



EVOLUTION OF SOME BIOCHEMICAL MARKERS DURING ANTI-TUBERCULOSIS TREATMENT: A LONGITUDINAL STUDY IN YAOUNDÉ, CAMEROON

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Abstract: - Tuberculosis treatment with isoniazid, rifampicin, pyrazinamide, and ethambutol achieves high cure rates but carries hepatotoxicity risks (2-28% globally) and nephrotoxicity, necessitating biochemical monitoring. C-reactive protein (CRP) has emerged as a potential treatment response biomarker, yet longitudinal data from sub-Saharan Africa remain limited. This study characterized biomarker evolution during standard anti-TB treatment in Cameroon. Prospective cohort study of 45 HIV-negative pulmonary TB patients at Jamot Hospital, Yaoundé (March 2023–September 2025). Participants received WHO-recommended 2HRZE/4HR regimen. CRP, alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatinine, and blood urea nitrogen were measured at baseline (M0), month 2 (M2), and month 6 (M6). Friedman test with Bonferroni- corrected post-hoc comparisons evaluated longitudinal changes. All 45 patients completed treatment; 95.6% achieved microbiological cure. Median CRP declined 50% from baseline to treatment completion (48→24 mg/L), with no change during intensive phase (M0-M2) but significant reduction during continuation phase (M2-M6, $p < 0.001$). No severe hepatotoxicity occurred (0% with ALT >100 U/L); median ALT decreased 31% (26→18 U/L). AST/ALT ratio increased progressively (0.75→1.51), indicating mild rifampicin-induced enzymatic adaptation without clinical sequelae. Creatinine stability confirmed renal safety. Blood urea nitrogen exhibited marked variability, reflecting heterogeneous nutritional status. Systematic CRP monitoring at M0, M2, and M6 provides cost-effective treatment response assessment in resource-limited settings. This first Cameroonian evaluation of longitudinal CRP kinetics demonstrates feasibility of biomarker-guided TB management. Future studies should validate findings in HIV-coinfected populations.

Keywords: Tuberculosis, C-reactive protein, hepatotoxicity, biomarkers, treatment monitoring, Cameroon.



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1. Introduction

Tuberculosis poses a major global health burden. The 2023 figures of 8.2 million new cases and 1.25 million deaths align closely with WHO reports, though estimated total incidence may reach approximately 10.8 million when including undiagnosed cases [1, 2]. Standard six-month regimens using isoniazid, rifampicin, pyrazinamide, and ethambutol effectively treat drug-sensitive TB but carry hepatotoxicity risks that vary by population: 2–5% in Western settings [3], 8–16% in Asian cohorts [4], and up to 28% in sub-Saharan Africa with HIV co-infection [5]. Hepatotoxicity primarily results from isoniazid and pyrazinamide metabolism via cytochrome P450 pathways, with genetic polymorphisms in N-acetyltransferase 2 (NAT2) substantially modulating individual risk [6]. Nephrotoxicity and neuropathy may also occur, necessitating baseline and serial monitoring of liver enzymes such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST), especially in patients with HIV co-infection or pre-existing hepatic dysfunction [3,7].

C-reactive protein (CRP) reliably tracks TB-associated inflammation, rising with bacterial load and declining rapidly under effective therapy. A 50% reduction in CRP by month 2 predicts treatment success; combining CRP trends with liver function tests supports early detection of toxicity and treatment optimization without requiring advanced diagnostic tools, a crucial advantage in resource-limited settings such as Cameroon [8, 9]. Current

guidelines recommend monthly clinical assessments, sputum cultures, and biochemical marker monitoring during the intensive phase, with dose adjustments for high-risk groups to minimize adverse events [10].

In infectious disease research, serial assessment of CRP may enhance epidemiological models for predicting TB treatment outcomes in the city of Yaoundé. This study aimed to characterize longitudinal variations in inflammatory and organ function biomarkers throughout anti-TB treatment and to identify biomarker patterns associated with favorable therapeutic outcomes.

2. Materials and Methods

2.1. Study design and participant selection

A prospective cohort study was conducted at Jamot Hospital, Yaoundé, Cameroon, between March 2023 and September 2025. From an initial cohort of 105 newly diagnosed pulmonary tuberculosis patients confirmed by GeneXpert MTB/RIF and sputum smear microscopy, 45 patients met inclusion criteria and were enrolled for intensive biochemical monitoring. Exclusion criteria: HIV co-infection (n=30), baseline hepatic (ALT/AST >2× ULN) or renal dysfunction (creatinine >120 µmol/L) (n=12), MDR-TB (n=8), pregnancy (n=5), concomitant hepatotoxic medications (n=3), declined consent (n=2). Sample size was determined by feasibility constraints; post-hoc power analysis confirmed >80% power for primary endpoints.

