

## Effect of Severe Malaria on Biochemical Markers (Renal Functions Tests) among Severe Malaria Patients Attending to Kosti Teaching Hospital, White Nile State, Sudan

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### Abstract

Malaria is a life-threatening disease caused by the infection of red blood cells with protozoan parasites of the genus *Plasmodium*. When untreated or improperly treated, it leads to fatal complications such as liver disease, organ dysfunction, and death.

This case-control study was conducted to estimate levels of serum total bilirubin and direct and indirect bilirubin among patients with severe malaria in Kosti Teaching Hospital during the period from October 2024 – November 2024.

Results showed a significant increase in plasma creatinine and proteinuria among cases compared with the control ( $P=0.000$ ,  $P=0.000$ ). They also showed a mild significant positive correlation between age and BMI ( $r=0.586$ ,  $P=0.000$ ) and between plasma creatinine with age and BMI ( $r=0.270$ ,  $P=0.000$ ) ( $r=0.361$ ,  $P=0.000$ ) respectively, and between plasma creatinine with creatinine clearance ( $r=0.838$ ,  $P=0.000$ ) in the case study group. The results showed that plasma creatinine and proteinuria levels were increased among severe malaria patients compared with normal controls and also revealed a significant increase in plasma urea and uric acid among cases compared with controls ( $P$  Value = 0.000,  $P$  Value = 0.000). It also showed a mild significant positive correlation between age with BMI ( $r=0.586$ ,  $P$  Value=0.000), and between plasma urea with age and BMI ( $r=0.104$ ,  $P$  Value =0.109) ( $r=0.076$ ,  $P$  Value=0.240) respectively, also result showed significant increase uric acid with age and BMI ( $r=0.292$ , $p=0.000$ ) ( $r=0.402$ , $p=0.000$ ) and between plasma urea with uric acid ( $r=0.520$ , $P$  Value=0.000) in case study group.

Additionally, the reduction of sodium and potassium in malaria infections can be attributed to hyponatremia and hypokalemia ( $p = 0.000$ ), with statistical significance. Additionally, the results showed no correlation between plasma Calcium and age and BMI in the case study group.

In conclusion, Malaria affects patients' electrolytes and renal function.

**Keywords:** Malaria, Hyperparasitemia, Renal Functions, Electrolytes, Urea, Uric Acid, Creatinine, GFR, Sodium, Potassium, Calcium, Phosphorus

### 1. INTRODUCTION

Malaria is a life-threatening disease caused by the infection of red blood cells with protozoan parasites of the genus *Plasmodium*. (1) Malaria and infections can produce numerous complications in various organs, including the kidneys. (2, 3) Malaria is estimated to cause 2 – 3 million deaths and 300 – 500 million clinical

cases in the world. (4) Severe Malaria is a life-threatening condition. It hurts adults and children; (5) the effect of parasitemia in severe Malaria has various changes in clinical biomarkers, mainly renal functions and causes serious complications. (6)

Identifying the early kidney involvement allows the early management of dysfunctions. (7) The

renal involvement in Malaria varies widely, from asymptomatic proteinuria to acute renal failure. (8) Increased creatinine can result from prerenal azotemia through an inadequate kidney blood flow and a glomerular hydrostatic pressure insufficient to maintain the glomerular filtration rate [GFR]; long-lasting prerenal azotemia can produce tubular necrosis, the most common form of renal injury in Malaria, (9) additionally, renal failure when the presence of oliguria and increase level of blood urea.(10) Increased plasma uric acid levels in malaria patients correlate with a surge in inflammatory cytokines such as tumour necrosis factor (TNF)- $\alpha$ , interleukin (IL)-6, IL-10, and IL-8 in *P. falciparum* patients.(11)

Additionally, in various infections, including Malaria, electrolyte imbalances and mineral disturbances have been identified as the most indicative clinical symptoms. Hyponatraemia and hyperkalaemia usually develop as a result of infection with *Plasmodium*. (12) A low level of Ca is a common observation during malaria infection. The decline in calcium occurs due to clinical symptoms associated with Malaria, such as fever, a high pulse rate, sweating, and shivering. (13) Phosphate plays many essential roles in our body. To accomplish these functions, serum phosphate levels must be maintained within a specific range. Serum phosphate level is regulated by intestinal phosphate absorption, renal phosphate handling, and the equilibrium of extracellular phosphate with that in bone or intracellular fluid. (14).

