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Hematological Changes in Children with Severe Malaria Under 5 Years of Age

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ABSTRACT

OBJECTIVE: To assess hematological changes and evaluate associated parameters such as nutritional status (BMI), dietary patterns, lifestyle factors, and socioeconomic status in children under five years of age diagnosed with severe malaria**.**

METHODOLOGY: This descriptive cross-sectional study was conducted in the Department of Pediatrics, Indus Medical College and Hospital, Tando Muhammad Khan, from November 2024 to April 2025. A total of 282 children aged 6 months to 5 years of either sex with fever, convulsions, pallor, hypoglycemia, jaundice, acidosis, or impaired consciousness and positive for *P. vivax* and/or *P. falciparum* were included through non-probability consecutive sampling. Those with confirmed CNS infections, hemolytic anemias, thalassemia, G6PD deficiency, aplastic anemia, or other bone marrow disorders were excluded. Blood samples were collected and analyzed using an automated hematology analyzer to evaluate hemoglobin, white blood cell count, neutrophil and lymphocyte counts, and platelet levels. Nutritional status was assessed via BMI percentile using WHO growth charts. Dietary intake, use of mosquito nets, and socioeconomic conditions were recorded. Data analyzed using SPSS 19. A p-value of <0.05 was considered significant.

RESULTS: Severe anemia (74.5%) and thrombocytopenia (67.4%) were the most prevalent hematological abnormalities, particularly in children infected with *P. falciparum* ($p = 0.001$ and $p = 0.003$, respectively). Underweight children (BMI <5th percentile), those with insufficient protein/iron intake, and children from low socioeconomic backgrounds had a significantly higher prevalence of anemia, leukopenia, and thrombocytopenia.

CONCLUSION: Early identification through blood counts, along with community-level interventions targeting malnutrition and poverty, is crucial in improving outcomes in resource-limited settings.

KEYWORDS: Malaria, anemia, thrombocytopenia, undernutrition, body mass index, socioeconomic status, children under five.

INTRODUCTION

Malaria is still one of the most important causes of morbidity and mortality in children under 5 years of age in endemic settings, especially in sub-Saharan Africa and South Asia. Younger children are at a high risk because of underdeveloped immunity, nutritional status and the presence of co-infections. Of the Plasmodium species, Plasmodium falciparum accounts for the most severe malaria and potentially life-threatening complications, including cerebral malaria, severe anemia, metabolic acidosis, and hypoglycaemia[1].

The malaria burden in Pakistan has been on the rise in recent years, with over 3.4 million suspected cases recorded in 2022, in part due to natural disasters, such as flooding, and substandard infrastructure[2]. Hematological anomalies are often present in malaria and can appear before parasitological confirmation, making them essential diagnostic indicators, especially in resource-poor settings[3]. The most commonly observed hematological changes are anemia, thrombocytopenia, and leukopenia, primarily due to the direct destruction of blood cells by the parasite, marrow suppression, and immune-mediated processes[4-6].

Significant anemia and thrombocytopenia are linked to increased mortality and hospital stay. In children with malaria, normocytic, normochromic anemia, because of hemolysis and thrombopoietin suppression, is the most common hematologic finding[6]. Thrombocytopenia is found in >60% of patients in a meta-analysis and may be a valuable predictor at initial presentation, particularly in the setting where parasite burden is not clear[7].

However, data are scarce to describe the frequency and association of these hematological estimators with the severity of disease in young children under 5 years of age in Pakistan. The current study's objective is to describe the spectrum of hematological alterations in children with severe malaria, as well as to evaluate the associations between these alterations and nutritional and socioeconomic variables, thereby contributing to the early recognition and management of this condition.