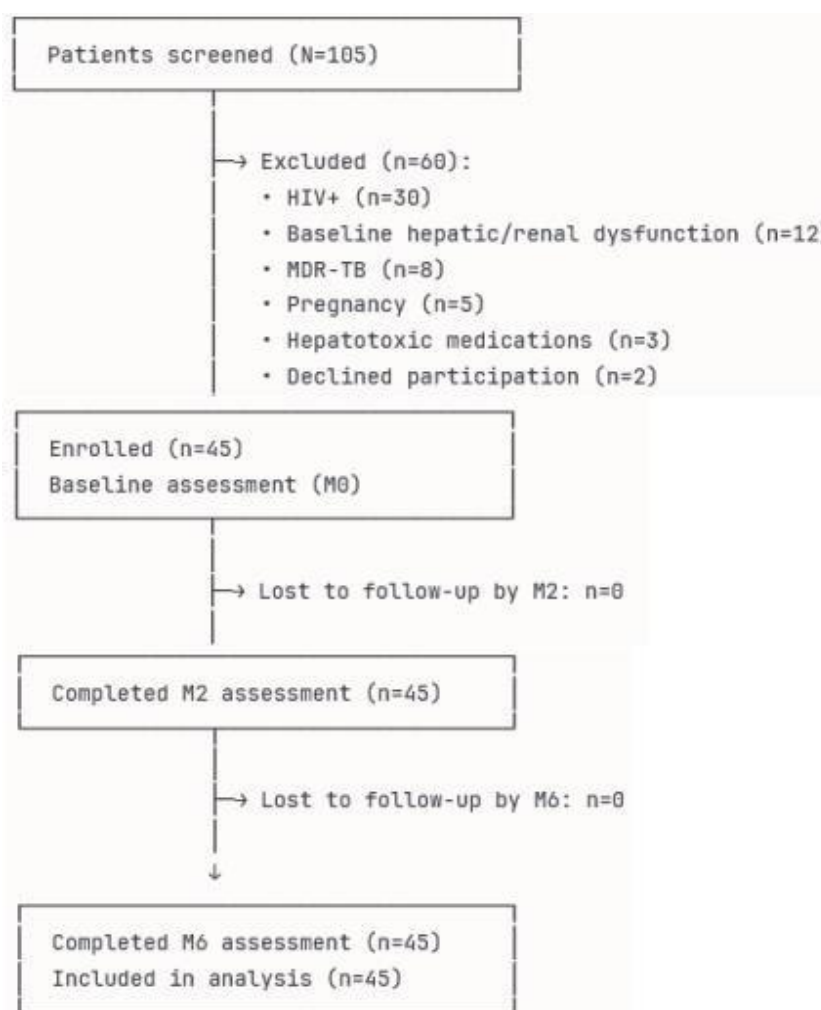


Figure 1: Flow Diagram of Patient Screening, Enrollment, and Follow-up

All participants provided written informed consent, and the study protocol received ethical clearance from the Regional Ethics Committee for Human Health Research (approval number CE N°1297/CRERSHC/2022), in accordance with the Declaration of Helsinki.

Baseline assessments included: demographic data (age, sex), anthropometric measurements (weight, height, BMI), behavioral history (smoking status with pack-years, alcohol consumption frequency), clinical symptoms (cough duration, hemoptysis, night sweats, weight loss), radiological findings (cavitary disease, bilateral involvement), and microbiological severity (sputum smear grade). Treatment adherence was monitored through daily directly observed therapy (DOTS) during the intensive phase and weekly pill counts during the continuation phase.

2.2. Anti-tuberculosis treatment protocol and biological sampling

Participants received the standard World Health Organization (WHO)-recommended treatment regimen: 2HRZE/4HR (two months of isoniazid 5 mg/kg, rifampicin 10 mg/kg, pyrazinamide 25 mg/kg, and ethambutol 15 mg/kg, followed by four months of isoniazid and rifampicin). Venous blood samples (5 mL) were collected via antecubital venipuncture under aseptic conditions at three critical time points: baseline (M0, pre-treatment), end of intensive phase (M2), and end of treatment (M6). Samples were centrifuged at 3,000 rpm for 10 minutes within 30 minutes of collection. Serum aliquots were stored at -80°C in cryovials until batch analysis to minimize inter-assay variability.

