# DETERMINATION OF HAEMATOLOGICAL PARAMETERS OF CHILDREN THAT SUFFERED FROM ACUTE MALARIA IN NIGERIA

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**ABSTRACT**

Malaria remains a major public health issue, particularly in sub-Saharan Africa, with children being disproportionately affected. This study investigates the haematological parameters in children suffering from acute malaria in Nigeria, focusing on parameters such as hemoglobin concentration, platelet count, and white blood cell levels. The aim is to provide insights into how these parameters are altered in pediatric patients during acute malaria episodes and how these alterations correlate with disease severity. A cross-sectional study design was employed, involving children aged 1–12 years who presented with confirmed cases of acute malaria at a tertiary healthcare facility in Nigeria. Blood samples were collected, and laboratory analysis was performed to measure haematological parameters, including hemoglobin levels, platelet counts, white blood cell (WBC) counts, and reticulocyte production. These results were analyzed using statistical methods to determine correlations with malaria severity and compare the findings with existing literature. The findings revealed that anemia, characterized by reduced hemoglobin levels, was the most common haematological abnormality, affecting nearly 60% of the study population. Thrombocytopenia (low platelet count) was also prevalent, with more severe malaria cases exhibiting a greater reduction in platelet numbers. Leukocyte alterations, particularly lymphopenia, were observed, further confirming the immune dysregulation associated with malaria. The study also noted significant differences in haematological parameters between children with severe and mild malaria, emphasizing the importance of these parameters as markers for disease progression. The study highlights the critical role of haematological parameters in the diagnosis and management of malaria in children. These findings contribute to the growing body of literature on malaria’s impact on child health and underscore the need for enhanced diagnostic and therapeutic interventions in resource-limited settings. Additionally, the study identifies gaps in existing research, particularly regarding long-term haematological recovery and the influence of socioeconomic factors on health outcomes. In conclusion, this study provides important insights into the haematological changes associated with acute malaria in Nigerian children. It underscores the need for early detection and management of haematological abnormalities to improve clinical outcomes. Recommendations include further research on long-term recovery patterns and the development of targeted treatment strategies to mitigate the haematological impacts of malaria.

**Keywords:** *Acute malaria, children, haematological parameters, anemia, thrombocytopenia, Nigeria, public health.*

**CHAPTER 1**

**INTRODUCTION**

**1.1 Background of the Study**

Malaria, a life-threatening disease caused by Plasmodium parasites, remains a significant public health challenge, particularly in sub-Saharan Africa. Children, especially those under the age of five, are highly susceptible to malaria infections due to their developing immune systems. In Nigeria, which accounts for a large proportion of global malaria cases, acute malaria contributes significantly to child mortality (World Malaria Report, 2018). Understanding the hematological parameters in children suffering from acute malaria provides insights into the severity of the disease and its systemic effects, as these parameters can offer crucial diagnostic information and guide treatment approaches (Godse, 2013).

Hematological parameters such as hemoglobin (Hb) levels, platelet count, and white blood cell (WBC) profiles are particularly useful in understanding the impact of malaria. Anemia is one of the most common complications, often resulting from the destruction of red blood cells during the infection and associated immune responses (Muwonge et al., 2013). The anemia caused by malaria is a direct result of the parasite's invasion and destruction of red blood cells, leading to reduced hemoglobin levels. Additionally, children who suffer from malaria often experience leukopenia or thrombocytopenia (Martínez-Salazar & Tobón-Castaño, 2014).

In Nigeria, malaria control programs have been implemented, but the disease burden remains high. Factors such as poverty, lack of access to healthcare, and environmental conditions conducive to mosquito breeding exacerbate the situation (Morakinyo et al., 2018). While various studies have highlighted the importance of hematological assessments in diagnosing and managing malaria, there is limited data specific to children in Nigeria, particularly on the relationship between malaria severity and hematological changes (Bawah et al., 2018).

The need to determine hematological changes in children suffering from malaria is essential to improving treatment outcomes. It is well-documented that children with severe malaria often display abnormal blood profiles, which can predict disease severity and complications (Das et al., 2017). Analyzing these hematological parameters in children will provide clinicians with better tools for diagnosing and managing acute malaria cases. Furthermore, it could also assist in creating targeted interventions aimed at reducing the high morbidity and mortality rates among Nigerian children.

**1.2 Statement of the Problem**

Despite ongoing efforts to combat malaria, the disease remains endemic in Nigeria, affecting millions of children annually. Acute malaria continues to be a leading cause of hospitalization and death among children under five, often due to complications such as severe anemia and thrombocytopenia (Francis et al., 2014). These hematological abnormalities, if not promptly diagnosed and treated, can lead to severe complications and death. However, there is limited research focusing on the specific hematological changes in Nigerian children suffering from acute malaria, particularly in regions where malaria is hyperendemic (Conroy et al., 2019).

This study seeks to fill the gap in the literature by determining the hematological parameters of children who suffer from acute malaria in Nigeria. Understanding these changes can provide healthcare providers with critical diagnostic and prognostic information, thereby improving clinical outcomes. Moreover, the study aims to contribute to the development of better management strategies for malaria, particularly in high-risk pediatric populations.

**1.3 Research Questions**

1. What are the hematological parameters commonly affected in children suffering from acute malaria in Nigeria?
2. How do these hematological changes correlate with the severity of malaria in children?
3. What is the diagnostic significance of hematological parameters in managing acute malaria in Nigerian children?

**1.4 Objectives of the Study**

1. To identify the hematological parameters that are altered in children suffering from acute malaria in Nigeria.
2. To assess the correlation between hematological changes and the severity of malaria in these children.
3. To evaluate the diagnostic value of hematological parameters in the management of pediatric acute malaria.

**1.5 Significance of the Study**

The study is significant for several reasons. First, it will provide vital information on the hematological changes in children with acute malaria, contributing to the existing body of knowledge on malaria pathophysiology in Nigeria. Secondly, it will enhance the diagnostic capabilities of healthcare providers, enabling early identification of severe malaria cases and better management of the disease. Lastly, the findings will assist policymakers in refining malaria control programs, particularly in areas with high pediatric malaria incidence (Clark et al., 2006).

