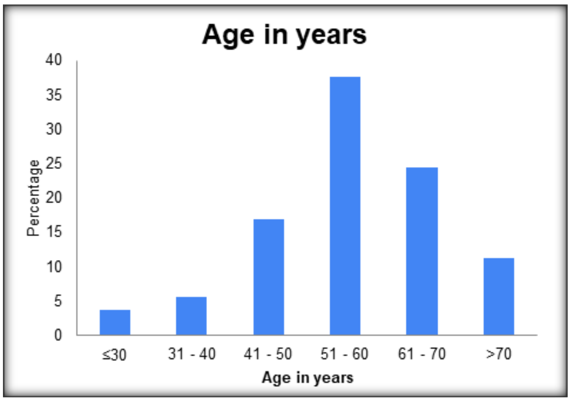

Figure 1: Age in years

The age distribution table categorizes the 53 study participants into six age groups. Notably, the majority of patients (37.7%) fall within the 51–60 years bracket, with a significant number also in the 61–70 years range (24.5%). Only a small fraction of patients are in the younger age groups (≤30 years at 3.8% and 31–40 years at 5.7%). The overall average age of 56.6 ± 11.9 years (ranging from 23 to 75 years) suggests that the study predominantly involved middle-aged to elderly individuals. [Table 1]

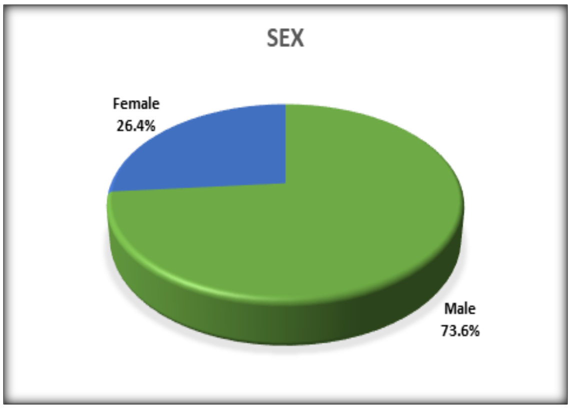

Figure 2

The gender distribution table indicates that out of 53 patients, 39 (73.6%) were male and 14 (26.4%) were female. This marked male predominance could reflect a higher incidence of presumptive pulmonary tuberculosis among men in the studied population. Factors such as occupational exposure, lifestyle differences, and healthcare-seeking behaviors might contribute to this disparity. Understanding gender distribution is essential for tailoring public health interventions and ensuring equitable resource allocation in tuberculosis management.

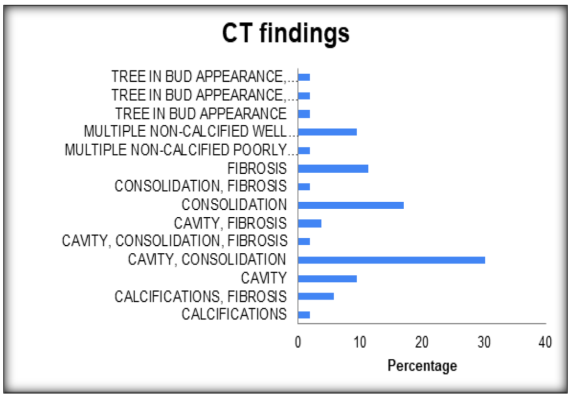

Figure 3: CT findings

The CT findings table provides a breakdown of the various radiological features identified on high-resolution CT thorax scans. The findings include calcifications, fibrosis, cavities, consolidation, and nodular patterns, either as isolated findings or in combination. The most frequently observed pattern was "CAVITY, CONSOLIDATION," present in 16 patients (30.2%), followed by consolidation alone in nine patients (17%). Other features, such as calcifications, fibrosis, and the tree-in-bud appearance, were noted in smaller proportions.

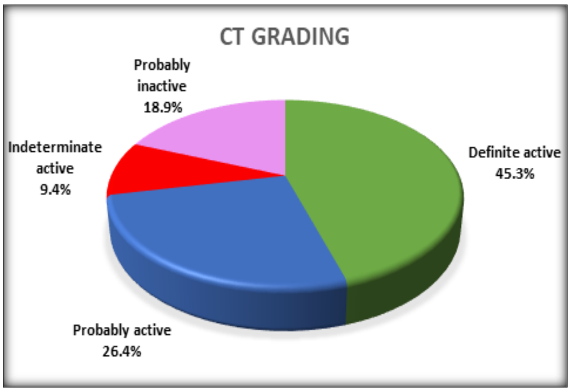

Figure 4: CT grading

The CT grading table classifies patients based on the radiological activity of their disease into four distinct categories. Definite active (45.3%), 24 patients showing clear radiological signs of active disease. Probably active (26.4%), 14 patients with findings suggestive of active infection, though not as definitive as the first group. Indeterminate active (9.4%), 5 patients with ambiguous findings that fall between active and inactive disease. Probably inactive (18.9%), 10 patients with radiological features that lean towards inactive or healed disease.

