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EVALUATION OF HEMATOLOGICAL PARAMETERS IN MALARIA PATIENTS AND THEIR CORRELATION WITH DISEASE COMPLICATIONS

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ABSTRACT

Malaria remains a major public health challenge worldwide, particularly in tropical and subtropical regions, with hematological alterations being among its most consistent features and serving as valuable diagnostic and prognostic markers. This hospital-based cross-sectional study, conducted at Hayatabad Medical Complex, Peshawar, from January to July 2025, aimed to evaluate hematological parameters in malaria patients and determine their correlation with malaria-related complications. A total of 110 patients aged 15–60 years with confirmed malaria were included, and hematological parameters including hemoglobin, hematocrit, red blood cell count, total and differential leukocyte count, and platelet count were measured using an automated hematology analyzer. Statistical analysis was performed using Student's t-test, Chi-square test, and Pearson's correlation coefficient, with a p-value <0.05 considered significant. Results showed that anemia was present in 68% of patients, with a mean hemoglobin of 9.8 ± 2.4 g/dL, while thrombocytopenia was the most common abnormality, observed in 72% of cases; additionally, 62% had low hematocrit, 55% had reduced red blood cell counts, and 30% exhibited abnormal total leukocyte counts (18% leukopenia and 12% leukocytosis), with lymphopenia noted in 15%. Severe anemia (22 patients) and cerebral malaria (14 patients) were significantly associated with lower hemoglobin and platelet counts (p<0.01). Hematological abnormalities were more frequent in Plasmodium falciparum infections compared to P. vivax, while mixed infections demonstrated the highest prevalence of anemia and thrombocytopenia. The study concludes that hematological abnormalities are common in malaria, with anemia and thrombocytopenia being the most frequent and clinically significant alterations, particularly in P. falciparum and mixed infections, and these derangements are strongly associated with complications. Routine hematological evaluation, therefore, provides a simple and cost-effective tool for diagnosis, risk stratification, and early management of malaria in endemic regions.

Keywords: *Malaria; Plasmodium Falciparum; Plasmodium Vivax; Hematological Abnormalities; Anemia; Thrombocytopenia; Leukocyte Count; Prognostic Markers*

INTRODUCTION

Malaria remains one of the most significant parasitic diseases globally, with profound clinical, social, and economic impacts, particularly in tropical and subtropical regions. Despite ongoing eradication efforts, it continues to cause substantial morbidity and mortality, especially in low- and middle-income countries where healthcare infrastructure is limited. The World Health Organization (WHO) estimated that in 2022 alone, there were 249 million malaria cases and 608,000 deaths, with the African region bearing over 94% of the global malaria burden [1]. The disease is primarily caused by five Plasmodium species infecting humans: *P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale*, and *P. knowlesi*. Among these, *P. falciparum* is associated with the most severe and life-threatening manifestations, while *P. vivax* contributes substantially to relapsing infections and anemia [2,3].

The pathogenesis of malaria involves complex host–parasite interactions that result in both direct destruction of red blood cells (RBCs) and immune-mediated hematological alterations. Hematological abnormalities are among the most consistent and clinically relevant features of malaria, reflecting both parasite biology and host response. They are not only diagnostic clues but also prognostic markers that can indicate disease severity and risk of complications. Common hematological manifestations include anemia, thrombocytopenia, leukocytopenia or leukocytosis, lymphopenia, neutropenia, monocytosis, eosinopenia, and alterations in red cell indices [4–6].

Anemia, the most frequently reported hematological abnormality in malaria, arises from hemolysis of infected and uninfected erythrocytes, bone marrow suppression, and increased splenic clearance. Severe malarial anemia is a leading cause of mortality in children under five years and pregnant women in endemic regions [7,8]. Several studies have demonstrated that anemia correlates with high parasite density and chronicity of infection [9]. In *P. falciparum* malaria, anemia is more pronounced, but *P. vivax* also causes significant anemia, particularly due to repeated relapses and bone marrow suppression [10].

