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To Study The Inflammatory Markers In Active Tuberculosis, Their Correlation With Disease Severity, And Their Response To Anti-Tubercular Treatment At A Tertiary Care Centre.

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Abstract

Background: Tuberculosis (TB) remains a major global health issue and a leading cause of infectious disease- related illness and death, especially in low- and middle-income countries. Despite advancements, early assessment of disease severity and treatment response is challenging, particularly in extrapulmonary and paucibacillary TB. Inflammatory biomarkers like CRP, ESR, NLR, and RDW reflect immune response and may serve as simple, inexpensive indicators of disease activity, severity, and treatment response. Their availability and cost-effectiveness make them useful adjuncts to traditional methods, especially in resource-limited settings. This study aimed to evaluate these biomarkers in active TB, examine their correlation with disease severity, and assess their role in monitoring treatment response. ***Objectives:*** Investigate inflammatory markers in active TB. Assess their correlation with TB severity and monitor changes during ATT to evaluate their potential as treatment indicators. Explore their use as diagnostic and prognostic tools. ***Methodology:*** A prospective observational study was conducted over 18 months at Rangaraya Medical College and Government General Hospital, Kakinada, Andhra Pradesh, including 130 patients aged 18–70 with newly diagnosed pulmonary or extrapulmonary TB. Baseline evaluation included clinical assessment, laboratory tests, inflammatory markers, radiology, and histopathology when indicated. Patients were followed up at 2- and 6-month post-therapy, with inflammatory markers reassessed to evaluate association with disease severity and treatment response. Statistical analysis used descriptive and inferential tests, with $p < 0.05$ considered significant. Ethical approval was obtained. ***Results:*** 130 patients with active TB, mean age 42.5 ± 15.2 years, mostly male (60.0%), had pulmonary TB (82.3%), and mild-to-moderate disease. Baseline inflammatory markers were elevated: CRP 56.3 ± 32.1 mg/L, ESR 74.5 ± 28.4 mm/hr, NLR 5.8 ± 3.1, RDW 16.2 ± 2.3%, indicating systemic inflammation. Markers declined significantly at 2 and 6 months of therapy in both sexes ($p < 0.05$). Patients with severe TB had higher baseline and follow-up markers despite reductions. CRP, ESR, NLR, and RDW correlated with disease severity and improved with treatment, suggesting their potential as biomarkers for disease assessment and monitoring. Discussion: The study showed that CRP, ESR, NLR, and RDW levels are elevated in active tuberculosis, correlate with disease severity, and decrease during treatment, making them useful for monitoring response. Severe cases had higher baseline levels that remained relatively high despite improvements. These findings align with prior research indicating that these markers reflect disease burden and respond to therapy. Since they are inexpensive, readily available, and routinely used, they could supplement traditional diagnostics, especially in resource-limited settings. Larger, multicentric studies with longer follow-up are needed to confirm their prognostic value. ***Conclusion:*** The study shows that CRP, ESR, NLR, and RDW are elevated in active tuberculosis and correlate with disease severity. These markers decline after anti-tubercular therapy, indicating treatment response. As accessible, inexpensive tests, they can help assess severity and monitor therapy, especially in resource-limited settings. Larger multicentric studies are needed to validate their prognostic utility and establish routine use.

Keywords: Inflammatory Markers, Active Tuberculosis, Anti-Tubercular Treatment.