CBNAAT Results

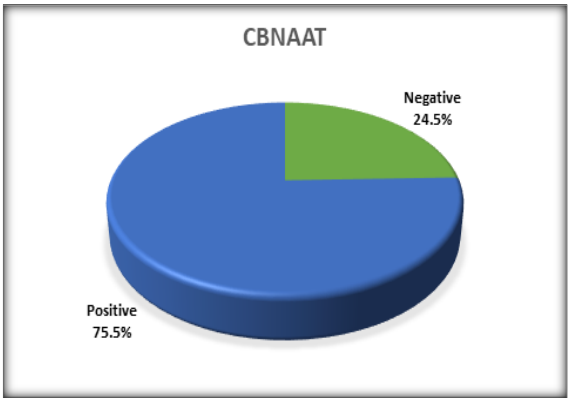

Figure 5: CBNAAT Results

The CBNAAT results reveals that out of the 53 patients, 40 (75.5%) tested positive for Mycobacterium tuberculosis, while 13 (24.5%) were negative. Given that CBNAAT is a rapid and highly sensitive molecular diagnostic tool, the high positivity rate among these presumptive cases reinforces the accuracy of the clinical and radiological suspicion of tuberculosis. This strong correlation between CBNAAT positivity and active radiological findings on CT thorax supports the integrated use of molecular testing alongside imaging in the early and precise diagnosis of pulmonary tuberculosis.

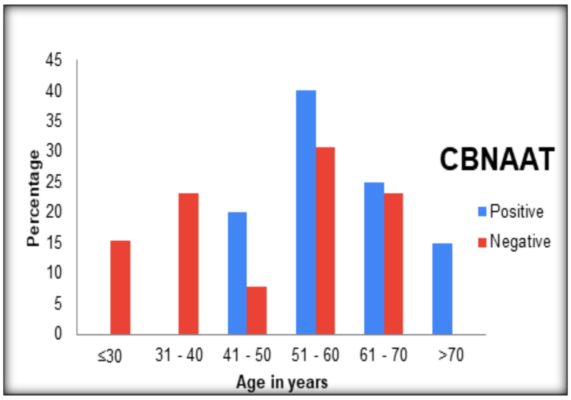

Figure 6: Association between CBNAAT and age distribution

This table examines the distribution of CBNAAT (Cartridge Based Nucleic Acid Amplification Test) results—categorized as Positive or Negative—across different age groups for a total of 53 patients. The table also provides the percentage distribution within each age group and an overall Fisher's Exact test p-value of 0.005, indicating a statistically significant association between age and CBNAAT results. Age Group ≤30 Years, there were no patients with a positive CBNAAT result (0%), while 2 patients (15.4% of the negatives) were CBNAAT-negative. Overall, 2 patients (3.8% of the total sample) belong to this age group. The absence of positive cases here suggests that, in this small subset, younger individuals did not yield a positive result on the CBNAAT assay. Age Group 31–40 Years, similar to the ≤30 group, there were no positive results in this age bracket. All 3 patients in this group (accounting for 23.1% of the negatives) were CBNAAT-negative. This again reflects a trend where the younger age groups tend to have fewer or no positive findings by CBNAAT. Age Group 41–50 Years, among the patients in this category, 8 patients (20% of the positives) tested CBNAAT-positive, while only 1 patient (7.7% of the negatives) tested negative. A total of 9 patients (17% of the overall sample) fell into this age range. This suggests that a majority of patients in the 41–50 age group had a positive CBNAAT result. Age Group 51–60 Years, this group had the highest representation in the study with 20 patients (37.7% of the total). Out of these, 16 patients (40% of the positives) were CBNAAT-positive and 4 patients (30.8% of the negatives) were negative. The high number of positives in this age group underscores a significant occurrence of tuberculosis as detected by CBNAAT among middle-aged individuals. Age Group 61–70 Years, In this bracket, 10 patients (25% of the positives) were CBNAAT-positive and 3 patients (23.1% of the negatives) were negative. This group comprised 13 patients (24.5% of the total sample). The distribution here indicates a relatively balanced outcome with a slightly higher proportion of positive results. Age Group >70 Years, All 6 patients in this oldest age group (11.3% of the total sample) were CBNAAT-positive, with no patients testing negative. This 100% positivity in the >70 group further supports the observation that older patients tend to show a higher rate of CBNAAT positivity. Out of 53 patients, 40 (75.5%) tested positive for TB using CBNAAT, while 13 (24.5%) were negative. The Fisher's Exact test yields a p-value of 0.005, indicating that the differences in CBNAAT results across the various age groups are statistically significant. This result suggests that age may be an influential factor in the likelihood of a CBNAAT positive result, with older age groups generally showing higher positivity rates.

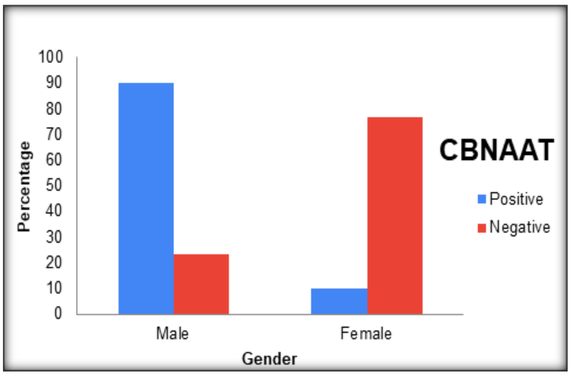

Figure 7: Association between CBNAAT and gender distribution

Sex Distribution and CBNAAT Results

This table compares the CBNAAT results between male and female patients among the 53 individuals in the study. The data are broken down into CBNAAT-positive and CBNAAT-negative groups, and the distribution is analyzed using Fisher's Exact test, which yields a p-value of 0.001. This statistically significant p-value indicates that there is a meaningful association between a patient's sex and their CBNAAT result. 36 out of the 40 positive cases (90%) were males. CBNAAT Negative: Only 3 out of the 13 negative cases (23.1%) were males. These results suggest that a significantly higher proportion of male patients tested positive for tuberculosis on the CBNAAT assay compared to female patients.