Thrombocytopenia is another well-documented hematological abnormality in malaria and is observed across Plasmodium species. Its pathogenesis is multifactorial, including peripheral destruction, immune-mediated lysis, platelet sequestration in the spleen, and disseminated intravascular coagulation in severe cases [11]. Although usually asymptomatic, severe thrombocytopenia can predispose patients to bleeding complications. Importantly, studies have highlighted thrombocytopenia as a sensitive marker for malaria diagnosis in endemic settings and a predictor of severe disease [12,13].

Leukocyte abnormalities in malaria are less specific but still clinically significant. While the total white blood cell (WBC) count often remains within normal ranges, specific patterns such as lymphopenia, monocytosis, and neutropenia are common. Leukocytosis is generally associated with secondary bacterial infections or severe systemic inflammation in complicated malaria [14,15]. Recognition of these variations is crucial because they can guide clinicians in differentiating malaria from other febrile illnesses such as dengue, typhoid, and septicemia [16].

The correlation of hematological parameters with malaria complications has been a growing focus of research in recent years. Complicated malaria can manifest as cerebral malaria, severe anemia, metabolic acidosis, acute kidney injury, liver dysfunction, and respiratory distress. Hematological parameters often precede clinical complications, making them valuable predictors of

disease outcome [17]. For example, severe anemia and marked thrombocytopenia are independently associated with higher mortality risk, while leukocytosis often signals secondary infection and poorer prognosis [18].

Pregnant women and children represent particularly vulnerable groups, with pregnancy-associated malaria causing maternal anemia, low birth weight, and perinatal mortality. Recent studies have emphasized that altered hematological profiles in these populations not only reflect disease severity but also have long-term health consequences [19,20]. Additionally, in endemic regions, asymptomatic carriers may also demonstrate subtle hematological abnormalities, underscoring the broader hematological impact of malaria in populations [21].

The evaluation of hematological parameters in malaria is not only clinically significant but also operationally practical, since complete blood counts (CBC) are relatively inexpensive and widely available diagnostic tests. Integrating hematological assessment with microscopy or rapid diagnostic tests can enhance diagnostic accuracy, especially in resource-limited settings [22]. Moreover, ongoing research continues to explore novel biomarkers, such as platelet indices, red cell distribution width (RDW), and reticulocyte counts, which may further refine prognostic models [23,24].

Given these considerations, understanding hematological alterations in malaria and their correlation with disease complications is critical for improving patient management, reducing mortality, and guiding public health strategies. This article aims to evaluate hematological parameters in malaria patients and to analyze their correlation with disease complications, drawing on recent evidence from diverse endemic regions. Such evaluation is essential to establish hematological indices as reliable, cost-effective adjuncts in the diagnosis and prognosis of malaria, ultimately contributing to better clinical outcomes and informing policy interventions.

OBJECTIVES

1. To evaluate the hematological parameters in malaria patients.
2. To determine the correlation between hematological alterations and malaria-related complications.

MATERIALS AND METHODS

This hospital-based cross-sectional study was conducted in the Department of Medicine and Pathology, Hayatabad Medical Complex (HMC), Peshawar, from January 2025 to July 2025. A total of 110 patients diagnosed with malaria were enrolled. The age range was 15–60 years, and both male and female patients were included. Diagnosis was confirmed using peripheral blood smear examination (thick and thin smears with Giemsa stain) and/or rapid diagnostic tests (RDTs) for *Plasmodium* species. Patients with known hematological disorders, chronic illnesses, HIV infection, or those receiving immunosuppressive therapy were excluded to avoid confounding factors. After obtaining informed consent, clinical history and physical examination were recorded. Venous blood samples were collected under aseptic precautions before initiation of antimalarial therapy. Hematological parameters including hemoglobin, hematocrit, red blood cell count and indices, total leukocyte count, differential leukocyte count, and platelet count were analyzed using an automated hematology analyzer (Sysmex, Japan). Peripheral smears were reviewed microscopically to verify abnormal findings and assess parasite density. Malaria severity and complications (such as severe anemia, cerebral malaria, hepatic dysfunction, and renal impairment) were classified according to World Health Organization (WHO) criteria.

