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Evaluation of complete blood count and inflammatory markers in pulmonary tuberculosis: A retrospective cross-sectional study at Al-Daran hospital

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ABSTRACT

Background: Pulmonary tuberculosis (PTB) remains a major global health challenge, with significant morbidity and mortality. Beyond its respiratory manifestations, PTB is frequently associated with hematological alterations and elevated inflammatory markers, which may reflect disease severity and systemic inflammation. Data on these parameters among Libyan patients with PTB remain limited.

Aim: This study aimed to evaluate complete blood count (CBC) parameters and inflammatory biomarkers, including the erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP), in patients with PTB and to investigate the correlations between these inflammatory markers and CBC parameters.

Methods: A retrospective cross-sectional study was conducted on 64 patients diagnosed with pulmonary TB between 2023 and 2025 at Al-Daran Hospital. Demographic data and laboratory results, including CBC and inflammatory markers (ESR and CRP), were extracted from medical archives. Statistical analysis included descriptive statistics, *t*-tests for group comparisons, and Pearson correlation to assess the relationships between inflammatory markers and CBC parameters.

Results: Males comprised 71.8% of the study population, indicating a higher burden of PTB in men. CBC analysis demonstrated mild normocytic normochromic anemia, with a mean hemoglobin of 12.6 ± 2.6 g/dl and hematocrit of 38.1% ± 6.8%. Neutrophil percentages were slightly elevated (65.5% ± 15.8%), while lymphocyte counts remained within normal limits (26.9% ± 12.7%). Inflammatory markers were markedly elevated, with an ESR of 44.0 ± 38.4 mm/hour and a CRP level of 31.0 ± 48.1 mg/l, indicating active systemic inflammation. Females showed significantly lower hemoglobin, hematocrit, and MCH compared to males ($p < 0.05$). Correlation analysis revealed positive associations of CRP and ESR with total WBC count, neutrophils, and platelet count, and negative correlations with lymphocyte percentage and red blood cell indices (MCV and MCH), hemoglobin, and hematocrit.

Conclusion: PTB is associated with mild normocytic normochromic anemia, neutrophilia, and elevated inflammatory markers. Although lymphocyte counts remained within normal ranges, they showed significant inverse correlations with inflammatory markers. Complete blood count and inflammatory parameters are strongly interrelated, highlighting their potential utility in assessing disease severity and monitoring patients with PTB.

Keywords: Complete blood count, C-reactive protein, Erythrocyte sedimentation rate, Pulmonary tuberculosis.

Introduction

Pulmonary tuberculosis (PTB) is the most common and infectious form of tuberculosis, a contagious bacterial disease caused by *Mycobacterium tuberculosis* that continues to rank among the leading causes of infectious disease-related mortality worldwide (Ryan *et al.*, 2025). The disease is primarily transmitted through airborne droplets expelled when individuals with active pulmonary infection cough or sneeze (Sarkar and Sarkar, 2025). Clinically, PTB is characterized by a persistent cough, chest pain, hemoptysis, fever, night sweats, weight loss, and generalized fatigue AlOsaimi *et al.*, 2024).

In 2023, tuberculosis affected an estimated 10.8 million people globally, reflecting its ongoing public health burden. In Libya, the incidence was estimated at 40 cases per 100,000 population, corresponding to nearly 2,800 new cases annually and indicating a moderate but persistent disease burden. Available regional data also suggest a higher prevalence among males, which has been attributed to occupational exposure, smoking habits, and differences in healthcare-seeking behavior (Organization, 2024; Lee *et al.*, 2025).

PTB is increasingly recognized as a systemic inflammatory condition that produces characteristic hematological changes beyond its respiratory

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manifestations. These alterations may provide useful adjuncts for disease assessment, particularly in settings where advanced diagnostic tools are limited (Batool *et al.*, 2022; Asari *et al.*, 2025). Reported abnormalities include anemia, changes in white blood cell counts (leukocytosis or leukopenia), neutrophilia, lymphocyte alterations, and platelet variations, along with elevated inflammatory markers such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) (Ştefanescu *et al.*, 2021; Kumar *et al.*, 2024). Among these, anemia remains the most frequently observed abnormality, affecting a substantial proportion of patients with active disease, with reported prevalence ranging from 30% to 85%, depending on population and disease severity (Dasaradhan *et al.*, 2022; Tiu *et al.*, 2025).