The table comparing various CT findings with CBNAAT results shows a statistically significant association (Fisher's Exact test p = 0.002) between specific radiological features and the likelihood of a positive molecular diagnosis for tuberculosis. Notably, classic features of active TB—such as "CAVITY" and "CAVITY, CONSOLIDATION"—were observed exclusively in CBNAAT-positive patients (with 5 and 16 cases, respectively), while they were completely absent among the CBNAAT-negative group. In contrast, findings like "CALCIFICATIONS" appeared only in the negative group, and certain patterns such as "FIBROSIS" and "CONSOLIDATION" were found in both groups but with varying frequencies. Additionally, the "MULTIPLE NON-CALCIFIED WELL CIRCUMSCRIBED NODULES" finding was predominantly seen in the CBNAAT-negative group. This distribution suggests that CT findings indicative of active disease are strongly associated with a positive CBNAAT result, while features more typical of inactive or healed disease tend to correlate with negative results. The significant p-value confirms that these observed differences are unlikely to be due to chance, reinforcing the role of CT imaging as a valuable complementary tool in the diagnosis and assessment of pulmonary tuberculosis. [Table 5]

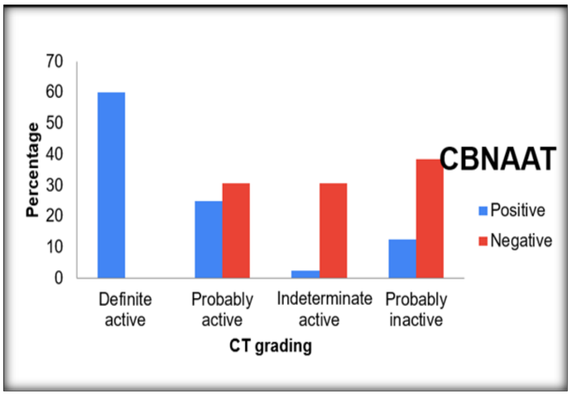

Figure 8: Association between CBNAAT and CT grading

The table illustrates the association between CT grading and CBNAAT results among the 53 patients, highlighting a statistically significant relationship (Fisher's Exact test p = 0.001). Notably, all 24 patients categorized as having "Definite active" disease on CT were CBNAAT positive (60.0% of the CBNAAT positive group), with no patients in this CT category being CBNAAT negative, underscoring a strong link between radiologically active disease and a positive molecular test result. In contrast, for the "Probably active" category, 10 patients (25.0%) were CBNAAT positive while 4 (30.8%) were CBNAAT negative, indicating a more mixed pattern. The "Indeterminate active" group comprised only 1 CBNAAT positive patient (2.5%) compared to 4 CBNAAT negative patients (30.8%), suggesting that these indeterminate CT findings are more commonly associated with negative CBNAAT results. Similarly, in the "Probably inactive" category, the distribution was evenly split with 5 patients (12.5%) being CBNAAT positive and 5 (38.5%) negative. Overall, these results demonstrate that CT findings consistent with "Definite active" tuberculosis are strongly predictive of a positive CBNAAT result, while less active or inactive radiological patterns are more frequently associated with negative CBNAAT outcomes.

The table presents the distribution of CT grading—categorized as Definite active, Probably active, Indeterminate active, and Probably inactive—across different age groups and between sexes, along with their respective p-values. Among the age groups, patients aged 51–60 years form the largest cohort

(37.7% of the total) and show a notable concentration in the Definite active category (11 cases, 45.8%) as well as in the Indeterminate active category (4 cases, 80% of that group). In contrast, the younger age groups (≤30 and 31–40 years) contribute very few cases overall, with minimal representation in the Definite active and Probably active categories. Although some variation in CT grading is apparent across age groups, this trend did not reach statistical significance ($p = 0.087$). In terms of sex, the differences are more pronounced and statistically significant ($p = 0.02$). Among the 24 patients classified as having Definite active disease, 21 (87.5%) were male, while only 3 (12.5%) were female. Similarly, a higher proportion of males were present in the Probably active category (10 males [71.4%] versus 4 females [28.6%]). Conversely, the Indeterminate active category was dominated by females (4 out of 5 cases, 80%), and the Probably inactive category also showed a male predominance (7 males [70.0%] versus 3 females [30.0%]). Overall, these findings indicate that while age shows a non-significant trend in influencing CT grading, sex is significantly associated with the radiological activity of pulmonary tuberculosis, with male patients more frequently exhibiting radiological features of active disease. [Table 7]

The table demonstrates a significant association ($p < 0.001$) between CBNAAT results and the CT grading categories of pulmonary tuberculosis. In the "Definite active" category, all 24 cases (100%) were CBNAAT positive, with no negatives, indicating that clear radiological evidence of active disease is strongly correlated with a positive molecular diagnosis. In contrast, the "Probably active" category had a mixed profile, with 10 patients (71.4%) testing positive and 4 (28.6%) negative. The "Indeterminate active" group revealed a higher proportion of negative results, as only 1 patient (20.0%) was CBNAAT positive compared to 4 (80.0%) who were negative, suggesting that indeterminate radiological findings may correspond more frequently with a negative molecular test. Similarly, in the "Probably inactive" category, half of the patients (50.0%) were CBNAAT positive while the remaining half were negative. Overall, out of 53 patients, 40 (75.5%) were CBNAAT positive and 13 (24.5%) negative. This distribution underscores that definite active radiological findings on CT are highly predictive of a positive CBNAAT result, whereas less definitive CT findings show a higher likelihood of negative CBNAAT outcomes. [Table 8]