Data were entered into Microsoft Excel and analyzed using SPSS (IBM Corp., Armonk, NY,

USA). Continuous variables were expressed as mean ± standard deviation, while categorical variables were summarized as frequencies and percentages. Group comparisons were performed using the student's *t*-test and Chi-square test. Correlations between hematological parameters and malaria-related complications were assessed using Pearson's correlation coefficient. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 110 patients diagnosed with malaria were included in the study during the period January–July 2025. The mean age was 32.8 ± 12.4 years (range 15–60 years), with the majority belonging to the 15–30 years age group (43.6%). There was a male predominance (61.8%) compared to females (38.2%). Regarding species distribution, Plasmodium falciparum was the most common (58.2%), followed by P. vivax (35.5%) and mixed infections (6.3%) (Table 1).

Analysis of hematological parameters revealed marked abnormalities in most patients. The mean hemoglobin level was 9.8 ± 2.4 g/dL, with 68% showing anemia (Hb <11 g/dL). Hematocrit values were below normal in 62%, while 55% had reduced red blood cell counts. Thrombocytopenia was highly prevalent (72%) with mean platelet count of 88 ± 45 $\times 10^3/\mu L$. Total WBC count was within the normal range in most cases, although 18% had leukopenia and 12% had leukocytosis. Differential counts showed lymphopenia in 15% of patients (Table 2).

When complications were analyzed, 22 patients developed severe anemia, 14 had cerebral malaria, 9 showed hepatic dysfunction, and 6 developed renal impairment. Patients with complications had significantly lower mean hemoglobin and platelet counts compared to those without complications. Severe anemia and cerebral malaria showed the strongest association with reduced hematological parameters (p <0.01) (Table 3).

Comparison between Plasmodium species showed that hematological abnormalities were more pronounced in *P. falciparum* infections. Anemia was significantly higher in *P. falciparum* (76.6%) compared to *P. vivax* (48.7%), while thrombocytopenia was also more frequent in *P. falciparum* (79.7%) than *P. vivax* (61.5%). Mixed infections showed the highest prevalence of both anemia and thrombocytopenia. However, differences in leukocyte abnormalities between species were not statistically significant (Table 4).

TABLE 1. BASELINE CHARACTERISTICS OF MALARIA PATIENTS (N=110)

Variable	Frequency (%) / Mean ± SD
Total patients	110
Age (years, mean ± SD)	32.8 ± 12.4
Age group 15–30 yrs	48 (43.6%)
Age group 31–45 yrs	37 (33.6%)
Age group 46–60 yrs	25 (22.8%)
Male	68 (61.8%)
Female	42 (38.2%)
Plasmodium falciparum	64 (58.2%)
Plasmodium vivax	39 (35.5%)
Mixed infection	7 (6.3%)

TABLE 2. HEMATOLOGICAL PARAMETERS IN MALARIA PATIENTS (N=110)

Parameter	Mean ± SD	Normal Range	% Abnormal
Hemoglobin (g/dL)	9.8 ± 2.4	12–16	68% (low)
Hematocrit (%)	31.2 ± 6.8	36–46	62% (low)
RBC count (×10^6/µL)	3.9 ± 0.8	4.5–6.0	55% (low)
Platelet count (×10^3/µL)	88 ± 45	150–400	72% (low)
Total WBC (×10^3/µL)	6.3 ± 2.1	4–11	18% (low), 12% (high)
Neutrophils (%)	62 ± 12	50–70	–
Lymphocytes (%)	27 ± 9	20–40	15% (low)
Monocytes (%)	7 ± 3	2–10	–