**1.6 Scope and Limitation of the Study**

The study will focus on children aged 0-12 years suffering from acute malaria in selected hospitals in Nigeria. Hematological parameters such as hemoglobin levels, white blood cell counts, and platelet counts will be evaluated. However, the study may face limitations such as the availability of medical records, access to laboratory facilities, and regional variations in malaria severity. Additionally, the study will not cover biochemical parameters, which could also provide insights into malaria's systemic effects (Awoke & Arota, 2019).

**1.7 Definition of Terms**

**Acute Malaria:** A severe form of malaria characterized by high parasitemia and complications such as anemia, respiratory distress, and cerebral involvement.

**Hematological Parameters:** Blood components such as red blood cells, white blood cells, hemoglobin, and platelets that provide diagnostic information about health status.

**Anemia:** A condition where the hemoglobin level in the blood is lower than normal, often seen in children with malaria due to red blood cell destruction.

**Thrombocytopenia:** A reduction in platelet count, which can lead to an increased risk of bleeding and is common in severe malaria cases.

White Blood Cell Count: A measure of the number of white blood cells, which can be altered in malaria, leading to either leukopenia or leukocytosis.

**CHAPTER 2**

**LITERATURE REVIEW**

**2.1 Overview of Malaria in Nigeria**

Malaria remains a major public health issue in Nigeria, with the country accounting for a significant proportion of the global malaria burden. According to the World Malaria Report, Nigeria alone accounts for approximately 27% of global malaria cases and 23% of global malaria deaths (World Health Organization, 2021). The high malaria transmission rates are largely due to the country’s tropical climate, which supports the breeding of Anopheles mosquitoes, the vector responsible for malaria transmission. Malaria is endemic in all regions of Nigeria, although the transmission intensity varies by geographic location, with the highest prevalence in the northern and southwestern parts of the country (Amajoh et al., 2022).

Malaria is predominantly caused by Plasmodium falciparum, the most virulent species, responsible for the majority of severe malaria cases and deaths in Nigeria (Ceesay et al., 2018). The disease disproportionately affects vulnerable groups, particularly children under five years of age and pregnant women. According to estimates, 97% of the Nigerian population is at risk of malaria, with over 300,000 deaths occurring annually, primarily among children (Bashir & Amuta, 2020).

The Nigerian government has made significant efforts to reduce malaria incidence through various initiatives, such as the National Malaria Elimination Program (NMEP) and the distribution of insecticide-treated bed nets (ITNs), rapid diagnostic tests (RDTs), and artemisinin-based combination therapies (ACTs). Despite these interventions, the disease remains a major public health challenge due to factors such as poor access to healthcare, drug resistance, and widespread poverty (Oluwatosin & Asaolu, 2019). Additionally, vector control strategies, including indoor residual spraying, have been implemented, but the coverage remains limited due to logistical and financial constraints.

Furthermore, the impact of malaria on the Nigerian economy is substantial, with the disease contributing to losses in productivity, increased healthcare costs, and school absenteeism. A study by Uzochukwu et al. (2020) estimated that malaria costs Nigeria over $3 billion annually in terms of treatment and lost income. The burden of the disease is exacerbated by inadequate healthcare infrastructure and the high cost of medical care, which further limits access to timely diagnosis and treatment, particularly in rural areas (Goselle et al., 2021).

Efforts to address malaria in Nigeria require continued investment in both prevention and treatment strategies, with a focus on improving access to healthcare, scaling up vector control interventions, and addressing socioeconomic factors that contribute to the disease burden. International partnerships, such as those with the World Health Organization and the Global Fund, have played a crucial role in supporting Nigeria’s malaria control efforts, but sustained progress will require a multi-sectoral approach that integrates health, education, and economic development policies (WHO, 2021).

**2.2 Epidemiology and Pathophysiology of Malaria**

Malaria is one of the oldest and most persistent infectious diseases, caused by protozoan parasites of the genus Plasmodium. Of the five species that infect humans, Plasmodium falciparum is the most widespread and responsible for the majority of severe cases and deaths, particularly in sub-Saharan Africa, including Nigeria (Phillips et al., 2017). The epidemiology of malaria is strongly linked to environmental, social, and biological factors that influence transmission rates, such as climate, geography, and population movement.

The transmission of malaria occurs through the bite of an infected female Anopheles mosquito, which introduces the Plasmodium parasite into the bloodstream. Following the bite, the parasite travels to the liver, where it matures and multiplies. After an incubation period of about 7 to 30 days, depending on the species, the parasite enters the bloodstream and infects red blood cells, leading to the clinical manifestations of malaria, including fever, chills, headache, and muscle aches (Schwartz et al., 2020).

In endemic regions like Nigeria, transmission is year-round, with peaks during the rainy season when mosquito breeding conditions are optimal (WHO, 2021). Children and pregnant women are particularly vulnerable due to their reduced immunity. In children, severe malaria often presents with complications such as cerebral malaria, anemia, and respiratory distress. In pregnant women, malaria can lead to adverse outcomes such as low birth weight, premature delivery, and maternal anemia, which are significant contributors to infant and maternal mortality (Desai et al., 2018).

The pathophysiology of malaria involves complex interactions between the parasite and the host's immune system. As the Plasmodium parasite invades and multiplies within red blood cells, it causes the destruction of these cells, leading to hemolytic anemia, one of the most common and serious complications of malaria (Clark et al., 2014). The release of inflammatory cytokines during the immune response also contributes to the symptoms of malaria, such as fever and malaise, and can lead to severe complications like cerebral malaria and acute respiratory distress syndrome (Das et al., 2017).

Cerebral malaria, a life-threatening complication, occurs when infected red blood cells adhere to the walls of cerebral blood vessels, causing microvascular obstruction and inflammation. This leads to coma and seizures, and without prompt treatment, cerebral malaria has a high mortality rate, especially in children (Dondorp et al., 2010). Severe malaria is also characterized by metabolic acidosis, a condition that results from the accumulation of lactic acid due to impaired oxygen delivery to tissues, and hypoglycemia, which is particularly dangerous in children and pregnant women (White et al., 2014).

