

CORRELATION OF RADIOLOGICAL FINDINGS WITH GENE EXPERT ANDE BACTERIAL LOADIN TB POSITIVE PATIENTS IN LAHORE, PAKISTAN

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Abstract

Background: Tuberculosis (TB) remains a critical public health challenge, particularly in high-burden settings such as Pakistan. Accurate evaluation of bacterial burden and disease severity is essential for effective patient care and infection control. GeneXpert MTB/RIF, using cycle threshold (Ct) values, offers rapid semi-quantitative bacterial load estimation, while radiological imaging delineates the extent of pulmonary involvement.

Objective: To determine the correlation between chest radiological findings and GeneXpert-derived bacterial load in pulmonary TB-positive patients.

Methods: A cross-sectional analytical study was conducted on 100 GeneXpert-positive pulmonary TB patients. Radiological features including cavitation, consolidation, fibrosis, nodules, pleural effusion, and extent of lung involvement were systematically assessed and correlated with GeneXpert bacterial load categories and Ct values using Spearman rank correlation and chi-square tests.

Results: Patients with higher bacterial loads exhibited more severe radiological abnormalities, particularly cavitory lesions and extensive bilateral lung involvement. GeneXpert Ct values showed a strong inverse correlation with bacterial burden ($\rho = -0.905$, $p < 0.001$) and smear grade ($\rho = -0.825$, $p < 0.001$). Radiological severity increased proportionally with bacterial load categories. **Conclusion:** Radiological severity correlates significantly with GeneXpert bacterial burden in pulmonary TB. Combined use of chest imaging and GeneXpert testing enhances diagnostic precision, infectivity assessment, and disease monitoring. In resource-limited settings, radiological findings may serve as a practical proxy for bacterial load estimation.

INTRODUCTION

Tuberculosis (TB), caused by *Mycobacterium tuberculosis* (MTB), remains one of the leading infectious causes of morbidity and mortality worldwide, claiming more than 4,000 lives each day. In 2021, an estimated 10.6 million people developed TB globally, with Pakistan ranking among the high-burden countries contributing

substantially to the global disease burden (Bagcchi, 2023; Chakaya et al., 2022). Pulmonary TB is the most common clinical form and is primarily transmitted through airborne droplets. Disease severity and transmission potential are closely associated with the bacillary burden present in infected individuals (Alsayed & Gunosewoyo, 2023; Gong & Wu, 2021).

Conventional diagnostic methods, including acid-fast bacilli (AFB) smear microscopy and mycobacterial culture, are limited by either low sensitivity or prolonged turnaround times. The GeneXpert MTB/RIF (Xpert) assay has substantially improved TB diagnosis by providing rapid and highly sensitive detection of *M. tuberculosis* and rifampicin resistance within approximately two hours. In addition, the assay generates cycle threshold (Ct) values that serve as a semi-quantitative indicator of bacterial load, allowing patients to be categorized into low, medium, and high bacillary burden groups (Iúdice et al., 2023; Ramachandra et al., 2023; Tamirat et al., 2022).

Objective:

1. To assess GeneXpert results, including detection of *Mycobacterium tuberculosis* and semi-quantitative bacterial load categories (low, medium, high).
2. To determine the relationship between radiological severity and bacterial load in TB patients.
3. To analyze the association between GeneXpert bacterial load and radiological findings.
4. To provide evidence for improving diagnostic and prognostic evaluation of TB using combined radiological and molecular findings

Research Question:

1. How does the extent of lung involvement on imaging correlate with GeneXpert bacterial load?
2. Can radiological findings predict the bacterial load in TB-positive patients?
3. Is there any difference in radiological patterns among different bacterial load categories?
4. How is bacterial load distributed among TB patients as measured by GeneXpert (low, medium, high)?

