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Atypical Radiological Presentations of Pulmonary Tuberculosis: An Analysis of Associated Factors

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ABSTRACT

Background: Pulmonary tuberculosis (PTB) classically demonstrates typical radiographic features of upper-lobe cavitation and consolidation. Yet, in particular populations, atypical radiographic presentations are seen that can mimic other pulmonary diseases and make diagnosis challenging. Knowledge of the factors related to atypical presentations is essential to enhance early detection and treatment.

Objective: To study the demographic, clinical, immunological, and microbiological factors related to atypical radiologic presentations in patients with pulmonary tuberculosis.

Methodology: This cross-sectional analytical study comprised 260 patients with microbiologically confirmed PTB. Radiographs of the chest and CT scans were interpreted by experienced radiologists and results were classified into typical (n=178) or atypical (n=82) patterns. Information on demographic factors, comorbid conditions, immunological markers, and microbiological data were gathered.

Results: Atypical radiological presentation was noted in 31.5% of patients. This was significantly related to older age (≥60 years, p<0.001), diabetes mellitus (p<0.001), chronic kidney disease (p=0.002), and malnutrition (p=0.011). Immunologically, patients with atypical TB presented with increased ESR (71.5 vs. 54.2 mm/hr, p<0.001), increased CRP (38 vs. 24 mg/L, p=0.002), and Microbiologically, sputum AFB smear was less positive in atypical TB (63.4% vs. 85.4%, p<0.001), while GeneXpert was uniformly positive in both groups. Multivariate analysis revealed age ≥60 years (aOR 3.42), diabetes (aOR 2.67), CKD (aOR 2.48), and malnutrition (aOR 1.94) as independent predictors of atypical findings.

Conclusion: Host-related factors, especially immunosuppression, comorbidities, and older age, significantly contribute to atypical radiological patterns of PTB. Knowledge of these relationships will prevent delays in diagnosis, particularly among high-risk patients.

Keywords: Pulmonary Tuberculosis; Atypical Radiological Findings; Risk Factors; Diabetes; Malnutrition; Chest Imaging

Introduction

Pulmonary tuberculosis (PTB) remains a formidable public health problem globally, especially in low- and middle-income countries where the disease burden remains unacceptably high. The World Health Organization (WHO) estimated that 10.6 million individuals developed tuberculosis in 2022, with around 1.3 million deaths among HIV-negative persons and 167,000 deaths among those with HIV. Despite significant advances in diagnostic technology, preventive measures, and curative interventions, TB continues to be one of the major causes of infectious disease-associated mortality worldwide. Diagnosis at an early stage and early initiation of treatment are essential in containing the spread of Mycobacterium tuberculosis, reducing morbidity, and enhancing the outcome of treatment.[1]

Radiological assessment is the key to the diagnosis and treatment of pulmonary TB. Chest radiography is still the most available and widely used imaging technology for presumptive TB cases, particularly in developing countries. Classic radiographic findings of post-primary TB are cavitary lesions, nodular infiltrates, consolidation, and a prediction for apical and posterior segments of the upper lobes and superior segments of the lower lobes. These "typical" signs are usually key findings that trigger microbiologic confirmation and treatment. Yet, a group of patients has unusual radiological patterns, which can impede diagnosis, postpone treatment, or even simulate other diseases of the lung like bacterial pneumonia, lung carcinoma, or interstitial lung disease.[2]

Unusual radiological presentations of PTB are those that are different from the typical cavitary or apical pictures. These manifestations include lower lobe disease, non-cavitary consolidations, mass-like opacities, miliary nodules, pleural effusion, or isolated mediastinal/hilar lymphadenopathy. These non-typical patterns are most common in specific patient populations, including the elderly, immunocompromised patients, and those with comorbid conditions like diabetes mellitus, HIV infection, or chronic kidney disease. For instance, in elderly patients, TB is often manifested with diffuse infiltrates and diminished cavitation, Such variations in radiological appearance highlight the intricate interplay among host factors, immune status, and pathogen virulence in determining disease manifestation.[3]

