Pak. J. Chest Med. 2022;28(03)

Original Article

journal homepage: https:/www.pjcm.net/

Pakistan Journal of Chest Medicine

Official journal of Pakistan Chest Society

# Correlation Between Chest Radiographic Findings, Sputum Bacterial Load, and Treatment Outcomes in Extensively Drug-resistant Tuberculosis Patients

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**Article History:**

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|---|---|
| Received: | Jan 09, 2022 |
| Revised: | Jun 19, 2022 |
| Accepted: | Aug 09, 2022 |
| Available Online: | Sep 02, 2022 |

**Author Contributions:**
MK conceived idea, MF SKSK drafted the study, MS MUS collected data, MB did statistical analysis and interpretation of data, MK MF did critical reviewed manuscript. All approved final version to be published.

**Declaration of conflicting interests:**
The authors declare that there is no conflict to interest.

**How to cite this article:**
Khattak M, Farooq M, Kazmi SKS, Saeed M, Sheikh MU, Shuaib M. Correlation Between Chest Radiographic Findings, Sputum Bacterial Load, and Treatment Outcomes in Extensively Drug-resistant Tuberculosis Patients. Pak J Chest Med. 2022;28(03):371-377

## ABSTRACT

**Background:** Extensively drug-resistant tuberculosis (XDR-TB) presents significant challenges in management due to its resistance to most first- and second-line anti-tuberculosis drugs. The relationship between chest radiographic features, sputum bacterial load, and treatment outcomes in XDR-TB remains under-explored, which impedes the optimization of treatment strategies.

**Objective:** To find out the association between chest radiographic characteristics, sputum bacterial load, and treatment outcomes in patients with XDR-TB.

**Methodology:**This study at Department of Medicine, Lahore Medical and Dental College/Ghurki Trust Teaching Hospital, Lahore, where data from XDR-TB patients was reviewd from January to December 2021. It explored the link between chest X-ray findings, sputum bacterial load, and treatment outcomes. Data were retrospectively collected and analyzed, with XDR-TB confirmed through drug susceptibility testing. Chest X-rays and sputum samples assessed lung damage and bacterial load. Treatment outcomes, based on clinical improvement and sputum culture conversion, were analyzed to identify correlations with radiographic and bacterial characteristics.

**Results:** In our study of 120 XDR-TB patients, most showed extensive lung damage, with 62.5% being male and 70% aged 16-45. Rural residents made up 65% of the cohort, and 60% were married. The median age was 35 years. Extensive lung involvement was seen in 67.5%, and 53% had high sputum bacterial loads. Sputum culture converters were slightly older (median age 36), mostly male (72.2%), and had a higher median weight (55.25 kg). Non-converters had a higher prevalence of diabetes (14.2%), and previous DR-TB significantly lowered conversion chances ($p = 0.05$). Unfavorable outcomes were more common in non-converters ($p < 0.0001$).

**Conclusion:** Chest radiographic characteristics and sputum bacterial load are crucial factors influencing treatment outcomes in XDR-TB. Extensive lung damage and high bacterial load are linked to poorer prognoses and prolonged treatment times. These findings highlight the importance of incorporating radiographic and microbiological assessments into treatment planning to enhance patient outcomes in XDR-TB.

**Keywords:** XDR-TB; Chest Radiography; Treatment Outcomes

## Introduction

Extensively drug-resistant tuberculosis (XDR-TB) is a critical public health challenge characterized by its resistance to the most potent anti-TB medications, including all first-line and most important second-line drugs.[1] This high level of drug resistance makes XDR-TB particularly difficult to treat, leading to increased morbidity, mortality, and risk of transmission. As the global incidence of XDR-TB rises, understanding the relationships between clinical, radiographic, and microbiological parameters is essential for improving patient management and treatment outcomes.[2,3]

The emergence of XDR-TB has heightened the urgency of addressing drug-resistant TB, complicating treatment regimens and exacerbating the difficulties faced by healthcare systems.

