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DIAGNOSTIC ACCURACY OF CHEST X-RAY IN CASES OF ACTIVE PULMONARY TUBERCULOSIS TAKING HIGH RESOLUTION COMPUTED TOMOGRAPHY (HRCT) AS GOLD STANDARD

Dr Erum Muhammad[*1], Dr Faryal Farooq Butt[2], Dr Rubab Saleem[3], Maj. Gen (R) Dr Shamrez Khan[4]

[*1,2,3]*Post Graduate Resident, FCPS-Radiology Islamabad Diagnostic Centre, Islamabad*
[4]*Consultant Radiologist Head Department of Radiology Islamabad Diagnostic Centre, Islamabad*

[*1]dr_713@hotmail.com, [2]faryal_sagittarian14@hotmail.com, [3]drrubabkhwaja@gmail.com

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Corresponding Author: *
Dr Erum Muhammad

Abstract

Introduction: *Pulmonary tuberculosis continues to pose a significant global health challenge, highlighting the need for precise and readily available diagnostic tools. Chest X-ray is commonly utilized for TB screening; however, its diagnostic efficacy relative to high-resolution computed tomography (HRCT), which offers greater sensitivity, necessitates additional assessment, especially in high-burden contexts.*

Objective: *To determine the diagnostic accuracy of Chest X-ray in cases of active pulmonary tuberculosis taking HRCT as gold standard.*

Methodology: *This cross-sectional validation study was performed at Islamabad Diagnostic Centre over a six-month period (September 2024–March 2025). A total of 322 patients, aged 20 to 70 years, with suspected pulmonary tuberculosis were enrolled. Chest X-rays and HRCT scans were performed and analyzed by the qualified radiologists. HRCT was established as the gold standard. Data were analyzed using SPSS 25 to determine sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of chest X-ray, while accounting for confounding variables.*

Results: *Active PTB was detected in 60.6% (n=195) of cases on HRCT, while chest X-ray identified 65.5% (n=211) as positive (table 2). Chest X-ray found to be highly sensitive (92.8%), however specificity was moderate (76.4%). Chest X-ray has shown overall diagnostic accuracy, PPV and NPV as 86.3%, 85.8% and 87.4% in diagnosis of pulmonary TB keeping HRCT as gold standard.*

Conclusion: *The research demonstrates that chest X-ray serves as an effective first-line detection method for active pulmonary TB, exhibiting high sensitivity and moderate specificity. The diagnostic performance is affected by patient factors including smoking status, gender, and duration of symptoms. HRCT acts as a supplementary imaging technique, especially when chest X-ray results are ambiguous or in the context of early-stage disease.*

INTRODUCTION

Tuberculosis (TB) is the most prevalent disease resulting from a single infectious agent. It ranks among the ten leading causes of death worldwide. Tuberculosis is present in all countries and among all age groups, despite being a preventable and treatable condition. In 2019, approximately 10 million individuals were infected worldwide, comprising 5.6 million men, 3.2 million women, and 1.2 million children.[i] Pakistan ranks fifth among 22 high-burden tuberculosis (TB) countries globally and contributes to 61% of the TB burden in the World Health Organization (WHO) Eastern Mediterranean region. The WHO estimates that 510,000 new cases of tuberculosis develop annually, presenting significant challenges as an emerging health issue.[ii] Pulmonary tuberculosis is commonly identified through clinical and radiological assessments.[iii] Active case finding through TB screening is a critical component in the establishment of effective TB control services. The objective of screening is the early identification and management of disease.[iv]

Chest X-ray (CXR) is an efficient imaging modality that facilitates the detection of pulmonary abnormalities. CXR serves as a diagnostic tool for assessing conditions within the thoracic cavity, encompassing the airways, ribs, lungs, heart, and diaphragm.[v] CXR has traditionally served as a key instrument for the detection of tuberculosis, particularly pulmonary TB. CXR demonstrates high sensitivity for pulmonary TB, making it an essential tool for identifying TB as a differential diagnosis in patients, particularly when the X-ray is analyzed for abnormalities consistent with TB.[vi] Nonetheless, chest X-ray (CXR) exhibits limited specificity; while certain CXR abnormalities, such as cavities, are relatively specific to pulmonary tuberculosis (TB), numerous CXR abnormalities associated with pulmonary TB are also observed in various other lung conditions, indicating the presence of not only TB but also alternative pathologies.[vii]

As the previous literature has shown the controversy and large variation in the diagnostic accuracy of chest x-ray in diagnosing pulmonary tuberculosis and there is a need of a study on this topic for resolving the controversy, so the rationale of this study is to determine the diagnostic accuracy of Chest X-ray in diagnosing active pulmonary tuberculosis, taking High Resolution Computed Tomography (HRCT) as gold standard.