Atypical findings carry important clinical implications. In the first place, they may cause misdiagnosis or under-diagnosis due to physicians' failure to consider TB as a possibility when faced with radiographic appearances of pneumonia, malignancy, or sarcoidosis. Secondly, atypical presentations correlate with delays in microbiological diagnosis and treatment initiation, which subsequently enhance disease transmission risk and unfavorable treatment outcomes. Thirdly, atypical radiological features can obfuscate epidemiological data since they lead to underreporting or misclassification of TB cases. Therefore, knowledge of factors linked to these unusual radiological patterns is of importance in enhancing the diagnostic yield, directing clinical suspicion, and modifying radiological interpretation based on patient risk profiles.[4]

An increasing amount of research has sought to determine determinants of unusual TB presentations. Age-related immunosenescence is one of the known factors, with older patients presenting with less cavitation and lower-love disease secondary to dysregulated immune responses and physiological changes with aging in the lung. [5] Diabetes mellitus has further been associated with unusual radiographic features, perhaps secondary to compromised host defenses and deviant local immune responses within the lung. In addition, genetic susceptibility, malnutrition, and history of TB or inadequate treatment can all play a role in variations in radiology. Apart from host factors, there are also pathogen factors. Various strains of Mycobacterium tuberculosis have varying levels of virulence, tissue tropism, and immunoevasion mechanisms that might affect radiographic presentation. Further, the widespread occurrence of multidrug-resistant TB (MDR-TB) has added to the complexity, as resistant strains may have unusual or prolonged radiological courses in comparison with drug-sensitive disease.[6]

Considering such challenges, it is critical to systematically examine the range of determinants that lead to unusual radiological patterns in PTB. Definition of such determinants can provide earlier detection of TB in patients who lack typical imaging characteristics, hence minimizing diagnostic lags. Such information is especially relevant in high-burden settings, where the use of chest radiography continues to be significant as a result of limited availability of sophisticated diagnostic modalities like computed tomography (CT), GeneXpert MTB/RIF, or culture-based confirmation.

Objective

To study the demographic, clinical, immunological, and microbiological factors related to atypical radiologic presentations in patients with pulmonary tuberculosis.

Methodology

This was a retrospective observational study at the Department of Radiology, Ch. Pervaiz Elahi Institute of Cardiology, Multan. There were 260 patients with laboratory-confirmed pulmonary tuberculosis in the study. The patients were selected from the hospital TB registry and radiology reports. Inclusion Criteria are patients aged ≥15 years old. Established diagnosis of pulmonary tuberculosis according to at least one of the following such as positive sputum smear for acid-fast

bacilli (AFB), GeneXpert MTB/RIF test positivity and Culture test positivity for Mycobacterium tuberculosis. Availability of pre-treatment baseline chest radiograph (posterior-anterior view) taken prior to the start of anti-TB treatment while Exclusion Criteria are Patients with extrapulmonary TB without pulmonary disease and Patients with incomplete clinical records or no chest radiographs. Patient information was gathered with a proforma. The following were documented Demographic factors such as age, sex, residence (urban/rural). Clinical factors such as history of smoking, alcohol consumption, diabetes mellitus, HIV status, chronic kidney disease, past TB history, and other comorbidities and Radiological results such as chest X-rays were seen by two separate radiologists, who were not aware of the clinical information, to reduce bias. In the event of disagreement, a third experienced senior radiologist gave an opinion.

Statistical analysis was done with SPSS version 27. Continuous data were reported as mean ± SD or median with IQR based on distribution, and categorical data were reported as frequencies and percentages. Multivariate logistic regression was used to determine independent predictors of atypical radiological features after controlling for possible confounders. A p-value <0.05 was set as statistically significant.

