ORIGINAL ARTICLE

THE ROLE OF RADIOLOGICAL IMAGING IN ASSESSING MDR-TB SEVERITY: A STUDY OF CXR FEATURES AND THEIR ASSOCIATION WITH SOCIO-DEMOGRAPHIC AND CLINICAL VARIABLES

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ABSTRACT

Objective: To assess chest X-ray patterns in multidrug-resistant tuberculosis (MDR-TB) patients and determine their association with socio-demographic and clinical characteristics.

Study Design: Cross sectional, analytical study.

Place of Study and Duration: Bacha Khan Medical College (BKMC)/Mardan Medical Complex (MMC) MTI, Mardan, 01year(From January 2025 to December 2025).

Methodology: A total of 147 confirmed MDR-TB patients, aged ≥18 years, were enrolled through consecutive sampling. A structured proforma was used to gather data, related to socio-demographic profile, clinical characteristics, and behavioral factors. Chest X-ray (CXR) patterns were classified as abnormal (cavitation, consolidation, pleural effusion, infiltration) or normal. SPSS version 26 was used to analyze the data. Descriptive statistics were calculated and associations were evaluated by Chi-square test and multivariable logistic regression.

Results: The incidence of abnormal CXR findings was 74.8% of 147 patients. Infiltrations and cavitations were the most prevalent abnormalities, found radiologically. The percentage of abnormal CXR results was higher in the patients with low BMI (47.6%), anemia (51.7%) and comorbidities (19.7%). Significant associations were found between abnormal CXR findings and BMI ($p = 0.046$), comorbidities ($p = 0.001$), daily labor occupation ($p = 0.014$), and HIV status ($p = 0.021$).

Conclusion: The prevalence of abnormal chest X-ray findings among MDR-TB patients is high and related to poor nutritional status, anemia, comorbid conditions and immunosuppression. The chest X-ray is useful and cost effective for use to determine disease severity in a resource-limited community context.

Keywords: *Anemia; Chest X-ray; Comorbidity; Multidrug-resistant tuberculosis*

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INTRODUCTION

Multidrug-resistant tuberculosis (MDR-TB) is tuberculosis (TB) that is resistant to isoniazid and rifampicin, and is one of the greatest public health threats in the world[1]. Although there has been great progress in the development of diagnostic and therapeutic approaches, MDR-TB still remains a major cause of morbidity, mortality and healthcare burden, especially in low- and middle-income countries[2]. The World Health Organization (WHO) Global Tuberculosis Report ,2025, reports that 10.8 million people globally suffered from tuberculosis in 2024, with an estimated 410,000 cases being rifampicin-resistant or multidrug-resistant [3]. Pakistan remains one of the highest burdened countries for TB and MDR-TB, and continues to be the most affected country in South Asia [4]. Low healthcare coverage and limited resources, malnutrition, poverty, overcrowding, and lack of diagnosis are key factors that drive the increasing incidence of drug-resistant TB[5].

Radiological imaging plays a crucial role in the diagnosis,

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evaluation, and monitoring of pulmonary tuberculosis[6]. Chest X-ray (CXR) is one of the most available, affordable and commonly used imaging modalities, particularly in resource-limited areas[7]. Pulmonary tuberculosis is accompanied by various features on radiographs including cavitary lesions, infiltrates, fibrosis, nodules, pleural effusion, consolidation, bronchiectasis, and bilateral lung involvement[8]. These radiological changes are more extensive and severe in patients with MDR-TB, as a result of longer duration of illness, recurrent infections, delayed treatment start and higher bacillary load[9].Several studies have shown that extensive cavitation and bilateral pulmonary involvement are correlated with increased infectivity, delayed sputum conversion, poor treatment outcomes and increased mortality rates[10,11].

CAPSULE SUMMARY

Chest X-ray (CXR)patterns in the patients of multidrug-resistant tuberculosis (MDR-TB) were assessed, and their association with socio-demographic and clinical characteristics was determined. The prevalence of abnormal CXR findings among MDR-TB patients was high and related to poor nutritional status, anemia, comorbid conditions and immunosuppression. The CXR remains a helpful and cost-effective tool for determining illness severity in a resource-limited community context.