MATERIAL AND METHODS

This cross-sectional validation study was performed at the Radiology Department of Islamabad Diagnostic Centre, Islamabad, during a six-month duration (15 September 2024 to March 2025) subsequent to obtaining ethical approval. A sample size of 322 was determined utilizing a sensitivity and specificity calculator, predicated on a 95% confidence level, a 44.4% prevalence of active pulmonary tuberculosis, a 7% desired precision, and previously documented sensitivity and specificity of chest X-ray (93% and 65%, respectively, as reported by Nalunjogi J et al). The inclusion criteria comprised individuals aged 20 to 70 years, regardless of gender, exhibiting probable active pulmonary tuberculosis with symptoms persisting for over one month. The exclusion criteria encompassed people already on anti-tuberculosis treatment and individuals with established COPD, tuberculosis, cancer, or asthma, as verified by medical history and records. A total of 322 qualified patients were enrolled following informed consent. Demographic and clinical information was documented. Chest X-rays were conducted and analyzed by a consultant radiologist possessing a minimum of three years of post-fellowship experience, evaluating for radiographic indicators of active pulmonary tuberculosis. All patients underwent High Resolution Computed Tomography (HRCT) on a dual-slice scanner with enhanced spatial resolution settings. Scans were obtained in a supine position during a single breath-hold, oriented from cranial to caudal. The HRCT pictures were assessed by a consultant radiologist with at least five years of post-fellowship experience. HRCT functioned as the definitive standard for diagnosis. All findings were documented on a standardized proforma. Data were evaluated with SPSS version 25. The diagnostic accuracy of chest X-ray was assessed using a 2×2 contingency table, calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and total accuracy. Stratification was conducted for confounding variables, and post-stratification diagnostic values were calculated.

RESULTS

The study included 322 participants diagnosed with pulmonary tuberculosis, with a mean age of 48.88 ± 9.11 years (range: 20–75 years). Male to female ratio was nearly similar with, with no significant age difference between genders (males: 48.87 ± 9.49, females: 48.88 ± 8.76). A majority of participants were from rural areas (61.2%), and the most common occupation was domestic work (43.5%), followed by field work (37.6%) and office work (18.9%). The mean duration of symptoms was 5.13 ± 2.35 months, with 68.6% of cases presenting with symptoms lasting >3 months (table 1). Active PTB was detected in 60.6% (n=195) of cases on HRCT, while chest X-ray identified 65.5% (n=211) as positive (table 2). Chest X-ray found to be highly sensitive (92.8%), correctly identifying 181 out of 195 HRCT-confirmed PTB cases, however specificity was moderate (76.4%), with 97 out of 127 HRCT-negative cases correctly ruled out. Detailed analysis of diagnostic accuracy parameters is presented in table 3. Upon stratification analysis, performance of the chest-Xray found best in smokers, males, and chronic cases and weakest in early-stage (≤3 months) and female patients. False positives were more common in non-smokers, urban residents, and domestic workers, possibly due to alternative lung pathologies. Detailed stratification analysis is illustrated in table 4.