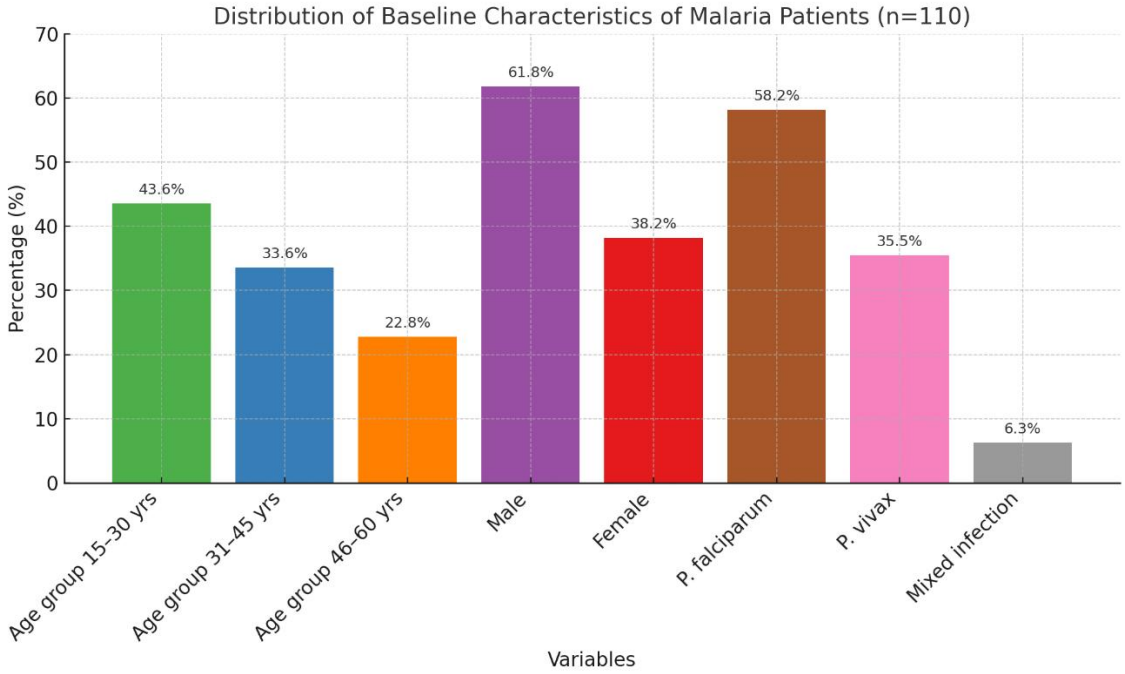
TABLE 3. CORRELATION OF HEMATOLOGICAL ABNORMALITIES WITH MALARIA COMPLICATIONS

Complication	Patients (n)	Mean Hb (g/dL)	Mean Platelet (×10^3/µL)	Association (p-value)
Severe anemia (Hb <7 g/dL)	22	6.2 ± 0.5	96 ± 40	<0.001
Cerebral malaria	14	7.8 ± 1.1	74 ± 32	0.002
Hepatic dysfunction	9	8.5 ± 1.8	81 ± 38	0.014
Renal impairment	6	7.9 ± 2.0	69 ± 29	0.021
No complications	59	10.8 ± 1.9	132 ± 36	Reference

TABLE 4. DISTRIBUTION OF HEMATOLOGICAL ABNORMALITIES AMONG PLASMODIUM SPECIES

Abnormality	P. falciparum (n=64)	P. vivax (n=39)	Mixed (n=7)	p-value
Anemia (Hb <11 g/dL)	49 (76.6%)	19 (48.7%)	6 (85.7%)	0.011
Thrombocytopenia	51 (79.7%)	24 (61.5%)	6 (85.7%)	0.043
Leukopenia	14 (21.9%)	6 (15.4%)	2 (28.6%)	0.421
Leukocytosis	9 (14.1%)	4 (10.3%)	1 (14.3%)	0.678

FIGURE 1: DISTRIBUTION OF BASELINE CHARACTERISTICS OF MALARIA PATIENTS



DISCUSSION

The present study evaluated hematological alterations among 110 malaria patients and demonstrated that anemia, thrombocytopenia, and leukocyte abnormalities were frequent, particularly in cases of *Plasmodium falciparum* infection. These findings are consistent with prior reports from endemic regions, confirming the pivotal role of hematological parameters as indicators of disease severity.