METHODOLOGY

This descriptive cross-sectional study was conducted in the Department of Pediatrics, Indus Medical College and Hospital, Tando Muhammad Khan, from November 2024 to April 2025. Following approval from the Institutional Review Board and the Research Evaluation Unit (REU) of the College of Physicians and Surgeons, Pakistan. Children aged 6 months to 5 years who presented with clinical suspicion of malaria (including symptoms such as fever, seizures, pallor, jaundice, altered sensorium, metabolic acidosis, or hypoglycemia) were included. It was necessary to perform a smear or use rapid diagnostic tests to identify Plasmodium vivax, Plasmodium falciparum or the co-occurrence of these. Children with known hematological disorders (e.g., thalassemia, aplastic anemia, G6PD deficiency), central nervous system infections (e.g., meningitis, encephalitis), or febrile seizures unrelated to malaria were excluded from the study. The Raosoft calculator estimated that 282 responses are needed for a 95% confidence level, a 7.1% frequency, and a 3% error margin. Only non-probability consecutive sampling was used. Treatment data, such as antimalarial therapy or blood transfusions, were not recorded, which may influence hematological outcomes. After gaining permission from parents or guardians, each patient's data was entered into a proforma. Anemia was defined using WHO criteria: hemoglobin <11 g/dL for children under five, with a value of <7 g/dL considered severe anemia. The following parameters were also assessed: total white blood cell count, absolute neutrophil count (ANC), lymphocyte count, and platelet count. A Microscopic examination of stained blood smears was performed to spot the malaria species. Parasitemia was not quantitatively assessed, which limited the interpretation of malaria severity.

Along with tests on blood, investigators collected measurements and information about eating, habits and social status. The Body Mass Index (BMI) was calculated using measured weight and height, and interpreted using the WHO growth charts for age- and sex-specific percentiles. Children whose BMI was under the 5th percentile were included in the undernourished category. To assess the diet, I asked parents about their child's intake, primarily checking for various foods and food groups that contain protein and iron over the last week. Lifestyle exposure variables included mosquito net usage, sleeping location (indoor vs outdoor), and proximity to stagnant water sources. Parents' work, family income, the home they lived in and its access to healthcare and sanitation were used to determine socioeconomic status. The data collected were analyzed using the statistical software SPSS 19. Age and blood test values were analyzed using the Kolmogorov–Smirnov method and presented as mean ± standard deviation or median with interquartile range. Categorical variables (e.g., anemia, thrombocytopenia, low BMI) were presented as frequencies and percentages. To examine whether there is a link between categorical variables, the Chi-square test or Fisher's exact test was used if necessary. A p-value of less than 0.05 indicated a statistically significant difference.

RESULTS

A total of 282 very young children with severe malaria were involved in the research. The majority belonged to the 1–2-year age group (24%), followed by the 2–3-year age group (21%) and the 6–12-month age group (19.5%). Children aged 3–4 years accounted for 17.7%, and those 4–5 years old comprised 17.3% (**Table I**).

Table I: Age-wise Distribution of Children with Severe Malaria

Age Group	Number of Patients (n=282)
6–12 months	55
1–2 years	68
2–3 years	60
3–4 years	50
4–5 years	49

Analysis of malaria species revealed Plasmodium vivax in 175 children (62%), Plasmodium falciparum in 85 (30%), and mixed infections in 22 (8%) (**Table II**).

Table II: Type of Malaria Identified

Type of Malaria	Number of Patients (n=282)	Percentage
Plasmodium vivax	175	62.0%
Plasmodium falciparum	85	30.1%
Mixed Infection	22	7.8%

Percentages: Plasmodium vivax – 62.0%, Plasmodium falciparum – 30.1%, Mixed Infection – 7.8%

Many of the patients had altered hematological characteristics. Anemia was observed in 210 children (74.5%), thrombocytopenia in 190 (67.4%), leukopenia in 95 (33.7%), lymphocytopenia in 80 (28.4%), and neutropenia in 60 (21.3%) (**Table III**).

