Original Article

Analysis of CXCL11 Levels and Chest X-Ray Findings In Drug-Sensitive and Drug-Resistant Tuberculosis Patients

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Abstract

Background: Tuberculosis (TB) remains a major global health problem, with an increasing incidence of drug-resistant tuberculosis (DR-TB) contributing to low treatment success rates. This study aimed to evaluate the association between serum CXCL11 levels and chest X-ray severity in pulmonary tuberculosis and to compare CXCL11 levels between drug-sensitive and drug-resistant tuberculosis patients.

Methods: This was an observational analytic study with a cross-sectional design. The study subjects were patients with drug-sensitive tuberculosis (DS-TB) and DR-TB who were hospitalized or followed up. Serum CXCL11 levels were measured using the enzyme-linked immunosorbent assay (ELISA) method. Chest X-ray findings were assessed based on the severity of pulmonary lesions. Statistical analysis was performed to compare CXCL11 levels and chest X-ray severity between the two groups and to evaluate the correlation between them.

Results: CXCL11 levels were higher in patients with DR-TB compared to those with DS-TB. Chest X-ray findings in DR-TB patients showed greater severity, with more extensive lesions and multiple cavitations. A significant correlation was found between CXCL11 levels and the severity of radiological findings in both DS-TB and DR-TB patients ($r = 0.477$; $P<0.05$).

Conclusion: CXCL11 levels are higher in patients with DR-TB than in those with DS-TB and are associated with the severity of chest X-ray findings. CXCL11 has the potential to be used as an inflammatory biomarker to assist in stratifying drug sensitivity in tuberculosis patients.

Keywords: chest X-ray, CXCL11, drug-sensitive tuberculosis, drug-resistant tuberculosis, tuberculosis

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INTRODUCTION

Tuberculosis (TB) remains a significant global health challenge, with more than 10 million people still infected each year, according to the Global Tuberculosis Report 2024. TB cases are predominantly drug-sensitive (DS-TB) at 85–90%, but around 10–15% are drug-resistant (DR-TB), with increasing resistance in countries such as Indonesia. Drug-resistant TB is more challenging to treat, with lower success rates compared to drug-sensitive TB, especially in Indonesia, which ranks second globally for TB burden.[1–3]

A key issue in TB management is misdiagnosis, where drug-resistant TB is often mistaken for drug-sensitive TB due to false-negative diagnostic results. This leads to ineffective treatment, worsening patient conditions, and the continued spread of resistant strains. Identifying biomarkers such as CXCL11 may improve our understanding of the inflammatory response in tuberculosis and its association with disease severity, although their role in distinguishing drug-sensitive from drug-resistant tuberculosis remains uncertain.[4,5]

The CXCL11 levels have been shown to correlate with inflammation in patients with tuberculosis, with higher levels being associated with more extensive pulmonary inflammation and radiological abnormalities. However, research on the relationship between serum CXCL11 levels and chest X-ray severity, particularly across different drug-resistance profiles, remains limited.[6,7]

Therefore, the primary objective of this study was to evaluate the association between serum CXCL11 levels and chest X-ray severity in patients with pulmonary tuberculosis, which can contribute to more accurate diagnostic strategies for TB management. A secondary objective was to compare

serum CXCL11 levels between drug-sensitive and drug-resistant tuberculosis patients.

METHODS

This study was an analytical observational study with a cross-sectional design and involved patients diagnosed with DS-TB or DR-TB through bacteriological testing. The research was conducted at several hospitals in East Java, including RSUD Dr. Saiful Anwar Malang, RS Universitas Muhammadiyah Malang, RSUD Ngudi Waluyo Wlingi, and RSU Karsa Husada Batu.

The study population consisted of DS-TB and DR-TB patients undergoing treatment at these hospitals. A purposive sampling method was used, selecting patients confirmed by sputum microscopy, GeneXpert MTB/RIF, or *Mycobacterium tuberculosis* culture. Patients were divided into two groups, DS-TB and DR-TB, with a minimum sample size for each group of 33 subjects, accounting for a 10% dropout rate.

Inclusion criteria included patients diagnosed with DS-TB or DR-TB, aged 18 years or older, in stable condition, and willing to participate after informed consent. Exclusion criteria included patients with comorbidities that would affect CXCL11 levels or chest X-ray results. Exclusion criteria included patients with comorbid lung diseases, such as chronic obstructive pulmonary disease (COPD) or asthma, that may affect the results.