The development of anemia in PTB is multifactorial. The most common mechanism is chronic anemia, characterized by impaired iron utilization, reduced erythropoietic activity, and altered iron storage profiles (Shah *et al.*, 2022). Iron deficiency anemia may also coexist in some cases, particularly in populations affected by malnutrition (Begum and Latunde-Dada, 2019). At the molecular level, inflammatory cytokines, especially interleukin-6 (IL-6), stimulate hepatic hepcidin production, which reduces iron availability by trapping it within macrophages and limiting intestinal absorption, ultimately contributing to inflammation-associated anemia (Wrighting and Andrews, 2006; John and J, 2026).

Several studies have supported these hematological patterns. Shah *et al.* (2022) reported decreased hemoglobin and hematocrit levels alongside elevated white blood cell counts and ESR in patients with PTB compared with healthy controls (Shah *et al.*, 2022). Similar patterns have been observed in Eastern Sudan and Egypt, suggesting a consistent regional profile characterized by mild normocytic normochromic anemia, neutrophilia, and relative lymphocyte reduction in patients with pulmonary TB (Idriss *et al.*, 2013; Ali *et al.*, 2024). Although available data are limited and outdated in Libya, reports still indicate a male predominance and a notable burden of PTB, emphasizing the need for updated local evidence.

Despite these findings, there remains a clear gap in current knowledge regarding the hematological and inflammatory profiles of patients with PTB in Libya, as most existing studies were conducted more than a decade ago and may not reflect current epidemiological or clinical patterns (Latifa Abdel-Hafid Jwieli and El-Majbri, 2020). A clearer understanding of these changes is important not only for improving diagnostic support but also for monitoring disease activity and guiding clinical management.

Therefore, this study aimed to evaluate hematological alterations in patients with PTB at Al-Darnah Hospital, assess inflammatory biomarkers (ESR and CRP), and explore their correlations with complete blood count parameters to better characterize disease-related hematological and inflammatory changes.

Materials and Methods

Study design and setting

This retrospective cross-sectional analysis was conducted using previously documented medical records. Data were obtained from the medical archives of Al-Daran Hospital. Case records were reviewed over a 2-month period (October–November) and included patients diagnosed with PTB between 2023 and 2025.

Study population

The study population comprised 64 patients with microbiologically confirmed PTB. The diagnoses were established by the treating physicians at Al-Daran Hospital, following the institution's routine diagnostic protocol. This protocol encompassed clinical presentation, radiological findings, and microbiological confirmation through AFB smear microscopy and/or the GeneXpert MTB/RIF assay. All eligible cases identified in the hospital records during the study period were included, without age- or sex-based selection. Inclusion was solely contingent on the availability of complete and clearly documented medical records. Information regarding the anti-TB treatment status of patients at the time of laboratory testing was not consistently available in the archived records and was therefore not assessed in the present study.

Data collection

Data were extracted from archived medical records, including patients' demographic characteristics (age and sex) and complete blood count (CBC) parameters, such as hemoglobin (HGB), red blood cell (RBC) count, total white blood cell (WBC) count, lymphocyte and neutrophil percentages, hematocrit (HCT), platelet (PLT) count, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and MCHC. Complete blood count analysis was performed using the Mission HA-360 Hematology Analyzer. Inflammatory biomarkers, including ESR and CRP, were also measured. ESR was measured using the Westergren method and reported in mm/hour, whereas CRP levels were determined using the Cobas Integra automated chemistry analyzer (Roche Diagnostics, Germany).

