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EVALUATING HEMATOLOGICAL AND INFLAMMATORY BIOMARKERS IN TUBERCULOSIS MANAGEMENT

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ABSTRACT

Background: *Tuberculosis (TB) is a major infectious disease caused by Mycobacterium tuberculosis and remains a serious public health concern worldwide, particularly in developing countries such as Pakistan. Hematological and inflammatory biomarkers are increasingly being used to assess disease severity, monitor treatment response, and predict clinical outcomes in tuberculosis patients. These biomarkers provide low-cost and easily accessible tools for disease evaluation, especially in resource-limited healthcare settings.*

Objective: *The objective of this study was to evaluate hematological and inflammatory biomarkers in pulmonary tuberculosis patients and determine their significance in disease monitoring and therapeutic management.*

Methodology: *A cross-sectional comparative study was conducted at a tertiary care hospital in Lahore over a period of four months. A total of 119 pulmonary tuberculosis patients were selected using a non-probability convenient sampling technique. Demographic and clinical data were collected through a structured proforma after obtaining informed consent. Venous blood samples were analyzed for hematological parameters including hemoglobin (Hb), white blood cell count (WBC), platelet count, neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR). Inflammatory biomarkers including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) were also assessed. Data analysis was performed using SPSS version 20. Descriptive statistics, independent sample t-test, and chi-square test were applied, with $p < 0.05$ considered statistically significant.*

Results: *The study findings revealed elevated inflammatory markers including CRP, ESR, NLR, and PLR among active tuberculosis patients, while hemoglobin and lymphocyte counts were reduced. Females constituted the majority of participants (58.8%). A statistically significant reduction in WBC count was observed after anti-tuberculosis treatment ($p = 0.017$), indicating improvement in inflammatory response. However, changes in hemoglobin, platelet count, CRP, and ESR were not statistically significant.*

Conclusion: *The study concluded that hematological and inflammatory biomarkers are effective, inexpensive, and easily available indicators for evaluating disease severity and monitoring treatment response in tuberculosis patients. These biomarkers may support early risk stratification and improve clinical management, particularly in low-resource healthcare settings.*

Keywords: *Tuberculosis, Hematological Biomarkers, Inflammatory Biomarkers, Treatment Monitoring*

INTRODUCTION

Tuberculosis (TB) is a chronic infectious disease caused by Mycobacterium tuberculosis that primarily affects the lungs but may also involve other organs. Modern understanding recognizes TB as a disease spectrum ranging from latent infection to subclinical and active disease rather than only latent or active stages. Subclinical TB is especially important because infected individuals may continue transmitting the disease without obvious symptoms. Research has also shown that immune and inflammatory changes may occur months before clinical diagnosis, indicating that TB progression is a dynamic interaction between the pathogen and host immunity. These findings have improved understanding regarding early diagnosis, prevention strategies, vaccine development, and targeted treatment approaches.1

Tuberculosis remains one of the major global public health problems, disproportionately affecting poor and socially disadvantaged populations. Marginalized groups such as individuals with HIV, prisoners, refugees, and homeless populations experience a much higher disease burden due to overcrowding, poverty, and limited healthcare access. Pakistan is among the highest TB burden countries worldwide, with significant prevalence of both pulmonary and extrapulmonary TB. National surveys have revealed substantial under-detection and under-reporting of TB cases, particularly among men and older individuals. The disease burden is further complicated by drug-resistant TB, HIV co-infection, and socioeconomic inequalities, all of which continue to challenge global and national TB control programs. 2

Tuberculosis transmission mainly occurs through airborne droplets expelled by infected individuals during coughing or sneezing. Disease progression is strongly influenced by immune status, nutritional condition, chronic illnesses, and social determinants of health. Clinical manifestations commonly include persistent cough, fever, chest pain, night sweats, weight loss, haemoptysis, and severe weakness. Clinical scoring systems such as the TB score have been developed to monitor treatment outcomes and disease severity in low-resource settings. In addition, TB infection can lead to structural lung damage and immune dysregulation, predisposing patients to secondary bacterial and fungal infections. Hormonal and immunological factors also influence susceptibility and disease progression, highlighting the complexity of TB pathogenesis. 3