This table shows the distribution of CBNAAT results across four CT grading categories. In the Definite active group, all 24 cases were CBNAAT positive and none were negative, indicating a strong association between clear radiological evidence of active tuberculosis and a positive molecular diagnosis. In the Probably active category, 10 cases were positive while 4 were negative, suggesting a less definitive but still notable correlation. In the Indeterminate active group, only 1 case was CBNAAT positive compared to 4 negatives, highlighting the difficulty in diagnosing cases with indeterminate radiological features. For the Probably inactive group, the results were evenly split with 5 positive and 5 negative cases. Overall, out of 53 cases, 40 were CBNAAT positive and 13 negative, emphasizing that the degree of radiological activity on CT is significantly associated with CBNAAT outcomes. [Table 9]

For patients classified under the definite active CT grading, the diagnostic performance is robust. The sensitivity is estimated at 60.00% (95% CI: 43.33%–75.14%), meaning that 60% of patients with definite active radiological findings are correctly identified as CBNAAT positive. The specificity is perfect at 100.00% (95% CI: 75.29%–100.00%), indicating no false positives in this group. The diagnostic accuracy stands at 69.81% (95% CI: 55.66%–81.66%), while the positive predictive value (PPV) is 100.00% (95% CI: 85.75%–100.00%), showing that all patients identified with definite active findings truly have a positive CBNAAT result. However, the negative predictive value (NPV) is only 44.83% (95% CI: 26.45%–64.31%), and the likelihood ratio for a negative test is 0.4 (95% CI: 0.274–0.585). The Youden's index of 0.6 reflects a moderate overall test performance in this category. [Table 10

In the Probably active CT grading category, the sensitivity is considerably lower at 25.00% (95% CI: 12.69%–41.20%), indicating that only a quarter of these cases are detected as CBNAAT positive. The specificity is 69.23% (95% CI: 38.57%–90.91%), and the overall diagnostic accuracy is 35.85% (95% CI: 23.14%–50.20%), which is relatively poor. The PPV is moderately high at 71.43% (95% CI: 41.90%–91.61%), but the NPV is only 23.08% (95% CI: 11.13%–39.33%). The likelihood ratio for a positive test is 0.813 (95% CI: 0.306–2.157) and for a negative test is 1.083 (95% CI: 0.723–1.623). With a Youden's index of –0.058, this category shows limited discriminatory power in differentiating between CBNAAT-positive and negative cases. [Table 11]

When combining the definite active and probably active CT grading categories, the diagnostic performance improves markedly. The sensitivity increases to 85.00% (95% CI: 70.16%–94.29%), meaning that the majority of patients with either definite or probably active radiological findings are correctly identified as CBNAAT positive. The specificity is 69.23% (95% CI: 38.57%–90.91%), and the diagnostic accuracy reaches 81.13% (95% CI: 68.03%–90.56%). The PPV is high at 89.47% (95% CI: 75.20%–97.06%), while the NPV is 60.00% (95% CI: 32.29%–83.66%). The likelihood ratio for a positive test is 2.7625 (95% CI: 1.2098–6.3082), and for a negative test, it is 0.217 (95% CI: 0.095–0.493). A Youden's index of 0.542 indicates a good balance between sensitivity and specificity when both active categories are considered together. [Table 12]

For the Indeterminate active category, the diagnostic performance is notably poor. The sensitivity is extremely low at 2.50% (95% CI: 0.06%–13.16%), suggesting that almost all patients in this group are not identified as CBNAAT positive. Although the specificity remains at 69.23% (95% CI: 38.57%–90.91%), the overall diagnostic accuracy is only 18.87% (95% CI: 9.44%–31.97%). The PPV is 20.00% (95% CI: 0.51%–71.64%) and the NPV is 18.75% (95% CI: 8.95%–32.63%). The likelihood ratio for a positive test is a very low 0.081 (95% CI: 0.010–0.664), and for a negative test, it is 1.408 (95% CI: 0.977–2.030). With a Youden's index of –0.283, this category does not effectively discriminate between CBNAAT-positive and negative cases. [Table 13]

In the Probably inactive category, the sensitivity is 12.50% (95% CI: 4.19%–26.80%), indicating that only a small proportion of these patients are correctly identified as CBNAAT positive. The specificity is 61.54% (95% CI: 31.58%–86.14%), and the overall diagnostic accuracy is low at 24.53% (95% CI: 13.76%–38.28%). The PPV stands at 50.00% (95% CI: 18.71%–81.29%) while the NPV is 18.60% (95% CI: 8.39%–33.40%). The likelihood ratio for a positive test is 0.325 (95% CI: 0.112–0.948) and for a negative test is 1.422 (95% CI: 0.911–2.220). A Youden's index of –0.260 further indicates that the Probably inactive grading has limited utility in distinguishing between those with and without a positive CBNAAT result. [Table 14]

Table 1: Age Distribution

Age in years	Frequency	Percent
≤30	2	3.8
31 - 40	3	5.7
41 - 50	9	17
51 - 60	20	37.7
61 - 70	13	24.5
>70	6	11.3
Total	53	100