To ensure data accuracy, only complete medical records were included in the analysis. All data were handled with strict confidentiality, and no personal identifiers were collected. The reference ranges for CBC parameters were based on the Practical Hematology of Dacie and Lewis 2006). Reference values for ESR and CRP were obtained from the Tietz Textbook of Clinical Chemistry and Molecular Diagnostics (Bruns *et al.*, 2012).

Statistical analysis

Data were analyzed using the appropriate statistical software. Continuous variables were expressed as mean ± SD, whereas categorical variables were expressed as frequencies and percentages. The independent

sample *t*-test was used to assess differences between groups, and associations between variables were evaluated using Pearson's correlation coefficient. The chi-square test was used to assess associations between categorical variables. A *p*-value of <0.05 was considered statistically significant.

Ethical approval

This retrospective study was conducted following an official request from the Faculty of Medical Technology, University of Tripoli, to the relevant authority at Al-Daran Hospital for permission to access archived medical records and collect data for research purposes. The hospital administration granted approval before data collection. This study involved only a retrospective review of archived records, with no direct patient contact and no collection of identifiable personal information. Therefore, informed consent was not required. Patient confidentiality and data privacy were strictly maintained throughout the study.

Results

Demographic characteristics of the study population

Table 1 presents the demographic characteristics of patients with PTB. A total of 64 patients were included during the study period (2023–2025). Males constituted the majority of cases (71.8%, $n = 46$), whereas females accounted for 28.1% ($n = 18$), with a statistically significant difference in gender distribution ($\chi^2 = 12.25$, $p = 0.0004$). Patients were distributed across different age groups, with the highest proportion observed among those aged 41–50 years (26.6%), followed by 31–40 years (21.9%), 21–30 years (18.8%), ≥51 years (17.1%), and ≤20 years (15.6%). The mean age of the study population was 38.07 ± 15.02 years. No statistically significant difference was detected in age distribution ($\chi^2 = 2.406$, $p = 0.6615$).

Complete blood count parameters

Table 2 summarizes the hematological profile of patients with pulmonary TB. The mean total WBC count was 8.4 ± 4.0 × 10^9/l, which is within the reference range. The mean lymphocyte percentage was 26.9% ± 12.7%, which was also within normal limits, whereas the mean neutrophil percentage was 65.5% ± 15.8%, which slightly exceeded the normal range and showed a statistically significant difference ($p = 0.0429$). The mean RBC count was 4.6 ± 0.8 × 10^6 /µl and remained within normal limits. However, the mean HGB level was 12.6 ± 2.6 g/dl, and the mean HCT was 38.1% ± 6.8%, both of which were slightly below the standard reference range, with a statistically significant reduction in HCT ($p = 0.0427$). RBC indices showed mean values of 82.7 ± 9.2 fL for MCV and 27.3 ± 4.9 pg for MCH, both within normal ranges. The mean PLT count was 320.4 ± 147.6 ×10^9/l, which also falls within the reference range (Table 2).

Gender-based comparison of the CBC parameters

Table 3 illustrates the comparison of CBC parameters between male and female patients. No statistically significant differences were observed between genders with respect to total WBC count, lymphocyte percentage, neutrophil percentage, RBC count, MCV, or platelet count ($p > 0.05$). However, females exhibited significantly lower mean HGB levels (11.44 ± 2.23 g/dl) and HCT values (35.66% ± 5.26%) than males (13.00 ± 2.54 g/dl and 39.09% ± 7.11%, respectively), with statistically significant differences ($p = 0.0124$ and $p = 0.0224$). In addition, MCH was significantly lower in females (25.93 ± 4.09 pg) than in males (27.90 ± 3.75 pg) ($p = 0.0487$).

Inflammatory biomarkers

Table 4 presents the inflammatory markers assessed in this study. The mean ESR was markedly elevated at 44.0 ± 38.4 mm/hour compared with the normal

Table 1. Demographic information distribution among the samples.