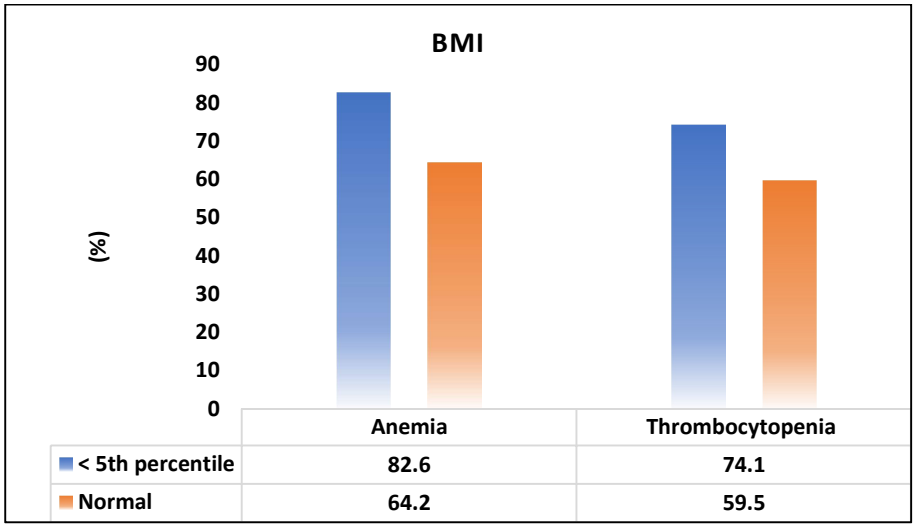
Table III: Hematological Changes in Severe Malaria

Hematological Parameter	Number of Patients(n=282)	Percentage (%)
Anemia	210	74.5
Thrombocytopenia	190	67.4
Leukopenia	95	33.7
Lymphocytopenia	80	28.4
Neutropenia	60	21.3

P. falciparum was significantly associated with both anemia (p = 0.001) and thrombocytopenia (p = 0.003), underscoring its severity. Note: Confidence intervals and effect sizes were not reported; only p-values were provided

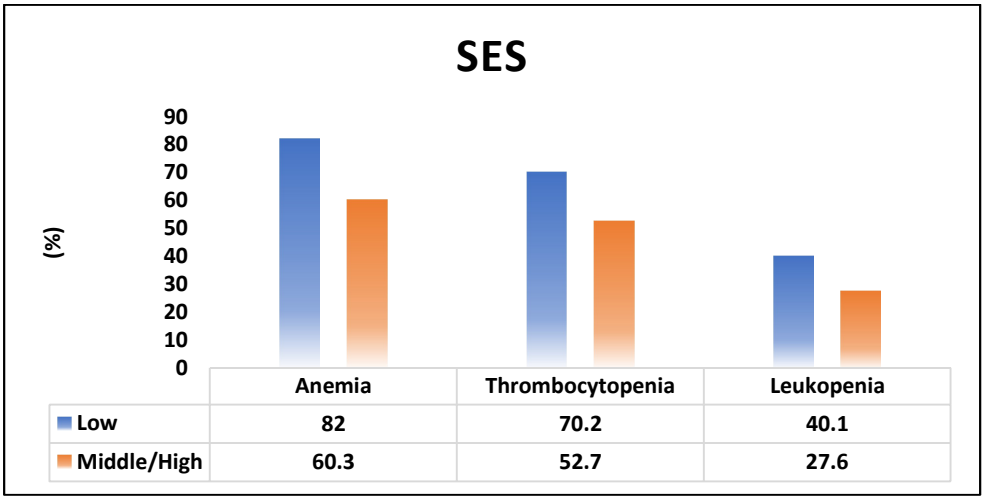
Further stratification based on BMI revealed that children below the 5th percentile had significantly higher rates of anemia (82.6%) and thrombocytopenia (74.1%) compared to those with a normal BMI (**Figure I**).