Table 2: CT Findings

CT finding	Frequency	Percent
Calcifications	1	1.9
Calcifications, fibrosis	3	5.7
Cavity	5	9.4
Cavity, consolidation	16	30.2
Cavity, consolidation, fibrosis	1	1.9
Cavity, fibrosis	2	3.8
Consolidation	9	17
Consolidation, fibrosis	1	1.9
Fibrosis	6	11.3
Multiple non-calcified poorly circumscribed nodules without cavity, consolidation	1	1.9
Multiple non-calcified well circumscribed nodules	5	9.4
Tree in bud appearance	1	1.9
Tree in bud appearance, consolidation	1	1.9
Tree in bud appearance, consolidation, fibrosis	1	1.9
Total	53	100

Table 3: Age Distribution according to CBNAAT Results

Age	CBNAAT				Total		Fisher's Exact test p
	Positive		Negative				
	N	%	N	%	N	%	
≤30	0	0	2	15.4	2	3.8	0.005
31 - 40	0	0	3	23.1	3	5.7	
41 - 50	8	20	1	7.7	9	17	
51 - 60	16	40	4	30.8	20	37.7	
61 - 70	10	25	3	23.1	13	24.5	
>70	6	15	0	0	6	11.3	
Total	40	100	13	100	53	100	

Table 4: Sex Distribution according to CBNAAT Results

Sex	CBNAAT				Total		Fisher's Exact test p
	Positive		Negative				
	N	%	N	%	N	%	
Male	36	90	3	23.1	39	73.6	0.001
Female	4	10	10	76.9	14	26.4	
Total	40	100	13	100	53	100	

Table 5: Distribution of CT findings and CBNAAT

CT findings	CBNAAT				Total	
	Positive		Negative			
	N	%	N	%	N	%
Calcifications	0	0.0	1	7.7	1	1.9
Calcifications, fibrosis	2	5.0	1	7.7	3	5.7
Cavity	5	12.5	0	0.0	5	9.4
Cavity, consolidation	16	40	0	0.0	16	30.2
Cavity, consolidation, fibrosis	1	2.5	0	0.0	1	1.9
Cavity, fibrosis	2	5.0	0	0.0	2	3.8
Consolidation	6	15.0	3	23.1	9	17.0
Consolidation, fibrosis	1	2.5	0	0.0	1	1.9
Fibrosis	3	7.5	3	23.1	6	11.3
Multiple non-calcified poorly circumscribed nodules without cavity, consolidation	1	2.5	0	0.0	1	1.9
Multiple non-calcified well circumscribed nodules	1	2.5	4	30.8	5	9.4
Tree in bud appearance	1	2.5	0	0.0	1	1.9
Tree in bud appearance, consolidation	1	2.5	0	0.0	1	1.9
Tree in bud appearance, consolidation, fibrosis	0	0.0	1	7.7	1	1.9
Total	40	100.0	13	100.0	53	100.0

Fisher's Exact test p =0.002

Table 6: Association between CT grading and CBNAAT

CT grading	CBNAAT				Total		Fisher's Exact test p
	Positive		Negative				
	N	%	N	%	N	%	
Definite active	24	60.0	0	0.0	24	45.3	0.001
Probably active	10	25.0	4	30.8	14	26.4	
Indeterminate active	1	2.5	4	30.8	5	9.4	
Probably inactive	5	12.5	5	38.5	10	18.9	
Total	40	100.0	13	100.0	53	100.0	

Table 7: Age and sex distribution according to CT grading

	Definite active	Probably active	Indeterminate active	Probably inactive	Total	p
Age						
≤30	0 (0.0)	1 (7.1)	0 (0.0)	1 (10.0)	2 (3.8)	0.087
31 - 40	0 (0.0)	0 (0.0)	1 (20.0)	2 (20.0)	3 (5.7)	
41 - 50	5 (20.8)	3 (21.4)	0 (0.0)	1 (10.0)	9 (17.0)	
51 - 60	11 (45.8)	4 (28.6)	4 (80.0)	1 (10.0)	20 (37.7)	
61 - 70	6 (25.0)	5 (35.7)	0 (0.0)	2 (20.0)	13 (24.5)	
>70	2 (8.3)	1 (7.1)	0 (0.0)	3 (30.0)	6 (11.3)	
Sex						
Male	21 (87.5)	10 (71.4)	1 (20.0)	7 (70.0)	39 (73.6)	0.02
Female	3 (12.5)	4 (28.6)	4 (80.0)	3 (30.0)	14 (26.4)	

Table 8: Association between CBNAAT results & the CT grading categories of pulmonary tuberculosis

CBNAAT	Definite active	Probably active	Indeterminate active	Probably inactive	Total	p
Positive	24 (100.0)	10 (71.4)	1 (20.0)	5 (50.0)	40 (75.5)	<0.001
Negative	0 (0.0)	4 (28.6)	4 (80.0)	5 (50.0)	13 (24.5)	

Table 9: CT Grading vs. CBNAAT Cross

CT grading	CBNAAT	
	Positive	Negative
Definite active	24	0
Probably active	10	4
Indeterminate active	1	4
Probably inactive	5	5
Total	40	13

Table 10: CT Grading – Definite Active

CT Grading – Definite active	Estimate	95% Confidence Interval	
		Lower	Upper
Sensitivity	60.00%	43.33%	75.14%
Specificity	100.00%	75.29%	100.00%
Diagnostic accuracy	69.81%	55.66%	81.66%
Positive predictive value	100.00%	85.75%	100.00%
Negative predictive value	44.83%	26.45%	64.31%