Demographic information	*N* (%)	X^2Test	*p* value
Gender			
Male	46 (71.8%)	12.25	0.0004*
Female	18 (28.1%)		
Age group			
20 or less	10 (15.6%)	2.406	0.6615
21–30 years	12 (18.8%)		
31–40 years	14 (21.9%)		
41–50 years	17 (26.6%)		
51 or above	11 (17.1%)		
Mean ± SD		38.07 ± 15.02	

Table 2. Mean and SD of the CBC parameters among the total samples.

CBC parameters	Mean ± SD
Total WBC	8.4 ± 4.0
LYMPH	26.9 ± 12.7
NEUT	65.5 ± 15.8
RBC	4.6 ± 0.8
HGB	12.6 ± 2.6
HCT	38.1 ± 6.8
MCV	82.7 ± 9.2
MCH	27.3 ± 4.9
PLT	320.4 ± 147.6

Table 3. Descriptive statistics of differences in CBC parameters between males and females.

CBC parameters	Male	Female	*T*-test	*p*-value
Total WBC	8.55 ± 4.02	7.84 ± 3.96	0.626	0.2678
LYMPH	25.39 ± 11.51	30.98 ± 14.59	–1.422	0.0853
NEUT	66.98 ± 15.46	61.57 ± 16.10	1.193	0.1233
RBC	4.65 ± 0.66	4.38 ± 0.96	1.074	0.1484
HGB	13.00 ± 2.54	11.44 ± 2.23	2.367	0.0124*
HCT	39.09 ± 7.11	35.66 ± 5.26	2.072	0.0224*
MCV	83.28 ± 9.48	81.04 ± 8.27	0.913	0.1866
MCH	27.90 ± 3.75	25.93 ± 4.09	1.727	0.0487*
PLT	316.28 ± 152.86	331.06 ± 132.58	–0.374	0.3550

Table 4. Mean and SD of inflammation parameters among the total samples.

Inflammation parameters	Mean ± SD	*T*-test	*p*-value
ESR	44.0 ± 38.4	15.830	0.0000*
CRP	31.0 ± 48.1	12.853	0.0000*

Table 5. Descriptive statistics of differences in inflammation parameters between males and females.

Inflammation parameters	Male	Female	*t*-test	*p*-value
ESR	40.8 ± 36.9	52.2 ± 40.9	–0.998	0.1635
CRP	35.6 ± 52.8	19.4 ± 30.47	2.496	0.0404*

reference range. The mean CRP level was 31.0 ± 48.1 mg/l, which is considerably higher than the normal values. Both ESR and CRP levels were significantly elevated ($p < 0.001$).

Gender-based comparison of inflammatory markers

As shown in Table 5, females demonstrated higher mean ESR values (52.2 ± 40.9 mm/hour) than males (40.8 ± 36.9 mm/hour); however, this difference was not statistically significant ($p = 0.1635$). In contrast, males had significantly higher mean CRP levels (35.6 ± 52.8 mg/l) than females (19.4 ± 30.5 mg/l), with a statistically significant difference ($p = 0.0404$).

Correlation between inflammatory markers and CBC parameters

Pearson's correlation analysis revealed significant associations between inflammatory markers and hematological parameters (Table 6). CRP levels were moderately positively correlated with total WBC count ($r = 0.3760$, $p = 0.0010$), neutrophil percentage ($r = 0.3227$, $p = 0.0044$), and PLT count ($r = 0.2690$, $p = 0.0156$). In contrast, CRP levels were strongly negatively correlated with lymphocyte percentage ($r = −0.5423$, $p < 0.001$) and red blood cell indices, including red blood cell count, hemoglobin, hematocrit, MCV, and MCH ($p < 0.05$).

Similarly, ESR was positively correlated with total WBC count ($r = 0.3647$, $p = 0.0013$) and PLT count ($r = 0.5369$, $p < 0.001$), while showing strong negative correlations with lymphocyte percentage and RBC parameters, particularly hemoglobin ($r = −0.6435$, $p < 0.001$) and hematocrit ($r = −0.5864$, $p < 0.001$). The correlation between ESR and the percentage of neutrophils was weak and not statistically significant ($p = 0.0692$).