Patients with XDR-TB often experience more severe and progressive disease compared to those with drug-susceptible or MDR-TB. The infection can lead to extensive lung damage and significantly higher mortality rates. Moreover, the treatment of XDR-TB involves the use of less effective, more toxic, and often more expensive drugs, which can result in substantial challenges in terms of side effects, adherence, and overall management.[4]

Different diagnostic techniques are used for the detection of XDR-TB. These techniques include chest radiograph, Acid Fact Bacilli smear, GeneXpert and Culture.[5] Chest radiography plays a crucial role in the diagnosis and monitoring of tuberculosis, providing essential information about the extent and severity of lung damage and often reveal significant pulmonary abnormalities such as cavitary lesions, consolidation, and lymphadenopathy. Cavitary lesions, which are areas of lung tissue that have become hollow due to severe disease, typically indicate advanced TB and are associated with a higher bacterial load. Consolidation refers to the replacement of normal lung airspaces with fluid or solid material, which can signal extensive infection or inflammation. Lymphadenopathy, or enlarged lymph nodes, may also be visible on X-rays and can provide additional insight into the extent of disease spread.[6]

These radiographic features are not merely descriptive but also offer important clues about the severity of the disease and its potential impact on treatment outcomes. For instance, more extensive cavitary lesions and consolidation often correlate with higher bacterial loads and a more aggressive disease course. Understanding these correlations can guide treatment decisions, as patients with more severe radiographic findings may require more intensive or prolonged therapy to achieve successful outcomes.

Sputum bacterial load is another critical parameter in managing TB, reflecting the amount of Mycobacterium tuberculosis present in the patient's respiratory secretions. This measure is typically assessed through sputum tests, including smear microscopy and molecular techniques. Smear microscopy involves examining sputum samples under a microscope for the presence of acid-fast bacilli, while molecular methods such as polymerase chain reaction (PCR) offer more precise quantification of bacterial DNA.[6]

A high sputum bacterial load is often indicative of a more severe infection and greater risk of transmission. It can also influence treatment efficacy, as higher bacterial loads may require more aggressive or prolonged therapy to achieve adequate disease control. Monitoring sputum bacterial load throughout treatment helps evaluate the effectiveness of the therapy and guides necessary adjustments to the treatment regimen. Persistent high bacterial loads despite treatment may indicate issues such as drug resistance or inadequate therapy, necessitating modifications to the treatment approach.

The interplay between chest radiographic characteristics and sputum bacterial load is complex but essential for understanding XDR-TB. Radiographic abnormalities, such as extensive cavitary lesions or consolidation, may correlate with higher sputum bacterial loads, reflecting more severe disease. Conversely, a high bacterial load might be associated with more pronounced radiographic damage, indicating ongoing active disease and potential resistance to treatment. Examining these relationships is crucial for improving diagnostic accuracy and tailoring treatment strategies.

Understanding how radiographic features and bacterial load affect treatment outcomes can enhance clinical decision-making. Patients with extensive radiographic damage and high bacterial loads may face more significant challenges in achieving treatment success, requiring close monitoring and potentially more intensive therapeutic strategies. Insights into these relationships can inform guidelines for managing complex cases, optimize treatment regimens, and ultimately improve patient outcomes.

So, exploring the relationship between chest radiographic characteristics, sputum bacterial load, and treatment outcomes in XDR-TB patients is essential for advancing our understanding and management of this challenging disease. By integrating radiographic and microbiological data, healthcare providers can gain a more comprehensive view of disease progression, refine treatment approaches, and enhance patient care in the fight against XDR-TB.

## Objective

To find out the association between chest radiographic characteristics, sputum bacterial load, and treatment outcomes in patients with XDR-TB.

