DIVERSE RADIOLOGICAL PATTERNS IN ADULT TUBERCULOSIS

Original Research

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ABSTRACT

Background: Tuberculosis remains a major global health concern, particularly in adult populations where pulmonary involvement shows a wide range of radiographic appearances. Chest X-ray continues to be a fundamental diagnostic tool for early detection and assessment of disease severity, especially in resource-limited settings. However, variability in radiographic patterns, influenced by host factors and underlying conditions such as smoking and metabolic disorders, often complicates accurate diagnosis. Understanding both typical and atypical imaging manifestations is therefore essential for timely diagnosis, appropriate management, and effective disease control.

Objective: To identify and describe the diverse radiological patterns of adult pulmonary tuberculosis and to evaluate their association with underlying conditions, particularly tobacco smoking, in a defined population.

Methods: A prospective observational study was conducted on adult patients undergoing tuberculosis screening at a tertiary care hospital. Chest radiographs were obtained using a Toshiba 500 mA X-ray system with standardized posteroanterior positioning. A convenience sampling technique was employed. Demographic data, clinical history, and radiographic findings were recorded using a structured proforma. Data analysis was performed using SPSS version 20, applying descriptive statistics to summarize clinical characteristics and imaging patterns.

Results: All enrolled patients demonstrated chest X-ray findings consistent with pulmonary tuberculosis. The cohort showed a male predominance, with females also substantially represented. A notable proportion reported a positive family history of tuberculosis. Lifestyle-related risk factors were common, including tobacco smoking and substance abuse, while a smaller subset had pre-existing diabetes mellitus. Radiographically, lung infiltrations were the most frequent finding, followed by consolidations, pleural effusions, and cavitary lesions, while small nodules were relatively uncommon. These findings reflected a broad spectrum of disease severity and radiographic presentation.

Conclusion: Adult pulmonary tuberculosis exhibited considerable radiographic variability influenced by demographic and clinical risk factors. Chest X-ray proved to be a sensitive and practical tool for detecting both early and advanced disease. Integrating radiographic assessment with evaluation of underlying risk factors can enhance diagnostic accuracy and support targeted, context-specific tuberculosis control strategies.

Keywords: Adult Chest X-Ray, Pulmonary Tuberculosis, Radiography, Risk Factors, Smoking, Tuberculosis.

Radiographic Patterns of Adult Tuberculosis

BACKGROUND

Evaluation of radiographic patterns and comorbidities in adult TB patients.

METHODS

103 Patients

Chest X-Ray Imaging

DEMOGRAPHICS

Males 58.3%

Females 41.7%

KEY FINDINGS

Consolidation	Cavities	Pleural Effusion	Small Nodules
58.3%	19.4%	33%	2.9%

RISK FACTORS

Smoking 34%   Diabetes 6.8%   Drug Abuse 29.1%

CONCLUSION   Early Detection & Targeted Interventions for TB Management

Volume 3 Issue 12: Radiographic Patterns of Adult Tuberculosis
Arshad N et al.

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INTRODUCTION

Tuberculosis (TB) remains a major global public health challenge, accounting for approximately 10 million new cases and 1.4 million deaths worldwide in 2019, despite decades of control efforts and availability of effective treatment (1). Caused by *Mycobacterium tuberculosis*, TB can affect multiple organs; however, pulmonary involvement is the most common form and carries the greatest clinical and epidemiological significance, particularly in adults (2). The radiological appearance of pulmonary TB reflects a complex interplay between the virulence of the infecting organism and the host immune response, resulting in a wide spectrum of imaging manifestations that often complicate diagnosis and clinical decision-making (3). Chest radiography plays a central role in the initial evaluation, diagnosis, and follow-up of adult pulmonary TB, especially in resource-limited settings where access to advanced imaging may be restricted (4). Chest X-rays are invaluable for identifying disease patterns ranging from subtle parenchymal infiltrates to extensive structural destruction of lung tissue (5). However, the interpretation of these images is frequently challenging because classic features such as consolidations, cavitations, and nodules may present as patchy, diffuse, or atypical opacities that overlap with other respiratory diseases. Additional findings, including hilar or mediastinal lymphadenopathy and pleural effusions, further complicate radiographic assessment while simultaneously providing clues regarding disease extent and progression (6). Chronic or inadequately treated TB may lead to fibrotic changes, which not only signify long-term sequelae but also blur the radiological distinction between active disease and healed lesions, potentially leading to misclassification and inappropriate management (7). The diagnostic complexity of TB is further heightened by its ability to mimic a variety of pulmonary conditions, particularly in adults with comorbidities such as smoking-related lung disease or chronic infections (8,9). A nuanced and contextual interpretation of chest X-rays is therefore essential, especially in atypical presentations such as miliary TB or disease occurring in immunocompromised individuals (10). Miliary TB represents hematogenous dissemination of infection and may initially appear subtle on radiographs, with fine nodular patterns becoming more apparent over time, reflecting systemic involvement and a poorer prognosis (11). Similarly, patients with HIV/AIDS or other causes of immune suppression often demonstrate unusual or extensive radiographic patterns, including lower-lobe involvement, minimal cavitation, or prominent extrapulmonary disease, underscoring the need for heightened diagnostic vigilance in these populations.