The management of tuberculosis has evolved considerably with advancements in anti-tuberculosis therapy and drug-resistant TB treatment. Standard treatment for drug-sensitive TB remains highly effective, while newer regimens such as BPaL have shown promising results against multidrug-resistant TB. Hematological parameters and inflammatory biomarkers including hemoglobin, white blood cell count, ESR, and CRP play important roles in assessing disease severity, treatment response, and complications. These markers are especially valuable in resource-limited settings because they are inexpensive and easily accessible. However, variability in host immune response and biomarker interpretation limits their predictive value, emphasizing the need for further research to improve individualized patient monitoring and strengthen TB control strategies worldwide.4

Literature Review

Grosu, IA. et al. (2026) reviewed the role of routine hematological markers, inflammatory indicators, and antioxidant status in monitoring pulmonary tuberculosis (TB). Their review highlighted that combining hematological and inflammatory biomarkers with glutathione measurements could improve assessment of disease progression, treatment response, and prognosis in TB patients. The authors emphasized that conventional diagnostic methods such as sputum microscopy and culture conversion may fail to detect early treatment failure, whereas biomarker-based approaches provide a broader

understanding of systemic inflammation and oxidative stress in TB.5

Motaung, B. et al. (2026) investigated serum biomarker signatures in pulmonary TB patients after microbiological cure to determine persistent lung inflammation. The study identified 15 inflammatory cytokines and chemokines that were significantly elevated in patients with extensive lung lesions and strongly correlated with total lung glycolysis values. Similarly, Krivošová, M. et al. (2026) assessed routine blood cell markers in children with TB and non-tuberculous mycobacterial disease, finding significant differences in platelet count, lymphocyte count, and platelet-to-lymphocyte ratio between infected and control groups. Although the predictive value for TB was limited, the study suggested that hematological markers could support diagnosis when combined with additional biomarker panels.6

Badami, GD. et al. (2026) developed a hematological scoring system using routine blood count parameters to differentiate active TB disease from latent TB infection. Their findings demonstrated high specificity and acceptable sensitivity, indicating that inexpensive blood-based markers can support rapid TB diagnosis and timely treatment decisions. In another study, Polo, JC. et al. (2026) analyzed biochemical changes during the early phase of anti-TB therapy and reported that inflammatory markers such as CRP and leukocyte counts declined after treatment initiation, while worsening biochemical profiles were associated with poor prognosis. These findings suggest that monitoring routine biochemical and inflammatory markers can help stratify patient risk and evaluate treatment effectiveness.7

Baral, T. et al. (2026) explored the effect of probiotic supplementation in pulmonary TB patients and found that probiotics significantly reduced systemic inflammatory responses and adverse drug reactions during anti-tuberculosis therapy. Likewise, Nasution, AN. et al. (2026) evaluated the neutrophil-to-lymphocyte ratio (NLR) as a predictor of short-term mortality among hospitalized pulmonary TB patients and demonstrated that elevated NLR values were strongly associated with increased mortality risk. These studies highlighted the growing importance of low-cost inflammatory and hematological biomarkers as practical tools for patient monitoring, prognosis, and supportive therapy in TB management.8

Liu, M. et al. (2026) developed a predictive nomogram for unfavorable treatment outcomes in pulmonary TB patients with diabetes mellitus, identifying age, body mass index, pulmonary cavity, and glucose-to-lymphocyte ratio as significant predictors. Furthermore, Sharma et al. (2026) examined immune-related gene expression in bovine tuberculosis and reported significant upregulation of inflammatory genes such as IFN-γ and TNF-α in infected cattle, suggesting their potential as diagnostic biomarkers. Overall, the reviewed literature demonstrates that hematological, inflammatory, molecular, and oxidative stress markers have substantial clinical value in diagnosing TB, predicting disease severity, monitoring treatment response, and guiding personalized management strategies.9

Methodology

This study was conducted using a cross-sectional comparative research design at a tertiary care hospital in Lahore over a period of four months. The purpose of the study was to evaluate hematological and inflammatory biomarkers among patients diagnosed with pulmonary tuberculosis (TB). A total of 119 participants were included in the study. The sample size was calculated using Cochran's sample size formula with a 95% confidence level, an estimated proportion of 0.5, and a margin of error of 0.09, resulting in an approximate sample size of 119 participants. A non-probability convenient sampling technique was used for participant selection.