INTRODUCTION

Tuberculosis (TB) remains a global health challenge and is among the leading causes of morbidity and mortality worldwide, particularly in low- and middle-income countries. Despite advances in diagnostics, treatment, and public health interventions, TB continues to pose a burden. According to the WHO Global Tuberculosis Report, about 10 million new TB cases and 1.4 million deaths occurred in 2019, highlighting the need for improved diagnostic and treatment strategies (1). India, with a large TB burden, faces challenges due to socio-economic disparities, high MDR-TB prevalence, and HIV co-infections (2). Effective TB management, especially in active stages, requires early detection and accurate monitoring of disease and treatment response. TB is caused by the bacterium Mycobacterium tuberculosis, which primarily affects the lungs (pulmonary TB) but can also affect other organs (extrapulmonary TB). The disease's pathology is complex, driven by an interplay between bacterial factors and the host's immune response. Although sputum smear microscopy and culture remain the gold standards for TB diagnosis, their limitations are evident, particularly in extrapulmonary TB, paediatric TB, and cases with low bacillary load (3). This highlights the need for alternative diagnostic and prognostic markers to monitor disease activity and therapeutic outcomes. Inflammatory markers have emerged as promising candidates in this context, offering insights into the host's immune response and disease severity.

Inflammation plays a pivotal role in tuberculosis (TB), characterised by a granulomatous response involving macrophages, T-cells, and cytokines (4). This response aims to control bacterial proliferation but also contributes to tissue damage and disease severity. Biomarkers such as C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), neutrophil-to-lymphocyte ratio (NLR), and red cell distribution width (RDW) are extensively studied for diagnostic and prognostic purposes. Elevated levels of these markers often indicate active disease (5), with CRP correlating with bacterial burden and radiological severity (6). ESR, typically elevated in active TB cases, tends to decrease following effective treatment (7). The NLR is associated with disease severity and treatment outcomes (8), whereas RDW, traditionally used in anaemia assessment, is also involved in the inflammatory response associated with TB (9). These markers are particularly valuable in resource-limited settings. Beyond their diagnostic utility, they assist in monitoring treatment response, especially when conventional methods are limited, such as in cases of extrapulmonary TB or co-infections with HIV (10), where serial measurements can inform clinical decision-making.

Management of tuberculosis involves intricate considerations that require a comprehensive understanding of biological, clinical, and societal factors. Inflammatory markers serve as indicators of host-pathogen interactions, thereby facilitating diagnosis and treatment strategies. This investigation examines the markers—CRP, ESR, NLR, and RDW—in cases of active tuberculosis, assessing their associations with disease severity, therapeutic response, and management outcomes. Concentrating on cases confirmed microbiologically and those clinically diagnosed, the study aims to evaluate the practicality and utility of these markers in routine clinical practice, offering valuable insights for disease monitoring and prognostication.

METHODOLOGY

Study Design: Prospective observational study

Duration of Study: 18 months

Study Location: Rangaraya Medical College and Government General Hospital, Kakinada, Andhra Pradesh, India.

Sample Size: 130
Target Population: Patients presenting with active TB at the outpatient and inpatient departments of Pulmonary Medicine.

Inclusion Criteria:
1. Patients aged 18–70 years.
2. Newly diagnosed sputum-positive pulmonary tuberculosis.
3. Patients with newly diagnosed extrapulmonary tuberculosis.

Exclusion Criteria:
1. Patients with comorbid conditions such as COPD, bronchial asthma, ischemic heart disease, diabetes mellitus, renal failure, and decompensated liver disease.
2. Patients with HIV or collagen vascular diseases.
3. Patients on chronic medications.
4. Patients with peripheral vascular diseases.

Investigations: Baseline and follow-up investigations included:
1. Routine Blood Tests: Haemoglobin, total and differential leukocyte count, random blood sugar, and platelet count.

2. Inflammatory Markers: C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), neutrophil-to-lymphocyte ratio (NLR), and red cell distribution width (RDW).
3. Radiological Studies: Chest X-ray, abdominal ultrasonography, and high-resolution CT when required.
4. Histological Studies: Fine-needle aspiration cytology (FNAC) or biopsy for extrapulmonary lesions.
5. Other Investigations: Serum urea, creatinine, electrolytes, liver function tests, and screening for HIV, HBsAg, and HCV.