Likelihood ratio of a positive test	-	-	-
Likelihood ratio of a negative test	0.4	0.274	0.585
Youden's index	0.6		

Table 11: CT Grading – Probably Active

CT Grading – Probably active	Estimate	95% Confidence Interval	
		Lower	Upper
Sensitivity	25.00%	12.69%	41.20%
Specificity	69.23%	38.57%	90.91%
Diagnostic accuracy	35.85%	23.14%	50.20%
Positive predictive value	71.43%	41.90%	91.61%
Negative predictive value	23.08%	11.13%	39.33%
Likelihood ratio of a positive test	0.813	0.306	2.157
Likelihood ratio of a negative test	1.083	0.723	1.623
Youden's index	-0.058		

Table 12: CT grading – Definite + Probably Active Combined

CT Grading – Definite + Probably active combined	Estimate	95% Confidence Interval	
		Lower	Upper
Sensitivity	85.00%	70.16%	94.29%
Specificity	69.23%	38.57%	90.91%
Diagnostic accuracy	81.13%	68.03%	90.56%
Positive predictive value	89.47%	75.20%	97.06%
Negative predictive value	60.00%	32.29%	83.66%
Likelihood ratio of a positive test	2.7625	1.2098	6.3082
Likelihood ratio of a negative test	0.217	0.095	0.493
Youden's index	0.542		

Table 13: CT Grading – Indeterminate Active

CT Grading – Indeterminate active	Estimate	95% Confidence Interval	
		Lower	Upper
Sensitivity	2.50%	0.06%	13.16%
Specificity	69.23%	38.57%	90.91%
Diagnostic accuracy	18.87%	9.44%	31.97%
Positive predictive value	20.00%	0.51%	71.64%
Negative predictive value	18.75%	8.95%	32.63%
Likelihood ratio of a positive test	0.081	0.010	0.664
Likelihood ratio of a negative test	1.408	0.977	2.030
Youden's index	-0.283		

Table 14: CT Grading – Probably Inactive

CT Grading – Probably inactive	Estimate	95% Confidence Interval	
		Lower	Upper
Sensitivity	12.50%	4.19%	26.80%
Specificity	61.54%	31.58%	86.14%
Diagnostic accuracy	24.53%	13.76%	38.28%
Positive predictive value	50.00%	18.71%	81.29%
Negative predictive value	18.60%	8.39%	33.40%
Likelihood ratio of a positive test	0.325	0.112	0.948
Likelihood ratio of a negative test	1.422	0.911	2.220
Youden's index	-0.260		

DISCUSSIONS

The present study aimed to evaluate the correlation between radiological activity on computed tomography (CT) of the thorax and molecular diagnosis using Cartridge Based Nucleic Acid Amplification Test (CBNAAT) in cases of presumptive pulmonary tuberculosis (PTB). By analyzing 53 patients with symptoms or signs suggestive of TB, the study integrated various parameters including demographic characteristics, detailed CT findings, CT grading categories, and CBNAAT results. The findings provide important insights into the utility of CT imaging as a complementary tool to rapid molecular diagnostics, with significant implications for early diagnosis and effective management of tuberculosis.

In terms of demographics, the study population had a mean age of 56.6 ± 11.9 years, with the majority of patients falling within the 51–60 years age group (37.7%), followed by the 61–70 years group (24.5%). Only a small proportion of the subjects were younger than 40 years, with the ≤30 and 31–40 years groups accounting for 3.8% and 5.7%, respectively. This age distribution suggests that middle-aged and older individuals are more frequently affected by pulmonary tuberculosis, a finding consistent with the epidemiology of reactivation TB in populations with higher age and possibly more comorbidities. Additionally, the sex distribution revealed a marked male predominance, with 73.6% of the patients being male compared to 26.4% being female. This disparity was further underscored by the CBNAAT results: a significantly higher proportion of male patients (90% of CBNAAT-positive cases) were identified compared to female patients, as indicated by a highly significant p-value of 0.001. Such demographic patterns are critical, as they may influence targeted screening and diagnostic strategies in high-risk groups.

The radiological evaluation via CT thorax allowed the categorization of patients into four distinct CT grading groups: Definite active (45.3%), Probably active (26.4%), Indeterminate active (9.4%), and Probably inactive (18.9%). Each CT grading category is characterized by specific radiological features. The “Definite active” category predominantly included cases with classic features such as cavity, which is a hallmark of active pulmonary tuberculosis. In contrast, the “Probably active” category, while suggestive of active infection, may present with less definitive findings like consolidation. The “Indeterminate active” group includes cases with ambiguous or borderline features, and the “Probably inactive” category generally includes patients with radiological signs of healed or inactive disease, such as calcifications or fibrotic bands. This stratification of CT findings is pivotal as it provides a framework for correlating radiological severity with bacteriological confirmation through CBNAAT.