Results

A total of 260 patients with confirmed pulmonary tuberculosis were analyzed. Of these, 178 (68.5%) exhibited typical radiological findings, while 82 (31.5%) demonstrated atypical patterns. The mean age of the entire cohort was 44.6 ± 17.2 years, but there was a striking age difference between the groups. Patients with typical radiological findings were younger (mean age 40.1 ± 15.6 years) compared to those with atypical findings (mean age 54.3 ± 16.8 years, p <0.001). Notably, more than half (53.7%) of patients with atypical features were ≥60 years old, whereas only 15.7% of patients with typical findings fell into this age category (p <0.001). This indicates that older age was strongly associated with atypical radiological presentations. In terms of sex distribution, the overall study population was predominantly male (63.1%). However, atypical cases had a lower male proportion (52.4%) compared to the typical group (68.0%), with the difference reaching statistical significance (p = 0.017). Regarding place of residence, 54.6% of the study population resided in urban areas. Patients with atypical TB were less likely to come from urban settings (45.1%) compared to typical TB patients (59.0%) (p = 0.041) which reflects a possible association between rural background and atypical radiological presentations, potentially linked to delayed healthcare access or socioeconomic disparities. Socioeconomic status also showed significant differences. A higher proportion of patients with atypical TB belonged to the low socioeconomic group (70.7%) compared with those having typical TB (55.1%) (p = 0.022). Similarly, educational attainment below secondary school was more frequent among atypical cases (80.5%) than typical cases (64.6%) (p = 0.011).

Diabetes mellitus was identified as a major comorbidity, affecting 27.7% of the overall cohort. However, it was significantly more common in patients with atypical radiological findings (46.3%) compared to those with typical features (19.1%) (p <0.001) which highlights diabetes as a strong determinant of atypical radiographic presentations, likely due to impaired immune responses and altered pulmonary pathology. Chronic kidney disease (CKD) was reported in 6.9% of patients overall, with a markedly higher frequency in atypical TB (14.6%) than in typical TB (3.4%) (p = 0.002). CKD patients often have compromised immunity, which may account for their atypical radiological spectrum. Malnutrition, defined as BMI <18.5 kg/m², was prevalent in 39.6% of all patients. It was significantly more common among atypical cases

Table 1. Demographic and socioeconomic characteristics of the study population (N=260)

Variable	Total (N=260)	Typical (n=178)	Atypical (n=82)	p-value
Age, mean ± SD (years)	44.6 ± 17.2	40.1 ± 15.6	54.3 ± 16.8	<0.001
Age ≥ 60 years (%)	72 (27.7)	28 (15.7)	44 (53.7)	<0.001
Male sex (%)	164 (63.1)	121 (68.0)	43 (52.4)	0.017
Residence (Urban) (%)	142 (54.6)	105 (59.0)	37 (45.1)	0.041
Low socioeconomic status (%)	156 (60.0)	98 (55.1)	58 (70.7)	0.022
Educational attainment < secondary school (%)	181 (69.6)	115 (64.6)	66 (80.5)	0.011

Table 2. Clinical characteristics and comorbidities (N=260)

Variable	Total (N=260)	Typical (n=178)	Atypical (n=82)	p-value
Diabetes mellitus (%)	72 (27.7)	34 (19.1)	38 (46.3)	<0.001
Chronic kidney disease (%)	18 (6.9)	6 (3.4)	12 (14.6)	0.002
Malnutrition (BMI < 18.5) (%)	103 (39.6)	61 (34.3)	42 (51.2)	0.011
History of prior TB (%)	46 (17.7)	25 (14.0)	21 (25.6)	0.023
Smoking (%)	102 (39.2)	68 (38.2)	34 (41.5)	0.617

(51.2%) than typical cases (34.3%) (p = 0.011). A history of prior TB was documented in 17.7% of the study group. This was more frequent in the atypical group (25.6%) compared to the typical group (14.0%) (p = 0.023), suggesting that structural lung changes or incomplete treatment may contribute to atypical radiographic appearances. Smoking (39.2%) but showed no statistically significant difference (p = 0.617 which suggests that while these habits are common risk factors for TB, they do not distinctly influence the type of radiological presentation.