Drug resistance is a significant concern in the treatment of malaria, particularly with P. falciparum, which has developed resistance to multiple antimalarial drugs over the years. The introduction of artemisinin-based combination therapies (ACTs) has been a major advancement in malaria treatment, providing effective therapy against resistant strains. However, the emergence of artemisinin resistance in Southeast Asia has raised concerns about the potential spread of resistant strains to Africa, where malaria burden is highest (Ashley et al., 2018).

The epidemiology of malaria is also influenced by socioeconomic factors such as poverty, poor sanitation, and limited access to healthcare. These factors contribute to higher transmission rates in regions with inadequate infrastructure and healthcare services. Efforts to control malaria in Nigeria have focused on vector control, early diagnosis, and effective treatment, but challenges such as drug resistance, climate change, and political instability continue to hinder progress (Uzochukwu et al., 2020).

The pathophysiology of malaria underscores the need for prompt diagnosis and treatment to prevent severe complications. Current treatment guidelines recommend the use of ACTs as the first-line treatment for uncomplicated P. falciparum malaria, with intravenous artesunate for severe cases. Preventive measures, such as the use of insecticide-treated bed nets, indoor residual spraying, and intermittent preventive treatment in pregnancy (IPTp), have been effective in reducing malaria transmission and morbidity, although their coverage in Nigeria remains suboptimal (Dlamini et al., 2021).

**2.3 Haematological Changes in Malaria-Infected Children**

Malaria, particularly caused by Plasmodium falciparum, results in several haematological abnormalities, many of which are more pronounced in children due to their vulnerable immune systems and developmental stage. Understanding the haematological changes in malaria-infected children is essential as these alterations can serve as both diagnostic markers and indicators of disease severity, helping guide clinical management. The primary haematological changes include anemia, thrombocytopenia, leukocytosis or leukopenia, and changes in reticulocyte counts.

**Anemia in Malaria-Infected Children**

Anemia is one of the most common and severe haematological abnormalities observed in children with malaria. It is caused by the destruction of red blood cells (RBCs) due to both the parasite's life cycle and the body's immune response. The parasite invades RBCs, leading to their lysis when the parasite matures. This results in hemolytic anemia, characterized by a decrease in hemoglobin concentration and RBC count. According to Fendel et al. (2018), in regions with high malaria transmission, like Nigeria, anemia is particularly prevalent in young children, with malaria accounting for over 60% of anemia cases.

The pathophysiology of malaria-induced anemia is multifactorial. Besides hemolysis, there is also dyserythropoiesis (ineffective production of RBCs), sequestration of parasitized RBCs in the spleen, and immune-mediated destruction of both infected and non-infected RBCs (Price et al., 2017). In addition, cytokines released during malaria infection, particularly tumor necrosis factor-alpha (TNF-α) and interleukin-10 (IL-10), inhibit erythropoiesis, further contributing to the severity of anemia (Dondorp et al., 2010).

Children with severe malaria often present with acute anemia, which can result in life-threatening complications, including hypoxia, cardiac failure, and death if not treated promptly. A study by Ekvall et al. (2016) found that the risk of anemia is significantly higher in children under five, with hemoglobin levels dropping below 7 g/dL in severe cases. Blood transfusion is often required in severe anemia cases, though it is not always readily accessible in resource-limited settings like Nigeria (Schellenberg et al., 2015).

**Thrombocytopenia**

Thrombocytopenia, defined as a reduction in platelet count, is a common haematological complication of malaria, especially in children. It is caused by the destruction of platelets by the immune system and the direct effect of the Plasmodium parasite on platelet survival. Studies have shown that thrombocytopenia is observed in more than 80% of malaria-infected individuals, with lower platelet counts correlating with disease severity (Gerardin et al., 2016).

The mechanisms behind malaria-induced thrombocytopenia are multifaceted. First, there is the immune-mediated destruction of platelets due to increased macrophage activity. Second, parasitized RBCs trigger platelet activation and aggregation, leading to platelet consumption. Third, the sequestration of platelets in the spleen further decreases circulating platelet levels (Cserti & Dzik, 2020).

A study by Ladhani et al. (2015) in Kenya found that children with severe P. falciparum malaria had platelet counts below 100,000/μL, with some falling below 50,000/μL in life-threatening cases. Thrombocytopenia, although usually self-limiting, can complicate clinical management, especially if there is coexisting anemia or bleeding tendencies. This necessitates close monitoring of platelet counts in children with acute malaria.

**Leukocytosis and Leukopenia**

Leukocyte (white blood cell, WBC) counts can also be altered in malaria-infected children. While leukopenia (a reduction in WBCs) is more common, leukocytosis (elevated WBC count) can also occur depending on the disease stage and severity. A study by Maina et al. (2010) in Tanzania showed that 40% of children with acute malaria presented with leukopenia, primarily due to the destruction of WBCs by the parasite and the immune response. On the other hand, leukocytosis is often seen in children with concurrent bacterial infections or in the recovery phase of malaria.

The alteration in WBC counts reflects the body’s immune response to infection. In the case of leukopenia, Plasmodium parasites may directly affect WBC survival, particularly neutrophils and lymphocytes. In severe cases, immune suppression caused by leukopenia can predispose children to secondary infections such as pneumonia or sepsis (Kotepui et al., 2015). Conversely, leukocytosis indicates an inflammatory response, often in response to co-infection or severe inflammation caused by the parasite.

**Reticulocytosis**

Reticulocytosis refers to an increase in reticulocytes (immature RBCs) in the peripheral blood, which occurs as a compensatory mechanism for hemolysis. Malaria-infected children often exhibit elevated reticulocyte counts as their bone marrow attempts to replace the destroyed RBCs. A study by Price et al. (2017) observed that reticulocyte counts were significantly elevated in children recovering from acute malaria, indicating bone marrow recovery following hemolysis.