The overall CBNAAT results revealed that 75.5% (40 out of 53) of the patients tested positive for Mycobacterium tuberculosis, while 24.5% (13 out of 53) were negative. When these molecular results were cross-tabulated with the CT grading categories, a significant association was observed ($p < 0.001$). In the “Definite active” CT group, all 24 patients (100%) were CBNAAT positive, and none were negative, underscoring that unmistakable radiological features of active TB correlate very strongly with a positive CBNAAT result. On the other hand, the “Probably active” group had a mixed profile, with 10 patients (71.4%) testing positive and 4 (28.6%) testing negative. The “Indeterminate active” category showed an even more pronounced discrepancy, with only 1 patient (20%) being CBNAAT positive compared to 4 patients (80%) who were negative, suggesting that indeterminate CT findings are less predictive of active bacteriological infection. The “Probably inactive” category presented an even split, with 5 patients testing positive and 5 testing negative, indicating that features suggestive of inactive disease do not reliably predict the presence of active bacilli. These differences, supported by robust p-values, highlight the strong correlation between the intensity of radiological activity and molecular confirmation of tuberculosis.

An in-depth analysis of the diagnostic performance of CT grading as a predictor of CBNAAT positivity was carried out using several performance parameters. For the “Definite active” CT grading category, the sensitivity was calculated at 60.00% (95% CI: 43.33%–75.14%), indicating that 60% of the patients with clearly active radiological findings were correctly identified by CBNAAT. The specificity in this group was perfect at 100.00% (95% CI: 75.29%–100.00%), meaning that no patient with non-active findings was erroneously classified as having active disease. The diagnostic accuracy stood at 69.81% (95% CI: 55.66%–81.66%), with a positive predictive value (PPV) of 100.00% (95% CI: 85.75%–100.00%). These results imply that when CT shows definite active findings, the probability that the patient will test positive by CBNAAT is extremely high. However, the negative predictive value (NPV) was only 44.83% (95% CI: 26.45%–64.31%), suggesting that the absence of definite active radiological features does not reliably exclude the presence of tuberculosis. Additionally, the likelihood ratio of a negative test was 0.4 (95% CI: 0.274–0.585), and the Youden's index was calculated to be 0.6, reflecting a moderate overall diagnostic performance.

The “Probably active” CT grading category demonstrated much lower diagnostic performance. Here, the sensitivity was only 25.00% (95% CI: 12.69%–41.20%), indicating that only a quarter of the patients with possibly active findings were detected by CBNAAT. Specificity in this group was 69.23% (95% CI: 38.57%–90.91%), and the overall diagnostic accuracy was 35.85% (95% CI: 23.14%–50.20%). Although the PPV was moderately high at 71.43% (95% CI: 41.90%–91.61%), the NPV was quite low at 23.08% (95% CI: 11.13%–39.33%). The likelihood ratios were also suboptimal, with a positive likelihood ratio of 0.813 (95% CI: 0.306–2.157) and a negative likelihood ratio of 1.083 (95% CI: 0.723–1.623). The Youden's index was −0.058, indicating that the “Probably active” category alone offers limited discriminatory power for predicting CBNAAT positivity.

Notably, when the “Definite active” and “Probably active” categories were combined, the diagnostic performance improved considerably. The sensitivity increased to 85.00% (95% CI: 70.16%–94.29%), meaning that a large majority of patients with either clear or suggestive active CT findings were correctly identified by CBNAAT. Specificity remained at 69.23% (95% CI: 38.57%–90.91%), and the overall diagnostic accuracy reached 81.13% (95% CI: 68.03%–90.56%). The combined PPV was high at 89.47% (95% CI: 75.20%–97.06%), and the NPV was 60.00% (95% CI: 32.29%–83.66%). Additionally, the likelihood ratio of a positive test was 2.7625 (95% CI: 1.2098–6.3082), and the likelihood ratio of a negative test was 0.217 (95% CI: 0.095–0.493). The Youden's index for the combined categories was 0.542, suggesting a good balance between sensitivity and specificity. This finding indicates that considering both “Definite active” and “Probably active” CT features together creates a more robust and reliable diagnostic indicator for active TB as confirmed by CBNAAT.

In contrast, the diagnostic performance for the “Indeterminate active” category was notably poor. With a sensitivity of just 2.50% (95% CI: 0.06%–13.16%) and an overall diagnostic accuracy of only 18.87% (95% CI: 9.44%–31.97%), this category failed to effectively predict CBNAAT positivity. The PPV was 20.00% (95% CI: 0.51%–71.64%) and the NPV was 18.75% (95% CI: 8.95%–32.63%), while the positive likelihood ratio was extremely low at 0.081 (95% CI: 0.010–0.664) and the negative likelihood ratio was 1.408 (95% CI: 0.977–2.030). The negative Youden's index of −0.283 further underscores the inability of the indeterminate active CT findings to discriminate effectively between CBNAAT-positive and CBNAAT-negative cases. Similarly, the “Probably inactive” category showed limited diagnostic utility, with a sensitivity of 12.50% (95% CI: 4.19%–26.80%) and a diagnostic accuracy of 24.53% (95% CI: 13.76%–38.28%). The PPV was 50.00% (95% CI: 18.71%–81.29%), and the NPV was 18.60% (95% CI: 8.39%–33.40%). The likelihood ratios (0.325 for a positive test and 1.422 for a negative test) and a negative Youden's index of −0.260 confirm that the radiological features in the “Probably inactive” category are not reliable predictors of active TB as determined by CBNAAT.

The statistical significance observed in many of these analyses, with p-values often less than 0.001, reinforces the reliability of these associations. The strong correlation between definite radiological signs of active TB on CT and a positive CBNAAT result supports the integration of imaging and molecular diagnostics in clinical practice. Particularly, the finding that all patients within the “Definite active” CT category were CBNAAT positive suggests that CT imaging can serve as a powerful triage tool in the diagnosis of pulmonary tuberculosis. In contrast, the poor performance of the “Indeterminate active” and “Probably inactive” categories in predicting CBNAAT positivity highlights the need for cautious interpretation of indeterminate or suggestive findings. These groups may require further investigation or follow-up, as the absence of definitive active disease on CT does not necessarily rule out the possibility of active infection.