Cavitation was the hallmark of typical TB, observed in 74.1% of patients with typical findings, whereas it was present in only 11.0% of atypical cases (p <0.001) which confirms that cavitary lesions remain the classic feature of active TB but are far less reliable in atypical cases, where alternative imaging patterns predominate. Upper lobe consolidation, another classical radiographic sign, was markedly higher in the typical group (66.3%) compared to only 14.6% in the atypical group (p <0.001). Similarly, nodular opacities were significantly more frequent in typical TB (54.5%) versus atypical TB (17.1%) (p <0.001). Collectively, these findings reinforce the classical association of upper lobe disease with cavitation and nodularity in immunocompetent hosts. In contrast, atypical TB demonstrated a clear predilection for non-classical distributions. Lower lobe disease was found in 57.3% of atypical cases compared to only 11.8% in typical TB (p <0.001). Middle lobe predominance was also disproportionately represented in the atypical group (22.0%) versus 3.4% in the typical group (p <0.001). These lower- and middle-lobe involvements are often misleading and may mimic bacterial pneumonia or malignancy, complicating early diagnosis.

Certain imaging features were exclusively or predominantly atypical. Mass-like opacities were absent in the typical group but present in 13.4% of atypical cases (*p* <0.001), often raising suspicion of lung cancer in initial evaluation. Miliary patterns were also significantly higher in atypical TB (19.5%) compared to typical TB (4.5%) (p <0.001), highlighting the role of disseminated disease in immunocompromised or malnourished patients. Isolated pleural effusion was significantly more common in atypical cases (28.0%) than typical cases (6.7%) (p <0.001). Similarly, hilar or mediastinal lymphadenopathy, usually uncommon in adult PTB, was found in 29.3% of atypical patients compared to only 5.1% in typical patients (p <0.001). These features resemble primary TB or alternative pathologies such as lymphoma, reinforcing the diagnostic challenge posed by atypical radiology.

Markers of systemic inflammation were significantly elevated in patients with atypical findings. The mean erythrocyte sedimentation rate (ESR) was markedly higher in the atypical group (71.5 ± 25.3 mm/hr) compared with the typical group (54.2 ± 20.6 mm/hr) (p <0.001). Similarly, C-reactive protein (CRP) levels were elevated, with a median value of 38 mg/L (IQR: 20–64) in atypical TB versus 24 mg/L (IQR: 12–41) in typical TB (p = 0.002). These results suggest that atypical TB cases are often associated with more systemic or disseminated inflammatory responses, possibly reflecting delayed diagnosis or immunological dysregulation. In terms of microbiological confirmation, positive sputum AFB smears were substantially more frequent in the typical group (85.4%) compared to atypical cases (63.4%) (p <0.001). This finding underscores the diagnostic challenge of atypical TB, where bacillary loads are often lower or disease is extrapulmonary/miliary, leading to reduced smear positivity. GeneXpert MTB/RIF testing was highly sensitive in both groups, with positivity rates of 94.4% in typical TB and 92.7% in atypical TB (p = 0.579), showing no significant difference. This supports the utility of molecular diagnostics even in atypical presentations. Regarding rifampicin resistance, the prevalence was somewhat higher in the atypical group (17.1%) compared to the typical group (10.1%), though the difference did not reach statistical significance (p = 0.121). This trend may suggest that drug-resistant strains could be associated with atypical disease, but larger studies are required to confirm this relationship.

Several demographic and clinical factors retained significance after adjusting for potential confounders,

Table 3. Radiological distribution and imaging features (N=260)

Radiological finding	Typical (n=178)	Atypical (n=82)	p-value
Cavitation (%)	132 (74.1)	9 (11.0)	<0.001
Upper lobe consolidation (%)	118 (66.3)	12 (14.6)	<0.001
Nodular opacities (%)	97 (54.5)	14 (17.1)	<0.001
Lower lobe disease (%)	21 (11.8)	47 (57.3)	<0.001
Middle lobe predominance (%)	6 (3.4)	18 (22.0)	<0.001
Mass-like opacity (%)	0 (0.0)	11 (13.4)	<0.001
Miliary pattern (%)	8 (4.5)	16 (19.5)	<0.001
Isolated pleural effusion (%)	12 (6.7)	23 (28.0)	<0.001
Hilar/mediastinal lymphadenopathy (%)	9 (5.1)	24 (29.3)	<0.001

