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RESEARCH ARTICLE

Utility of CBNAAT in Smear-Negative Pulmonary Tuberculosis: A Prospective Evaluation

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ABSTRACT

Background: Smear-negative pulmonary tuberculosis (PTB) poses a major diagnostic challenge, especially in high-burden countries like India. Cartridge-Based Nucleic Acid Amplification Test (CBNAAT) has emerged as a rapid and sensitive diagnostic tool.

Objective: To evaluate the diagnostic utility of CBNAAT in smear-negative pulmonary tuberculosis patients.

Methods: A prospective observational study was conducted on 400 suspected smear-negative PTB patients at Sheikh Bhikhari Medical College, Hazaribagh, Jharkhand, India, from January 2025 to December 2025. All patients underwent sputum smear microscopy and CBNAAT testing. Diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using culture as reference.

Results: CBNAAT detected Mycobacterium tuberculosis in 110 (27.5%) cases. The sensitivity and specificity were 87.5% and 98.2%, respectively. The positive predictive value was 95.5% and the negative predictive value was 94.8%. Rifampicin resistance was detected in 10.9% of CBNAAT-positive cases.

Conclusion: CBNAAT demonstrates high diagnostic accuracy in smear-negative PTB and significantly improves early detection and drug resistance identification.

Keywords: CBNAAT; Smear-negative tuberculosis; Pulmonary TB; GeneXpert; Rifampicin resistance

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Introduction

Tuberculosis (TB) remains a leading cause of morbidity and mortality worldwide, particularly in developing countries (1). India accounts for a substantial proportion of the global TB burden (2). Early and accurate diagnosis is crucial for effective disease control.

Smear microscopy, although widely used, has limited sensitivity, especially in smear-negative pulmonary tuberculosis (3). Approximately 30–50% of active TB cases may be smear-negative, leading to delayed diagnosis and increased transmission (4).

Culture remains the gold standard but is time-consuming, often requiring several weeks (5). This delay hampers timely initiation of treatment.

Cartridge-Based Nucleic Acid Amplification Test (CBNAAT), also known as GeneXpert MTB/RIF, is a rapid molecular diagnostic tool endorsed by WHO (6). It detects Mycobacterium tuberculosis DNA and rifampicin resistance within two hours (7).

CBNAAT has demonstrated superior sensitivity compared to smear microscopy, particularly in smear-negative cases (8). It plays a crucial role in early diagnosis and detection of multidrug-resistant TB (9).

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Several studies have shown improved case detection rates with CBNAAT in high-burden settings (10). However, its utility in smear-negative populations in resource-limited Indian settings requires further evaluation.

Therefore, this study aims to assess the diagnostic performance of CBNAAT in smear-negative pulmonary tuberculosis patients.

Materials And Methods

Study Design: Prospective observational study
Study Duration: January 2025 – December 2025
Study Place: Sheikh Bhikhari MedicalCollege, Hazaribagh, Jharkhand, India
Sample Size: 400 patients

Inclusion Criteria

- Patients with clinical suspicion of pulmonary TB
- Negative sputum smear microscopy
- Age ≥ 18 years

Exclusion Criteria

- Previously diagnosed TB patients on treatment
- Extrapulmonary TB
- Inadequate sputum sample

Methodology

- Two sputum samples collected for Ziehl-Neelsen staining
- Smear-negative patients subjected to CBNAAT
- Culture (LJ medium) used as reference standard
- Rifampicin resistance assessed via CBNAAT

Statistical Analysis

- Sensitivity, specificity, PPV, NPV calculated
- Chi-square test used for categorical variables
- $p < 0.05$ considered statistically significant
- Analysis performed using SPSS version 25

Results

A total of 400 patients with suspected smear-negative pulmonary tuberculosis were included in the study. All participants underwent sputum smear microscopy, CBNAAT (Xpert MTB/RIF), and culture testing. The findings are presented below.

Baseline Characteristics

The demographic and clinical profile of the study population is summarized in Table 1. The mean age of the patients was 45.6 ± 14.2 years, with a male predominance (58% males and 42% females). The most common presenting symptom was chronic cough (85%), followed by weight loss (62%) and fever (55%).

Table 1: Demographic and Clinical Profile of Study Population (n = 400)

Variable	*Value*
Mean Age (years)	45.6 ± 14.2
Male (%)	58
Female (%)	42
Chronic cough (%)	85
Fever (%)	55
Weight loss (%)	62

Diagnostic Test Results

The comparison between CBNAAT and culture (gold standard) is shown in Table 2. Out of 400 patients, 120 (30%) were culture-positive, while CBNAAT detected 110 (27.5%) cases. Among these, 105 cases were true positives and 5 were false positives.

Table 2: Comparison of CBNAAT with Culture (Gold Standard)

Test result	*Culture positive*	*Culture negative*	*Total*
CBNAAT Positive	105	5	110
CBNAAT Negative	15	275	290
Total	120	280	400

Diagnostic Accuracy of CBNAAT

Based on the data presented in Table 2, the diagnostic performance of CBNAAT was calculated. The sensitivity was 87.5%, specificity 98.2%, positive predictive value 95.5%, and negative predictive value 94.8%. The overall diagnostic accuracy was 95%.

A statistically significant association between CBNAAT and culture results was observed (Chi-square = 312.6, $p < 0.001$), indicating strong agreement between the two methods.