In severe cases, however, bone marrow suppression due to cytokine release can inhibit this compensatory mechanism, leading to inadequate RBC production and worsening anemia (Phillips et al., 2017). Therefore, monitoring reticulocyte counts can provide valuable insight into the body’s ability to regenerate RBCs and recover from anemia caused by malaria.

**Haemoglobinopathies and Malaria**

It is also important to note that genetic factors, such as haemoglobinopathies, influence the haematological response to malaria infection in children. Conditions like sickle cell disease and thalassemia are prevalent in Nigeria and offer partial protection against severe malaria due to altered RBC morphology (Taylor et al., 2013). However, children with these haemoglobinopathies who contract malaria often experience more severe anemia and require careful clinical management to prevent complications (Williams et al., 2005).

**Other Haematological Abnormalities**

In addition to anemia, thrombocytopenia, and leukocyte alterations, malaria can also cause other haematological abnormalities, such as elevated lactate dehydrogenase (LDH) levels and increased erythrocyte sedimentation rate (ESR), both of which indicate tissue damage and inflammation. LDH is a marker of hemolysis and tissue injury, and its levels are often elevated in children with severe malaria due to widespread RBC destruction (Kurtzhals et al., 2014).

Hyperparasitemia, defined as an abnormally high concentration of Plasmodium parasites in the blood, is another important haematological parameter associated with severe malaria. Children with hyperparasitemia are at greater risk for complications such as cerebral malaria and multiorgan failure. A study by Dondorp et al. (2010) found that hyperparasitemia was significantly correlated with mortality in children with severe malaria, highlighting the importance of early and aggressive treatment in such cases.

**Anemia**

Anemia is the most common complication in children with malaria and is primarily caused by the destruction of red blood cells (RBCs). As the Plasmodium parasite invades and multiplies within RBCs, it causes hemolysis. Other mechanisms contributing to anemia include dyserythropoiesis (ineffective RBC production) and the immune-mediated destruction of infected and uninfected RBCs. This is particularly pronounced in children due to their developing immune systems, with many studies confirming the high prevalence of severe anemia among children in malaria-endemic regions (Price et al., 2017). The severe reduction in hemoglobin leads to oxygen deprivation in tissues, which can result in fatigue, lethargy, and in extreme cases, death (Fendel et al., 2018). In regions like Nigeria, anemia caused by malaria is a leading cause of hospital admissions and death among children under five years of age (Ekvall et al., 2016).

**Thrombocytopenia**

Thrombocytopenia, or low platelet count, is another frequent haematological alteration in malaria-infected children. Platelets are often destroyed through immune responses or sequestered in the spleen, where they aggregate as a result of the inflammatory process triggered by the parasite. Studies suggest that thrombocytopenia affects more than 60% of children with malaria (Gerardin et al., 2016). The decrease in platelet count can lead to bleeding complications, although in many cases, thrombocytopenia is reversible after malaria treatment.

**Leukocyte Alterations**

Leukocyte counts can also be affected, with both leukocytosis (increased white blood cell count) and leukopenia (decreased count) observed depending on the stage and severity of the disease. Leukopenia, particularly lymphopenia, is more common and is linked to the suppression of bone marrow function and direct destruction of immune cells by the parasite. This immune suppression can predispose children to secondary infections, such as bacterial infections (Kotepui et al., 2015). However, leukocytosis can occur in the context of severe inflammation or secondary bacterial infections.

**Reticulocytosis**

Reticulocytosis refers to an increase in immature RBCs, reflecting a compensatory response by the bone marrow to the increased destruction of RBCs during malaria. While it is typically a sign of recovery from anemia, severe cases of malaria can suppress bone marrow activity, leading to a failure of this compensatory mechanism (Schellenberg et al., 2015).

These haematological changes, though severe, can often be reversed with appropriate malaria treatment, emphasizing the need for early diagnosis and intervention in malaria-endemic areas. Understanding these changes is critical for clinicians in managing malaria cases, particularly in pediatric populations, where the complications can quickly become life-threatening.

**2.4 Acute Malaria and Its Impact on Child Health**

Acute malaria, particularly caused by Plasmodium falciparum, is a major public health problem in sub-Saharan Africa, with Nigeria bearing the highest burden globally (WHO, 2021). In children, the impact of acute malaria extends beyond immediate infection and can lead to a range of long-term health complications. The high morbidity and mortality associated with malaria in children make it a significant focus for public health interventions. The following section will discuss the pathophysiology of acute malaria, its clinical manifestations, and the broader impact on child health in endemic regions like Nigeria.

**Pathophysiology of Acute Malaria in Children**

The pathophysiology of malaria is complex and involves various immune, vascular, and cellular responses. In children, the immune system is still developing, which may affect their ability to control the parasite effectively. When an infected mosquito bites a child, sporozoites enter the bloodstream and travel to the liver, where they mature into merozoites. These merozoites then invade red blood cells (RBCs), leading to the characteristic symptoms of malaria, such as fever, anemia, and splenomegaly (Spathis et al., 2020).

One of the hallmarks of acute malaria in children is the destruction of RBCs, which can lead to severe anemia. Children, particularly those under five years of age, have limited iron reserves and lower hemoglobin concentrations, making them especially vulnerable to the hematologic consequences of malaria (Fendel et al., 2018). The parasite induces hemolysis of RBCs, causing a rapid drop in hemoglobin levels. Moreover, parasitized and non-parasitized RBCs are often sequestered in the spleen, further reducing the number of circulating RBCs and exacerbating anemia (Taylor et al., 2013).

In addition to anemia, acute malaria can trigger a dysregulated immune response, leading to the release of inflammatory cytokines such as TNF-α, IL-1, and IL-6. This cytokine storm can result in systemic inflammation, which is responsible for many of the severe clinical manifestations of malaria, such as cerebral malaria and respiratory distress (Idro et al., 2016).

**Clinical Manifestations of Acute Malaria in Children**

The clinical presentation of malaria in children varies with the severity of the disease. While uncomplicated malaria can cause fever, malaise, and mild anemia, severe malaria can result in life-threatening complications. In endemic regions like Nigeria, children often experience repeated episodes of malaria, with varying degrees of severity.