Discussion

This retrospective cross-sectional study evaluated hematological and inflammatory alterations among patients with pulmonary TB at Al-Daran Hospital. The findings demonstrate characteristic abnormalities in CBC parameters and markedly elevated inflammatory markers, with strong correlations between inflammation and hematological changes. Overall, the results are consistent with those of previous regional and international studies, although some variations were observed in the magnitude of the changes.

Males constituted most pulmonary TB cases (71.8%) in the current study, indicating a pronounced male predominance. This finding is consistent with several international studies reporting higher prevalence of pulmonary TB among men. Batool *et al.* reported a male-to-female ratio of 2.5:1, while Mohammed *et al.* observed that 62.5% of patients with PTB were male (Mohammed, 2016; Batool *et al.*, 2022). Similar

Table 6. Pearson correlation coefficient between CRP/ESR and CBC parameters.

CBC Parameters	CRP		ESR	
	R-value	*p-value*	*R-value*	*p-value*
WBC	0.3760	0.0010*	0.3647	0.0013*
LYMPH	–0.5423	0.0000*	–0.4739	0.0000*
NEUT	0.3227	0.0044*	0.1874	0.0692
RBC	–0.3748	0.0010*	–0.3757	0.0010*
HGB	–0.4805	0.0000*	–0.6435	0.0000*
HCT	–0.5209	0.0000*	–0.5864	0.0000*
MCV	–0.2319	0.0325*	–0.3452	0.0024*
MCH	–0.2532	0.0215*	–0.4689	0.0003*
PLT	0.2690	0.0156*	0.5369	0.0000*

trends have also been reported in regional data from Libya, where pulmonary TB notifications show a clear male predominance (Balakrishnan, 2022). The higher burden of pulmonary TB among males than females may be attributed to multiple factors, including increased occupational exposure, higher smoking rates, delayed healthcare-seeking behavior, and greater social mobility. These explanations have been widely suggested in epidemiological studies of PTB in low- and middle-income countries (Yang *et al.*, 2024).

This study identified several hematological abnormalities associated with pulmonary TB. The mean hemoglobin (12.6 ± 2.6 g/dl) and hematocrit levels (38.1% ± 6.8%) were slightly below normal ranges, indicating mild anemia, predominantly of the normocytic normochromic type, as supported by normal MCV and MCH values. These findings agree with those of Shah *et al*, who reported significantly reduced hemoglobin and hematocrit levels in patients with PTB (Shah *et al.*, 2022). Similar observations were reported in patients from Eastern Sudan by Idriss *et al.* (2013) and by Mohammed (2016) reinforcing the consistency of anemia as a common hematological manifestation of PTB (Idriss *et al.*, 2013; Mohammed, 2016). The relatively mild degree of anemia observed in this study may reflect earlier diagnosis, less advanced disease, or variations in nutritional status and comorbidities among the study population (de Mendonça *et al.*, 2021). Gender-based analysis revealed that females had significantly lower hemoglobin, hematocrit, and MCH values than males. This finding is consistent with previous studies and may be attributed to a higher susceptibility to iron deficiency among females, compounded by chronic inflammation associated with PTB (De Mendonça *et al.*, 2021; Abaynew *et al.*, 2023).

The neutrophil percentage was slightly elevated (65.5% ± 15.8%), reflecting an active inflammatory response typical of pulmonary TB. This finding aligns with Shah *et al,* who reported significantly increased neutrophil counts in patients with PTB (Shah *et al.*, 2022). In contrast, lymphocyte percentages in the present study remained within the normal range, although correlation analysis revealed significant negative associations with inflammatory markers (Omair *et al.*, 2024). Differences in lymphocyte responses have been previously reported. For example, Ali *et al.* (2024) observed elevated lymphocyte counts in certain pulmonary TB populations, suggesting that lymphocyte dynamics may vary depending on disease severity, immune status, or drug-resistance patterns (Ali *et al.*, 2024). These variations may explain the relatively preserved lymphocyte levels observed in the current study (Kulesh *et al.*, 2025).