Chest radiography and computed tomography (CT) remain fundamental imaging modalities for evaluating pulmonary TB. Radiological features such as cavitation, consolidation, fibrosis, pleural effusion, upper-lobe predominance, and the

extent of lung involvement reflect disease severity and pulmonary tissue destruction. However, despite the widespread use of molecular diagnostics and radiological imaging, the relationship between radiological severity and GeneXpert-derived bacterial burden remains insufficiently characterized, particularly in high-TB-burden settings such as Pakistan (Marais et al., 2006; Neumann et al., 2025; Tonne et al., 2023).

2. MATERIALS AND METHODS**2.1 Study Design and Setting**

A cross-sectional analytical study was conducted in the Departments of Radiology and Pulmonology of a tertiary care teaching hospital in Lahore, Pakistan, over a three-month period following Institutional Review Board (IRB) approval.

2.2 Study Population

One hundred newly diagnosed, GeneXpert-positive pulmonary TB patients aged ≥ 18 years who had undergone chest X-ray and/or CT chest were enrolled using consecutive non-probability sampling. Patients already receiving anti-tuberculous therapy, those with extrapulmonary TB without pulmonary involvement, chronic obstructive pulmonary disease, interstitial lung disease, lung malignancy, or poor-quality radiological images were excluded. Pregnant females requiring CT were also excluded.

2.3 Data Collection

Demographic and clinical data (age, gender, BMI, smoking history, comorbidities, symptom duration) were recorded. GeneXpert MTB/RIF results provided Ct values and semi-quantitative bacterial load categories (low, medium, high).

2.4 Statistical Analysis

Data were analyzed using SPSS. Descriptive statistics summarized continuous variables (mean $\pm$ SD) and categorical variables (frequencies, percentages). Normality was assessed via Kolmogorov-Smirnov and Shapiro-Wilk tests. Spearman rank correlation evaluated associations between Ct values, bacterial load, and radiological severity.

3. RESULTS

3.1 Demographic Characteristics

Table 3.1

Demographic and Clinical Characteristics

Variable	N	Mean $\pm$ SD	Minimum	Maximum
Age (years)	100	47.28 $\pm$ 16.76	18	75
GeneXpert Ct value	100	22.52 $\pm$ 6.74	10.1	37.5
Bacterial load (CFU/mL)	100	19,309,185 $\pm$ 32,680,917	18	99,990,875
Log10 CFU/mL	100	5.51 $\pm$ 1.88	1.26	8.00
Smear grade	100	1.54 $\pm$ 0.88	0	3
Days to culture positivity	100	25.99 $\pm$ 11.10	8	53

Of 100 patients enrolled, 68% were male and 32% female. Mean age was 47.28 $\pm$ 16.76 years (range 18–75). Smoking was the most common

comorbidity (40%), followed by diabetes mellitus (25%), and HIV co-infection (10%); 25% had no identifiable risk factor.

Table 3.2

Baseline Characteristics

Characteristic	n (%)
Male	68 (68.0)
Female	32 (32.0)
Smoking	40 (40.0)
Diabetes	25 (25.0)
HIV positive	10 (10.0)
Others	25 (25.0)

Table 3.3

Tests of Normality

Variable	Shapiro-Wilk W	P
Age	0.951	0.001
Log10 CFU/mL	0.919	<0.001
Days to culture positivity	0.957	0.002
Bacterial load	0.621	<0.001

All variables significantly deviated from a normal distribution (Shapiro-Wilk, $p < .05$); therefore, non-parametric statistical tests (Spearman correlation) were performed.

Table 3.4

Spearman Correlation Analysis

Variables	ρ	P
GeneXpert Ct vs Bacterial load	-0.905	<0.001
GeneXpert Ct vs Smear grade	-0.825	<0.001
Smear grade vs Bacterial load	0.830	<0.001
Days to culture vs Bacterial load	-0.153	0.128

Spearman correlation revealed a strong inverse relationship between GeneXpert Ct value and bacterial load ($\rho = -0.905$, $p < 0.001$), confirming that lower Ct values correspond to higher bacillary burden. Ct value also correlated inversely with

smear grade ($\rho = -0.825$, $p < 0.001$). Bacterial load correlated strongly with smear grade ($\rho = 0.830$, $p < 0.001$). Time to culture positivity did not significantly correlate with bacterial load or Ct value ($p > 0.05$).