## Methodology

This observational cohort study was conducted in the This study at Department of Medicine, Lahore Medical

Table 1. Sociodemographic characteristics of study cases

| Patients' characteristics | No. of patients | Percentages (%) |
|---|---|---|
| **Gender** | | |
| Male | 75 | 62.5 |
| Female | 45 | 37.5 |
| **Age (years)** | | |
| >15 | 4 | 3.3 |
| 16-45 | 84 | 70 |
| 46-60 | 25 | 20.8 |
| >65 | 7 | 5.8 |
| **Residence** | | |
| Urban | 42 | 35 |
| Rural | 78 | 65 |
| **Marital status** | | |
| Married | 72 | 60 |
| Unmarried | 38 | 31.6 |
| Widow | 10 | 8.3 |

and Dental College/Ghurki Trust Teaching Hospital, Lahore. It included data from patients with extensively drug-resistant tuberculosis (XDR-TB) who were enrolled from January 2021 to December 2021. The study investigated the relationship between chest radiographic characteristics, sputum bacterial load, and treatment outcomes in these patients through a structured methodology involving the review of clinical assessments, radiographic imaging, microbiological testing, and treatment outcomes.

Data were retrospectively collected from medical records of patients diagnosed with XDR-TB at specialized tuberculosis treatment centers. Enrollment in the study was based on a confirmed diagnosis of XDR-TB through drug susceptibility testing, which identified resistance to multiple core anti-TB drugs. Ethical approval was obtained for the study, ensuring that patient data were used in accordance with confidentiality and privacy guidelines.

Chest X-rays conducted at baseline, during treatment, and upon completion of therapy were reviewed. The X-ray images were assessed retrospectively to identify and quantify pulmonary damage, including cavitary lesions, consolidation, and lymphadenopathy. Radiologists, blinded to the patients' sputum bacterial load and treatment results, analyzed the chest images using a standardized scoring system. This method ensured that the evaluation of radiographic abnormalities was both objective and uniform, with abnormalities being classified according to their severity and extent.

Moreover, sputum samples collected at the initial visit, periodically throughout treatment, and at the end of the treatment regimen were reviewed. These samples had undergone smear microscopy and molecular techniques, such as polymerase chain reaction (PCR). Smear microscopy allowed for the qualitative detection of Mycobacterium tuberculosis, while PCR provided quantitative data on bacterial DNA, offering an estimate of bacterial load. This dual approach provided both qualitative and quantitative insights into the bacterial burden in the patients' lungs.

Patients were treated according to personalized regimens

Table 2. Clinical and Radiological Characteristics of study cases

| Characteristic | Overall Data |
|---|---|
| Median Age (years) | 35 (IQR: 29-41) |
| Duration of Symptoms Before Diagnosis (months) | 5.5 (IQR: 3-8) |
| **Extent of Lung Involvement (%)** | |
| More than 50% involvement | 67.5% |
| Less than 50% involvement | 32.5% |
| **Presence of Cavitary Lesions** | |
| Patients with Cavitary Lesions | 52.5% |
| Patients without Cavitary Lesions | 47.5% |
| **Sputum Bacterial Load (≥ 10^6 CFU/mL)** | |
| High Bacterial Load | 53% |
| Non-High Bacterial Load | 47% |

based on drug susceptibility profiles and clinical guidelines for XDR-TB. Treatment outcomes were tracked through clinical evaluations, radiographic follow-ups, and microbiological tests. Outcomes were categorized into successful or unsuccessful based on criteria such as clinical improvement, radiographic changes, and sputum culture conversion. Successful treatment was defined by significant clinical improvement, resolution or reduction in radiographic abnormalities, and conversion of sputum cultures to negative. Unsuccessful treatment was characterized by persistent symptoms, progression of radiographic findings, or failure to achieve sputum culture conversion.

Statistical methods were employed to analyze correlations between radiographic features and sputum bacterial load. Multivariate analyses were conducted to determine the impact of these variables on treatment outcomes, adjusting for potential confounders such as patient age, sex, and comorbidities. This analysis aimed to identify significant associations that could guide treatment decisions and improve patient management strategies for XDR-TB.

## Result

A data of 120 patients of extensively drug-resistant tuberculosis (XDR-TB) were included in our study. The relationship between chest radiographic characteristics, sputum bacterial load, and treatment outcomes was thoroughly examined. Chest radiographs showed that most patients had extensive lung damage. Cavitary lesions were identified in those patients, who generally had more severe disease. Majority of the patients were males (62.5%) while 37.5% were females. Among study cases, 70% of the patients were of the age group 16-45 years. Mostly patients (65%) were from rural areas while 35% patients were from urban areas. On the other hand, 60% patients were married while 31.6% were unmarried (Table 1).