Inflammatory biomarkers were significantly elevated in the current study, with a mean ESR of 44.0 ± 38.4 mm/h and a CRP level of 31.0 ± 48.1 mg/l, indicating active systemic inflammation. These results are consistent with those of previous studies by Shah *et al.* and Rohini *et al.*, which also reported notably increased ESR and CRP levels in patients with pulmonary TB (Rohini *et al.*, 2016; Shah *et al.*, 2022). In addition, Batool *et al.* (2022) found elevated ESR in nearly all pulmonary TB cases (Batool *et al.*, 2022). Gunluoglu *et al.* (2014) further demonstrated that ESR and CRP levels were significantly higher in patients with active pulmonary TB than in healthy controls (Gunluoglu *et al.*, 2014). Together, these findings underscore the reliability of ESR and CRP as disease activity and inflammatory burden indicators in pulmonary TB.

Correlation analysis revealed significant relationships between inflammatory markers and hematological parameters. CRP and ESR were positively correlated with total WBC count, neutrophils, and platelet count, indicating leukocytosis and reactive thrombocytosis in the presence of heightened inflammation (Tang *et al.*, 2025). Similar correlations were reported by Batool *et al.* (2022) supporting the role of inflammatory cytokines

in stimulating leukocyte and PLT production during active pulmonary TB (Batool *et al.*, 2022). Conversely, lymphocyte counts were strongly negatively correlated with CRP and ESR, suggesting inflammation-associated lymphopenia. This observation is consistent with the findings of studies conducted in Egypt by Ali *et al.* (2024)and Rohini *et al.* (2016). In addition, negative correlations were observed between inflammatory markers and RBC indices, including HGB, HCT, MCV, and MCH. These findings indicate anemia related to chronic inflammation, potentially mediated by iron sequestration and impaired erythropoiesis, mechanisms commonly described in TB-associated anemia (John and J, 2026). Mohammed *et al.* and Idriss *et al.* reported similar inverse relationships between inflammatory markers and red cell parameters, further highlighting the impact of chronic inflammation on hematological profiles in patients with pulmonary TB (Idriss *et al.*, 2013; Mohammed, 2016).

Overall, the current study underscores the association of PTB with substantial hematological and inflammatory alterations, characterized by significant deviations in complete blood count parameters alongside elevated ESR and CRP levels. Although such associations are well-documented in international literature, empirical data within the Libyan context remain sparse. Consequently, this study offers locally derived evidence that enhances the regional understanding of TB-related laboratory abnormalities and establishes a critical baseline for future investigations in comparable clinical settings.

This study has several limitations. Its retrospective cross-sectional design precludes the establishment of causal relationships. Additionally, the single-center setting and relatively small sample size may limit the generalizability of the findings. Although all patients were diagnosed according to the hospital's routine diagnostic protocol using clinical, radiological, and microbiological criteria, the archived medical records did not consistently provide sufficient detail to permit subgroup analyses based on clinical or radiological findings. Information regarding anti-TB treatment status at the time of laboratory testing was also unavailable. Therefore, further prospective multicenter studies are warranted to validate and extend these findings.

Conclusion

This study demonstrates that PTB is significantly associated with mild normocytic normochromic anemia, neutrophilia, and markedly elevated inflammatory markers. An inverse relationship was observed between lymphocyte counts and systemic inflammation markers. These findings suggest that routine hematological and inflammatory parameters may serve as valuable, cost-effective adjunctive tools for the clinical assessment and monitoring of patients with PTB, particularly in resource-limited settings.

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Authors' contributions

Eman Abdulwahed conceived and developed the study concept, supervised the research, and contributed to the drafting and critical revision of the manuscript. Narjes Naser served as the co-supervisor and contributed to the study design, manuscript writing, editing, and final revision. Eman Abdullh, Esra Oweidat, and Boshra Altegazi were responsible for data collection and analysis. All authors have reviewed and approved the final version of the manuscript.

Conflict of interest

The authors have no conflicts of interest to declare regarding the publication of this paper.

Data availability

All data supporting this study's findings are available within the manuscript.

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