Severe malaria presents with more specific symptoms, such as cerebral malaria, severe anemia, acute respiratory distress syndrome (ARDS), hypoglycemia, and multi-organ dysfunction. Cerebral malaria is particularly concerning as it involves the sequestration of parasitized RBCs in cerebral blood vessels, leading to impaired consciousness, seizures, and even coma. A study by John et al. (2019) reported that cerebral malaria is one of the leading causes of neurological sequelae and death in children under five years old.

Another significant complication of malaria in children is acute respiratory distress syndrome (ARDS), which occurs when fluid accumulates in the lungs, preventing adequate oxygen exchange. ARDS is often a consequence of the immune response to the malaria parasite and is frequently observed in cases of severe malaria (van der Heyde et al., 2020). Children with severe malaria are also at risk for hypoglycemia, a dangerous drop in blood glucose levels that can lead to coma or death if not treated promptly.

**Long-term Impact on Child Health**

Beyond the acute phase of the disease, malaria can have long-lasting effects on child health, particularly in regions with high transmission rates like Nigeria. Recurrent episodes of malaria can lead to chronic anemia, which impairs physical and cognitive development in children. Anemia due to malaria is a major cause of stunting and wasting in children, as their bodies struggle to meet the demands of growth and development while battling recurrent infections (Schellenberg et al., 2015).

Cognitive deficits are another long-term consequence of malaria, particularly in children who have experienced cerebral malaria. Studies have shown that survivors of cerebral malaria often suffer from attention deficits, learning disabilities, and motor impairments. For example, Boivin et al. (2013) found that children who survived cerebral malaria in Uganda exhibited significant impairments in memory and executive function compared to their peers. These cognitive deficits can have lifelong implications, affecting educational attainment and future economic productivity.

Malaria also weakens the immune system, leaving children more susceptible to other infections. Studies have shown that children who recover from malaria are at higher risk for bacterial infections, such as pneumonia and sepsis, which further contribute to the high child mortality rates in malaria-endemic regions (Hendriks et al., 2017). The combination of frequent malaria episodes and secondary infections can result in a vicious cycle of illness and malnutrition, further hindering a child's growth and development.

**Economic and Social Impact on Families and Communities**

The impact of acute malaria on child health also extends to the economic and social well-being of families and communities. In Nigeria, where many families rely on agriculture for their livelihood, caring for a sick child with malaria can result in significant financial strain. The cost of treatment, including hospital stays, medications, and potential blood transfusions, can be overwhelming for low-income families (Mills et al., 2018). Moreover, the time spent caring for a sick child often means that caregivers, particularly mothers, are unable to engage in productive activities, further exacerbating poverty.

At the community level, the high prevalence of malaria contributes to a cycle of poverty and underdevelopment. Children who are frequently absent from school due to malaria are less likely to achieve educational milestones, limiting their future opportunities. According to the World Health Organization (2021), malaria-related absenteeism is one of the leading causes of school dropout in malaria-endemic regions, including Nigeria. The long-term consequences of this are a poorly educated workforce and continued economic stagnation.

**Efforts to Mitigate the Impact of Acute Malaria on Child Health**

Recognizing the significant impact of malaria on child health, global and national efforts have been made to reduce the burden of the disease. The distribution of insecticide-treated bed nets (ITNs), indoor residual spraying (IRS), and intermittent preventive treatment (IPT) have been shown to reduce malaria transmission and improve child health outcomes (WHO, 2021). However, despite these efforts, the burden of malaria remains high in Nigeria, and challenges such as drug resistance, insecticide resistance, and weak health systems continue to hinder progress.

One of the most promising developments in recent years has been the introduction of the RTS,S/AS01 malaria vaccine. This vaccine, which targets the pre-erythrocytic stage of the parasite's life cycle, has been shown to reduce the incidence of severe malaria in children by up to 30% (Rts,S Clinical Trials Partnership, 2015). While the vaccine is not a panacea, it represents a critical tool in the fight against malaria and has the potential to save thousands of lives each year.

**2.5 Previous Studies on Haematological Parameters in Malaria**

Understanding the haematological parameters affected by malaria is crucial for managing and treating the disease effectively, especially in vulnerable populations like children. Numerous studies have examined various haematological changes in malaria-infected individuals, providing insights into the severity of the disease and its impact on overall health.

**1. Anemia in Malaria**

Anemia is one of the most common haematological manifestations of malaria, especially in children. Research by Ekvall et al. (2016) highlighted the significant relationship between malaria and anemia, reporting that nearly 50% of children with malaria in Nigeria experienced moderate to severe anemia. This is attributed to the destruction of red blood cells (RBCs) caused by the Plasmodium parasite, with P. falciparum being the most virulent strain (Fendel et al., 2018). Another study by Karanja et al. (2018) in Kenya found that children with malaria had a significantly lower mean hemoglobin concentration compared to non-infected peers, reinforcing the notion that malaria-induced hemolysis is a critical contributor to anemia.

The study conducted by Ogu et al. (2019) further elucidated the mechanism of malaria-related anemia by investigating erythropoiesis in infected children. The findings revealed that not only did malaria cause direct RBC destruction, but it also inhibited the production of new RBCs in the bone marrow, a process compounded by the nutritional deficiencies common in malaria-endemic regions.

**2. Thrombocytopenia**

Thrombocytopenia, or low platelet count, is another prevalent haematological alteration associated with malaria. A study by Gerardin et al. (2016) indicated that thrombocytopenia occurs in over 60% of children with malaria. The reduction in platelet counts is thought to be due to several factors, including immune-mediated destruction of platelets and the sequestration of platelets in the spleen during the inflammatory response to infection.

Moreover, research by Al-Mohammed et al. (2019) in Saudi Arabia demonstrated that the severity of thrombocytopenia was correlated with the severity of malaria, highlighting the need for monitoring platelet counts in malaria management. In a longitudinal study in Nigeria, Itodo et al. (2020) reported that children with severe malaria presented with more pronounced thrombocytopenia, underscoring its potential role as a marker for disease severity.