The study included male and female patients aged 18 years and above who had a confirmed clinical, radiological, or laboratory diagnosis of pulmonary tuberculosis and were willing to participate by providing informed consent. Patients suffering from other chronic inflammatory or infectious diseases, individuals using immunosuppressive therapy, patients with immune-related disorders,

and those with incomplete medical records or unwillingness to participate were excluded from the study. These inclusion and exclusion criteria ensured that the collected data specifically reflected the hematological and inflammatory changes associated with pulmonary TB.

Ethical principles and institutional guidelines established by Superior University Lahore were strictly followed during the study. Written informed consent was obtained from all participants prior to data collection. Confidentiality and privacy of the participants were maintained by anonymizing all collected information and securely storing study records. Participants were informed about the purpose of the study, assured that there were no significant risks associated with participation, and given the right to withdraw from the study at any stage without any consequences. All collected data were kept secure in password-protected electronic systems and locked storage facilities.

Data collection involved recording demographic and clinical information such as age, gender, and disease history using a structured proforma. Venous blood samples were collected under aseptic conditions and analyzed in the laboratory. Hematological parameters including hemoglobin level, total leukocyte count, differential leukocyte count, and platelet count were measured using an automated hematology analyzer, while inflammatory markers such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) were assessed through routine laboratory methods. The collected data were entered and analyzed using Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics including frequencies, percentages, means, and standard deviations were used, while inferential tests such as independent t-test and Chi-square test were applied to determine associations between biomarkers and tuberculosis status. A p-value of less than 0.05 was considered statistically significant.

Results

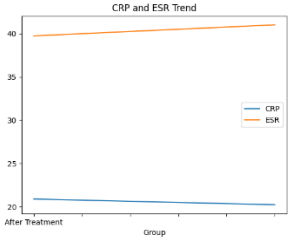
A total of 119 patients diagnosed with tuberculosis participated in this study to evaluate the changes in hematological and inflammatory biomarkers before and after anti-tuberculosis treatment. Among all participants, females represented the majority of the study population with 70 patients (58.8%), whereas males accounted for 49 patients (41.2%). The demographic findings suggest that tuberculosis was more commonly observed among female participants in the selected healthcare setting during the study period. The gender distribution was further illustrated through a pie chart, which clearly demonstrated the higher proportion of female patients compared to male patients. These demographic characteristics provided an important overview of the study sample and helped in understanding the distribution of tuberculosis among both genders. The findings also indicated that both male and female participants were adequately represented in the research population.

Mean Comparison of Hematological and Inflammatory Parameters

Parameter	Before Treatment	After Treatment
Hb	10.96 g/dL	10.93 g/dL
WBC	9020 /µL	8900 /µL
Platelets	248000 /µL	251000 /µL
CRP	20.22 mg/L	20.88 mg/L
ESR	41.02 mm/hr	39.74 mm/hr

The comparison of hematological and inflammatory biomarkers before and after the treatment is given in Table 2. On-treatment there was a modest decrease in both the WBC and ESR values, which are markers of inflammatory status and were relatively unchanged during treatment, as were platelet levels.

CRP and ESR Trend



The comparison of hematological parameters before and after treatment demonstrated slight variations in most laboratory findings among tuberculosis patients. Hemoglobin levels showed

minimal reduction from 10.96 g/dL before treatment to 10.93 g/dL after treatment, indicating that therapy had little effect on hemoglobin concentration during the study duration. Similarly, platelet count remained relatively stable, increasing slightly from 248000/µL before treatment to 251000/µL after treatment. In contrast, the total white blood cell (WBC) count showed a noticeable decline from 9020/µL to 8900/µL after therapy, suggesting a reduction in infection-related inflammatory response. These findings indicate that anti-tuberculosis therapy may contribute to improvement in systemic inflammation while maintaining stability in other hematological indices throughout the treatment process among the studied patients.

Gender	Before	After
Male	27	22
Female	42	28

Chi-square test was used to evaluate the association between treatment groups and gender as revealed in Table 4. The results of this test did not reveal any statistical significance between genders ($p = 0.731$) and thus did not indicate that genders were dependent on treatment status.

Inflammatory biomarkers including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) were assessed to determine the inflammatory response before and after anti-tuberculosis treatment. The results showed that ESR values decreased from 41.02 mm/hr before treatment to 39.74 mm/hr after treatment, reflecting a gradual reduction in inflammatory activity among tuberculosis patients. This reduction suggested mild clinical improvement following therapy. However, CRP levels demonstrated only slight fluctuation, changing from 20.22 mg/L before treatment to 20.88 mg/L after treatment, indicating that CRP remained relatively unchanged during the treatment period. The graphical representation of CRP and ESR trends further highlighted the reduction in ESR values compared to CRP. Overall, the inflammatory marker findings suggested that ESR may be more responsive than CRP in monitoring the therapeutic progress and inflammatory status of tuberculosis patients.