The independent variables were DS-TB and DR-TB status, while the dependent variable was chest X-ray findings. Confounding variables included age, gender, BMI, smoking history, disease duration, and comorbidities.

Data collection involved venous blood samples for serum CXCL11 measurement using a commercially available Human I-TAC/CXCL11 (Interferon-Inducible T-cell Alpha Chemoattractant) ELISA Kit (ELABSCIENCE, Wuhan, China; Catalog No. E-EL-H0051), according to the manufacturer's instructions. Chest radiographs were independently reviewed by two experienced pulmonologists who were blinded to the serum CXCL11 results. Chest X-ray severity was classified into mild, moderate, and severe categories based on the extent of pulmonary lesions and the presence of cavitary lesions using predefined radiographic criteria. Any discrepancies in interpretation were resolved by consensus. Clinical data, including age, sex, body mass index (BMI), smoking history, disease duration, and comorbidities, were also collected from medical records.

The numeric data were assessed for normal distribution, and the results were found not to be normally distributed. The categorical data were assessed with the Chi-square test for differences in the distribution of patients' demographics among the groups. The CXCL11 levels between the groups were also assessed using the Kruskal-Wallis test and the Mann-Whitney U test between the TB groups. A value of $P<0.05$ indicates a statistically significant result.

RESULTS

A total of 88 subjects were analyzed to describe the sociodemographic and clinical characteristics of the respondents. General characteristics were obtained through descriptive analysis. The detailed distribution of sociodemographic characteristics of all subjects is presented in Table 1.

Table 1. Demographics of patients

Variables	Healthy Control (n=26)	DS-TB (n=32)	DR-TB (n=30)	*P*
Age, years				
19–25	0 (0.0%)	4 (12.5%)	5 (16.7%)	
26–35	24 92.3%)	2 (6.3%)	9 (30.0%)	
36–50	2 (7.7%)	5 (15.6%)	5 (16.7%)	0.0001*
51–65	0 (0.0%)	10 (31.3%)	9 (30.0%)	
>65	0 (0.0%)	11 (34.4%)	2 (6.7%)	
Gender				
Male	11 (42.3%)	22 (68.8%)	19 (63.3%)	0.106*
Female	15 (57.7%)	10 (31.3%)	11 (36.7%)	
Occupation				
Housewife	0 (0.0%)	7 (25.0%)	11 (23.3%)	
Student	0 (0.0%)	4 (12.5%)	3 (10.0%)	
Entrepreneur	0 (0.0%)	7 (21.9%)	7 (23.3%)	0.0001*
Laborer	0 (0.0%)	7 (21.9%)	6 (20.0%)	
Doctor	26 (100.0%)	0 (0.0%)	0 (0.0%)	
Private	0 (0.0%)	4 (12.5%)	2 (6.7%)	

Table 1. Demographics of patients (continued)

Variables	Healthy Control (n=26)	DS-TB (n=32)	DR-TB (n=30)	*P*
BMI				
Underweight	1 (3.8%)	10 (31.3%)	12 (40.0%)	
Normal	7 (26.9%)	20 (62.5%)	17 (56.7%)	
Overweight	14 (53.8%)	2 (6.3%)	0 (0.0%)	0.0001*
Obese Gr. I	2 (7.7%)	0 (0.0%)	1 (3.3%)	
Obese Gr. II	2 (7.7%)	0 (0.0%)	0 (0.0%)	
TB Treatment History				
New Case	0 (0.0%)	29 (90.6%)	21 (70.0%)	
Relapsed Case	0 (0.0%)	3 (9.4%)	8 (26.7%)	0.0001*
Treatment Failure	0 (0.0%)	0 (0.0%)	1 (3.3%)	
None	26 (100.0%)	0 (0.0%)	0 (0.0%)	
Comorbidity				
None	26 (100.0%)	20 (62.5%)	24 (80.0%)	
DM	0 (0.0%)	5 (15.6%)	6 (20.0%)	
Hypertension	0 (0.0%)	3 (9.4%)	0 (0.0%)	0.033*
COPD	0 (0.0%)	1 (3.1%)	0 (0.0%)	
DM+HT	0 (0.0%)	2 (6.3%)	0 (0.0%)	
Malignancy	0 (0.0%)	1 (3.1%)	0 (0.0%)	
BCG Vaccination Status				
Yes	26 (100.0%)	22 (68.8%)	24 (80.0%)	
No	0 (0.0%)	6 (18.8%)	2 (6.7%)	0.027*
Unknown	0 (0.0%)	4 (12.5%)	4 (13.3%)	
HIV Status				
Yes	0 (0.0%)	0 (0.0%)	1 (3.3%)	
No	26 (100.0%)	30 (93.8%)	24 (80.0%)	0.106
Unknown	0 (0.0%)	2 (6.3%)	5 (16.7%)	
Smoking History				
Yes	0 (0.0%)	14 (43.8%)	15 (50.0%)	0.0001
No	26 (100.0%)	18 (56.3%)	15 (50.0%)	
Brinkman Index				
Score 1	0 (0.0%)	2 (16.7%)	3 (25.0%)	
Score 2	0 (0.0%)	5 (41.7%)	8 (66.7%)	0.169
Score 3	0 (0.0%)	5 (41.7%)	1 (8.3%)	
Alcohol Consumption History				
Yes	0 (0.0%)	0 (0.0%)	0 (0.0%)	---
No	26 (100.0%)	32 (100.0%)	30 (100.0%)	
TB Contact History				
Yes	0 (0.0%)	0 (0.0%)	8 (26.7%)	0.0001*
No	26 (100.0%)	32 (100.0%)	22 (73.3%)	