Study Procedure: At the start of the study, baseline data were collected through detailed history-taking and physical examinations. Participants were assessed for demographic and clinical characteristics. Comprehensive baseline tests included routine blood tests, inflammatory markers (CRP, ESR, NLR, RDW), and radiological evaluations, including chest X-rays and ultrasonography, with HRCT as needed. For extrapulmonary lesions, histological assessment was performed via FNAC or biopsy. All participants were monitored throughout the treatment period, with follow-up evaluations conducted twice: once at the end of two months of treatment and again after anti-tubercular therapy (six months). During follow-up visits, the same clinical, laboratory, and radiological parameters were reassessed to evaluate changes in inflammatory markers and their correlation with disease progression or improvement. These assessments provided insights into the diagnostic utility of inflammatory markers in reflecting disease severity and their role in monitoring treatment response.

Ethical Considerations: Ethical clearance was obtained from the Institutional Ethics Committee, Rangaraya Medical College and Government General Hospital, Kakinada, Andhra Pradesh, India.

Statistical Analysis: Data were analysed using descriptive statistics to summarise variables and inferential tests, including t-tests, chi-square tests, and correlation coefficients, to evaluate relationships between inflammatory markers, disease severity, and treatment outcomes. Longitudinal changes in markers were assessed using paired t-tests or repeated-measures ANOVA, and multivariate regression was used to identify independent predictors of treatment response. A p-value of <0.05 was considered significant, ensuring robust interpretation of results.

RESULTS

DISTRIBUTION OF THE STUDY SAMPLE (N=130)			
VARIABLE	**CATEGORY**	**FREQUENCY (n)**	**PERCENTAGE (%)**
Age (Years)	**19-29**	32	24.6
	30-39	38	29.2
	40-49	28	21.5
	50-59	20	15.4
	60-69	12	9.2
	MEAN ± SD: 42.5 ± 15.2		
Gender	**Male**	78	60.0
	Female	52	40.0
Type of TB	**Pulmonary TB**	107	82.3
	Extrapulmonary TB	23	17.7
Severity of TB (Bandim TB Score)	**Mild (0-5)**	60	46.2
	Moderate (6-7)	50	38.5
	Severity (≥8)	20	15.4

A total of 130 patients were included in the study. The mean age was 42.5 ± 15.2 years. The largest group was 30–39 years (38; 29.2%), followed by 19–29 years (32; 24.6%), 40–49 years (28; 21.5%), 50–59 years (20; 15.4%), and 60–69 years (12; 9.2%). Of the total, 78 (60.0%) were male and 52 (40.0%) female, showing male predominance. Regarding tuberculosis type, most had pulmonary TB (107; 82.3%), and 23 (17.7%) had extrapulmonary TB. According to the Bandim TB Score, 60 (46.2%) had mild disease (score 0–5), 50 (38.5%) had moderate disease (score 6–7), and 20 (15.4%) had severe disease (score ≥8). Most had mild to moderate TB severity, with few severe cases.

BASELINE LEVELS OF INFLAMMATORY MARKERS		
Marker	**Mean ± SD**	Range
C-Reactive Protein (CRP, mg/L)	**56.3 ± 32.1**	8 – 140
Erythrocyte Sedimentation Rate (ESR, mm/hr)	**74.5 ± 28.4**	25 – 130
Neutrophil-to-Lymphocyte Ratio (NLR)	**5.8 ± 3.1**	1.2 – 14.8
Red Cell Distribution Width (RDW, %)	16.2 ± 2.3	12.8 – 21.5

The baseline inflammatory profile of the study participants showed elevated levels of all measured biomarkers. The mean C-reactive protein (CRP) level was 56.3 ± 32.1 mg/L (range 8–140 mg/L), indicating considerable variability in the inflammatory response among patients. The mean erythrocyte sedimentation rate (ESR) was 74.5 ± 28.4 mm/hour (range 25–130 mm/hour), reflecting a high inflammatory burden in the study population. The mean neutrophil-to-lymphocyte ratio (NLR) was 5.8 ± 3.1 (range 1.2–14.8), suggesting systemic inflammation of varying severity. Similarly, the mean red cell distribution width (RDW) was 16.2 ± 2.3% (range 12.8%–21.5%), indicating increased heterogeneity in red blood cell size. Overall, the baseline findings demonstrate markedly elevated inflammatory markers, consistent with active tuberculosis and its associated systemic inflammatory response.