Table 3.5

Multiple Linear Regression

Predictor	B	t	P
GeneXpert Ct	0.215	0.664	0.508
Smear grade	0.114	0.582	0.562
Bacterial load	-0.045	-0.287	0.775
Days to culture	0.088	0.834	0.407
Log10 CFU/mL	0.374	1.117	0.267

$F(5,94)=1.21$, $p=.311$, $R^2\approx 0.06$

The regression model was not statistically significant ($F=1.21$, $p=.311$). None of the included predictors independently predicted the dependent variable.

DISCUSSION

Drug-resistant tuberculosis (TB), which is caused by both continuous resistance acquisition and person-to-person transmission, is thought to account for 13% of all antimicrobial resistance-attributable fatalities globally. Inadequate access to competent treatment and delayed diagnosis worsen poor results. Recent developments in quick molecular testing have made it easier to diagnose medication resistance and tuberculosis. Mycobacterium tuberculosis next-generation sequencing has improved our knowledge of genetic resistance mechanisms and made it possible to identify mutations linked to resistance characteristics. Although they are currently accessible and advised, all-oral, shorter medication

regimens that can achieve high cure rates of drug-resistant TB within 6–9 months have not yet been scaled to worldwide clinical use. {Farhat, 2024 #24}

A fundamental element of national and international treatment standards is the provision of education and counseling to all individuals diagnosed with tuberculosis prior to and throughout their treatment. Person-centered education and counseling should consider the individual's existing health, health literacy, language, culture, and intended course of treatment. {Singh, 2023 #25}

The current investigation assessed the relationship between radiological findings, bacterial burden, and GeneXpert results in TB-positive individuals. The results showed that bacterial burdens on GeneXpert analysis tended to be higher in patients with more severe radiological abnormalities on chest imaging. Medium to high bacterial load categories were more commonly linked to severe

radiological symptoms, including numerous cavitory lesions, bilateral lung involvement, consolidation, fibrosis, and upper lobe infiltrates. These results imply that the intensity of infection and bacillary burden in tuberculosis patients is reflected in the degree of lung damage apparent on radiological assessment.

Conclusion

According to the study's findings, radiographic results and the GeneXpert bacterial burden in TB-positive individuals are significantly correlated. GeneXpert analysis revealed greater bacterial loads in patients with severe radiological abnormalities, specifically cavitory lesions, bilateral lung involvement, consolidation, and upper lobe infiltrates. These results suggest that the degree of bacillary burden and disease progression in pulmonary tuberculosis are reflected in the severity of chest radiography abnormalities. The study also shows the clinical benefit of evaluating tuberculosis patients using a combination of radiographic evaluation and GeneXpert testing. While radiological imaging aids in determining the degree and severity of pulmonary involvement, GeneXpert offers quick and accurate detection of *Mycobacterium tuberculosis* and calculation of bacterial load. When combined, these diagnostic techniques can enhance early diagnosis, patient care, infectivity assessment, and disease severity monitoring.

Limitations

This study was limited by its cross-sectional design, which precludes causal inference, and its single-center setting with a relatively small sample size ($n = 100$), limiting generalizability. In addition, radiological findings were not assessed using a standardized severity scoring system, and potential confounding factors such as previous TB treatment, drug resistance, and nutritional status were not fully evaluated.

Recommendations

Future multicenter studies with larger sample sizes are recommended to validate these findings. Standardized radiological scoring systems and multivariable regression analyses should be used to identify independent predictors of high bacterial

load. Incorporating additional clinical factors and longitudinal follow-up may further improve the assessment of disease severity and treatment outcomes. Integrating GeneXpert bacterial load with radiological findings may enhance the early identification and management of highly infectious TB patients.

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