Note: *significant with *P*<0.05; BMI=body mass index; COPD=chronic obstructive pulmonary disease; DM=diabetes mellitus; HT=hypertension; BCG=Bacillus Calmette-Guérin; HIV=*Human Immunodeficiency Virus*; TB=tuberculosis

In the DS-TB group, the majority of respondents were older, with the largest proportion being elderly (>65 years) at 34.4%, followed by older adults (51–65 years) at 31.3%. In the DR-TB group, there was a more even age distribution, with the largest proportions in the young adult (26–35 years) and older adult (51–65 years) groups, each at 30%. The control group mostly consisted of young adults (26–35 years) at 92.3%. The age distribution across the groups showed a statistically significant difference (*P*=0.0001), indicating that TB patients were generally older than the control group.

In the DS-TB group, 68.8% of the respondents were male, similar to the DR-TB group, where 63.3% were male. In the control group, 57.7% of the respondents were female. However, the Chi-square analysis showed no significant gender difference between the groups (*P*=0.106), indicating that gender did not significantly differentiate TB status in this study.

The distribution of occupation was similar across the DS-TB and DR-TB groups, with the largest proportion of respondents being housewives (25% and 23.3%, respectively). Chi-square analysis showed a statistically significant difference in occupation distribution between the groups (*P*=0.0001).

In the DS-TB group, the majority were of normal weight (62.5%), while 31.3% were underweight. In the DR-TB group, 56.7% had a normal BMI, with 40% being underweight. Otherwise, the control group showed a higher proportion of overweight individuals (53.8%). These differences highlight that TB patients showed significant differences among the groups, particularly those with DR-TB, who are more likely to have lower nutritional status compared to the control group (*P*=0.0001).

In the DS-TB group, most patients were new cases (90.6%), while 9.4% had a history of recurrence. In the DR-TB group, 70% were new cases, with a higher proportion of recurrent cases (26.7%). Chi-square analysis showed a significant difference in treatment history distribution across the groups (*P*=0.0001).

The majority of respondents across all groups did not have comorbid conditions. Among those with comorbidities, diabetes mellitus was most common in both TB groups. The Chi-square test showed a significant difference in comorbidity distribution (*P*=0.033), indicating that comorbid conditions, especially DM, were more common in TB patients compared to the control group.

The BCG vaccination status varied across groups. A higher proportion of DR-TB patients (80%) had a history of BCG vaccination compared to DS-TB patients (68.8%). Meanwhile, in the control group, all respondents had received the BCG vaccine. The Chi-square test showed a significant difference in vaccination status between the groups (*P*=0.027), suggesting that BCG vaccination may protect against TB infection. On the other hand, based on HIV status, most respondents in all groups tested negative for HIV. However, no significant differences in HIV status were found between the groups (*P*=0.106), indicating that HIV status did not significantly differentiate the TB groups from the control group.

The Brinkman index showed that most DS-TB and DR-TB patients were exposed to moderate or heavy smoking, with a higher exposure rate compared to the control group. However, no statistically significant differences in Brinkman Index were found between the groups (*P*=0.169). Meanwhile, based on smoking history, statistically significant differences in smoking history were found between the groups (*P*=0.0001).