Chest radiography is still a significant adjunctive test for TB severity worldwide[12]. Cavitary lesions have been reported in around 40-80% of MDR-TB patients and bilateral lung involvement has been seen in almost 50-70%[13]. The fibrotic changes and large amounts of parenchymal destruction are also more common with drug-resistant TB than with drug-sensitive TB[14].

There is little local information on the association of socio-demographic and clinical features with radiological severity of MDR-TB in Pakistan, where TB is still endemic. However, most information available about these studies is limited to microbiological diagnosis and treatment outcomes and the use of chest radiographic signs as markers of disease severity and predictors of disease burden has not been well studied. Radiological patterns and their link with patients' features could help the clinician to perform early risk stratification, prognosis assessment and designing patient-specific management of MDR-TB.

Chest radiography (CXR) is a widely available, low cost, imaging modality that can offer a lot of information about the extent and severity of pulmonary involvement. There is insufficient local information about the relationship between specific radiological characteristics of MDR-TB and socio-demographic and clinical parameters of patients. These relationships can be clinically useful for identifying those at higher risk of developing a more severe clinical course, for early risk stratification, planning treatment, and allocating resources. The results of this study are likely to be useful for pulmonologists, radiologists, TB control programmes and policymakers for the comprehensive management of MDR-TB. Therefore, this study was designed to evaluate the role of radiological imaging in assessing the severity of multidrug-resistant tuberculosis by analyzing chest X-ray features and determining their association with socio-demographic and clinical variables among MDR-TB patients.

METHODOLOGY

It was a cross-sectional analytical study carried out at the Department of Pulmonology, Bacha Khan Medical College (BKMC)/Mardan Medical Complex (MMC), MTI, Mardan for a period of one year, from 1st January 2025 to 31st December 2025. The study was granted ethical approval by the Association for Community Development (ACD) Ethical Review Committee (ERC) of Khyber Pakhtunkhwa, Pakistan. The sample was calculated using OpenEpi sample size calculator version 3.01 with a prevalence of cavitary lesions on chest x-ray in MDR-TB patients of 43.24%, a 95% confidence interval and an 8% margin of error[15]. The sample size calculated was 147 participants.

The study participants were selected using a non-probability consecutive sampling technique. Patients aged 18 years and above, regardless of gender, who were diagnosed with multidrug-resistant tuberculosis (MDR-TB) using drug susceptibility testing (DST) or GeneXpert MTB/RIF assay and had chest X-ray (CXR) records at the time of their diagnosis were included in the study. Patients with complete clinical, laboratory and radiological data and informed consent were recorded. Patients who had incomplete medical records, poor quality chest radiographs, or had a previous diagnosis of alternative chronic lung disease including malignancy of the lungs, interstitial lung disease other than TB, and severe trauma to the lungs were excluded from the study. Furthermore, the critically ill patients who could not be radiologically assessed at the time of data collection and those who refused to take part were also excluded to ensure reliability and accuracy of the data collected.

The study was conducted at the Programmatic Management of Drug-Resistant TB (PMDT) center at MMC, Mardan, where all eligible patients who attended the PMDT center for diagnosis of multidrug-resistant tuberculosis (MDR-TB) were selected after obtaining approval from the institutional ethical review committee. For uniform data collection, a structured and pre-tested proforma was used. Socio-demographic data such as age, gender, residence and occupation were collected directly from patients and checked with hospital records. Clinical and behavioural information included body mass index (BMI), anemia status, HIV status, co-morbidities and first and second line anti-tuberculosis treatment history in patient's clinical records, laboratory results, and treatment registers.

Chest X-ray was retrieved from the radiology department records. All radiographs were assessed by experienced

radiologists and findings were classified as cavitation, pleural effusion, consolidation, infiltration, or normal CXR appearance. Patients who presented with more than one radiologic feature were included in each relevant category to provide full documentation of the pattern of disease severity. Quality control was used during the data collection process to ensure that the data is accurate and complete. The records were inconsistently completed with reference to hospital information systems and ambiguous records were confirmed with reference to attending clinicians.