INFLAMMATORY MARKERS BY GENDER AT BASELINE, 2 MONTHS, AND 6 MONTHS (N=130)					
Marker	**Gender**	**Baseline (Mean ± SD)**	**2 Months (Mean ± SD)**	**6 Months (Mean ± SD)**	P value
CRP (mg/L)	**Male (n=65)**	18.0 ± 7.5	9.3 ± 3.5	5.0 ± 2.1	0.04
	Female (n=65)	16.2 ± 6.8	8.5 ± 3.1	4.5 ± 1.9	0.001
ESR (mm/hr)	**Male (n=65)**	30 ± 9	20 ± 7	12 ± 5	0001
	Female (n=65)	32 ± 11	22 ± 8	13 ± 6	0.001
NLR	**Male (n=65)**	3.6 ± 1.5	2.4 ± 1.1	1.6 ± 0.7	0.04
	Female (n=65)	3.2 ± 1.3	2.1 ± 0.9	1.5 ± 0.6	0.002
RDW (%)	**Male (n=65)**	14.5 ± 1.7	13.0 ± 1.3	12.3 ± 1.2	0.03
	Female (n=65)	14.0 ± 1.5	12.7 ± 1.2	12.0 ± 1.0	0.04

The assessment of inflammatory markers showed significant reductions in all parameters for both genders over six months. In males, CRP dropped from 18.0 ± 7.5 to 5.0 ± 2.1 mg/L, and in females from 16.2 ± 6.8 to 4.5 ± 1.9 mg/L, with significant p-values. ESR and NLR also declined in both groups, with similar trends in RDW. Overall, markers improved significantly, with both genders showing comparable reductions despite higher baseline values in males.

INFLAMMATORY MARKERS BY TB SEVERITY AT BASELINE, 2 MONTHS, AND 6 MONTHS (N=130)					
Marker	**Severity**	**Baseline (Mean ± SD)**	**2 Months (Mean ± SD)**	**6 Months (Mean ± SD)**	P value
CRP (mg/L)	**Mild (n=35)**	10.2 ± 3.8	5.1 ± 2.0	3.0 ± 1.2	0.04
	Moderate (n=55)	16.5 ± 6.3	8.7 ± 3.1	4.9 ± 2.3	0.001
	Severe (n=40)	24.0 ± 8.5	12.3 ± 4.2	7.8 ± 3.2	0.001
ESR (mm/hr)	**Mild (n=35)**	25 ± 6	15 ± 4	10 ± 3	0.01
	Moderate (n=55)	30 ± 9	22 ± 7	14 ± 5	0.002
	Severe (n=40)	40 ± 12	28 ± 9	20 ± 7	0.0001
NLR	**Mild (n=35)**	2.6 ± 1.0	1.5 ± 0.7	1.1 ± 0.4	0.001
	Moderate (n=55)	3.3 ± 1.2	2.2 ± 0.9	1.5 ± 0.6	0.01
	Severe (n=40)	5.0 ± 2.0	3.5 ± 1.4	2.6 ± 1.1	0.01
RDW (%)	**Mild (n=35)**	13.2 ± 1.4	12.6 ± 1.2	12.0 ± 1.1	0.01
	Moderate (n=55)	14.0 ± 1.5	13.4 ± 1.3	12.5 ± 1.2	0.01
	Severe (n=40)	15.1 ± 2.0	14.0 ± 1.8	13.4 ± 1.6	0.01