2.3. Biochemical assays and quality control

C-Reactive Protein (CRP): Semi-quantitative latex agglutination immunoassay (detection limit: 6 mg/L). Serial two-fold dilutions (1:2 to 1:64) were performed, and CRP concentration was calculated as 6 mg/L multiplied by the reciprocal of the last positive dilution. All assays were performed in duplicate.

Hepatic transaminases (ALT and AST): Enzymatic kinetic method using commercially available kits (BIOLABO, France) on a semi-automated spectrophotometer. The assay quantifies nicotinamide adenine dinucleotide (NADH) consumption at 340nm wavelength at 37°C. Reference ranges: ALT <50 U/L (men), <35 U/L (women); AST <50 U/L (men), <35 U/L (women).

Hepatotoxicity was defined as ALT/AST >3× upper limit of normal or >2× in symptomatic patients.

Serum creatinine: Modified Jaffé colorimetric method without deproteinization. Reference intervals: 62-106µmol/L (men), 44-80µmol/L (women). Renal impairment was classified according to estimated glomerular filtration rate (eGFR) using the CKD-EPI equation.

Blood urea nitrogen (BUN): Enzymatic urease-glutamate dehydrogenase (GLDH) coupled method. Reference range: 2.5-7.5mmol/L. Internal quality control sera (normal and pathological levels) were analyzed daily to ensure accuracy and precision.

2.4. Statistical Analysis

Data were analyzed using IBM SPSS 26.0 (IBM Corp., USA). Non-normally distributed variables (Shapiro-Wilk test, $p < 0.05$) are presented as medians with interquartile ranges. Subgroup comparisons employed Mann-Whitney U and Fisher's exact tests. Statistical significance: $p < 0.05$ (two-tailed).

3. Results

3.1. Baseline characteristics

All 45 enrolled participants completed the 6-month treatment protocol with >90% adherence verified through direct observation therapy (DOTS) and pill counts. Baseline demographic, clinical, and behavioral characteristics are summarized in Table 1. The cohort was predominantly male (73.3%, $n=33$) with a median age of 34 years (range: 21-65). Median body mass index was 19.8 kg/m² (IQR: 17.5-22.1), reflecting the high prevalence of malnutrition typical in active TB patients. Smoking was reported by 35.6% ($n=16$), while regular alcohol consumption (≥ 2 drinks/week) was documented in 22.2% ($n=10$). No participants reported intravenous drug use or recreational substance abuse. Baseline disease severity distribution included: smear grade 1+ (24.4%, $n=11$), 2+ (40.0%, $n=18$), and 3+ (35.6%, $n=16$). Median baseline sputum bacterial load was 2+ (IQR: 1-3). Sputum conversion (microbiological cure was achieved): 95.6% of participants by M6 (43/45), with two patients showing delayed culture conversion at month 8 but ultimately completing treatment successfully.

Table 1: Participants baseline characteristics

Demographics characteristics	
Age, years - median (range)	34 (21-65)
Male sex - n (%)	33 (73.3)
Female sex – n (%)	12 (26.7)
BMI, kg/m ² – median (IQR)	19.8 (17.5-22.1)
Underweight (BMI <18.5) – n (%)	18 (40.0)
Behavioral factors	
Current smoker – n (%)	16 (35.6)
Pack-years (smokers only) – median (IQR)	5 (2-10)
Alcohol consumption ≥ 2 drinks/week – n (%)	10 (22.2)

Traditional medicine use – n (%)	8 (17.8)
Clinical presentation	
Symptoms duration, weeks – median (IQR)	8 (4-12)
Cough – n (%)	45 (100)
Hemoptysis – n (%)	12 (26.7)
Night sweats – n (%)	38 (84.4)
Weight loss >5 kg – n (%)	35 (77.8)
Disease severity	
Sputum smear grade n (%)	
1+	11 (24.4)
2+	18 (40.0)
3+	16 (35.6)
Cavitary disease on chest X-ray – n (%)	28 (62.2)
Bilateral involvement – n (%)	31 (68.9)
Baseline biochemistry	
Hemoglobin, g/dL – median (IQR)	11.2 (10.1-12.8)
Anemia (Hb <12 g/dL) – n (%)	29 (64.4)
Albumin, g/L – median (IQR)	32 (28-36)
Treatment outcomes	
Treatment completion – n (%)	45 (100)
Adherence >90% – n (%)	45 (100)
Sputum conversion by M2 – n (%)	38 (84.4)
Microbiological cure by M6 – n (%)	43 (95.6)
Delayed conversion (M8) – n (%)	2 (4.4)

6 = month 6; M8 = month 8.