Table 1: Demographic and clinical details of the study subjects (n=322)

Variable	Frequency	Percentage
Gender		
Male	157	48.8
Female	165	51.2
Age Groups		
≤45 Years	115	35.7
>45 Years	207	64.3
Duration of Symptoms of Pulmonary TB		
Upto 3 Months	101	31.4
>3 Months	221	68.6
Residence		
Rural	197	61.2
Urban	125	38.8
Smoker		
Yes	88	27.3
No	234	72.7
Occupation		
Office	61	18.9
Field	121	37.6
Domestic	140	43.5

Table 2: Overall results of chest X-ray and HRCT findings for the diagnosis of active pulmonary tuberculosis

Active Pulmonary Tuberculosis	Chest X-Ray	HRCT
Positive	211 (65.5%)	195 (60.6%)
Negative	111 (34.5%)	127 (39.4%)
Total	322 (100%)	322 (100%)

Table 3: Diagnostic accuracy of chest X-ray for diagnosis of active pulmonary tuberculosis keeping HRCT findings as gold standard

Active Pulmonary Tuberculosis on Chest X-Ray	Active Pulmonary Tuberculosis on HRCT		
	POSITIVE	NEGATIVE	TOTAL
POSITIVE	181 (56.21%) (True Positives)	30 (9.32%) (False Positives)	211 (65.53%)
NEGATIVE	14 (4.35%) (False Negatives)	97 (30.12%) (True Negatives)	111 (34.47%)
Total	195 (60.56%)	127 (39.44%)	322 (100.00%)

Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
92.8	76.4	86.3	85.8	87.4

PPV: Positive Predictive Value, NPV: Negative Predictive Value

Table 4: Diagnostic accuracy of chest X-ray for diagnosis of active pulmonary tuberculosis keeping HRCT findings as gold standard (stratification analysis for various study confounders)

Effect Modifiers	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
Gender					
Male	95.0	84.2	91.1	91.3	90.6
Female	90.5	70.0	81.8	80.4	84.5
Age Groups					
≤45 Years	91.3	80.4	87.0	87.5	86.0
>45 Years	93.7	74.1	85.5	84.9	88.2
Duration of Symptoms of Pulmonary TB					
Upto 3 Months	82.7	55.1	69.3	66.2	75.0
>3 Months	96.5	89.7	94.1	94.5	93.3
Residence					
Rural	91.6	74.4	85.3	84.5	85.3
Urban	94.7	79.6	88.0	87.8	90.7
Smoker					
Yes	98.6	94.4	97.7	98.6	94.4
No	89.6	73.4	82.1	79.4	86.0
Occupation					
Office	94.6	87.5	91.8	92.1	91.3
Field	92.5	78.0	87.6	89.2	84.2
Domestic	92.3	71.0	82.9	80.0	88.0

PPV: Positive Predictive Value, NPV: Negative Predictive Value

DISCUSSION

Tuberculosis remains a significant public health hazard, especially in high-burden nations such as Pakistan, where prompt and precise diagnosis is essential for diminishing morbidity, transmission, and healthcare expenditures. Although HRCT is esteemed for its exceptional sensitivity in identifying early and subtle parenchymal alterations, chest X-ray continues

to be the primary imaging modality owing to its accessibility, affordability, and user-friendliness. This study intended to reconcile practicality and precision in tuberculosis diagnoses. In our study, chest X-ray shown high sensitivity (92.8%) and intermediate specificity (76.4%) in comparison to HRCT among all the enrolled 322 patients. The findings indicate that chest X-ray is highly successful in confirming active pulmonary TB but has limitations in excluding the disease due to a higher incidence of false positives. The overall diagnostic accuracy was 86.3%, with a positive predictive value of 85.8% and a negative predictive value of 87.4%. These results correspond with existing literature indicating that chest X-ray sensitivity generally varies from 85% to 95% and specificity from 60% to 80%, contingent upon patient selection, radiologist proficiency, and concurrent pulmonary diseases.[viii,ix] A study has shown 55.6% patients with sputum smear negative and 44.4% with sputum smear positive tuberculosis.[x] In a study by Nalunjogi J, et al showed the sensitivity 93% and specificity 65% of chest X-ray in the diagnosis of active pulmonary tuberculosis.[xi] In another study, Sensitivity and specificity of chest x-ray in diagnosing pulmonary TB was 83.2% and 12.7% respectively.[7]