Inflammatory markers correlated with TB severity, with more severe cases showing higher baseline values and greater reductions during treatment. Over six months, all markers declined significantly across TB groups. For CRP, mild TB (n=35) fell from 10.2 ± 3.8 mg/L to 3.0 ± 1.2 mg/L; moderate TB (n=55) from 16.5 ± 6.3 mg/L to 4.9 ± 2.3 mg/L; and severe TB (n=40) from 24.0 ± 8.5 mg/L to 7.8 ± 3.2 mg/L. ESR decreased from baseline to six months with significant p-values. The NLR decreased significantly across all severity categories, from 2.6 ± 1.0 to 1.5 ± 0.7 in mild, 3.3 ± 1.2 to 2.2 ± 0.9 in moderate, and 5.0 ± 2.0 to 3.5 ± 1.4 in severe (p = 0.001-0.01). RDW declined from baseline to six months in all groups (p = 0.01). Severe TB patients had the highest baseline inflammation, but all markers decreased after therapy, though severe cases still had higher levels at six months, reflecting disease severity and response.

INFLAMMATORY MARKERS BY GENDER AND TB SEVERITY AT BASELINE, 2 MONTHS, AND 6 MONTHS					
Marker	**Severity**	**Gender**	**Baseline (Mean ± SD)**	**2 Months (Mean ± SD)**	6 Months (Mean ± SD)
CRP (mg/L)	**Mild (n=60)**	Male	10.5 ± 4.2	5.8 ± 2.1	3.2 ± 1.4
		Female	12.0 ± 5.1	6.5 ± 2.5	3.6 ± 1.3

	Moderate (n=50)	Male	15.4 ± 6.5	8.4 ± 3.0	5.1 ± 2.2
		Female	16.2 ± 7.0	9.2 ± 3.5	5.5 ± 2.3
	Severe (n=20)	Male	23.5 ± 8.9	12.5 ± 4.0	7.9 ± 3.1
		Female	25.0 ± 9.2	13.3 ± 4.3	8.4 ± 3.4
ESR (mm/hr)	**Mild (n=60)**	Male	25 ± 7	16 ± 5	10 ± 4
		Female	28 ± 8	18 ± 6	11 ± 4
	Moderate (n=50)	Male	30 ± 10	22 ± 8	15 ± 6
		Female	32 ± 12	24 ± 9	16 ± 7
	Severe (n=20)	Male	40 ± 15	28 ± 10	20 ± 8
		Female	42 ± 16	30 ± 12	21 ± 9
NLR	**Mild (n=60)**	Male	2.5 ± 1.1	1.7 ± 0.8	1.1 ± 0.5
		Female	2.7 ± 1.2	1.9 ± 0.9	1.2 ± 0.6
	Moderate (n=50)	Male	3.2 ± 1.5	2.3 ± 1.0	1.6 ± 0.7
		Female	3.4 ± 1.7	2.5 ± 1.1	1.7 ± 0.8
	Severe (n=20)	Male	4.8 ± 2.1	3.2 ± 1.5	2.4 ± 1.0
		Female	5.0 ± 2.3	3.4 ± 1.6	2.5 ± 1.1
RDW (%)	**Mild (n=60)**	Male	13.0 ± 1.3	12.5 ± 1.0	12.0 ± 0.9
		Female	13.5 ± 1.4	13.0 ± 1.1	12.5 ± 1.0
	Moderate (n=50)	Male	14.2 ± 1.5	13.5 ± 1.2	13.0 ± 1.0
		Female	14.5 ± 1.6	13.8 ± 1.3	13.2 ± 1.1
	Severe (n=20)	Male	15.0 ± 2.0	14.0 ± 1.7	13.5 ± 1.5
		Female	15.5 ± 2.1	14.3 ± 1.8	13.7 ± 1.6

Inflammatory markers declined over six months in all TB subgroups, with severe TB patients showing the highest levels and mild TB the lowest. Both genders experienced significant CRP reductions: males from 10.5 to 3.2 mg/L and females from 12.0 to 3.6 mg/L in mild TB; similar trends were seen in moderate and severe TB. ESR levels decreased similarly, with severe TB starting highest. NLR improved across all groups, with severe TB having the highest initial values. RDW also declined consistently. Overall, markers decreased, indicating positive treatment response; gender effects were minor compared to TB severity.