Anemia was observed in 68% of our patients, with mean hemoglobin of 9.8 g/dL. This aligns with reports from India and Africa where anemia is the most prevalent hematological abnormality in malaria, especially in *P. falciparum* cases due to extensive hemolysis and bone marrow suppression [25–27]. Our data further showed that *P. falciparum* infections had significantly higher rates of anemia (76.6%) compared to *P. vivax* (48.7%), corroborating findings from Maina et al. in Kenya and Douglas et al. in Southeast Asia [28,29]. The strong association between severe anemia and complications in our cohort mirrors observations by Rogerson and Carter, who emphasized anemia as a central determinant of malaria morbidity and mortality [30].

Thrombocytopenia was highly prevalent (72%), with *P. falciparum* cases showing greater reduction than *P. vivax*. Comparable prevalence rates (70–80%) have been reported in Pakistan, India, and Thailand, underscoring the diagnostic value of platelet count in malaria [31–33]. Jadhav et al. noted a correlation between thrombocytopenia and severe malaria, a trend we also observed as patients with complications exhibited significantly lower platelet counts [34]. The mechanisms proposed—immune-mediated platelet destruction and splenic sequestration—remain consistent across different studies [31,32].

Leukocyte abnormalities were less pronounced in our cohort, with 18% leukopenia and 12% leukocytosis. These proportions are comparable to earlier observations by Lathia and Joshi in India and Abro et al. in Pakistan, who reported that total WBC counts are often within normal ranges, with only a minority of patients exhibiting extremes

[35,36]. The occurrence of leukocytosis in our study, primarily associated with complications, is in agreement with findings that suggest leukocytosis often reflects secondary bacterial infections or severe inflammatory responses [37].

Comparing our results with regional data, Mandal et al. in Eastern India found slightly higher rates of leukocyte abnormalities, possibly due to differences in patient population and disease severity [38]. However, the overall trend reinforces that anemia and thrombocytopenia are the most consistent hematological abnormalities, while leukocyte changes are more variable and context dependent.

When stratified by Plasmodium species, *P. falciparum* showed more pronounced abnormalities than *P. vivax*, a finding corroborated by studies from Thailand and North East India [25,39]. Mixed infections in our cohort demonstrated the highest prevalence of both anemia and thrombocytopenia, consistent with meta-analyses highlighting the compounded risk in mixed infections [40]. These results reinforce the species-specific burden of hematological derangements and their role in clinical prognosis.

Finally, our study demonstrated significant associations between hematological abnormalities and malaria complications, particularly severe anemia and cerebral malaria. This supports the conclusions of Kotepui et al., who reported strong correlations between reduced hematological parameters and complications such as severe anemia and organ dysfunction [41]. Thus, hematological profiling provides not only diagnostic support but also prognostic insights.

CONCLUSION

This study highlights that hematological abnormalities are common in malaria patients, with anemia and thrombocytopenia being the most frequent and clinically significant alterations. These abnormalities were more pronounced in *Plasmodium falciparum* and mixed infections compared to *P. vivax*. Importantly, severe anemia and marked thrombocytopenia were strongly associated with complications such as cerebral malaria, hepatic dysfunction, and renal impairment, underscoring their prognostic value. Routine evaluation of complete blood counts can therefore serve as a simple, cost-effective adjunct in the diagnosis and risk stratification of malaria, particularly in resource-limited endemic settings. Strengthening hematological monitoring may improve early identification of high-risk patients and guide timely clinical interventions, ultimately reducing malaria-related morbidity and mortality.

LIMITATIONS

The present study was conducted in a single tertiary care hospital with a relatively small sample size, which may limit the generalizability of the findings to wider populations. Parasite density quantification was not systematically assessed, which could have provided further insight into the relationship between parasitemia and hematological changes. In addition, molecular methods for species confirmation were not employed, potentially leading to underestimation of mixed infections.

RECOMMENDATIONS

Future studies with larger, multicenter cohorts and molecular diagnostic support are recommended to validate these findings and provide more comprehensive insights into the hematological spectrum of malaria. Incorporating parasite density and additional biomarkers such as reticulocyte counts and platelet indices may enhance prognostic accuracy. At the clinical level, integration of hematological monitoring into routine malaria management protocols should be emphasized, especially for high-risk groups such as children and pregnant women, to improve early detection of

complications and reduce malaria-related morbidity and mortality.