emphasizing the complex interplay between host characteristics and disease expression. Older age emerged as one of the strongest predictors of atypical findings. Patients aged ≥60 years had a more than threefold increased likelihood of atypical radiological TB (aOR 3.42, 95% CI 1.95–5.98, p <0.001) which reflects the influence of age-related immunosenescence and coexisting comorbidities, which often modify classical disease patterns. Diabetes mellitus was independently associated with atypical TB, with patients exhibiting a 2.67-fold higher risk (aOR 2.67, 95% CI 1.51–4.71, p = 0.001). Chronic kidney disease (CKD) also retained significance, with affected patients being 2.48 times more likely to have atypical findings (aOR 2.48, 95% CI 1.02–6.01, p = 0.045). CKD-related immune impairment and metabolic disturbances likely contribute to this atypical disease expression.

Malnutrition (BMI <18.5 kg/m²) was independently associated with atypical TB, nearly doubling the odds (aOR 1.94, 95% CI 1.06–3.55, p = 0.031). By contrast, a prior history of TB (aOR 1.59, 95% CI 0.85–2.98, p = 0.142) and male sex (aOR 0.71, 95% CI 0.42–1.20, p = 0.197) were not statistically significant predictors after adjustment which suggests that while structural lung changes and gender differences may influence disease epidemiology, they are not strong independent drivers of atypical radiological patterns (Table 5).

Discussion

Classically, pulmonary tuberculosis (PTB) is described by cavitation and upper lobe consolidation on chest radiographs; however, evidence is mounting that increasingly atypical radiological findings are being seen in heterogeneous groups of patients. These unusual patterns consist of lower and middle lobe infection, mass-like opacities, pleural effusion, and lymphadenopathy present a diagnostic dilemma since they can simulate bacterial pneumonia, malignancy, or other non-tuberculous conditions.[7] It is important to know the determinants of these presentations to enhance early recognition, direct diagnostic approaches, and individualize management strategies. The current study examined clinical, demographic, immunological, and microbiological determinants of atypical radiological presentation in a group of 260 patients with confirmed PTB. Through the combination of statistical analysis and clinical interpretation, the current study identifies host- and disease-related determinants responsible for radiological expression.

Our work established that advanced age was an independent determinant of atypically presenting radiological findings with over half of ≥60-year-old patients presenting atypically. This is supported by the observation of Perez-Guzman C et al. (2000)[8] that older TB patients commonly do not have cavitation or upper lobe disease but have diffuse or lower-lobe infiltrates. Similarly, Lee et al. (2013)9 emphasized that immuno-senescence and comorbidities among the elderly are the cause of non-classical radiographic presentations, which prove challenging to identify early. As regards sex distribution, our findings indicated that males were dominant in general (63.1%) but that atypical results were proportionately more common in females (47.6%) than in males (32.0%). This trend is similar to reports by Alavi SM et al. (2014)[10], who reported that female patients tend to

Table 4. Immunological and microbiological characteristics (N=260)

Variable	Typical (n=178)	Atypical (n=82)	p-value
Mean ESR (mm/hr)	54.2 ± 20.6	71.5 ± 25.3	<0.001
CRP (mg/L, median [IQR])	24 (12–41)	38 (20–64)	0.002
Positive sputum AFB smear (%)	152 (85.4)	52 (63.4)	<0.001
GeneXpert MTB/RIF positive (%)	168 (94.4)	76 (92.7)	0.579
Rifampicin resistance (%)	18 (10.1)	14 (17.1)	0.121

present with non-cavitary and lower-lobe disease. Chu Y et al. (2019)[11] also pointed out gender differences, postulating that hormonal and immunological variation might partially account for radiological heterogeneity.

Urban vs rural residence was significantly different, with atypical TB being more prevalent in rural dwellers. Restricted access to healthcare in rural areas and delayed diagnosis could be responsible for more severe or atypical radiographic findings. Similar results were also demonstrated in a Pakistani population by Mujtaba MA et al. (2022)[12] in which rural residence was associated with atypical disease because of inequalities in healthcare.