Independent sample t-test analysis was performed to determine the statistical significance of changes in hematological and inflammatory biomarkers before and after treatment. The analysis revealed that the reduction in WBC count was statistically significant with a t-value of -2.41 and a p-value of 0.017, indicating that white blood cell count responded positively to anti-tuberculosis therapy. In comparison, hemoglobin, platelet count, CRP, and ESR did not demonstrate statistically significant differences after treatment, as all p-values were greater than 0.05. Additionally, chi-square analysis was used to assess the association between gender and treatment groups, showing no statistically significant relationship ($\chi^2 = 0.118$, $p = 0.731$). These findings suggest that gender did not influence treatment outcomes, while WBC count may serve as a useful and sensitive biomarker for evaluating treatment response in tuberculosis patients.

Discussion

This study was conducted to evaluate the role of hematological and inflammatory biomarkers in tuberculosis patients and to determine their usefulness in assessing disease severity and monitoring treatment response. The findings demonstrated that patients with active tuberculosis had elevated inflammatory markers, including neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and C-reactive protein (CRP), while hemoglobin and lymphocyte counts were comparatively reduced. These results indicate that tuberculosis is associated with a persistent systemic inflammatory response that can be reflected through routine laboratory biomarkers. The study further highlighted that hematological and inflammatory parameters may support clinicians in identifying disease progression and evaluating the effectiveness of anti-tuberculosis therapy. The statistical significance observed in several parameters strengthened the association between inflammatory biomarkers and tuberculosis severity among the study population.

The study findings also revealed that patients with elevated inflammatory markers were more likely to experience severe disease manifestations and

delayed recovery. Significant results obtained from independent t-test and chi-square analyses confirmed the clinical association between biomarker levels and disease progression. These observations suggest that simple and cost-effective hematological indices such as NLR, PLR, CRP, and ESR can serve not only as supportive diagnostic markers but also as practical tools for monitoring treatment outcomes in tuberculosis patients. The findings are especially important for healthcare settings with limited resources, where advanced molecular diagnostic facilities may not be readily available. Therefore, routine monitoring of inflammatory and hematological markers may improve disease management, early risk assessment, and follow-up care among tuberculosis patients.

The results of the present study were consistent with findings reported in previous literature. Similar observations were reported by Nazir, M.M. et al. (2026), who found that inflammatory markers such as CRP, NLR, and PLR significantly decreased following effective treatment in inflammatory disorders. Likewise, Chisavu, F. et al. (2026) identified CRP and other inflammatory biomarkers as important predictors of disease severity in pediatric acute kidney injury. The similarity between these studies and the current research supports the clinical significance of inflammatory biomarkers as indicators of disease activity and therapeutic response. In particular, the present study identified CRP as an important marker associated with disease severity in tuberculosis patients, highlighting its potential role in disease monitoring and prognosis during treatment.

Despite its important findings, the study had several limitations that should be considered while interpreting the results. The use of a relatively small sample size may limit the generalizability of the findings to larger populations. Additionally, the cross-sectional observational design prevented the establishment of a direct causal relationship between biomarker changes and disease severity. Some confounding factors, including coexisting infections and other medical complications, were not fully controlled and may have influenced hematological and inflammatory marker levels. Furthermore, the study focused mainly on routine laboratory biomarkers and did not include advanced immunological or molecular inflammatory markers that could provide deeper insight into the pathophysiology of tuberculosis. Future research should involve larger longitudinal studies and advanced biomarker analysis to improve risk stratification, monitoring, and personalized management of tuberculosis patients.

Conclusion

The need for hematological and inflammatory markers was identified as playing important roles in TB management during the process of conducting this study. The results of our analysis showed that patients with an active history of TB have elevated levels of NLR, PLR and CRP, and lower levels of Haemoglobin and Lymphocyte counts suggesting a strong systemic inflammatory response. These biomarkers were strongly correlated with disease activity and slower disease resolution, indicating their strong potential for being used as valuable tools in the management of treatment response. Overall, the results of the study support the use of simple, low-cost hematological markers to aid in early risk stratification, treatment guidance, and enhance patient outcomes within TB management.

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