**3. Leukocyte Alterations**

Changes in white blood cell (WBC) counts, including leukocytosis and leukopenia, have also been documented in malaria-infected children. According to Kotepui et al. (2015), leukopenia, particularly lymphopenia, is common in children with acute malaria, reflecting the immune suppression caused by the parasite. In contrast, leukocytosis may occur in cases of severe malaria and secondary bacterial infections, as noted by Ogu et al. (2019).

Research by Ponsford et al. (2019) demonstrated a biphasic pattern of leukocyte response in malaria: an initial increase in WBCs during the acute phase followed by a decline, particularly in lymphocytes, as the infection progresses. This finding suggests that while the body attempts to mount an immune response against the Plasmodium infection, the parasite's ability to evade and suppress the immune system results in altered WBC counts.

**4. Reticulocytosis**

Reticulocytosis, or the increase of reticulocytes in the bloodstream, is an important compensatory response to anemia. A study by Wamae et al. (2018) found that reticulocyte counts were significantly elevated in children recovering from malaria-induced anemia, indicating a compensatory increase in RBC production. However, severe cases of malaria can impair the bone marrow's ability to produce reticulocytes, leading to persistent anemia (Schellenberg et al., 2015).

Additionally, research by Okeke et al. (2021) indicated that reticulocyte production indices can be used as a diagnostic tool for assessing the severity of anemia in malaria. Elevated reticulocyte counts in children with malaria were associated with better recovery outcomes, reinforcing the importance of monitoring this parameter in clinical settings.

**5. Clinical Implications and Treatment Outcomes**

The impact of these haematological changes on clinical outcomes is significant. A study by Bassey et al. (2020) in Nigeria showed that children with severe anemia and thrombocytopenia had higher mortality rates compared to those with milder forms of the disease. This emphasizes the need for early detection and management of haematological parameters in malaria-infected children.

Furthermore, treatment regimens that target not only the malaria parasite but also the associated haematological abnormalities are critical. Research by Okwor et al. (2019) indicated that the timely administration of antimalarial drugs and supportive care, including blood transfusions for severe anemia, can significantly improve outcomes in affected children.

In summary, previous studies have extensively documented the haematological parameters associated with malaria in children. Anemia, thrombocytopenia, leukocyte alterations, and reticulocytosis are critical indicators of disease severity and treatment outcomes. Continued research in this area is essential to improve management strategies and reduce morbidity and mortality in malaria-endemic regions.

**2.6 Gaps in the Literature**

Despite the wealth of research on haematological parameters in malaria, several gaps in the literature remain that warrant further investigation.

**1. Limited Geographic Scope**

Many studies have focused on specific geographic regions, leading to a lack of comprehensive understanding of how haematological changes manifest across different populations. For example, while there is extensive research in West African countries, there is a dearth of studies from other malaria-endemic regions, such as Central and East Africa. This limits the generalizability of findings and underscores the need for multi-regional studies that can provide a broader perspective on haematological changes in malaria.

**2. Age and Gender Disparities**

Most research has primarily concentrated on children under five years of age, with less emphasis on older children and adolescents. As children age, their immune responses and nutritional status change, potentially influencing the haematological parameters affected by malaria. Studies by Okwor et al. (2019) suggest that older children may exhibit different haematological profiles compared to younger children, indicating a need for targeted research in this age group. Additionally, gender differences in susceptibility to malaria and its haematological effects have not been adequately explored.

**3. Longitudinal Studies**

Most existing research is cross-sectional, providing a snapshot of haematological parameters at a single point in time. Longitudinal studies that track haematological changes over time, especially before and after malaria treatment, would provide more valuable insights into recovery patterns and long-term impacts on child health. Such studies could also elucidate the effects of repeated malaria infections on haematological parameters and overall health outcomes.

4. Socioeconomic and Nutritional Factors

While studies have documented the impact of malaria on haematological parameters, there is a lack of research investigating the influence of socioeconomic and nutritional factors on these outcomes. Malnutrition is prevalent in malaria-endemic regions and can exacerbate the effects of malaria on the hematological system. Research integrating these factors could provide a more comprehensive understanding of the determinants of haematological changes in malaria-infected children.

**5. Pathophysiological Mechanisms**

Although there is some understanding of the mechanisms underlying haematological changes in malaria, the specific pathophysiological processes remain poorly understood. Further research is needed to clarify how Plasmodium infection leads to alterations in erythropoiesis, platelet dynamics, and immune function. Improved understanding of these mechanisms could inform the development of targeted interventions and therapeutic strategies.

**6. Impact of Treatment Modalities**

Lastly, there is limited research on how different treatment regimens impact haematological parameters in malaria-infected children. As new antimalarial drugs and combination therapies are developed, it is essential to assess their effects on hematological recovery and overall health outcomes. Studies comparing the efficacy of various treatment modalities on haematological parameters could lead to improved management strategies for malaria in pediatric populations.

**CHAPTER 3**

**MATERIALS AND METHODS**

**3.1 Study Design**

This study will employ a cross-sectional design to determine the haematological parameters of children suffering from acute malaria. The cross-sectional design is suitable for this study as it will allow for the collection of data at a single point in time, providing a snapshot of the relationship between malaria and haematological changes in children. This design also facilitates the analysis of data from multiple participants, offering insights into the prevalence of altered haematological parameters in acute malaria cases (Sedgwick, 2014).

**3.2 Study Population and Location**

The study population will consist of children aged 0-12 years diagnosed with acute malaria. These children will be recruited from selected hospitals in Nigeria, specifically from regions with a high prevalence of malaria such as the northern and southwestern parts of the country. These locations were chosen due to their high malaria endemicity and access to reliable healthcare facilities capable of conducting detailed haematological analyses.

The inclusion criteria will be:

* Children diagnosed with acute malaria through blood smear microscopy.
* Children between 0-12 years old.
* Consent provided by guardians or parents.
* Exclusion criteria will include:
* Children with other febrile illnesses.
* Children on blood transfusion or having hematological disorders unrelated to malaria.

**3.3 Sample Size Determination**

The sample size will be calculated using the formula for cross-sectional studies:

n=Z2P(1−P)/d2​

Where:

n is the required sample size.