All respondents in the DS-TB group had no history of contact with TB patients, and 26.7% of the DR-TB group reported having contact with TB patients, while the rest did not, with statistically significant differences found between the groups (*P*=0.0001). On the other hand, None of the respondents in any of the groups reported alcohol consumption, indicating that alcohol did not differentiate between the TB and control groups.

Table 2. The difference in CXCL11 levels between healthy controls, drug-sensitive TB, and drug-resistant TB

Groups	CXCL11 value (pg/dl) [Median (Min–Max)]	*P*	
Healthy Control	50.735 (38.28–122.99)		---
DS-TB	298.73 (38.04–2195.28)	0.0001[a]	0.549[b]
DR-TB	237.045 (27.72–2399.55)		

Note: *significant with *P*<0.05; [a]Kruskal-Wallis test; [b]Mann-Whitney U test

The comparison of CXCL11 levels among the groups showed significant differences among the three groups, with *P*=0.0001. Meanwhile, no significant differences in serum CXCL11 levels between the DS-TB and DR-TB groups (*P*=0.549). These findings indicate that serum CXCL11 levels distinguish patients with active tuberculosis from healthy individuals but do not differentiate between DS-TB and DR-TB.

Table 3. Comparison of chest X-ray lesion severity in healthy controls, drug-sensitive TB, and drug-resistant TB

Group	Chest X-ray				*P*
	Normal	Mild lesion	Moderate lesion	Severe lesion	
Healthy Control	26 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.0001*
DS-TB	0 (0.0%)	2 (6.3%)	21 (65.6%)	9 (28.1%)	
DR-TB	0 (0.0%)	2 (6.7%)	17 (56.7%)	11 (36.7%)	

Note: *significant with *P*<0.05

The comparison of chest X-ray findings across the groups revealed significant differences in the severity of lung lesions, with *P*=0.0001. However, there was no clear distinction between DS-TB and DR-TB in terms of radiological severity (Table 3).

Table 4. Correlation between serum CXCL11 levels and chest X-ray

Chest X-ray	CXCL11 value (pg/dl) [Median (Min–Max)]	*P*	*r*
Normal	70.735 (38.28-122.99)	0.0001*	0.477
Mild lesion	185.50 (39.12-1520.00)		
Moderate lesion	278.600 (38.04-2399.55)		
Severe lesion	512.95 (52.70-2399.55)		

Note: *significant with *P*<0.05

A significant positive correlation was observed between serum CXCL11 levels and chest X-ray severity (r = 0.477; *P*<0.001), indicating that higher serum CXCL11 levels suggest that serum CXCL11 reflects the inflammatory response associated with radiological severity in pulmonary tuberculosis (Table 4).

DISCUSSION

This study revealed significant differences in CXCL11 plasma levels between TB patients and healthy controls. The CXCL11 levels in DS-TB and DR-TB were significantly higher than those in healthy controls (*P*=0.0001). The highest median CXCL11 level was found in the DS-TB group (298.73 pg/mL), followed by DR-TB (237.045 pg/mL), with the healthy controls showing much lower levels (50.735 pg/mL). These findings suggest that serum CXCL11 levels are associated with active pulmonary TB and may

reflect the host inflammatory response during active infection. CXCL11 plays a key role in recruiting effector T cells, particularly $CD4^+$ Th1 and $CD8^+$ cytotoxic T cells, to the infection site.[8]

The increase in CXCL11 in active TB reflects the activation of the host's immune response against *Mycobacterium tuberculosis*. CXCL11, induced by interferon-gamma (IFN-γ), is crucial for Th1 immune responses. It recruits immune cells to infection sites, contributing to granuloma formation, a hallmark of the TB immune response. However, excessive chemokine production can lead to chronic inflammation and tissue damage, as seen in this study's correlation between CXCL11 levels and lesion severity on chest X-ray.[9,10]

There was no significant difference in CXCL11 levels between DS-TB and DR-TB patients. This finding highlights that CXCL11 primarily reflects the immune response to active TB, not resistance to drugs such as rifampicin. While resistance to drugs such as rifampicin involves bacterial mutations, it does not affect the immune recognition pathways that induce CXCL11. This study suggests that CXCL11 levels are influenced more by disease activity and inflammation rather than by the resistance status of the bacteria.[11]