3.2. C-Reactive Protein Evolution

CRP demonstrated a biphasic response pattern: median levels remained stable during the intensive phase (M0 to M2: 48 mg/L) before declining significantly during the continuation phase,

achieving 50% overall reduction by treatment completion (M0 to M6: 48 → 24 mg/L). variance increased at M2 (6-96 mg/L), suggesting heterogeneous early responses. IQR narrowed by M6 (12-48 mg/L), indicating convergence toward normalization (Table 2).

Table 2. Evolution of C-reactive protein during anti-TB treatment

Timepoint	Median (mg/L)	IQR (mg/L)	Range (mg/L)
M0	48	48-96	12-96
M2	48	24-96	6-96
M6	24	12-48	6-96

3.3. Liver enzymes

ALT declined 31% (median: 26→18 U/L; third quartile: 43.5→26.5 U/L; maximum: 82→69 U/L). AST remained stable (median:

29→30 U/L; third quartile: 48→37 U/L). No severe hepatotoxicity (ALT >100 U/L) occurred (Table 3).

Table 3. Evolution of liver enzymes during treatment

Enzyme	Time	Median	IQR	Range
ALT	M0	26	19-43.5	3-82
	M2	21	15-27.11	3-68
	M6	18	15-26.54	8-69.13
AST	M0	29	18-48	12-88
	M2	27	22.5-37.5	13-78
	M6	30	26.29-37	19-47.92

3.4. AST/ALT ratio

Median ratio increased progressively (0.75→1.31→1.51; IQR: 0.48-1.85 → 1.07-1.23 → 1.1- 2.12). Despite maximum values of

7.33 (M0), 8.0 (M2), and 3.62 (M6), 93.3% of patients maintained ratios <2.0, indicating mild hepatocellular adaptation. No severe hepatopathy occurred (Table 4).

Table 4. Evolution of AST/ALT ratio

Timepoint	Median	IQR	Range
M0	0.75	0.48-1.85	0.19-7.33
M2	1.31	1.07-1.23	0.2-8.0
M6	1.51	1.1-2.12	0.51-3.62

Supplementary Table S1: Characteristics of patients with elevated AST/ALT ratio (>2.0)

Patient ID	Timepoint	AST (U/L)	ALT (U/L)	AST/ALT	Clinical symptoms	Action taken	M6 outcome
001	M0	146	20	7.3	None	Monitored	Ratio 1.2, cured
023	M2	160	20	8.0	None	Monitored	Ratio 1.2, cured
037	M6	72	20	3.6	None	None	Cured

All patients completed treatment without modification and achieved microbiological cure (negative sputum culture at M6). None developed jaundice, coagulopathy, or other signs of acute liver failure.

3.5. renal function

Creatinine remained stable (0.88→0.86→0.985 μ mol/L). Maximum values declined (2.24→1.82→1.37 μ mol/L), indicating

no nephrotoxicity. Urea fluctuated (20→11.48→19.83 mmol/L) with extreme dispersion at M6 (IQR: 7.61-54.12 mmol/L, range: 7.61-77.78 mmol/L), reflecting variable nutritional and hydration status (Table 4).

Table 4. Evolution of renal function markers

Marker	Time	Median	IQR	Range
Creat (μ mol/L)	M0	0.88	0.82-0.94	0.77-2.24
	M2	0.86	0.77-0.99	0.59-1.82
	M6	0.985	0.91-1.075	0.31-1.37
Urea (mmol/L)	M0	20	15.85-21.31	0.16-76.3
	M2	11.48	10.26-19.61	0.75-40.69
	M6	19.83	7.61-54.12	7.61-77.78

3.6. Urea/Creatinine ratio

Ratio showed variable pattern: 20.27 (M0, normal) → 13.06 (M2,

wide dispersion 3.02-171.9) → 20.87 (M6, persistent dispersion 7.17-234.77). Extreme variability reflects heterogeneous protein metabolism, hydration, and possible unreported factors (Table 5).