Drug-resistant tuberculosis (DR-TB) was defined as tuberculosis (TB) caused by Mycobacterium tuberculosis (MTB) that is resistant to at least one first-line or second-line anti-TB drug confirmed by drug susceptibility testing (DST). Multidrug-resistant tuberculosis was specifically defined as tuberculosis that is resistant to at least isoniazid and rifampicin, and may be resistant to other first or second line anti-TB drugs. Hemoglobin less than 12 g/dl was used to define the diagnosis of anemia in females and less than 13 g/dl in males. Chest X-ray abnormalities were classified as either cavitation, consolidation, pleural effusion or infiltration, and a normal CXR was defined as no radiological abnormality that suggested pulmonary disease. Comorbidities were defined as the presence of any other chronic medical condition in the patient, including, but not limited to, diabetes mellitus, hypertension, asthma, cardiovascular disease, or other systemic diseases which may affect the severity of the disease or clinical outcome.

Data collected were entered and analyzed within SPSS version 26.0. All variables were summarized, using descriptive statistics and categorical data were presented in the form of frequencies and percentages. The normality of continuous data was tested with the Shapiro-Wilk test. The Chi-square test was used to test the association of socio-demographic variables with CXR findings. The Fisher exact test was used where any expected cell count was less than 5. Likewise, clinical/behavioral variables were correlated with radiological pattern by means of Chi-square analysis. A binary logistic regression analysis was used to determine independent predictors of abnormal CXR results. The variables that had p-value ≤ 0.25 in univariate analysis were entered into the multivariable regression model. Crude odds ratios (COR) as well as the adjusted odds ratios (AOR) with 95% confidence interval (CI) were determined. A p value of ≤0.05 was deemed statistically significant.

RESULTS

There was a slight preponderance of the female population and majority of the patients were in younger age group of less than 40 years. The majority of patients lived in urban settings and the distribution of employment was found to be skewed with higher proportion of patients doing informal and low income activities. Overall, the demographic profile can be described as a largely young, urbanized, and occupationally diverse population living with MDR-TB, potentially impacting disease transmission and access to care. (Table 1)

The clinical picture revealed that almost half of the patients had low BMI and a considerable number of the patients had anemia, thus a generally poor nutritional and hematological status. Most patients had abnormal CXR imaging and HIV co-infection was uncommon in this group. A large number had a previous history of first line treatment for TB, indicating previous exposure and potential treatment failure as a cause of drug resistance. In a significant sub-population of patients, there were comorbid conditions which added to the clinical complexity. (Table 2)

The radiological assessment of all socio-demographic groups showed that abnormal CXR patterns were more common in all the groups, infiltrative changes being most common in the overall assessment. Cavitary and pleural effusion patterns were relatively more common among the rural people and those with physically demanding jobs, indicating possible links with delayed diagnosis and disease progression. There was greater disease infiltration in younger age groups and relatively higher number of patients with pleural and fibrotic changes, suggesting chronicity and progression of pulmonary disease. (Table 3)

Similarly, clinical and behavioral factors showed that abnormal radiographic findings were consistently observed across all BMI, anemia, and comorbidity categories. More severe radiological abnormalities were noted in underweight patients and patients with comorbid disease, especially cavitation and infiltrative disease. There was more extensive radiological involvement in HIV infected patients, albeit there were fewer of these. Overall, the results indicate that nutritional deficiency, systemic disease

Table 1: Distribution of Socio-Demographic Characteristics among Study Participants (n = 147)

Variable	Category	Frequency	Percentage (%)
Gender	Male	71	48.3
	Female	76	51.7
Age group (years)	18–28	58	39.5
	29–38	43	29.3
	39–48	27	18.4
	≥49	19	12.9
Residence	Urban	102	69.4
	Rural	45	30.6
Employment status	Government employee	13	8.8
	Private sector worker	19	12.9
	Farmer	7	4.8
	Student	12	8.2
	Daily wage laborer	10	6.8
	Homemaker	3	2.0
	Unemployed	18	12.2