Although the median CXCL11 level was numerically higher in the DS-TB group than in the DR-TB group, the difference was not statistically significant (P=0.549). This numerical difference may be related to biological variability, differences in host immune responses, disease stage, bacterial burden, or the relatively small sample size. Therefore, these findings should be interpreted cautiously and do not support the conclusion that CXCL11 differentiates drug-sensitive from drug-resistant tuberculosis.[12]

The lack of difference in CXCL11 levels between DS-TB and DR-TB suggests that drug resistance does not directly affect the immune response mediated by CXCL11. Instead, CXCL11 levels reflect the systemic immune activation in both drug-sensitive and drug-resistant TB during active disease. Disease stage and inflammatory response, rather than bacterial strain or resistance, are more important factors in shaping immune responses and CXCL11 production.[13]

The study found a moderate positive correlation (r = 0.477) between CXCL11 levels and chest X-ray lesion severity, indicating that higher CXCL11 levels correlate with more extensive lung damage. However, no significant difference in lesion severity was found between DS-TB and DR-TB, suggesting that CXCL11 levels reflect overall disease activity and inflammation, not specific drug resistance. This finding is consistent with previous studies reporting an association between CXCL11 and inflammatory activity in tuberculosis. In the present study, CXCL11 levels were associated with the severity of chest X-ray abnormalities rather than overall disease severity.[14]

The correlation between CXCL11 and chest X-ray severity reflects the role of CXCL11 in the recruitment of immune cells to TB lesions, contributing to both immune response and tissue damage. The presence of bilateral lung involvement and cavitation is associated with severe disease, where CXCL11 contributes to the inflammatory cycle. This process involves CXCL11 recruiting immune cells such as macrophages, T cells, and neutrophils, which can cause further tissue damage and lesion progression.[9,15]

The CXCL11 levels are positively correlated with bacterial load, as reflected by smear grade. Higher bacterial load triggers a stronger immune response, leading to increased CXCL11 production. Previous studies have reported an association between CXCL11 levels and bacterial burden. However, bacterial load was not evaluated in the present study. Therefore, this relationship could not be confirmed in our population. Our findings only demonstrate an association between serum CXCL11 levels and radiological severity. Persistent high CXCL11 levels contribute to the ongoing inflammatory response, which can lead to tissue damage and worsen disease severity.[16,17]

The present study demonstrated that serum CXCL11 levels were associated with chest X-ray severity in patients with pulmonary tuberculosis. These findings suggest that CXCL11 reflects the

inflammatory response associated with radiological abnormalities rather than drug-resistance status. Because this study used a cross-sectional design, no conclusions can be drawn regarding the prognostic value of CXCL11, treatment monitoring, or its role in host-directed therapy. Further prospective longitudinal studies are required to evaluate these potential clinical applications.[8]

LIMITATIONS

This study's cross-sectional design limits the ability to assess dynamic changes in CXCL11 levels over the course of the disease and treatment. The small sample size may also limit the statistical power of the findings. Additionally, the study focused only on CXCL11, without evaluating other immune biomarkers that could provide a more comprehensive view of the immune response to TB. Further studies with larger sample sizes and more biomarkers are needed to confirm the clinical utility of CXCL11.

CONCLUSION

This study found that CXCL11 levels were significantly higher in patients with active TB, both drug-sensitive and drug-resistant, compared to healthy controls. CXCL11 plays a role in recruiting immune cells to infection sites, reflecting the activation of the immune response. The lack of significant difference between drug-sensitive and drug-resistant TB suggests that CXCL11 indicates disease activity rather than drug resistance. This aligns with similar chest X-ray findings in both groups, suggesting comparable disease stages. These results indicate that worse outcomes in drug-resistant TB are likely due to therapeutic and healthcare factors. CXCL11 could serve as a biomarker for monitoring TB activity and treatment response but should complement, not replace, molecular resistance testing.

Future studies should include longitudinal designs to track CXCL11 levels throughout treatment. Direct correlations between CXCL11 and validated clinical and radiological indicators would strengthen the findings. Expanding the sample size, including diverse populations, and incorporating a broader panel of biomarkers could enhance understanding of CXCL11's role in TB pathogenesis. Furthermore, exploring the genetic and health factors influencing CXCL11 variability will help refine its clinical application as a biomarker for TB prognosis and treatment monitoring.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this research.

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