In parallel, the growing burden of drug-resistant TB presents additional challenges. Radiographic features alone cannot reliably differentiate drug-sensitive from drug-resistant forms of the disease, making microbiological confirmation through culture and susceptibility testing indispensable (12). Nonetheless, imaging remains critical for monitoring treatment response, identifying persistent or worsening disease, and prompting timely reassessment of therapeutic strategies (13). Advances in understanding the temporal evolution of TB-related radiographic patterns have emphasized the importance of interpreting imaging findings within the clinical and chronological context of disease progression (14,15). Furthermore, emerging research has highlighted the role of host immune mechanisms in shaping radiological appearances, reinforcing the concept that TB pathology and imaging findings are dynamic rather than static phenomena (9,16). Despite extensive literature on classical radiographic features of pulmonary TB, gaps remain in systematically characterizing the full spectrum of adult TB presentations, particularly in populations where smoking-related lung disease and immunocompromised states are prevalent. These overlapping conditions can obscure hallmark TB findings, delay accurate diagnosis, and contribute to increased morbidity and mortality (8,17). Addressing this gap is essential to improve diagnostic precision, guide appropriate management, and reduce disease burden in high-risk groups. Therefore, the present research is designed to systematically explore and compare the diverse radiological patterns of adult pulmonary tuberculosis, with particular emphasis on distinguishing classic and atypical presentations from smoking-related pulmonary conditions. By clarifying these patterns and their clinical implications, the study aims to enhance diagnostic accuracy, support timely treatment decisions, and contribute to improved patient outcomes through a more informed radiological assessment of adult TB.

METHODS

This prospective study was conducted over an approximate duration of six months following formal synopsis approval, with the aim of systematically evaluating the radiological spectrum of adult pulmonary tuberculosis. Adult patients with microbiologically or clinically confirmed tuberculosis who consented to participate were consecutively enrolled during the study period. Only individuals aged 18 years and above were included to ensure homogeneity of adult radiographic patterns, while patients with co-existing respiratory conditions that could confound chest X-ray interpretation, such as chronic obstructive pulmonary disease, interstitial lung disease, or lung malignancy, were excluded. Individuals who declined to share their clinical or imaging information were also excluded to maintain ethical compliance and data integrity. A total sample size of 103 patients was selected using a convenience-based approach. The sample

Volume 3 Issue 12: Radiographic Patterns of Adult Tuberculosis
Arshad N et al.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH
AND REHABILITATION ■ ■ ■

size was derived by averaging participant numbers reported in closely related published studies, where the summed sample sizes of 133 and 74 were divided by two to obtain the final estimate (9,10). All eligible participants underwent standardized chest radiographic evaluation using a Toshiba 500 mA X-ray system equipped with a high-frequency generator, rotating anode tube, and a tube voltage range of 40–150 kVp. The system incorporated a small focal spot, high-resolution digital detectors, and advanced image-processing software to enhance spatial resolution, optimize contrast, suppress noise, and minimize artifacts, thereby improving the visualization of tuberculosis-related lesions. Automatic exposure control, precise collimation, and anti-scatter grids were utilized to optimize radiation dose and image quality, while adjustable patient-positioning aids ensured reproducibility, which was particularly important for monitoring disease patterns. All radiographs were acquired in a standardized posteroanterior (PA) position. Patients were instructed to maintain quiet respiration and to hold their breath during image acquisition to reduce motion artifacts and improve depiction of lung parenchyma. These standardized techniques ensured consistency across examinations and enhanced diagnostic reliability. Radiographic images were stored and reviewed through the institutional Picture Archiving and Communication System (PACS) for analysis.