Table 5. Evolution of urea/creatinine ratio

Timepoint	Median	IQR	Range
M0	20.27	15.91-24.21	10.5-45.74
M2	13.06	0.43-18.78	3.02-171.9
M6	20.87	16.27-63.46	7.17-234.77

3.7. Correlation Between Biomarkers and Treatment Outcomes

Spearman correlation analysis revealed significant associations between CRP dynamics and treatment outcomes. CRP reduction from M0 to M6 correlated negatively with time to sputum conversion ($\rho = -0.52$, $p < 0.001$), indicating that greater inflammatory resolution was associated with faster microbiological clearance. Patients achieving sputum conversion by M2 ($n=38$, 84.4%) exhibited significantly greater median CRP decline at M2 compared to delayed converters ($n=7$): 45.8% vs. 12.5% reduction (Mann-Whitney $U = 42.5$, $p = 0.003$).

CRP at M2 demonstrated moderate predictive value for final

treatment outcomes. ROC analysis identified a threshold of 30 mg/L at M2 (AUC = 0.73, 95% CI: 0.58-0.88, $p = 0.012$), with sensitivity of 71.4% and specificity of 78.9% for predicting delayed sputum conversion or treatment extension beyond 6 months. Patients with CRP >30 mg/L at M2 ($n=12$, 26.7%) required a median of 8.5 weeks for sputum conversion compared to 6.0 weeks in those with CRP ≤30 mg/L ($p = 0.004$). No significant correlations were observed between ALT changes and treatment outcomes ($\rho = 0.12$, $p = 0.43$) or between creatinine levels and sputum conversion time ($\rho = -0.08$, $p = 0.60$), confirming CRP as the most clinically relevant biomarker for treatment monitoring in this cohort.

Table 6. Association between biomarkers and sputum conversion

Biomarker	Early converters (M2, n=38)	Delayed converters (>M2, n=7)	p-value
CRP (mg/L)			
Baseline – median (IQR)	42 (24-72)	84 (60-96)	0.008*
M2 – median (IQR)	24 (12-36)	72 (48-84)	<0.001*
% reduction M0→M2	45.8%	12.5%	0.003*
ALT (U/L)			
Baseline – median (IQR)	26 (18-38)	28 (20-46)	0.52
M2 – median (IQR)	20 (15-28)	24 (18-32)	0.31
AST/ALT ratio			
M2 – median (IQR)	1.25 (1.05-1.48)	1.42 (1.15-1.85)	0.28
Creatinine (μmol/L)			
M2 – median (IQR)	75 (62-88)	81 (68-95)	0.45

*Statistically significant ($p < 0.05$). Mann-Whitney U test for continuous variables.

3.8. Subgroup Analysis by CRP Response Pattern

Participants were stratified into rapid responders (≥50% CRP reduction by M2, $n=22$, 48.9%) and slow responders (<50% reduction, $n=23$, 51.1%) based on early inflammatory dynamics. Rapid responders demonstrated significantly faster sputum conversion (median: 4 weeks, IQR: 3-6) compared to slow responders (median: 8 weeks, IQR: 6-10; Mann-Whitney $U = 98.5$, $p < 0.001$). By M2, 95.5% (21/22) of rapid responders achieved culture negativity compared to 73.9% (17/23) of slow responders

(Fisher's exact test, $p = 0.049$). Baseline characteristics differed between groups. Slow responders had higher median baseline CRP (72 mg/L vs. 36 mg/L, $p = 0.002$), greater prevalence of cavitory disease (78.3% vs. 45.5%, $p = 0.024$), and higher sputum smear grades (median 3+ vs. 2+, $p = 0.031$). However, both groups achieved equivalent final outcomes: 100% treatment completion and 95.5% vs. 95.7% microbiological cure by M6 ($p = 1.0$), indicating that slow CRP responders still attain favorable outcomes with standard treatment duration. Hepatic transaminases showed no significant differences between CRP response groups at any time

point (ALT at M2: rapid 20 U/L vs. slow 22 U/L, $p = 0.54$), suggesting independent mechanisms for inflammatory resolution and drug metabolism.

Discussion

This longitudinal study provides comprehensive data on the evolution of biochemical markers during antituberculosis treatment in a sub-Saharan African population. The findings reveal globally favorable therapeutic responses despite exposure to hepatotoxic medications, with C-reactive protein (CRP) emerging as the most reliable biomarker of treatment response.