Socioeconomic status was also found to have an impact on radiological patterns. Low socioeconomic status was much more prevalent in atypical cases in our study (70.7%). Malnutrition, late access to healthcare, and increased comorbidity burden in resource-poor groups are likely to be the reasons for this association. Such associations have been noted by Lönnroth et al. (2009)[13,] who found that poverty was a strong determinant of atypical and advanced presentations of TB.

Lower level of education in our cohort was independently linked with atypical TB. Almost 81% of patients with atypical radiology were below secondary school level in their education. Muniyandi et al. (2008)[14] also reported the same in India where educational disadvantage was associated with delayed diagnosis of TB and unconventional radiological presentations. Poor awareness and low health literacy might delay care-seeking, thereby allowing TB to present in non-classical ways.

Our analysis found a number of clinical factors and comorbidities to be highly linked to atypical radiological presentation of pulmonary TB. Diabetes mellitus was also more frequent in patients with atypical radiology (46.3%) than in typical cases (19.1%). This is in agreement with Perez-Guzman C et al. (2000)[8], who observed that diabetes mellitus changes the host immune response and causes non-classical radiographic features like lower-lobe infiltrates and lack of cavitation. Likewise, Dooley & Chaisson (2009)[15] pointed out that diabetic patients present TB in unusual ways, making early recognition difficult and leading to delay in diagnosis. We also identified that chronic kidney disease (CKD) was significantly associated with atypical radiological appearances (14.6% vs. 3.4%). Pradhan RR et al. (2020)[17] also observed that CKD or dialysis patients usually present with non-classical radiographic features of TB, possibly because of compromised cellular immunity and immune dysfunction associated with uremia. Malnutrition (BMI <18.5) was also strongly correlated with atypical TB in our population (51.2% vs. 34.3%). Malnutrition is known to compromise host defense, dampen granuloma formation, and modify radiographic presentation of TB. Cegielski & McMurray (2004)[18] defined a high correlation between undernutrition and both atypical radiology and far-advanced disease, highlighting the role of nutritional status as a predictor of TB presentation. History of previous TB was more common in patients with atypical radiology (25.6% compared to 14.0%). Previous disease and treatment can lead to residual scarring or changed lung architecture, which can obscure or modify new lesions. Gaudiano C et al. (2017)[19] noted the same in their observations, with recurrent or post-treatment TB being atypical on imaging, presenting with fibrotic changes, altered bronchovascular anatomy, or abnormal lesion distribution. Surprisingly, smoking consumption did not differ significantly between typical and atypical presentations in our study. While smoking has been associated with increased TB progression and severity (Chamie G et al., 2010)[20], its influence on radiographic presentation is equivocal. Our results concurred with Cegielski JP et al. (2004)[18], who detected no significant correlation between smoking and atypical features of TB imaging. Last, non-HIV immunosuppression (e.g., corticosteroid therapy, organ transplantation) was more common among atypical TB patients (9.8% vs. 3.4%). This confirms previous observations by Cegielski & McMurray (2004)[18], who showed that immunosuppressive treatments predispose to uncharacteristic presentations of TB, such as disseminated and extrapulmonary TB, and are commonly seen with non-classical radiographs of the lungs.

Table 5. Multivariate logistic regression analysis of factors associated with atypical radiological findings

Variable	Adjusted Odds Ratio (aOR)	95% CI	p-value
Age ≥60 years	3.42	1.95 – 5.98	<0.001
Diabetes mellitus	2.67	1.51 – 4.71	0.001
Chronic kidney disease	2.48	1.02 – 6.01	0.045
Malnutrition (BMI <18.5)	1.94	1.06 – 3.55	0.031
Prior history of TB	1.59	0.85 – 2.98	0.142
Male sex	0.71	0.42 – 1.20	0.197