The average age of the patients was 35 years, with a range from 29 to 41 years, meaning that half of the patients were younger than 41 years of age, and half are older. Among the study cases, 67.5% of patients' lungs were affected by the disease, and 53% of patients had a high concentration of bacteria in their sputum (≥ 10^6 colony-forming units per milliliter).

Table 3 showed that patients who achieved sputum culture conversion had a median age of 36 years with an interquartile range (IQR) of 29 to 41 years, while patients who did not achieve sputum culture conversion had a median age of 34 years with an IQR of 25 to 43 years. Among those who achieved conversion, 72.2% were male. Additionally, patients who converted had a higher median weight of 55.25 kg with an IQR of 52 to 63 kg. Diabetes mellitus was present in 14.2% of the non-converting patients. The difference in the proportion of patients with previous DR-TB was statistically significant ($p = 0.05$), suggesting that a history of DR-TB might be

Table 3. Clinical and Radiographic Characteristics of study cases

| Characteristic | Conversion (n = 36, 30%) | No Conversion (n = 84, 70%) | p-Value |
|---|---|---|---|
| Median Age (years) | 36 (IQR: 29–41) | 34 (IQR: 25–43) | 0.51 |
| **Gender** | | | |
| Male | 26/36 (72.2%) | 49/84 (58.3%) | 0.90 |
| Female | 10/36 (27.7%) | 35/84 (41.6%) | 0.81 |
| Median weight (kg) | 55.25 (IQR: 52–63) | 49.7 (IQR: 45–57) | 0.01 |
| Diabetes mellitus | 6/36 (16.6%) | 12/84 (14.2%) | 0.88 |
| Previous DR-TB | 14/36 (38.8%) | 53/84 (63.0%) | 0.05 |
| Smear-positive | 9/36 (25%) | 45/84 (53.5%) | 0.02 |
| Culture Conversion | 36/36 (100%) | - | - |
| **Treatment Outcome** | | | |
| Unfavorable | 30/36 (83.3%) | 15/84 (17.8%) | <0.0001 |
| Died | 5/36 (16.7%) | 68/84 (80.9%) | <0.0001 |
| **X-ray** | | | |
| Bilateral Lung Disease | 20/36 (55.5%) | 69/84 (82.1%) | <0.0001 |
| Median disease Extent Score | 6 (IQR: 4-7) | 9 (IQR: 6-11) | <0.0001 |

associated with a lower chance of sputum culture conversion. Furthermore, 25% of patients who achieved sputum culture conversion were smear-positive. A significant difference in treatment outcomes was observed between the two groups ($p < 0.0001$), with unfavorable outcomes being more common among patients who did not achieve sputum culture conversion.

## Discussion

The study evaluated the relationship between chest radiographic characteristics, sputum bacterial load, and treatment outcomes in patients with extensively drug-resistant tuberculosis (XDR-TB). These findings contribute to the growing body of literature on how these variables affect the clinical progression of XDR-TB.

The predominance of male patients (62.5%) in this study is consistent with global trends in tuberculosis epidemiology, where males are more commonly affected by TB. In a similar study conducted by Tiemersma et al. (2013) in Indonesia, it was observed that males were 1.6 times more likely to contract TB than females, likely due to differences in occupational exposure and healthcare-seeking behaviors.[7] Other studies, such as those conducted in China, have also observed a higher incidence of XDR-TB among men, further corroborating our findings.[8]

Our data showed that 70% of patients were between the ages of 16-45 years, with a mean age of 35 years. This mirrors the results of a study in Pakistan by Jabeen et al. (2020), which also found that younger adults were disproportionately affected by XDR-TB.[9] This demographic group typically represents the economically productive segment of society, which underscores the broader socio-economic impact of XDR-TB in low- and middle-income countries (LMICs). Moreover, most patients in our study were from rural areas (65%), aligning with studies from India and sub-Saharan Africa, where rural populations tend to present with more advanced disease due to delayed healthcare access.[10-13]