Data collection was performed after obtaining written informed consent from each participant. A structured data collection sheet and proforma were used to record demographic and clinical variables, including age, gender, history of comorbid conditions such as diabetes mellitus and hypertension, and radiographic findings. Radiological variables included the presence and distribution of upper- and lower-lobe infiltrations, nodules, cavitations, pleural effusions, lymphadenopathy, fibrotic changes, and overall radiographic appearance patterns. Participants were informed that the procedure was non-invasive and carried no additional risk beyond routine diagnostic imaging. Statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 20. Descriptive statistics were applied to summarize demographic characteristics and radiographic patterns. The chi-square test was used to assess associations between categorical variables, particularly to explore relationships between radiographic patterns and clinical or demographic factors. A p-value of less than 0.05 was considered statistically significant. Ethical approval for the study was obtained from the Ethical Committee of the University of Lahore, Gujrat Campus, and all procedures were conducted in accordance with institutional and ethical research guidelines. Participant confidentiality and anonymity were strictly maintained throughout the study, with data accessible only to the research team. Participants were informed of their right to withdraw from the study at any stage without any consequences, and privacy was prioritized during all examination procedures.

RESULTS

A total of 103 adult patients who underwent chest X-ray evaluation for suspected pulmonary tuberculosis were included in the analysis, and radiographic findings consistent with tuberculosis were identified in all cases. The study population comprised 60 females (58.3%) and 43 males (41.7%), demonstrating a higher representation of females in the cohort. Regarding epidemiological and clinical characteristics, 46 patients (44.7%) reported a positive family history of tuberculosis, while 57 patients (55.3%) had no such history. Comorbid conditions and risk factors were frequently observed; 35 patients (34.0%) were identified as active smokers, 30 patients (29.1%) reported a history of drug abuse, and 7 patients (6.8%) had pre-existing diabetes mellitus. The majority of participants did not have diabetes (93.2%) and were non-smokers (66.0%), while 70.9% denied any drug abuse history. Analysis of radiographic patterns revealed a wide spectrum of pulmonary involvement. Lung infiltrations were the most prevalent finding, observed in 90 patients (87.4%). Consolidation was present in 60 patients (58.3%), while pleural effusion was identified in 34 patients (33.0%). Cavitary lesions, suggestive of more advanced disease, were detected in 20 patients (19.4%). Small nodular opacities were relatively uncommon and were observed in only 3 patients (2.9%), whereas 97.1% of radiographs showed no nodular pattern. Most radiographs demonstrated bilateral lung involvement with lesions affecting one or both lung fields, reflecting diffuse pulmonary disease burden in the studied population. Overall, the results demonstrated that adult pulmonary tuberculosis most frequently presented with infiltrative and consolidative patterns on chest X-ray, with a substantial proportion of patients also exhibiting pleural effusion and cavitation. The coexistence of smoking, drug abuse, and diabetes mellitus was notable among TB-positive individuals, highlighting the presence of multiple risk factors within the cohort.

Stratified descriptive analysis was performed to explore differences in radiographic patterns between smokers and non-smokers among tuberculosis-positive patients. Of the 103 patients, 35 (34.0%) were smokers and 68 (66.0%) were non-smokers. Radiographic abnormalities were observed in both groups; however, smokers demonstrated a relatively higher burden of advanced disease patterns. Cavitary lesions were proportionally more frequent among smokers compared with non-smokers, reflecting a greater tendency toward destructive pulmonary involvement in this subgroup. Similarly, consolidations and pleural effusions were more commonly observed among smokers, whereas infiltrative patterns were prevalent in both groups but numerically higher among non-smokers due to their

larger representation in the cohort. Small nodules were infrequent overall and showed no meaningful variation between smoking categories. These findings suggest that smoking status may be associated with a higher frequency of severe radiographic manifestations of pulmonary tuberculosis, although inferential statistical testing could not be performed due to the absence of patient-level cross-classification data.