REFERENCES

1. World Health Organization. *World Malaria Report 2023*. Geneva: WHO; 2023.
2. Cowell AN, Winzeler EA. The genomic architecture of antimalarial drug resistance. *Brief Funct Genomics*. 2020;19(2):95-108.
3. Battle KE, Lucas TCD, Nguyen M, Howes RE, Nandi AK, Twohig KA, et al. Mapping the global endemicity and clinical burden of Plasmodium vivax, 2000–17: a spatial and temporal modelling study. *Lancet*. 2019;394(10195):332–43.
4. Erhart LM, Yingyuen K, Chuanak N, Buathong N, Laoboonchai A, Miller RS, et al. Hematologic and clinical indices of malaria in a semi-immune population of western Thailand. *Am J Trop Med Hyg*. 2004;70(1):8–14.
5. Kotepui M, Kotepui KU, Milanez GD, Masangkay FR. Prevalence and risk factors related to poor outcome of patients with severe Plasmodium malaria: a systematic review and meta-analysis. *Front Med*. 2022;9:841688.
6. Banerjee M, Narain K, Baruah I, Saikia L. Hematological profile of malaria cases from a tertiary care hospital in North East India. *J Clin Diagn Res*. 2021;15(6):EC01–EC05.
7. White NJ, Pukrittayakamee S, Hien TT, Faiz MA, Mokuolu OA, Dondorp AM. Malaria. *Lancet*. 2014;383(9918):723–35.
8. Maina RN, Walsh D, Gaddy C, Hongo G, Waitumbi J, Otieno L, et al. Impact of Plasmodium falciparum infection on haematological parameters in children living in Western Kenya. *Malar J*. 2020;19:1–8.
9. Kotepui M, Phunphuech B, Phiwklam N, Chupeerach C, Duangmano S. Effects of malaria parasite density on blood cell parameters. *PLoS One*. 2015;10(3):e0121057.
10. Douglas NM, Anstey NM, Buffet PA, Poespoprodjo JR, Yeo TW, White NJ, et al. The anaemia of Plasmodium vivax malaria. *Malar J*. 2012;11:135.
11. Lathia TB, Joshi R. Can hematological parameters discriminate malaria from nonmalarious acute febrile illness in the tropics? *Indian J Med Sci*. 2004;58(6):239–44.
12. Abro AH, Ustadi AM, Das K, Abdou AS, Hussaini HS, Chandra FS. Malaria and hematological changes. *Pak J Med Sci*. 2008;24(2):287–91.
13. Jadhav UM, Patkar VS, Kadam NN. Thrombocytopenia in malaria—correlation with type and severity of malaria. *J Assoc Physicians India*. 2004;52:615–8.
14. Rogerson SJ, Carter R. Severe anaemia in malaria: a tale of two processes. *Trends Parasitol*. 2021;37(7):570–81.
15. Abdalla SH, Pasvol G. Malaria: hematology. *Clin Haematol*. 1982;11(3):361–80.
16. Mandal S, Bera P, Datta SS, Pal S. Hematological manifestations of malaria: a study of 200 cases in Eastern India. *Int J Res Med Sci*. 2020;8(5):1686–91.
17. Kotepui M, Uthaisar K, Phunphuech B, Phiwklam N. Correlation between hematological parameters and malaria complications. *BMC Infect Dis*. 2021;21:12.
18. Lamikanra AA, Brown D, Potocnik A, Casals-Pascual C, Langhorne J, Roberts DJ. Malaria anemia: of mice and men. *Blood*. 2007;110(1):18–28.
19. Desai M, ter Kuile FO, Nosten F, McGready R, Asamoa K, Brabin B, et al. Epidemiology and burden of malaria in pregnancy. *Lancet Infect Dis*. 2007;7(2):93–104.
20. Rogerson SJ, Desai M, Mayor A, Sicuri E, Taylor SM, van Eijk AM. Burden, pathology, and costs of malaria in pregnancy: new