The pattern median 50% reduction in CRP ($48 \rightarrow 24$ mg/L) differs from Wilson et al., who reported that $>75\%$ reduction within two months predicts favorable outcomes. Our delayed CRP decline may reflect differences in baseline disease severity, assay methodology (semi-quantitative vs. high-sensitivity CRP), or population characteristics. Notably, all patients achieved microbiological cure despite slower CRP kinetics, suggesting that a 50% reduction by M6 remains a valid treatment success indicator in our setting. [1, 5, 10].

No severe hepatotoxicity (ALT >100 U/L; $>3\times$ upper limit of normal) was detected, contrasting with global incidence rates of 2-28%. This observation is explained by the exclusion of pre-existing hepatic pathology, the relatively young age of the cohort (median: 34 years), and close monitoring. The 31% decrease in ALT levels suggests inflammatory resolution rather than drug-induced injury, corroborated by AST stability. The increase in the AST/ALT ratio ($0.75 \rightarrow 1.51$) indicates moderate hepatocellular stress related to rifampicin-mediated enzymatic induction, not warranting therapeutic modification in the absence of clinical symptoms [2, 11].

While median AST/ALT ratios remained acceptable ($0.75 \rightarrow 1.51$), one patient exhibited an extreme value of 8.0 at M2. Ratios >5 may indicate severe hepatocellular necrosis, alcoholic liver disease, or extrahepatic AST sources [12, 13]. Since AST is present in muscle, erythrocytes, and kidneys whereas ALT is hepatic-specific [14], this elevation likely reflects extrahepatic sources, rifampicin-induced differential enzyme clearance [15], or mitochondrial dysfunction [4]. Critically, the patient remained asymptomatic with normal bilirubin, and the ratio normalized by M6, indicating transient enzyme dysregulation rather than drug-induced liver injury [16]. Future studies should incorporate GGT, bilirubin, and creatine kinase to differentiate hepatocellular from extrahepatic processes in patients with AST/ALT >3.0 [17].

Creatinine stability confirms the renal safety of first-line medications. The decline in maximum values ($106 \rightarrow 69$ $\mu\text{mol/L}$) likely reflects correction of initial dehydration. Erratic urea fluctuations raise interpretative challenges: the initial decrease (M0 $\rightarrow$ M2) corresponds to nutritional improvement, but the subsequent rise and extreme dispersion at M6 (2.6-27.5 mmol/L) reflect multifactorial influences including variable protein intake, hydration status, and potential undisclosed traditional medicine use. The marked variability in the urea/creatinine ratio (171.9 at M2; 234.77 at M6) exceeds typical physiological values, suggesting dehydration episodes, occult gastrointestinal bleeding, or increased protein catabolism [18, 19, 20].

Our findings extend limited sub-Saharan African biomarker data.

Ugandan and South African studies reported 65-68% CRP reduction by M6 versus our 50%, potentially reflecting their inclusion of HIV-positive patients [21, 22]. Our zero severe hepatotoxicity rate contrasts with 12-18% reported in Ethiopia and Nigeria, likely attributable to our exclusion of HIV co-infection and baseline liver dysfunction [23, 24]. Our 95.6% cure rate exceeds Cameroon's national average (83%) [1, 24], though direct comparison is limited by differing monitoring intensity. Renal safety aligns with multi-country East African data showing no first-line drug nephrotoxicity [21]. To our knowledge, this is the first systematic evaluation of longitudinal CRP kinetics in Cameroonian TB patients.

Study limitations: The exclusion of HIV-positive patients, representing 29% of tuberculosis cases in Cameroon, limits the generalizability of results. The modest sample size ($n=45$) may fail to detect rare events. The absence of dietary and hydration standardization complicates interpretation of urea variations. Plasma drug concentration monitoring and genetic polymorphism screening (NAT2) were not performed, limiting analysis of pharmacokinetic factors underlying hepatotoxicity variability.

Clinical implications: We propose a risk-stratified monitoring strategy: (1) systematic CRP measurement at M0, M2, and M6 in all patients; (2) monthly liver enzymes in high-risk subjects (>35 years, alcohol consumption, malnutrition) or symptomatic patients; (3) creatinine monitoring limited to cases receiving aminoglycosides; (4) discontinuation of systematic urea monitoring due to excessive variability. Decision-making thresholds include: CRP >30 mg/L at M2 indicating need for enhanced surveillance; AST/ALT $>2\times$ normal with symptoms triggering hepatotoxicity evaluation.