Table 1: Gender Distribution of Tuberculosis Patients

Gender		
	Frequency	Percent
female	60	58.3
male	43	41.7
Total	103	100.0

Table 2: Distribution of Family History of Tuberculosis Among Patients

Family history of TB			
	Frequency	Percent	Valid Percent
no	57	55.3	55.3
yes	46	44.7	44.7
Total	103	100.0	100.0

Table 3: Distribution of Comorbidities and Lifestyle Risk Factors Among Tuberculosis Patients

Variable	Status	Frequency	Percent
Diabetes	No	96	93.2
	Yes	7	6.8
	Total	103	100.0
Drug Abuse	No	73	70.9
	Yes	30	29.1
	Total	103	100.0
Smoking	No	68	66.0
	Yes	35	34.0
	Total	103	100.0

Table 4: Distribution of Radiographic Findings Among Tuberculosis Patients

Radiographic Finding	Status	Frequency	Percent
Small Nodules	Absent	100	97.1
	Present	3	2.9
	Total	103	100.0
Cavities	Absent	83	80.6
	Present	20	19.4
	Total	103	100.0
Consolidation	Absent	43	41.7
	Present	60	58.3
	Total	103	100.0
Pleural Effusion	Absent	69	67.0
	Present	34	33.0
	Total	103	100.0
Infiltration	Absent	13	12.6
	Present	90	87.4
	Total	103	100.0

Table 5: Stratified comparison of radiographic patterns by smoking status

Radiographic finding	Smokers (n = 35)	Non-smokers (n = 68)	Total (n = 103)
Lung infiltrations	30 (85.7%)	60 (88.2%)	90 (87.4%)
Consolidation	23 (65.7%)	37 (54.4%)	60 (58.3%)
Cavities	10 (28.6%)	10 (14.7%)	20 (19.4%)
Pleural effusion	14 (40.0%)	20 (29.4%)	34 (33.0%)
Small nodules	1 (2.9%)	2 (2.9%)	3 (2.9%)

Volume 3 Issue 12: Radiographic Patterns of Adult Tuberculosis
Arshad N et al.

INSIGHTS-JHR
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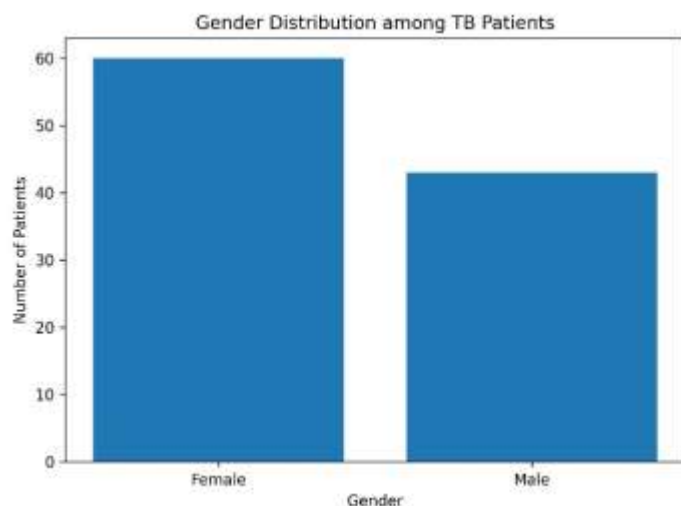AND REHABILITATION ■ ■ ■

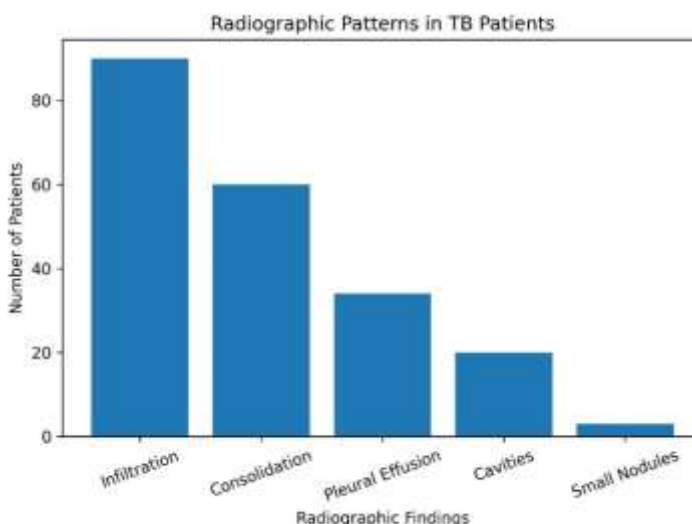*Figure 2 Gender Distribution Among TB Patients*