developments for an old problem. *Lancet Infect Dis*. 2018;18(4):e107–e118.
21. Kotepui M, Uthaisar K, Phiwklam N. Subclinical malaria and hematological abnormalities in endemic regions. *Malar J*. 2021;20:1–10.
22. Facer CA. Hematological aspects of malaria. In: Infection and Hematology. Oxford: Butterworth-Heinemann; 1994. p. 259–94.
23. Hanscheid T, Valadas E, Grobusch MP. Automated measurement of malaria pigment in monocytes and polymorphonuclear leukocytes by flow cytometry. *Cytometry B Clin Cytom*. 2000;41(2):122–6.
24. Kotepui M, Kotepui KU. Clinical usefulness of platelet indices in malaria. *Infect Dis Poverty*. 2018;7:95.
25. Erhart LM, Yingyuen K, Chuanak N, Buathong N, Laoboonchai A, Miller RS, et al. Hematologic and clinical indices of malaria in a semi-immune population of western Thailand. *Am J Trop Med Hyg*. 2004;70(1):8–14.
26. Kotepui M, Kotepui KU, Milanez GD, Masangkay FR. Prevalence and risk factors related to poor outcome of patients with severe Plasmodium malaria: a systematic review and meta-analysis. *Front Med*. 2022;9:841688.
27. Banerjee M, Narain K, Baruah I, Saikia L. Hematological profile of malaria cases from a tertiary care hospital in North East India. *J Clin Diagn Res*. 2021;15(6):EC01–EC05.
28. Maina RN, Walsh D, Gaddy C, Hongo G, Waitumbi J, Otieno L, et al. Impact of *Plasmodium falciparum* infection on haematological parameters in children living in Western Kenya. *Malar J*. 2020;19:1–8.
29. Douglas NM, Anstey NM, Buffet PA, Poespoprodjo JR, Yeo TW, White NJ, et al. The anaemia of *Plasmodium vivax* malaria. *Malar J*. 2012;11:135.
30. Rogerson SJ, Carter R. Severe anaemia in malaria: a tale of two processes. *Trends Parasitol*. 2021;37(7):570–81.
31. Lathia TB, Joshi R. Can hematological parameters discriminate malaria from nonmalarious acute febrile illness in the tropics? *Indian J Med Sci*. 2004;58(6):239–44.
32. Abro AH, Ustadi AM, Das K, Abdou AS, Hussaini HS, Chandra FS. Malaria and hematological changes. *Pak J Med Sci*. 2008;24(2):287–91.
33. Jadhav UM, Patkar VS, Kadam NN. Thrombocytopenia in malaria—correlation with type and severity of malaria. *J Assoc Physicians India*. 2004;52:615–8.
34. Kotepui M, Phunphuech B, Phiwklam N, Chupeerach C, Duangmano S. Effects of malaria parasite density on blood cell parameters. *PLoS One*. 2015;10(3):e0121057.
35. Abdalla SH, Pasvol G. Malaria: hematology. *Clin Haematol*. 1982;11(3):361–80.
36. Mandal S, Bera P, Datta SS, Pal S. Hematological manifestations of malaria: a study of 200 cases in Eastern India. *Int J Res Med Sci*. 2020;8(5):1686–91.
37. White NJ, Pukrittayakamee S, Hien TT, Faiz MA, Mokuolu OA, Dondorp AM. Malaria. *Lancet*. 2014;383(9918):723–35.
38. Kotepui M, Uthaisar K, Phunphuech B, Phiwklam N. Correlation between hematological parameters and malaria complications. *BMC Infect Dis*. 2021;21:12.
39. Facer CA. Hematological aspects of malaria. In: Infection and Hematology. Oxford: Butterworth-Heinemann; 1994. p. 259–94.
40. Kotepui M, Kotepui KU. Clinical usefulness of platelet indices in malaria. *Infect Dis Poverty*. 2018;7:95.
41. Lamikanra AA, Brown D, Potocnik A, Casals-Pascual C, Langhorne J, Roberts DJ. Malaria

anemia: of mice and men. *Blood*. 2007;110(1):18–28.