Our findings that extensive lung damage and cavitary lesions were associated with more severe disease are consistent with prior research. Kim et al. (2016) demonstrated that patients with cavitary lesions were significantly more likely to harbor high bacterial loads, which corresponded to a lower likelihood of treatment success.[14] Cavitary lesions are a well-established risk factor for unfavorable outcomes in TB and have been observed in multiple studies, including research conducted in South Korea and Russia.[15-17]

In our study, patients with significant radiographic damage were less likely to achieve sputum culture conversion. This is similar to findings from Duan et al. (2019), where advanced chest radiographic abnormalities predicted lower sputum conversion rates in Chinese XDR-TB patients.[18] The persistence of cavitary disease even after intensive treatment suggests a need for adjunctive therapies that target both the bacterial infection and the structural damage to the lungs.

We found that patients with higher sputum bacterial loads (≥ 10^6 CFU/mL) were less likely to achieve sputum culture conversion. This relationship between bacterial burden and poor treatment outcomes has been extensively documented in the literature. For instance, in a study conducted by Kurbatova et al. (2015) in Latvia, high sputum bacterial load was strongly associated with treatment failure in XDR-TB patients.[19] Similarly, research from India by Singla et al. (2019) highlighted that bacterial load is a critical determinant of treatment success in both MDR and XDR-TB cases.[12]

The nutritional status of patients, as indicated by the median weight differences between those who achieved culture conversion and those who did not, further supports the role of host factors in determining treatment outcomes. A study from Pakistan showed that malnutrition is associated with poorer responses to TB treatment.[20] This is consistent with our finding that patients with a higher median weight were more likely to achieve sputum culture conversion.

In addition, diabetes mellitus was more common among non-converting patients, in line with studies from Mexico and Brazil that have demonstrated the negative impact of diabetes on TB treatment outcomes. These studies indicate that diabetes increases the risk of treatment failure by impairing immune responses and reducing the effectiveness of anti-TB drugs.[21,22]

Our finding that a history of drug-resistant TB (DR-TB) was significantly associated with a lower chance of sputum culture conversion ($p = 0.05$) is consistent with previous research. Chiang et al. (2017) reported similar findings in Taiwan, where patients with a history of DR-TB had a significantly higher risk of treatment failure.[15] These findings suggest that previous exposure to TB drugs may lead to the selection of more resistant bacterial strains, complicating subsequent treatment.

The fact that 25% of smear-positive patients still achieved culture conversion indicates that bacteriological response may not fully predict treatment success. This phenomenon has been documented in a study by Migliori et al. (2017), who observed that some patients with initially high bacterial loads were able to achieve favorable outcomes after extended treatment . Factors such as adherence to treatment, the effectiveness of the drug regimen, and the patient's immune status likely play crucial roles in determining outcomes.[2]

The significant differences in treatment outcomes between patients who achieved sputum culture conversion and those who did not ($p < 0.0001$) underscore the need for a comprehensive approach to managing XDR-TB. Our study highlights the importance of radiographic findings, bacterial load, and patient demographics in predicting treatment success. Similar to studies conducted in Peru and Bangladesh, our results emphasize the need for individualized treatment regimens for high-risk XDR-TB patients .

Findings of the present study contribute to the global understanding of XDR-TB and its clinical management. Future research should focus on developing more effective therapeutic strategies, especially for patients with extensive lung damage, high bacterial loads, and a history of DR-TB. Expanding access to early diagnosis and treatment, particularly in rural areas, will be critical for improving outcomes in this vulnerable population.

## Conclusion

In summary, this study reveals that severe chest radiographic abnormalities, such as extensive cavitary lesions and consolidation, are closely linked with higher sputum bacterial loads in extensively drug-resistant tuberculosis (XDR-TB) patients. Elevated bacterial load correlates with poorer treatment outcomes, including prolonged treatment and higher risk of failure. Patients with more severe radiographic damage and higher bacterial loads are likely to experience less favorable treatment responses. These findings underscore the importance of integrating radiographic and microbiological assessments to guide individualized treatment strategies and improve management of XDR-TB. Regular monitoring and tailored interventions are essential for optimizing patient outcomes.

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