Figure I: Correlation of BMI with Hematological Abnormalities



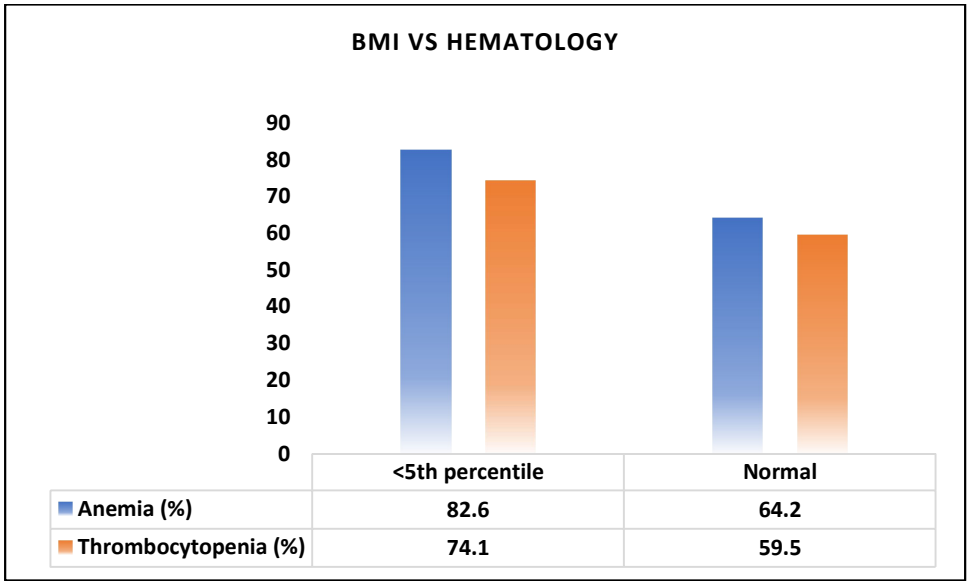
Poor nutritional status was also reflected in dietary diversity; children who lacked protein and micronutrient-rich diets (e.g., no meat, legumes, or iron-rich foods) were more prone to severe hematological abnormalities. People living in areas where poor sleep habits are the norm, without nets to protect themselves from mosquitoes and close to stagnant water, tended to get mixed or P. falciparum infections. Severe anemia and thrombocytopenia were common findings among the majority of children. Children from low socioeconomic households, as defined by parental income and living conditions, had markedly higher frequencies of anemia (82%), thrombocytopenia (70.2%), and leukopenia (40.1%) compared to children from middle- or high-income families (**Figure II**).

Figure II: Impact of Socioeconomic Status on Hematological Abnormalities



Failing to make early efforts to intervene and prevent issues is likely to cause the disease to advance more rapidly. Nutritional weaknesses, how people live, and poverty seem to boost malaria in children. The differences in hematological measurements according to BMI and social status are shown in **Figure III**.

Figure III: Association of BMI with Haematology



Furthermore, although p-values were calculated to assess statistical significance, this study did not report confidence intervals or effect sizes, which are critical for understanding the precision and magnitude of associations. Future reports should include these statistical estimates to provide more robust and clinically meaningful interpretations.

DISCUSSION

This study reveals the pattern and severity of hematological abnormalities in children with severe malaria, particularly emphasizing the impact of nutritional status, socioeconomic background, and environmental risk factors. Consistent with earlier research, anemia (74.5%) and thrombocytopenia (67.4%) were the most frequently observed abnormalities, especially among those infected with *Plasmodium falciparum*, which showed a statistically significant association with both conditions[8,9]. These findings align with other regional studies, which indicate that P. falciparum malaria poses a more severe hematological burden compared to *P. vivax* or mixed infections[10].

The mechanisms underlying these abnormalities are multifactorial. Anemia in malaria is often normocytic and normochromic, resulting from haemolysis, erythrophagocytosis, and suppressed erythropoiesis[11]. Similarly, thrombocytopenia is attributed to peripheral destruction, splenic sequestration, and immune-mediated lysis of platelets[12]. In this study, nearly three-fourths of the children demonstrated these hematological signs, making them reliable clinical indicators for early malaria suspicion in endemic settings[8,13].