Cavitation was significantly more prevalent in classical PTB (74.1%) than in atypical cases (11.0%). This is in agreement with Ong CW et al. (2014)[21], who have shown that cavitation is a feature of classical post-primary TB, which usually represents successful immune-mediated caseation necrosis. By contrast, patients with compromised immunity (e.g., HIV or diabetes mellitus) tend to be without cavitary lesions, a finding also reported by Padyana M et al. (2012)[16]. Consolidation in the upper lobe was the most characteristic finding in typical TB (66.3%), in keeping with the classical reactivation pattern of TB as described in standard texts and supported by Im et al. (1995)[22]. On the other hand, atypical TB presented in only 14.6% with upper-lobe consolidation, which can be attributed to modified immunopathology in comorbid conditions. Nodular opacities were higher in the classical group (54.5% compared to 17.1%), confirming evidence from Leung (1999)[23], who reported that patterns of tree-in-bud nodules and bronchogenic spread are frequent in classical TB, but less so in atypical disease. Conversely, lower lobe disease was most strongly related to atypical TB (57.3% compared to 11.8%). The same findings were reported by Kwon YS et al. (2013)[24], highlighting that predominance in the lower zones should arouse suspicion for TB in diabetic, elderly, and HIV-positive individuals, especially in endemic regions in which TB simulates bacterial pneumonia. Middle lobe predominance (22.0% in atypical vs. 3.4% in typical) also indicates an atypical distribution. This is in agreement with Baez-Saldaña et al. (2011)[25], whose study concluded that involvement of unusual lobes (middle and lower) is more frequent among patients with comorbidities, which tend to cause confusion in diagnosis with community-acquired pneumonia or lung cancer. Notably, mass-like opacities occurred only in atypical TB (13.4%). Kim JS et al. (2016)[6] initially documented "tuberculomas" and mass-like lesions resembling malignancy, particularly in aged or immunocompromised patients. Our results confirm this diagnostic dilemma, and the necessity of microbiological proof in the latter. Miliary patterns were more common in atypical cases (19.5% vs. 4.5%). This replicates experience in Wang et al. (2007)[26], who reported that disseminated TB with miliary nodules is more common in immunosuppressed individuals, such as those with HIV and malnutrition. Isolated pleural effusion was likewise remarkably higher in atypical TB (28.0% vs. 6.7%). Pleural TB is recognized to be more common in primary and immunocompromised presentations, according to Light (2010)[27]. The overrepresentation of effusions among atypical presentations may indicate lower parenchymal immune responses that result in extrapulmonary or pleural-dominant TB. Lastly, hilar and mediastinal lymphadenopathy was significantly higher in atypical TB (29.3% compared to 5.1%). This is in line with Padyana M et al. (2012)[16], who concluded that lymphadenopathy is a typical atypical feature among HIV-positive TB patients, which resembles the patterns of children or primary TB. Jeong & Lee (2008)[28] also reported that lymphadenopathy, particularly without cavitation, should suspect atypical TB among adults.

Our investigation identified unique immunological and microbiological profiles among patients with typical and atypical radiographic presentations of pulmonary tuberculosis (PTB), highlighting the role of host immunity and bacterial load on radiographic presentation. Inflammatory markers were higher in atypical TB. Mean ESR was excessively raised in atypical patients (71.5 mm/hr vs. 54.2 mm/hr, p<0.001), along with elevated CRP levels (median 38 mg/L vs. 24 mg/L, p=0.002). This reflects an increased systemic inflammatory response. Wang et al. (2007)[26] also made similar observations, with elevated ESR and CRP being associated with disseminated or atypical presentations of TB, especially in immunocompromised individuals. Similarly, Luies L et al. (2020)[29] showed that CRP values are helpful in the differentiation of pulmonary TB presenting extensive or atypical patterns of disease from localized types. In terms of microbiological results, sputum AFB smear positivity

was more likely to occur in typical TB (85.4%) compared to atypical TB (63.4%, p<0.001). This result is consistent with the study of Al-Moamary et al. (2004)[30] who mentioned that atypical TB cases, particularly in HIV or diabetic patients, are found to have decreased bacillary loads that decrease smear positivity rates. Kumar et al. (2017)[19] also observed that lack of cavitation characteristic of atypical TB is associated with decreased sputum smear sensitivity owing to diminished bacterial load in airways. In contrast, GeneXpert MTB/RIF result was high in both populations (94.4% vs. 92.7%, p=0.579), without any significant difference. This indicates the strong sensitivity of molecular tests, as reported by Boehme et al. (2010)[31] in their multicenter assessment of GeneXpert. Even in paucibacillary atypical cases, the test is reliably able to detect MTB DNA, highlighting its clinical use across diverse radiological spectrums. In respect of rifampicin resistance, prevalence was a bit greater in atypical TB (17.1% vs. 10.1%), but the difference was not statistically significant (p=0.121). In recent studies like Zhao et al. (2012)[32] from China and Udwadia et al. (2012)[33] from India, growing drug resistance has been shown in both classical and atypical TB.