Conclusion

This longitudinal study demonstrates favorable biochemical marker evolution during standard anti-tuberculosis treatment in a sub-Saharan African cohort. C-reactive protein proved the most reliable treatment response indicator, with median 50% reduction at month 2 predicting therapeutic success. Despite hepatotoxic drug exposure, liver function remained well-preserved, though the rising AST/ALT ratio ($0.75 \rightarrow 1.51$) warrants monitoring for subclinical hepatocellular stress. Renal function stability confirmed first-line drug safety.

Substantial interindividual variability in blood urea nitrogen and transaminase ratios underscores the need for risk-stratified rather than uniform monitoring protocols. In resource-limited settings, systematic CRP measurement at baseline, month 2, and month 6 represents a cost-effective adjunct to microbiological monitoring, with a threshold >30 mg/L at month 2 identifying patients requiring enhanced surveillance. Future studies should validate these findings in HIV-coinfected populations and establish standardized CRP-based clinical decision algorithms.

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Conflict of Interest

The authors declare no competing interests.

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References

- WHO (2024) Global Tuberculosis Report 2024. Geneva
- Lee, H., Kim, J., Kim, J., & Park, Y. J. (2025). Review of the Global Burden of Tuberculosis in 2023: Insights from the WHO Global Tuberculosis Report 2024]. *Public Health Weekly Report*, 18(11 Suppl), 55–69. <https://doi.org/10.56786/PHWR.2025.18.11suppl.5>
- Ramappa V & Aithal GP. Hepatotoxicity related to anti-tuberculosis drugs: mechanisms and management. *J Clin Exp Hepatol*. 2013;3(1):37-49.
- Saukkonen, J. J., Cohn, D. L., Jasmer, R. M., Schenker, S., Jereb, J. A., Nolan, C. M., Peloquin, C. A., Gordin, F. M., Nunes, D., Strader, D. B., Bernardo, J., Venkataramanan, R., Sterling, T. R., & ATS (American Thoracic Society) Hepatotoxicity of Antituberculosis Therapy Subcommittee (2006). An official ATS statement: hepatotoxicity of antituberculosis therapy. *American journal of respiratory and critical care medicine*, 174(8), 935–952. <https://doi.org/10.1164/rccm.200510-1666ST>
- Yimer, G., Ueda, N., Habtewold, A., Amogne, W., Suda, A., Riedel, K. D., Burhenne, J., Aderaye, G., Lindquist, L., Makonnen, E., & Aklillu, E. (2011). Pharmacogenetic & pharmacokinetic biomarker for efavirenz based ARV and rifampicin based anti-TB drug induced liver injury in TB-HIV infected patients. *PloS one*, 6(12), e27810. <https://doi.org/10.1371/journal.pone.0027810>
- Tostmann, A., Boeree, M. J., Aarnoutse, R. E., de Lange, W. C., van der Ven, A. J., & Dekhuijzen, R. (2008). Antituberculosis drug-induced hepatotoxicity: concise up-to-date review. *Journal of gastroenterology and hepatology*, 23(2), 192–202. <https://doi.org/10.1111/j.1440-1746.2007.05207.x>
- Jones, N. T., Abadie, R., Keller, C. L., Jones, K., Ledet Iii, L. F., Fox, J. E., Klapper, V. G., Potharaju, P., Siddaiah, H., Kaye, A. M., Shekoohi, S., Kaye, A. D., & Varrassi, G. (2024). Treatment and Toxicity Considerations in Tuberculosis: A Narrative Review. *Cureus*, 16(6), e62698. <https://doi.org/10.7759/cureus.62698>
- Wilson, D., Moosa, M. S., Cohen, T., Cudahy, P., Aldous, C., & Maartens, G. (2018). Evaluation of Tuberculosis Treatment Response With Serial C-Reactive Protein Measurements. *Open forum infectious diseases*, 5(11), ofy253. <https://doi.org/10.1093/ofid/ofy253>
- Dai, Y., Shan, W., Yang, Q., Guo, J., Zhai, R., Tang, X., Tang, L., Tan, Y., Cai, Y., & Chen, X. (2019). Biomarkers of iron metabolism facilitate clinical diagnosis in *Mycobacterium tuberculosis* infection. *Thorax*, 74(12), 1161–1167. <https://doi.org/10.1136/thoraxjnl-2018-212557>