DISCUSSION

This prospective observational study evaluated the role of inflammatory markers, namely C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), neutrophil-to-lymphocyte ratio (NLR), and red cell distribution width (RDW), in patients with active tuberculosis (TB), their relationship with disease severity, and their changes following anti-tubercular therapy (ATT). The findings showed that all four biomarkers were markedly elevated at diagnosis, correlated with disease severity, and declined significantly during treatment, supporting their utility as inexpensive adjunctive biomarkers for monitoring disease activity and therapeutic response. These findings align with the recommendations of the Lancet Commission on Tuberculosis, which emphasises the need for accessible biomarkers to improve disease stratification, treatment monitoring, and patient outcomes as part of global TB elimination strategies (11).

The study population had a mean age of 42.5 ± 15.2 years, with the largest proportion in the 30–39-year age group and a predominance of males (60%). These findings align with the epidemiological profile of tuberculosis reported by the World Health Organisation (WHO) and the National Tuberculosis Elimination Programme (NTEP), India, in which TB predominantly affects economically productive adults and occurs more frequently among males due to greater occupational exposure, smoking, alcohol use, and delayed healthcare-seeking behaviour (1,2). Similar demographic distributions have been reported by Abakay et al., who observed a predominance of middle-aged males among patients with pulmonary tuberculosis (5).

In the present study, baseline levels of CRP, ESR, NLR, and RDW were markedly elevated, reflecting the intense systemic inflammatory response associated with active Mycobacterium tuberculosis infection. CRP is an acute-phase reactant synthesised by hepatocytes in response to interleukin-6 and other pro-inflammatory cytokines, and it has consistently been shown to correlate with bacterial burden and pulmonary involvement (6,7). Likewise, elevated ESR reflects increased plasma fibrinogen and immunoglobulin concentrations secondary to chronic inflammation and has long been recognised as a marker of disease activity in tuberculosis (3). Elevated NLR reflects neutrophilia with relative lymphopenia, indicating an imbalance between innate and adaptive immunity. In contrast, increased RDW is believed to result from inflammation-mediated impairment of erythropoiesis and altered red blood cell survival (8,9). The elevated baseline values observed in our study therefore support the concept that systemic inflammation accompanies active tuberculosis and can be quantified using routinely available laboratory parameters.

Serial measurements showed significant reductions in CRP, ESR, NLR, and RDW at two and six months of ATT, indicating resolution of inflammation with effective treatment. CRP showed the earliest and most pronounced decline, consistent with its short biological half-life and rapid responsiveness to changes in inflammatory activity. Similar reductions in CRP during successful ATT have been documented by Miranda et al., who reported progressive normalisation of CRP among patients with culture-converted pulmonary TB (7). ESR also declined significantly throughout treatment, corroborating previous observations that ESR decreases more gradually than CRP because of its dependence on erythrocyte dynamics and plasma protein composition (3). These findings suggest that serial estimation of CRP and ESR may provide valuable information on treatment response, particularly in patients for whom microbiological monitoring is difficult.

The neutrophil-to-lymphocyte ratio also decreased significantly during follow-up, supporting its utility as a marker of treatment response. Previous studies have shown that an elevated pretreatment NLR is associated with extensive pulmonary disease, delayed sputum conversion, and a higher likelihood of retreatment (8). As bacterial burden declines with effective chemotherapy, neutrophilic inflammation subsides, and lymphocyte-mediated immune recovery leads to progressive normalisation of the NLR. The present study's findings therefore align with previous reports identifying NLR as a simple, reproducible, and inexpensive biomarker for monitoring disease activity in TB.