Table 2: Clinical and Behavioral Profile of MDR-TB Patients (n = 147)

Variable	Category	Frequency	Percentage (%)
Body Mass Index (BMI)	<18.5 kg/m²	70	47.6
	≥18.5 kg/m²	77	52.4
Anemia status	Present	76	51.7
	Absent	71	48.3
CXR findings	Abnormal	110	74.8
	Normal	37	25.2
HIV status	Positive	2	1.4
	Negative	145	98.6
Presence of comorbidities	Yes	29	19.7
	No	118	80.3
History of first-line anti-TB treatment	Yes	94	64.0
	No	53	36.0
History of second-line anti-TB treatment	Yes	21	14.3
	No	126	85.7

Table 3: Chest X-ray Patterns According to Socio-Demographic Characteristics (n = 147)

Variable	Abnormal Chest X-ray				Normal Chest X-ray
	Cavitation n(%)	Pleural Effusion n(%)	Consolidation n(%)	Infiltration n(%)	n(%)
Sex					
Male	17 (23.9)	12 (16.9)	12 (16.9)	16 (22.5)	14 (19.8)
Female	19 (25.0)	11 (14.5)	13 (17.1)	19 (25.0)	14 (18.4)
Age (years)					
18–28	13 (22.4)	6 (10.3)	9 (15.5)	20 (34.5)	10 (17.3)
29–38	14 (32.6)	7 (16.3)	8 (18.6)	7 (16.3)	7 (16.3)
39–48	7 (25.9)	8 (29.6)	6 (22.2)	3 (11.1)	3 (11.1)
≥49	2 (10.5)	5 (26.3)	4 (21.1)	4 (21.1)	4 (21.1)
Residence					
Urban	20 (19.6)	13 (12.7)	18 (17.6)	36 (35.3)	15 (14.7)
Rural	16 (35.6)	10 (22.2)	7 (15.6)	12 (26.7)	7 (15.6)
Occupational status					
Government employee	4 (30.8)	3 (23.1)	3 (23.1)	3 (23.1)	0 (0.0)
Private job	4 (21.1)	3 (15.8)	4 (21.1)	5 (26.3)	3 (15.8)
Farmer	3 (42.9)	2 (28.6)	1 (14.3)	1 (14.3)	0 (0.0)
Student	3 (25.0)	1 (8.3)	2 (16.7)	4 (33.3)	2 (16.7)
Daily laborer	5 (50.0)	2 (20.0)	2 (20.0)	1 (10.0)	0 (0.0)
Homemaker	1 (33.3)	1 (33.3)	1 (33.3)	0 (0.0)	0 (0.0)
Unemployed	4 (22.2)	4 (22.2)	3 (16.7)	3 (16.7)	4 (22.2)

Table 4: CXR Findings According to Clinical and Behavioral Variables (n = 147)

Variable	Abnormal Chest X-ray				Normal Chest X-ray
	Cavitation n(%)	Pleural Effusion n(%)	Consolidation n(%)	Infiltration n(%)	n(%)
BMI					
<18.5 kg/m²	14 (20.0)	12 (17.1)	13 (18.6)	19 (27.1)	12 (17.1)
≥18.5 kg/m²	22 (28.6)	10 (13.0)	14 (18.2)	19 (24.7)	12 (15.6)
Anemia status					
Yes	18 (23.7)	15 (19.7)	11 (14.5)	19 (25.0)	13 (17.1)
No	18 (25.4)	9 (12.7)	16 (22.5)	19 (26.8)	12 (16.9)
HIV status					
Positive	0 (0.0)	1 (50.0)	0 (0.0)	1 (50.0)	0 (0.0)
Negative	36 (24.8)	23 (15.9)	27 (18.6)	37 (25.5)	22 (15.2)
Comorbidities					
Yes	8 (27.6)	7 (24.1)	6 (20.7)	8 (27.6)	0 (0.0)
No	28 (23.7)	17 (14.4)	21 (17.8)	30 (25.4)	22 (18.6)

Table 5: Multivariable Logistic Regression Analysis of Factors Associated with Abnormal CXR Findings