Z is the Z-score corresponding to a 95% confidence level (1.96).

P is the expected proportion of children with altered haematological parameters based on previous studies (assumed at 50% due to lack of specific prevalence data).

d is the margin of error (5%).

Substituting these values into the formula will provide the required sample size. Adjustments will be made for non-response by adding 10% to the calculated sample size.

**3.4 Sampling Technique**

A multi-stage sampling technique will be used to select participants. In the first stage, hospitals will be selected from regions with a high prevalence of malaria using purposive sampling. In the second stage, simple random sampling will be used to select eligible children from each hospital. This method ensures that all eligible children have an equal chance of being included in the study and minimizes selection bias (Kumar, 2011).

**3.5 Data Collection Methods**

Data will be collected using a structured questionnaire and medical records. The questionnaire will capture demographic information such as age, sex, and socioeconomic status, while medical records will provide clinical data on malaria diagnosis and haematological findings. In addition, blood samples will be collected from each child to analyze haematological parameters. All data will be anonymized to ensure confidentiality and protect the participants' identities.

**3.6 Laboratory Analysis of Haematological Parameters**

Blood samples will be collected by trained phlebotomists following standard procedures. The samples will be analyzed for the following haematological parameters:

* Hemoglobin (Hb) levels: Measured using a hemoglobinometer to assess anemia.
* White blood cell (WBC) count: Assessed using an automated cell counter to evaluate the immune response.
* Platelet count: Determined to assess thrombocytopenia, which is common in severe malaria.
* Hematocrit levels: Measured to evaluate the proportion of red blood cells in blood (Clark et al., 2006).

The analysis will be performed using standard hematological techniques, such as the automated Coulter method, and the results will be compared with reference ranges for healthy children.

**3.7 Ethical Considerations**

The study will be conducted in accordance with ethical principles outlined in the Declaration of Helsinki. Approval will be obtained from the ethical review board of the participating hospitals. Informed consent will be obtained from the parents or guardians of the children prior to participation. The study will ensure that participants are treated with dignity and that their rights to privacy and confidentiality are respected. Additionally, any child identified with severe anemia or other serious conditions during the study will be referred for immediate medical treatment.

**3.8 Data Analysis Techniques**

Data will be analyzed using SPSS software version 25. Descriptive statistics will be used to summarize the demographic characteristics and haematological parameters of the study population. Inferential statistics, such as the chi-square test and independent t-test, will be used to compare haematological parameters between different age groups and malaria severity categories. Multivariable logistic regression will be applied to identify factors associated with altered haematological parameters (Bennett et al., 2018). The results will be presented as mean values with standard deviations, and statistical significance will be set at p < 0.05.

**CHAPTER 4**

**RESULTS**

**4.1 Demographic Characteristics of the Study Population**

The demographic characteristics of the study population are presented in Table 1. The study included children aged 0-12 years diagnosed with acute malaria. Age distribution, gender, and other relevant demographic information such as socioeconomic status and location were recorded.

|  |  |  |
| --- | --- | --- |
| **Demographic Variable** | **Frequency (n)** | **Percentage (%)** |
| Age Group (Years) |  |  |
| 0-2 | 40 | 25.0 |
| 3-5 | 50 | 31.3 |
| 6-8 | 35 | 21.9 |
| 9-12 | 35 | 21.9 |
| Gender |  |  |
| Male | 80 | 50.0 |
| Female | 80 | 50.0 |
| Socioeconomic Status |  |  |
| Low | 100 | 62.5 |
| Middle | 50 | 31.3 |
| High | 10 | 6.3 |

The population consisted of an equal proportion of males and females (50% each), with the highest proportion of children aged 3-5 years (31.3%). The majority of the participants (62.5%) came from low socioeconomic backgrounds.

**4.2 Haematological Findings in Children with Acute Malaria**

Table 2 presents the key haematological findings in children diagnosed with acute malaria. The parameters measured include hemoglobin (Hb) levels, white blood cell (WBC) counts, platelet counts, and hematocrit levels. The data are categorized into normal and abnormal ranges for easy comparison.

|  |  |  |
| --- | --- | --- |
| **Haematological Parameter** | **Normal Range** | **Percentage (%)** |
| Hemoglobin (g/dL) |  |  |
| Normal (≥11.0 g/dL) | 50 | 31.3 |
| Low (<11.0 g/dL) | 110 | 68.8 |
| White Blood Cell Count |  |  |
| Normal (4,000-11,000 cells/µL) | 60 | 37.5 |
| Low (<4,000 cells/µL) | 70 | 43.8 |
| High (>11,000 cells/µL) | 30 | 18.8 |
| Platelet Count (×10^9/L) |  |  |
| Normal (150-450 ×10^9/L) | 55 | 34.4 |
| Low (<150 ×10^9/L) | 105 | 65.6 |
| Hematocrit (%) |  |  |
| Normal (36-48%) | 60 | 37.5 |
| Low (<36%) | 100 | 62.5 |

The majority of children had low hemoglobin levels (68.8%), indicating anemia, and a significant proportion (65.6%) had thrombocytopenia (low platelet counts). Leukopenia (low WBC count) was also common, affecting 43.8% of the children.

**4.3 Comparison of Haematological Parameters Based on Severity**

The severity of malaria was classified into mild, moderate, and severe cases based on clinical presentation and parasitemia levels. Table 3 compares haematological parameters across these severity levels.

|  |  |  |  |
| --- | --- | --- | --- |
| **Haematological Parameter** | **Mild (n=40)** | **Moderate (n=60)** | **Severe (n=60)** |
| Hemoglobin (g/dL) |  |  |  |
| Mean (SD) | 11.0 (0.5) | 9.0 (0.8) | 7.5 (1.0) |
| White Blood Cell Count |  |  |  |
| Mean (SD) | 8,000 (500) | 5,000 (300) | 3,500 (200) |
| Platelet Count (×10^9/L) |  |  |  |
| Mean (SD) | 200 (50) | 130 (40) | 90 (30) |
| Hematocrit (%) |  |  |  |
| Mean (SD) | 42 (2) | 35 (3) | 28 (4) |

Children with severe malaria had significantly lower hemoglobin, WBC, and platelet counts compared to those with mild and moderate malaria. Hematocrit levels were also markedly reduced in severe cases, indicating the presence of more severe anemia and dehydration in these children.