Clinically, the combined analysis of “Definite active” and “Probably active” CT findings appears most promising. With a high sensitivity (85%) and a robust positive predictive value (89.47%), this combination could be used as a reliable screening method to identify patients who are most likely to benefit from rapid molecular testing. The improved diagnostic accuracy (81.13%) and acceptable specificity (69.23%) further suggest that integrating these CT grading categories into the diagnostic algorithm could optimize resource utilization, particularly in settings where rapid and accurate diagnosis is critical for initiating timely therapy.

In summary, the present study provides compelling evidence that there is a significant correlation between CT radiological activity and CBNAAT results in patients with presumptive pulmonary tuberculosis. The demographic analysis revealed that the affected population tends to be older and predominantly male, which aligns with the known epidemiological trends in TB. The detailed evaluation of CT findings and their classification into distinct grading categories demonstrated that definite active radiological features are highly predictive of CBNAAT positivity, while ambiguous or inactive findings are less reliable. Moreover, the diagnostic test results underscore that combining “Definite active” and “Probably active” CT findings yields a high sensitivity and diagnostic accuracy, making it a valuable strategy in clinical practice.

These findings underscore the importance of a multi-modal diagnostic approach in tuberculosis, where CT imaging and rapid molecular testing complement each other to improve diagnostic precision. Early and accurate diagnosis of pulmonary tuberculosis is crucial for effective treatment and reducing transmission, and the integration of CT grading with CBNAAT results represents a promising step in that direction. Future research with larger cohorts and prospective designs may further validate these results and help refine diagnostic protocols to ensure optimal patient outcomes in the battle against tuberculosis.

The findings suggest that CT imaging can serve as a valuable adjunct to rapid molecular diagnostics, enhancing early diagnosis and effective management of tuberculosis.

The demographic analysis of the study population revealed a mean age of 56.6 years, with a notable male predominance (73.6%). This aligns with existing literature that indicates a higher prevalence of tuberculosis among older adults and males, possibly due to increased exposure and comorbidities in these groups (Kumar & Bhardwaj, 2019; Vijay et al., 2022). The age distribution observed in this study is consistent with the epidemiological trends reported in other studies, which also highlight that middle-aged and older individuals are more frequently affected by pulmonary tuberculosis (Kumar & Bhardwaj, 2019; Vijay et al., 2022).

In terms of radiological findings, the study categorized patients into four distinct CT grading groups, with the “Definite active” category showing a strong correlation with positive CBNAAT results (100% positivity). This is consistent with previous research that has demonstrated the utility of specific radiological features, such as cavitation and consolidation, as indicators of active tuberculosis (Ko et al., 2018). The study by Ko et al. further supports the notion that distinct radiographic patterns are closely associated with microbiological confirmation of tuberculosis (Ko et al., 2018).

Conversely, the “Indeterminate active” and “Probably inactive” categories demonstrated poor predictive value for CBNAAT positivity, highlighting the need for careful interpretation of ambiguous radiological findings (Ko et al., 2018).

The diagnostic performance metrics of CT grading categories in the present study underscore the importance of integrating imaging with molecular diagnostics. The sensitivity and specificity of the “Definite active” category were notably high, with a sensitivity of 60% and perfect specificity of 100%. This finding is corroborated by other studies that emphasize the high specificity of radiological findings in diagnosing active tuberculosis (Shaik et al., 2021). The combined analysis of “Definite active” and “Probably active” categories yielded a sensitivity of 85% and a diagnostic accuracy of 81.13%, indicating that this approach could significantly enhance the diagnostic yield in clinical practice (Kumar & Bhardwaj, 2019).

Moreover, the study's findings regarding the poor performance of the “Indeterminate active” and “Probably inactive” categories resonate with previous literature that has reported similar challenges in diagnosing tuberculosis based on non-specific radiological features (Shaik et al., 2021). The limited diagnostic utility of these categories suggests that further investigation or follow-up may be necessary when such findings are encountered, as they do not reliably predict active infection (Shaik et al., 2021).

In conclusion, the present study reinforces the critical role of a multi-modal diagnostic approach in tuberculosis, where CT imaging and rapid molecular testing complement each other. The strong correlation between CT radiological activity and CBNAAT results provides a compelling argument for integrating these diagnostic modalities to improve the accuracy and timeliness of tuberculosis diagnosis. Future research with larger cohorts is warranted to validate these findings and refine diagnostic protocols for optimal patient outcomes.

CONCLUSION

HRCT thorax can complement the diagnosis of PTB with CBNAAT. It can be used to monitor the treatment response and possible complication and helps in planning further management if not responding to routine treatment. Patients with incidental CT findings that is suggestive of definitely active or probably active TB should be evaluated with sputum CBNAAT. Our study suggests that CT scan is better at correctly identifying individuals without the condition than identifying those with the condition. As CT is having high specificity and PPV, In patients with sputum CBNAAT negative and positive CT findings further interventional investigations including Bronchoscopy, BAL should be considered.

Limitations of the study

1. Small sample size.
2. Despite CT scans proving valuable in clinical practice, cannot provide a definitive diagnosis of PTB, because radiologic similarity has been observed in other disease entities too.

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