Our findings regarding leukopenia (33.7%), lymphocytopenia (28.4%), and neutropenia (21.3%) align with earlier observations that immune cell counts are frequently affected in paediatric malaria cases[14,15]. This may reflect the immune-modulatory effects of the parasite, resulting in altered leukocyte distribution and function. The appearance of lymphocytopenia and monocytosis has been associated with inflammatory responses and poor prognosis in prior literature[16].

A novel component of this study is its focus on BMI and dietary diversity as predictors of hematological complications. Children below the 5th BMI percentile were significantly more prone to anemia and thrombocytopenia, which supports evidence from studies in Ethiopia, Nigeria, and Uganda, indicating that malnutrition exacerbates malaria pathogenesis[17-19]. Poor nutritional intake, particularly low protein and iron consumption, weakens hematopoietic function and increases susceptibility to parasitic invasion. These dietary deficiencies were linked with higher parasite loads and greater cytopenias in comparable populations in India and Uganda[20,21].

Environmental and behavioral exposures also had a notable impact. Children who did not use mosquito nets, lived near stagnant water, or slept outdoors were more likely to contract *P. falciparum* or mixed infections. This pattern aligns with studies from Cambodia and Kenya, which have highlighted poor housing conditions, inadequate vector control, and geographic factors as key determinants of the malaria burden[22,23].

Perhaps most concerning is the disparity between socioeconomic classes. Children from lower-income households experienced significantly more severe hematological changes, including higher frequencies of anemia (82%) and thrombocytopenia (70.2%). These results highlight the complex interplay between poverty, delayed access to care, inadequate nutrition, and limited awareness of preventive measures. This aligns with findings from Pakistan and Nigeria, where social inequalities directly contributed to worse malaria outcomes and health indicators[24].

Taken together, this study not only reinforces the hematological profile of severe malaria but also highlights the need for integrated public health strategies. CBC analysis, when used early, can serve as a critical screening tool. Simultaneously, addressing malnutrition and poverty through nutritional programs, community awareness, and targeted interventions is essential to controlling the disease and improving outcomes in endemic areas.

CONCLUSION

This study highlights that *Plasmodium falciparum* is strongly associated with severe hematological disturbances in children under five, particularly anemia and thrombocytopenia. The findings underscore the need to integrate early diagnostic blood tests with nutritional assessments in malaria-endemic regions. Public health policies should focus on enhancing dietary diversity, promoting the use of mosquito nets, and addressing poverty through targeted community interventions. These strategies can reduce disease burden and improve child health outcomes.

LIMITATIONS

The study could not be done with different age groups and on other biochemical parameters. Additionally, the study design being cross-sectional limits causal inference. Dietary data were based on parental recall, which may introduce recall bias. Important variables such as parental education, deworming status, and breastfeeding practices were not assessed. The use of non-probability sampling increases the risk of selection bias and affects generalizability. Co-infections, such as intestinal parasites, were not assessed, which may confound the observed hematological changes and anemia.

The study did not include organ-specific dysfunction, such as the liver, kidney, and central nervous system, which could have allowed for a more comprehensive understanding of the disease pathophysiology. The generalizability and depth of findings could be increased by performing long-term and multi-site studies to better illustrate hematological changes during illness and recovery.

Future Directions

To investigate age-related variations in hematological parameters and disease severity, future research should encompass a broader range of age groups, extending beyond 5 years. Additionally, analyzing the root causes, such as poverty, poor sanitation, and limited access to healthcare, will broaden the understanding of risk factor contributors.

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Data Sharing Statement: The corresponding author can share the data supporting the studys conclusion upon request. We are unable to release data openly due to ethical or privacy constraints.

AUTHOR CONTRIBUTION

Kanwal N: Conceptualized and interpreted the data.

Qureshi R: Helped in the collection of data and initial drafting of the manuscript, and provided significant input in the study design.

Chander R: Involved in critical revision of the manuscript, provided significant input in data collection and management, ensuring data integrity and accuracy.

Mumtaz N: Involved in the graphical representation of data and the preparation of figures and tables.

Memon H: Helped in critical revision for important intellectual content.

Kumari J: Involved in drafting and proofreading, and made the final version of the paper to be published.

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