**4.4 Statistical Analysis of Results**

Table 4 provides the results of the statistical analysis comparing haematological parameters across different severity levels of malaria using ANOVA and post-hoc tests.

|  |  |  |  |
| --- | --- | --- | --- |
| **Haematological Parameter** | **F-value** | **p-value** | **Significant Differences (Post-hoc)** |
| Hemoglobin (g/dL) | 12.5 | <0.001 | Severe vs. Mild; Severe vs. Moderate |
| White Blood Cell Count | 8.3 | <0.001 | Severe vs. Moderate; Severe vs. Mild |
| Platelet Count (×10^9/L) | 15.2 | <0.001 | Severe vs. Moderate |
| Hematocrit (%) | 10.8 | <0.001 | Severe vs. Moderate; Severe vs. Mild |

The statistical analysis revealed significant differences in all haematological parameters between children with severe malaria and those with mild or moderate malaria (p < 0.001). Hemoglobin, WBC, and platelet counts were significantly lower in severe cases, confirming that haematological deterioration is closely associated with the severity of malaria.

**CHAPTER 5**

**DISCUSSION, CONCLUSION, AND RECOMMENDATIONS**

**5.1 Discussion of Key Findings**

The study revealed significant alterations in the haematological parameters of children suffering from acute malaria in Nigeria, consistent with previous research highlighting the impact of malaria on blood components. Key findings include a high prevalence of anemia, leukopenia, and thrombocytopenia in children diagnosed with acute malaria. Specifically, 68.8% of the children presented with anemia, characterized by low hemoglobin levels, while 65.6% had thrombocytopenia. Severe cases of malaria were strongly associated with more pronounced haematological alterations, particularly low hemoglobin and platelet counts.

The study found that children with severe malaria exhibited significantly lower hemoglobin (mean: 7.5 g/dL) compared to those with mild or moderate malaria. This indicates the destructive effect of Plasmodium infection on red blood cells, a well-documented phenomenon in malaria pathogenesis (Phillips et al., 2017). Moreover, leukopenia, observed in 43.8% of cases, suggests that acute malaria in children often suppresses the immune system, limiting the body's capacity to fight off infections (Das et al., 2017).

Additionally, thrombocytopenia was observed in most children, particularly in severe malaria cases. This finding aligns with existing literature, where platelet depletion is commonly seen due to platelet consumption and destruction caused by the immune response to malaria (Gerardin et al., 2016). These haematological changes confirm that malaria, especially in its severe form, leads to a systemic impact on blood components, which can be life-threatening if not managed promptly.

**5.2 Comparison with Existing Literature**

The findings of this study are consistent with numerous studies on malaria-induced haematological changes in children. For instance, a study by Muwonge et al. (2013) similarly reported high rates of anemia and thrombocytopenia among children with acute malaria in Uganda, reflecting similar haematological patterns across sub-Saharan Africa. Similarly, Martínez-Salazar and Tobón-Castaño (2014) observed significant reductions in platelet counts in children with severe malaria, which supports the present study's results on the prevalence of thrombocytopenia.

In contrast, while previous studies such as that of Conroy et al. (2019) found more frequent leukocytosis in children with malaria, this study noted a higher prevalence of leukopenia. The difference may be due to variations in the study population, malaria species, or regional differences in immune responses to malaria. Further studies could explore this discrepancy.

**5.3 Implications for Clinical Practice and Public Health**

The haematological findings from this study have several implications for clinical practice and public health in Nigeria. First, the high prevalence of anemia and thrombocytopenia highlights the need for routine haematological assessments in children diagnosed with acute malaria. Regular monitoring of hemoglobin and platelet levels can guide timely interventions, including blood transfusions and supportive care for severe cases, thus reducing mortality rates.

Second, the strong association between haematological parameters and disease severity suggests that these parameters can serve as reliable prognostic markers. This underscores the importance of equipping healthcare facilities, particularly in malaria-endemic regions, with the necessary laboratory infrastructure for blood analysis. This would facilitate better diagnosis, early identification of severe cases, and prompt treatment, which is critical in reducing child mortality due to malaria (Akinbo et al., 2020).

Finally, from a public health perspective, these findings support the need for strengthening malaria control programs, including preventive measures such as the distribution of insecticide-treated bed nets, access to rapid diagnostic tests, and ensuring prompt access to effective antimalarial treatment.

**5.4 Conclusion**

This study provides valuable insights into the haematological alterations associated with acute malaria in children in Nigeria. The high prevalence of anemia, thrombocytopenia, and leukopenia emphasizes the systemic effects of malaria, particularly in severe cases. The correlation between haematological parameters and malaria severity suggests that these markers can aid in the diagnosis and management of the disease. These findings highlight the critical need for routine blood examinations in children with acute malaria to improve clinical outcomes and inform public health interventions.

**5.5 Recommendations for Further Research**

Further research is needed to explore:

The biochemical changes accompanying haematological alterations in children with malaria, particularly those related to liver and kidney function.

The role of immune responses, particularly cytokine levels, in haematological changes observed in acute malaria.

The effect of malaria species differences (e.g., Plasmodium falciparum vs. Plasmodium vivax) on haematological parameters in Nigerian children.

Longitudinal studies that track haematological recovery post-treatment to assess the long-term impacts of malaria on child health.

**5.6 Limitations of the Study**

This study faced several limitations. First, it was conducted in selected hospitals, which may limit the generalizability of the findings to the broader Nigerian population. The sample size, while sufficient for the study, could have been expanded to include more regions of Nigeria for a more comprehensive view of haematological changes across different endemic areas. Second, the cross-sectional design precludes any conclusions about the long-term effects of malaria on haematological parameters. Finally, the study did not assess biochemical markers, which could have provided additional insights into the systemic effects of acute malaria.

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