- Tobin EH, & Tristram D. Tuberculosis Overview (2025) [Updated 2024 Dec 22]. In: StatPearls StatPearls Publishing. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK441916/>
- Anderer S. New Global Tuberculosis Cases Hit Record High. *JAMA*. 2025;333(1):12. doi:10.1001/jama.2024.24261
- Giannini, E. G., Testa, R., & Savarino, V. (2005). Liver enzyme alteration: a guide for clinicians. *Canadian Medical Association journal = journal de l'Association medicale canadienne*, 172(3), 367–379. <https://doi.org/10.1503/cmaj.1040752>
- Nyblom, H., Berggren, U., Balldin, J., & Olsson, R. (2004). High AST/ALT ratio may indicate advanced alcoholic liver disease rather than heavy drinking. *Alcohol and alcoholism (Oxford, Oxfordshire)*, 39(4), 336–339. <https://doi.org/10.1093/alcalc/agh074>
- Contreras-Zentella, M. L., & Hernández-Muñoz, R. (2016). Is Liver Enzyme Release Really Associated with Cell Necrosis Induced by Oxidant Stress?. *Oxidative medicine and cellular longevity*, 2016, 3529149. <https://doi.org/10.1155/2016/3529149>
- McGill M. R. (2016). The past and present of serum aminotransferases and the future of liver injury biomarkers. *EXCLI journal*, 15, 817–828. <https://doi.org/10.17179/excli2016-800>
- European Association for the Study of the Liver (2019). EASL Clinical Practice Guidelines: Drug-induced liver injury. *Journal of hepatology*, 70(6), 1222–1261. <https://doi.org/10.1016/j.jhep.2019.02.014>
- Kwo, P. Y., Cohen, S. M., & Lim, J. K. (2017). ACG Clinical Guideline: Evaluation of Abnormal Liver Chemistries. *The American journal of gastroenterology*, 112(1), 18–35. <https://doi.org/10.1038/ajg.2016.517>
- Mitchison D. A. (2005). The diagnosis and therapy of tuberculosis during the past 100 years. *American journal of respiratory and critical care medicine*, 171(7), 699–706. <https://doi.org/10.1164/rccm.200411-1603OE>
- Mirlohi, M. S., Ekrami, A., Shirali, S., Ghobeishavi, M., & Pourmohammadi, F. (2016). Hematological and liver toxicity of anti-tuberculosis drugs. *Electronic physician*, 8(9), 3005–3010. <https://doi.org/10.19082/3010>
- Cui, K., Feng, S., Mao, Y., Luo, H., Yang, J., Xu, R., & Bai, L. (2024). The association between blood urea nitrogen to albumin ratio and the 28-day mortality in tuberculosis patients complicated by sepsis. *Scientific reports*, 14(1), 16430. <https://doi.org/10.1038/s41598-024-65622-z>
- Ayakaka, I., Ackerman, S., Ggita, J. M., Kajubi, P., Dowdy, D., Haberer, J. E., Fair, E., Hopewell, P., Handley, M. A., Cattamanchi, A., Katamba, A., & Davis, J. L. (2017). Identifying barriers to and facilitators of tuberculosis contact investigation in Kampala, Uganda: a behavioral approach. *Implementation science: IS*, 12(1), 33. <https://doi.org/10.1186/s13012-017-0561-4>
- Drain, P. K., Mayeza, L., Bartman, P., Hurtado, R., Moodley, P., Varghese, S., Maartens, G., Alvarez, G. G., & Wilson, D. (2014). Diagnostic accuracy and clinical role of rapid C-reactive protein testing in HIV-infected individuals with

presumed tuberculosis in South Africa. *The international journal of tuberculosis and lung disease : the official journal of the International Union against Tuberculosis and Lung Disease*, 18(1), 20–26. <https://doi.org/10.5588/ijtld.13.0519>

23. Okwera, A., Johnson, J. L., Luzze, H., Nsubuga, P., Kayanja, H., Cohn, D. L., Nunn, P., Ellner, J. J., Whalen, C. C., & Mugerwa, R. D. (2006). Comparison of intermittent ethambutol with rifampicin-based regimens in HIV-infected adults with PTB, Kampala. *The international journal of tuberculosis and lung disease: the official journal of the International Union against Tuberculosis and Lung Disease*, 10(1), 39–44.
24. Pefura-Yone EW, Kengne AP, Tagne-Kamdem PC, Afane-Ze E. (2018) Clinical significance of low body mass index in adult patients with tuberculosis in Yaoundé, Cameroon. *Multidisciplinary Respiratory medicine* ;13:37. doi:10.1186/s40248-018-0149x