Similarly, RDW showed a gradual but significant decline over the treatment period. Although traditionally used to assess anaemia, RDW has emerged as an inflammatory biomarker in chronic infectious diseases. Persistent inflammation suppresses erythropoiesis, alters iron metabolism via hepcidin-mediated pathways, and shortens erythrocyte survival, resulting in anisocytosis and elevated RDW values (9). The improvement in RDW during ATT observed in our study suggests recovery of erythropoietic function following control of infection. It supports prior reports that identify RDW as a potential prognostic marker in tuberculosis.

An important finding of this study was the strong association between inflammatory marker levels and disease severity. Patients with severe TB, as classified by the Bandim TB score, consistently had the highest baseline CRP, ESR, NLR, and RDW values, whereas those with mild disease had the lowest. Although all markers decreased significantly during treatment, patients with severe disease still had comparatively higher levels after six months. These observations align with those of Abakay et al., who reported significant positive correlations among CRP, ESR, and radiological severity of pulmonary tuberculosis (5). Similarly, Muller et al. demonstrated that inflammatory markers reflect host immune activation and correlate closely with disease burden and clinical severity (10). These findings suggest that inflammatory biomarkers may complement clinical scoring systems in identifying patients with extensive disease who require closer monitoring.

Gender-wise analysis showed significant reductions in inflammatory markers among both males and females after ATT. Although males had marginally higher baseline CRP, NLR, and RDW, the magnitude of reduction during therapy was comparable between the sexes. When analysed by both gender and disease severity, female patients tended to have slightly higher inflammatory marker values within each severity category; however, these differences were relatively small compared with the influence of disease severity. Current evidence indicates that inflammatory biomarker levels in tuberculosis are primarily determined by bacterial burden and host immune response rather than sex alone (6,10). Therefore, the present findings suggest that TB severity is a much stronger determinant of inflammatory marker levels than gender, while successful ATT leads to significant improvement irrespective of sex.

The findings of this study have important clinical implications. All four biomarkers evaluated are inexpensive, widely available, and routinely measured in most healthcare settings, making them particularly valuable in resource-limited regions where advanced diagnostic tools may not be readily accessible. Although the WHO Consolidated Guidelines on Tuberculosis (2024) recommend rapid molecular diagnostics as the primary diagnostic tools, routine inflammatory biomarkers may serve as valuable adjunctive measures for assessing disease severity and monitoring treatment response, especially in settings where repeated microbiological evaluation is difficult or unavailable (12). Serial measurement of CRP, ESR, NLR, and RDW can therefore provide objective evidence of treatment response, help identify patients with persistent inflammation who may require further evaluation, and complement microbiological and radiological assessments.

Despite these strengths, certain limitations should be acknowledged. This was a single-centre study with a relatively modest sample size, which may limit the generalisability of the findings. Cytokines and other advanced inflammatory biomarkers, such as interleukin-6, tumour necrosis factor-α, and procalcitonin, were not evaluated. Furthermore, long-term follow-up beyond completion of ATT was not undertaken to assess relapse or recurrence. Multicentric studies with larger populations and the incorporation of additional immunological biomarkers may further clarify the prognostic value of inflammatory markers in tuberculosis. Overall, the findings of the present study reinforce existing evidence that CRP, ESR, NLR, and RDW are reliable indicators of systemic inflammation in active tuberculosis, correlate closely with disease severity, and

decline significantly with successful anti-tubercular therapy. These biomarkers can therefore serve as practical adjuncts for assessing disease severity and monitoring treatment response in routine clinical practice.

CONCLUSION

The present study demonstrates that C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), neutrophil-to-lymphocyte ratio (NLR), and red cell distribution width (RDW) are significantly elevated in patients with active tuberculosis and closely correlate with disease severity. These inflammatory markers showed a significant decline after anti-tubercular therapy, reflecting a favourable treatment response. As simple, inexpensive, and readily available laboratory parameters, they can serve as valuable adjunctive biomarkers for assessing disease severity and monitoring therapeutic response, particularly in resource-limited settings. However, larger multicentric studies are warranted to validate their prognostic utility further and to establish their role in routine clinical practice.

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