The higher sensitivity observed in our study endorses the ongoing utilization of CXR as a primary screening instrument in high-burden TB environments, where swift and economical diagnosis is crucial. The intermediate specificity reveals a significant false-positive rate (9.32%), consistent with research indicating that chest X-rays may misdiagnose other pulmonary conditions (e.g., pneumonia, fibrosis, or malignancies) as tuberculosis. This constraint highlights the necessity for confirmatory tests, especially in communities with a significant prevalence of non-TB pulmonary conditions. The PPV of CXR in our study was 85.8%, while the NPV was 87.4%. These values suggest that a positive CXR result has a high likelihood of indicating true pulmonary TB, but false positives remain a concern. In contrast, a negative CXR result provides reasonable confidence in excluding pulmonary TB, though false negatives still occur. These findings align with past studies, which highlighted that CXR's NPV is particularly useful in low-prevalence settings, whereas PPV improves in high-burden regions.[xii,xiii]

Our investigation exposed that CXR had superior performance in males relative to females. This gap may result from anatomical variations, elevated incidences of non-TB pulmonary diseases in females (e.g., post-infectious scarring), or hormonal effects on immune responses. [xiv,xv] The chest X-ray shown markedly reduced sensitivity and specificity in patients with symptoms persisting for ≤3 months in comparison to chronic cases (i.e., >3 months). This corresponds with research suggesting that early pulmonary tuberculosis frequently displays mild or unusual radiographic characteristics, while chronic tuberculosis shows more conventional cavitary or fibrotic alterations. The suboptimal performance in early-stage tuberculosis indicates that chest X-ray alone may be inadequate for early identification, requiring other tests such as GeneXpert or sputum culture.[xvi,xvii] Smokers demonstrated the highest accuracy in chest X-rays, exhibiting near-perfect sensitivity and specificity. This stands in stark contrast to non-smokers. Smoking-induced pulmonary disease (e.g., emphysema or chronic bronchitis) may resemble tuberculosis; nonetheless, our data paradoxically indicate superior differentiation in smokers. One potential explanation is that smokers with pulmonary tuberculosis have more pronounced radiographic patterns (e.g., upper lobe cavitation), while non-smokers may present with overlapping inflammatory alterations.[xviii,xix] Urban inhabitants exhibited marginally superior chest X-ray accuracy (88.0%) compared to their rural counterparts, potentially attributable to disparities in disease prevalence or healthcare accessibility. Domestic workers exhibited the lowest specificity, presumably because to exposure to biomass smoke or repeated illnesses, resulting in false positives. Field workers, frequently subjected to ambient dust, had diminished specificity.[xx]

The present study offers significant insights into the reliable diagnosis of chest X-ray for active pulmonary TB, utilizing HRCT as the reference standard, an advanced imaging technique with enhanced sensitivity for early parenchymal and cavitary lesions. Stratification by critical characteristics such as smoking status, illness duration, and occupation for a detailed evaluation of chest X-ray efficacy across diverse patient profiles. The application of established radiological criteria for PTB diagnosis reduced

heterogeneity in image interpretation, hence enhancing internal validity.

Notwithstanding these strengths, certain restrictions must be recognized. The single-center approach may restrict the generalizability of the findings to other communities with varying TB prevalence, demographic traits, or healthcare accessibility. Secondly, the assessment of inter-observer variability in chest X-ray interpretation was not conducted, which may affect diagnostic accuracy, as previous research have shown considerable variations among radiologists in the diagnosis of pulmonary tuberculosis. Third, although HRCT is regarded as the gold standard, the lack of microbiological confirmation (e.g., culture or PCR) implies that certain cases identified as pulmonary TB through imaging may be false positives attributable to non-tuberculous conditions. Conversely, HRCT may have overlooked very early infections, potentially resulting in an underestimation of false negatives. The exclusive focus on symptomatic patients may inflated the perceived efficacy of chest radiograph, as asymptomatic or subclinical TB, which frequently exhibits minimal or nonexistent radiographic indicators, was not assessed. These constraints underscore the necessity for multicenter investigations that include microbiological confirmation and evaluate inter-reader agreement to further substantiate these findings.

CONCLUSION

Chest X-ray is an exceptionally sensitive tool for detecting active pulmonary tuberculosis; nonetheless, its poor specificity and inconsistent efficacy among subgroups underscore the necessity for supplementary diagnostic approaches. HRCT should be utilized when chest X-ray results are ambiguous, especially in early-stage disease and high-risk groups. Future study should investigate AI-augmented CXR interpretation and economical approaches for incorporating advanced imaging in resource-constrained environments.

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