Variable	Chest X-ray		COR (95% CI)	AOR (95% CI)	P-value
	Abnormal n (%)	Normal n (%)			
Age 18–28	40 (69.0)	18 (31.0)	1.52 (0.68–3.41)	1.10 (0.40–3.02)	0.85
Age 29–38	33 (76.7)	10 (23.3)	1.05 (0.44–2.51)	0.88 (0.30–2.47)	0.81
Age 39–48	21 (77.8)	6 (22.2)	0.96 (0.38–2.47)	1.02 (0.34–3.10)	0.74
Urban residence	76 (74.5)	26 (25.5)	1.38 (0.79–2.42)	1.20 (0.61–2.34)	0.59
Daily laborer	9 (90.0)	1 (10.0)	0.11 (0.01–0.78)	0.12 (0.01–0.60)	0.014
BMI <18.5 kg/m²	51 (72.9)	19 (27.1)	1.18 (0.70–1.95)	1.76 (1.01–3.05)	0.046
HIV positive	1 (50.0)	1 (50.0)	2.10 (1.01–4.25)	0.42 (0.21–0.88)	0.021
Comorbidity present	25 (86.2)	4 (13.8)	0.35 (0.18–0.69)	0.31 (0.14–0.66)	0.001

and immunocompromised conditions may play a role in the more advanced pulmonary radiological features of MDR-TB. (Table 4)

Several factors were important in determining the presence of abnormal CXR findings in a multivariable procedure. Low BMI, HIV positivity, and presence of comorbidities were found to be significant predictor of abnormal CXR pattern, while occupation as a daily labourer was significantly associated with radiological severity. After adjustment, age and place of residence were not statistically significant. These results suggest that clinical and nutritional parameters are more influential than only demographic parameters in the prediction of radiological severity of MDR-TB. (Table 5)

DISCUSSION

The current study aimed to investigate the value of CXR finding in determining the radiological severity of MDR-TB and their correlation with social and demographic and clinical parameters. The results showed that the radiological patterns were abnormal in large proportions, including most cases of cavitation and infiltrative changes, and that there were significant relationships with important clinical and demographic factors. The study revealed that the male gender had a higher proportion of abnormal CXR findings, similar to previous studies showing that males are more likely to be affected by severe pulmonary TB as a result of higher exposure to environmental risk factors and delay in seeking healthcare. Ahmad et al. 2022 reported the same trend in Pakistan where male patients had significantly more cavitary lesions on CXR among MDR-TB patients[16]. Similarly, a large scale screening study by Zaidi et al. in Pakistan also showed that the younger and economically active populations were more likely to be diagnosed with more advanced forms of TBs, in line with the demographic pattern in the present study[17].

In the present study, abnormal chest radiographic findings were significantly higher in underweight individuals (BMI <18.5 kg/m^2). This is in accordance with that of Saqib et al. who found malnutrition to be a strong predictor of atypical and extensive radiological features of TB such as bilateral consolidation and cavitation[18]. Likewise, Khattak et al. noted that poor nutritional status was significantly associated with more bacillary load and greater disease extent in multi-drug resistant TB (MDR-TB) patients[19].

Abnormal CXR pattern was also significantly associated in the current study. This is consistent with other studies showing anemia as a marker of chronic disease burden and immunological suppression in TB patients. In TB patients, Dholakia et al. found that the haematological abnormalities, such as anaemia, were significantly associated with greater pulmonary involvement on X-rays, especially in patients with longer disease duration[20].

In our study, significant comorbidities were diabetes, COPD and cardiovascular disease, all of which showed significant associations with abnormal radiological findings. This was corroborated by previous study by Saqib et al. which reported high risk of development of cavitary lesions and multilobar involvement in TB patients with comorbid conditions[18]. These conditions have been reported to have a negative effect on immune response and are known to exacerbate the effects of disease.

The prevalence of HIV positivity was very low in our study population, but a higher proportion of HIV-positive patients had abnormal CXR findings. The same trend was noted in a study from Pakistan where the presence of HIV was associated with more diffuse and atypical radiological features, with a lack of classic cavitation in MDR-TB patients. However, because of the very few number of HIV positive cases in our study, meaningful statistical inference is limited.