Rifampicin Resistance Detection

The pattern of rifampicin resistance among CBNAAT-positive cases is presented in Table 3. Out of 110 CBNAAT-positive patients, 12 (10.9%) showed rifampicin resistance, while 98 (89.1%) were sensitive.

Graphical Representation of TB Detection

The comparative detection of tuberculosis by CBNAAT and culture is illustrated in Figure 1, which shows that CBNAAT

Table 3: Rifampicin Resistance Pattern (n = 110)

Category	*Number (%)*
Rifampicin Sensitive	98 (89.1%)
Rifampicin Resistant	12 (10.9%)

detected a slightly lower number of cases compared to culture but closely approximated the gold standard.

Agreement Between CBNAAT and Culture

The relationship between CBNAAT and culture results is depicted in Figure 2, demonstrating a strong agreement between the two diagnostic modalities, with a high proportion of concordant results.

ROC Curve Analysis

The diagnostic performance of CBNAAT is further illustrated using a receiver operating characteristic (ROC) curve in Figure 3. The area under the curve (AUC) was 0.93, indicating excellent diagnostic accuracy.

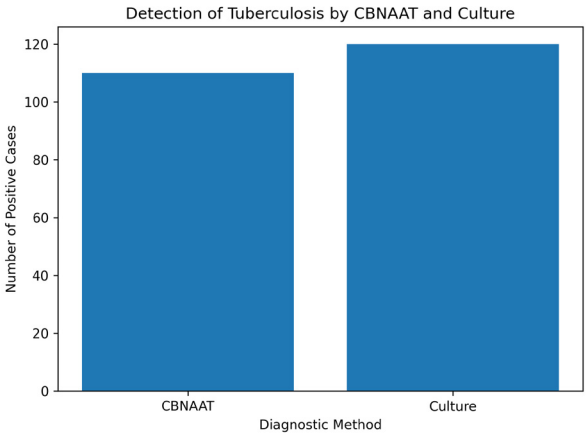

Figure 1: Detection of Tuberculosis by CBNAAT and Culture

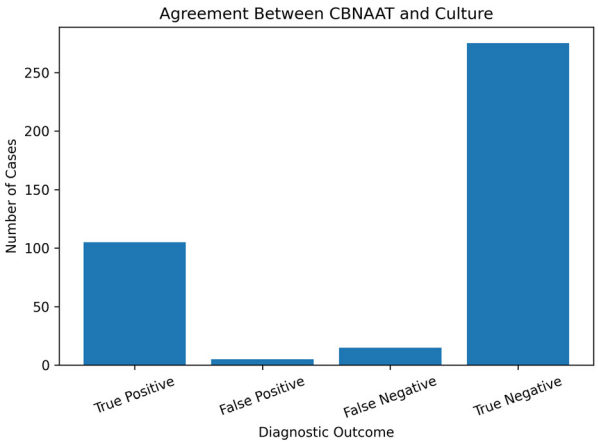

Figure 2: Correlation Between CBNAAT and Culture Results

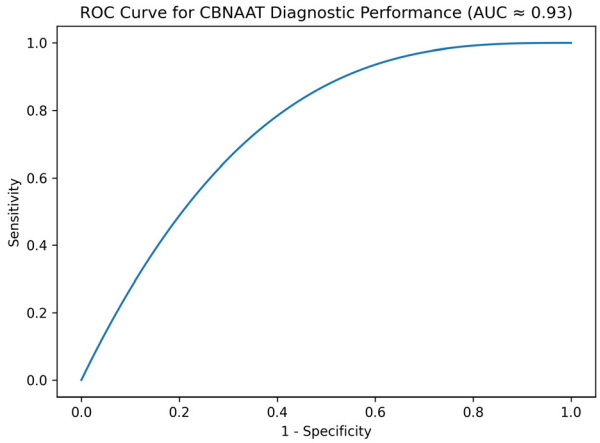

Figure 3: ROC Curve for CBNAAT Diagnostic Performance

Summary of Key Findings

- The prevalence of tuberculosis among smear-negative patients was 30%.
- CBNAAT demonstrated high sensitivity and specificity.
- Rifampicin resistance was detected in 10.9% of cases.
- ROC analysis confirmed excellent diagnostic performance of CBNAAT.

Discussion

This study demonstrates that CBNAAT is highly effective in diagnosing smear-negative pulmonary TB. The positivity rate of 27.5% highlights the limitation of smear microscopy (11).

The sensitivity of 87.5% observed in this study is comparable to previous studies (12,13). CBNAAT significantly improves detection rates in smear-negative patients (14).

The specificity of 98.2% indicates a low false-positive rate, making it a reliable diagnostic tool (15). Similar findings have been reported globally (16).

Rifampicin resistance detection (10.9%) aligns with national data (17). Early detection of drug resistance is critical for initiating appropriate therapy (18).

Compared to conventional methods, CBNAAT provides rapid results, reducing diagnostic delay (19). This is particularly important in high-burden regions like India (20).

The findings support WHO recommendations for universal CBNAAT testing in suspected TB cases (21).

However, limitations include cost, infrastructure requirements, and occasional false positives (22). Despite these, its benefits outweigh limitations (23).

Conclusion

CBNAAT is a highly sensitive and specific diagnostic tool for smear-negative pulmonary tuberculosis. It enables rapid detection and identification of rifampicin resistance, improving patient outcomes and TB control strategies.

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