Asymptomatic hematuria with proteinuria in children is less common but is associated with high-risk renal disease. (15)

## **2. MATERIALS AND METHODS**

The study was conducted as a case-control study at Kosti City, White Nile State, from Kosti Teaching Hospital, from September 2024 to December 2024.

The study was approved by the Ethical Committee of the University of El-imam El Mahdi and by Kosti Teaching Hospital.

The study aimed to estimate the levels of plasma urea, uric acid, creatinine, GFR, proteinuria, Sodium, Potassium, calcium, phosphorus, and BMI among patients with severe malaria. The study comprises 120 patients with severe malaria (the study group) and 120 healthy individuals (the control group), subdivided into male and

female and adults and children, selected through convenience sampling.

**Sampling:** 3 mL of blood was collected from all participants in a clean, dry container with lithium heparin, then labelled and transported to the laboratory without delay. A urine sample was collected in a clean, dry, and sterile container. The lithium heparin sample was separated by centrifuge force.

## **2.2. Statistical Analysis**

The data obtained were computerized and analyzed using SPSS (Statistical Package for the Social Sciences) version 21 (IBM Corp., Armonk, NY, USA). The data were assessed using independent sample t-tests and correlation tests. The results were expressed as mean (M) with standard deviation (SD), and a p-value of < 0.05 was considered significant.

Plasma urea, uric acid, creatinine, calcium, and phosphorus were estimated using a spectrophotometer (Mindray BA-88A). Electrolytes (sodium and potassium) were measured using the ion-selective electrode method, as outlined in the electrolyte analyzer operation manual (model: AC9100).

## **3. RESULTS**

This study accounts for a total of 240 individuals (120 severe malaria patients and 120 healthy controls) with ages ranging from 1-80 years. The mean age of severe malaria and healthy control groups was 28.08 years; adults were more frequent than children by a ratio of 3:1, respectively.

Table (1): The results showed that the estimated level of mean Value  $\pm$  SD of age and BMI of the case study group were (28.08  $\pm$  18.33 and 29.50 $\pm$  12.14.) respectively, while in the control group were (27.71  $\pm$  16.71 and 28.45 $\pm$ 11.36) (P=0.869 and 0.716) respectively. The difference between the two groups was insignificant, but the case study group had higher ages and BMIs than the control group.

Table (2): The results showed that the estimated level of mean Value  $\pm$  SD of plasma creatinine in the case study group was (1.51  $\pm$  0.42mg/dl) while in the control group was (0.93  $\pm$  0.27mg/dl) (P-Value=0.000) There was a significant increase in the levels of plasma creatinine compare with control. Also, the results showed that the estimated level of mean Value  $\pm$  SD of creatinine clearance in the case study group was (73.92  $\pm$  57.13 ml/min) while in the control group

was (93.76 ± 36.63ml/min) (P-Value=0.000), There was a significant increase in the levels of creatinine clearance in case study group compared with control group (93.76 ± 36.63ml/min) (P-Value=0.000). The results also showed that the estimated level of mean Value ± SD of proteinuria in the case study group was (0.73±0.44 g/dl) while in the control group was (0.18 ± 0.38 g/dl) (P=0.000). There were significantly higher levels of proteinuria in the case study group than in the control group. Also, the results showed that the estimated level of mean Value ± SD of plasma urea in the case study group was (46.96±9.67mg/dl) while in the control group was (32.45 ± 8.38mg/dl) (P-Value=0.000). There was a significant increase in the levels of plasma urea compared with the control, see table also; the results showed that the estimated level of mean Value ± SD of uric acid in the case study group was (8.18 ±2.37 mg/dl) while in the control group was (4.67± 1.36 mg/dl) (P-Value=0.000), There was a significant increase in the levels of uric acid in case study group compared with control group (73.76 ± 36.63ml/min) (P=0.000).

Additionally, the results showed that the (mean ± SD) and P.value of plasma sodium and potassium in the case study group were (133.4 ± 4.1 and 3.18 ± .29) while in the control group were (139±2.6, 4.06± .57), (PValue=0.000, P-Value=0.000), respectively. Also, results showed that the mean ± SD values of plasma calcium and plasma phosphate in patients with severe malarial were (8.5267±0.79808 and 3.6950±1.07374) while in non-infected individuals, were (9.1533±0.58381 and 4.1150±.85834), (PValue=0.001 and P-Value=0.02) respectively. There was a significant decrease in plasma calcium and phosphate levels in patients with severe malaria.