Interestingly, the history of previous first-line and second-line treatment with anti-TB drugs was not strongly associated with the presence of abnormal CXR findings. This result is opposite to Khattak et al. (2022) who found that there was more extensive destruction of the radiograph and that cavitation was more frequent in the treatment failure cases[19.] This difference may be attributed to the variability in treatment adherence and early detection among our study subjects.

Overall, cavitation and infiltration were the predominant radiological characteristics of MDR-TB in this study, consistent with global studies which highlight these as markers of advanced pulmonary destruction. The prevalence of cavitation has also been reported to be widely ranging from 8% to more than 80% in TB patients in general, depending on disease stage and population characteristics[21].

Importantly, contemporary imaging studies have again demonstrated the importance of using CXR as an initial and cost-effective screening test in TB endemic areas, especially for identifying abnormal lung patterns in resource-limited locations[22]. Recently, there have also been advances that make it possible to use radiological pattern recognition as a surrogate marker for disease severity, particularly in areas where advanced imaging such as CT is not readily available.

The study hypothesis was that there is a significant association between socio-demographic and clinical factors and radiological severity of MDR-TB on chest X-ray. This hypothesis is partially supported since the BMI, anemia, sex, age and comorbidities were associated. However, not all clinical variables appeared to have uniform statistical significance, with HIV status and previous history of anti-TB treatment not being significant. The results indicate that nutritional status, systemic comorbidities and demographic factors play a major role in the severity of the disease on chest radiography, which is consistent with the hypothesis that the radiological appearance of the disease is greatly determined by host factors.

Limitations: As a single center cross-sectional study, the relationship between socio-demographic and clinical

parameters and the radiological severity of MDR-TB could not be determined. This may have contributed to the fact that subtle or early changes in the lungs were not detected, which could have been better characterized using advanced imaging techniques like CT scan. Further, the size of the subgroups, especially the HIV-positive group, was relatively small which limited more powerful statistical comparisons. Self-reported clinical and treatment history may also be subject to recall bias, with an attempt to confirm information using medical records.

Recommendations: Future studies to further assess the causal association between risk factors and radiological progression of MDR-TB are suggested, which should be done in a multicenter longitudinal study with more number of participants. Advanced imaging techniques like high-resolution computed tomography could help give a more detailed picture of the severity of the disease and structural lung damage, in addition to chest X-ray. Routine screening of high-risk groups, including those with undernutrition and patients with comorbidities, could help to detect severe radiological patterns earlier. In addition, use of radiologic scoring systems for clinical practice is recommended to enhance the standardization of MDR-TB severity and treatment response. Using validated TB radiology scoring systems like, the Timika score or other standardised TB radiographic severity scores, would further improve objectivity and reproducibility.

CONCLUSION

Abnormal CXR findings are common among MDR-TB patients, and that low BMI, anemia and presence of comorbidities are significantly associated with abnormal CXR findings. Radiological features like cavitation and infiltration are still significant indicators of the severity of the disease. These results validate the utility of CXR as a useful and cost-effective tool for determining the severity of MDR-TB when using it in areas with limited resources and underscore the need to identify high-risk groups early to optimize clinical outcomes.

ETHICAL APPROVAL: *Ref No. 102/ERC/ACD dated 03/01/2022.*

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AUTHORS' CONTRIBUTION

- ***Sajjad Ali:*** *Conceptualization of study, supervision of research work, and final approval of manuscript.*
- ***Laila Khan:*** *Study design, radiological interpretation, and critical revision of the manuscript.*
- ***Aleina Ali Shah:*** *Data collection, literature review, and manuscript drafting.*
- ***Rumman:*** *Statistical analysis, interpretation of results, and preparation of tables.*
- ***Akmal Naveed:*** *Data acquisition, clinical evaluation of patients, and proofreading of the manuscript.*
- ***Umair Zaman:*** *Manuscript editing, review of references, and coordination of final submission.*

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