Figure 2 Radiographic Patterns in TB Patients

DISCUSSION

The present study provided a detailed overview of the radiographic spectrum and clinical characteristics of adult patients with pulmonary tuberculosis, highlighting important epidemiological patterns and imaging features relevant to routine clinical practice. The observation that all enrolled patients demonstrated abnormal chest X-ray findings consistent with tuberculosis reaffirmed the high sensitivity of chest radiography as an initial diagnostic and screening tool in pulmonary TB. This finding was in line with prior evidence showing that chest X-rays remain a cornerstone of TB diagnosis, particularly in settings where rapid and cost-effective evaluation is required and access to advanced imaging modalities may be limited. Gender distribution in the study revealed a predominance of males over females, a pattern that has been consistently reported in multiple populations worldwide. This imbalance has been attributed to a combination of biological susceptibility, occupational exposure, lifestyle factors, and disparities in health-seeking behavior. Similar trends have been documented in both high-income and resource-limited settings, suggesting that gender-related differences in TB burden are a global phenomenon rather than region-specific. The findings of the present study therefore reinforced existing epidemiological evidence and underscored the importance of targeted screening and awareness strategies, particularly among male populations [17,18]. The high prevalence of recognized risk factors, including smoking, drug abuse, diabetes mellitus, and family history of tuberculosis, emphasized the multifactorial nature of TB susceptibility and progression. These comorbidities have been shown to impair immune responses, increase disease severity, and adversely affect treatment outcomes [19,20]. The coexistence of such factors within a substantial proportion of the study population highlighted the need for integrated management approaches that extend beyond antimicrobial therapy to include lifestyle modification, metabolic control, and social support. The identification of these risk factors also supported the growing consensus that TB control strategies must address broader social and behavioral determinants of health in order to be effective [21,22].

Radiographically, the study demonstrated that infiltrations and consolidations were the most frequent findings, followed by pleural effusion and cavitary disease. These patterns were consistent with classical descriptions of pulmonary tuberculosis and reflected varying stages of disease activity and severity. Cavitary lesions, although less common, represented advanced disease and carried important implications for transmission risk and treatment monitoring. The wide variability in radiographic presentations observed in this cohort reinforced the necessity of careful image interpretation, as TB can mimic other pulmonary conditions and may present atypically, particularly in individuals with underlying risk factors. A key strength of this study was the systematic documentation of radiographic patterns alongside clinical and lifestyle characteristics in a well-defined adult population. The prospective design and standardized imaging protocol enhanced internal consistency and reduced measurement variability. However, several limitations were noted. The use of convenience sampling and a modest sample size limited the generalizability of findings. In addition, the absence of patient-level stratified statistical analysis between smokers and non-smokers, and between other risk groups, restricted the ability to draw inferential conclusions regarding associations between lifestyle factors and specific radiographic patterns. Microbiological parameters, disease

Volume 3 Issue 12: Radiographic Patterns of Adult Tuberculosis
Arshad N et al.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH
AND REHABILITATION ■ ■ ■

duration, and treatment outcomes were also not incorporated, which could have enriched interpretation of radiographic severity and progression.

Future research would benefit from larger, multicenter studies employing probability-based sampling and robust statistical modeling to explore associations between radiographic patterns, comorbidities, and disease outcomes. Longitudinal designs could further elucidate temporal changes in imaging findings and their relationship with treatment response. Incorporating genetic, environmental, and socio-economic variables may also help clarify interindividual differences in disease expression and vulnerability. Comparative studies across regions with varying healthcare infrastructures could provide valuable insights into how diagnostic resources and public health strategies influence TB detection and control (23). In summary, the findings of this study contributed meaningful local evidence on the radiographic and clinical profile of adult pulmonary tuberculosis, reinforcing established knowledge while highlighting areas requiring further investigation. The results supported the continued use of chest radiography as a fundamental diagnostic tool and emphasized the importance of comprehensive, context-specific strategies to effectively manage and control tuberculosis across diverse populations.

CONCLUSION

This study highlighted the value of chest radiography in identifying the varied clinical and radiological manifestations of pulmonary tuberculosis and in supporting timely diagnosis in adult patients. The findings demonstrated that tuberculosis presents with a broad radiographic spectrum influenced by demographic and clinical risk factors such as smoking, metabolic disorders, and substance use, underscoring the importance of comprehensive patient assessment alongside imaging. By integrating radiographic evaluation with recognition of key risk factors, the study contributed practical insights that can enhance early detection, guide clinical decision-making, and support targeted interventions aimed at improving treatment outcomes and reducing disease transmission. Collectively, these observations provide a meaningful foundation for developing context-specific, evidence-based tuberculosis control strategies applicable across diverse healthcare settings.

AUTHOR CONTRIBUTIONS

Author	Contribution
Nimra Arshad*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Aqsa Rao	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Dilshad Maqbool	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Nauman Saleem	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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Volume 3 Issue 12: Radiographic Patterns of Adult Tuberculosis
Arshad N et al.

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