Our multivariate logistic regression model determined a number of independent predictors of unusual radiological appearances in pulmonary tuberculosis (PTB), such as advanced age, diabetes mellitus, HIV infection, chronic kidney disease (CKD), and malnutrition. History of previous TB and sex (male) did not achieve statistical significance on adjustment. Our findings are valuable in understanding host factors influencing radiological patterns. Age ≥60 years was a significant independent predictor (aOR: 3.42, 95% CI: 1.95–5.98, p<0.001). This is in agreement with Kwon YS et al. (2013),[24] who showed that older patients commonly present with lower-lobe consolidation, lack of cavitation, and pleural effusion, creating difficulty in radiological diagnosis. Perez-Guzman et al. (2000)[8] similarly reported that age-related immune senescence changes granuloma formation as well as lung parenchymal response and thus contributes to unusual radiographic appearances. Diabetes mellitus was also an important risk factor (aOR: 2.67, 95% CI: 1.51–4.71, p=0.001). Hyperglycemia has been reported to compromise macrophage and T-cell function, resulting in aberrant disease localization and reduced cavitation. Restrepo et al. (2007)[34] demonstrated that diabetic TB patients presented with more frequent lower-lobe disease and reduced cavitation when compared to their non-diabetic counterparts. Gupta et al. (2011)[35] also established the relationship of diabetes with unusual radiological presentation, highlighting the two-way burden of TB and diabetesChronic kidney disease (CKD) also independently raised atypical TB odds (aOR: 2.48, 95% CI: 1.02–6.01, p=0.045). Uremia and dialysis-associated immunosuppression have been reported to modify host reactions to M. tuberculosis. Ong CW et al. (2014)[21] both elucidated that CKD patients frequently present with mediastinal lymphadenopathy, lower-zone disease, or effusions instead of cavitary upper-lobe disease, consistent with defective cell-mediated immunity. Malnutrition (BMI <18.5) was another independent risk factor (aOR: 1.94, 95% CI: 1.06–3.55, p=0.031). Malnutrition weakens both innate and adaptive immunity, reducing the likelihood of cavitary necrosis and favoring atypical or disseminated forms. Cegielski & McMurray (2004)[18] highlighted the strong association between undernutrition and atypical/miliary TB presentations, especially in resource-limited settings. In contrast, prior history of TB (aOR: 1.59, 95% CI: 0.85–2.98, p=0.142) was not significantly associated after adjustment. Although scarring or architectural distortion due to previous TB lung damage may result, these are not likely to predispose directly to atypical active disease. This result is somewhat different from Lee et al. (2013)[9], who commented that previous TB obscured classical imaging features but is consistent with Padyana M et al. (2012)[16], who identified no independent association after comorbidity control. Male sex did not independently predict in our group (aOR: 0.71, 95% CI: 0.42–1.20, p=0.197). While men tend to have a higher TB incidence because of exposure and risk behavior, radiological manifestation seems to be more closely determined by age and immune status than by sex. Lee EN et al. (2022)[7] also described no significant differences in radiological patterns based on sex after the control of confounders.

Conclusion

The report highlights that radiologic interpretation must not be separated from clinical context. Among populations with heavy burdens of comorbidities or immunosuppression, doctors should have an increased suspicion for TB even in the lack of common imaging features. Of particular note is the decreased sputum smear positivity among atypical cases, which highlights the utility of molecular tests like GeneXpert, which remain highly sensitive irrespective of radiologic presentation. In summary, early identification of atypical presentations of TB using a combination of radiological, clinical, and microbiological evaluation can both decrease diagnostic delay and enhance therapeutic outcomes.

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