Table (3): The results showed a significant medium positive correlation between age and BMI (r= 0.586, P-Value=0.000) and a significant weakly positive correlation between plasma creatinine with age and BMI (r=0.270, P-Value=0.000) (r=0.361, P-Value=0.000)

**Table 1.** Demographic data and clinical characteristic of study group and control group

Variables	Study Group n=120 (Mean ± SD)	Control Group n= 120 (Mean ± SD)	P. value
Age (years)	28.08 ± 18.33	27.71 ± 16.71	0.869
BMI (kg/m <sup>2</sup> )	29.50± 12.14	28.45±11.36	0.716
Variables	Frequency	Percentage (%)	P. value
Adults	180	75%	0.156
Children	60	25%	0.07

respectively, additionally a significant strongly positive correlation between plasma creatinine with creatinine clearance (r=0.838, P-Value=0.000) in the case study group. The results showed an insignificant negative correlation between age with creatinine clearance (r=-.435 , P-Value=0.084) and significant strongly positive correlation between creatinine clearance with BMI (r=0.696, P-Value=0.000), and a significant weakly positive correlation between creatinine clearance with proteinuria (r=0.224), P-Value=0.000) and insignificant, weak positive correlation between plasma urea with age and BMI (r=0.104, P-Value=0.109) (r=0.076, P-Value=0.240) respectively, additionally a significant moderate positive correlation between plasma urea with uric acid (r=0.520, P-Value=0.000) in case study group and showed significant moderate positive correlation between age and BMI with uric acid (r=0.292 P-Value=0.000),(r=0.402, p-Value =0.000) in case study group.

Table (4): Results showed an insignificant correlation between sodium and age (r=0,076, p=o, 590), the result showed an insignificant correlation between sodium and BMI (r=-0.07, p-Value=.912) Also showed an insignificant correlation between potassium and age (r=.048, p-Value=.133), the results showed an insignificant correlation between potassium and (r=.092, p=156). Additionally, results showed a significant correlation between plasma calcium and age (r = -0.134, p-Value = 0.038), and a significant correlation between plasma calcium and plasma phosphorus (r = 0.196, P-Value = 0.002). It also showed a significant correlation between plasma phosphorus and age, as well as between plasma phosphorus and BMI, among severe malaria patients (r = -0.279, p-value = 0.000) and (r = -0.445, p-value = 0.000), respectively. The results showed an insignificant correlation between plasma calcium and BMI among patients with severe malaria (r = -0.115, p-Value = .075).

**Table 2.** Comparison of plasma biomarkers (renal parameters) and electrolytes between study group and control group

Variables	Study Group (Mean ± SD) mg/dl	Control Group (Mean ± SD) mg/dl	P. value
Plasma creatinine	1.51 ± 0.42	0.93 ± 0.27	0.000
Creatinine clearance	73.92 ± 57.13	93.76 ± 36.63	0.000
proteinuria	<b>0.73 ± 0.44</b>	<b>0.18 ± 0.38</b>	<b>0.000</b>
Urea	46.96 ± 9.67	32.45 ± 8.38	0.000
Uric acid	8.18 ± 2.37	4.67 ± 1.36	0.000
Sodium(Na+) mmol/l	133.4 ± 4.1	139.9 ± 2.6	0.000
Potassium (K+)mmol/l	3.18 ± .29	4.06 ± .57	0.000
Calcium	8.5267 ± .79808	9.1533 ± .58381	0.001
Phosphorus	3.6950 ± 1.07374	4.1150 ± .85834	0.021

**Table 3.** Correlation between Renal biomarkers with age, BMI, and with each other's

Variable	Correlation coefficient	p. value
Plasma creatinine vs age	0.270	0.000
Plasma creatinine vs BMI	0.361	0.000
Plasma creatinine vs creatinine clearance	0.838	0.000
Creatinine clearance vs BMI	0.696	0.000
Creatinine clearance vs proteinuria	0.224	0.000
Urea vs age	0.104	0.109
Urea vs BMI	0.076	0.240
Urea vs uric acid	0.520	0.000
Uric acid vs age	0.292	0.000
Uric acid vs BMI	0.402	0.000

**Table 4.** Correlation between Plasma Electrolytes with age, BMI, and with Each Other's

Variable	Correlation coefficient	p. value
Sodium vs age	0.076	0.590
Sodium vs BMI	-0.007	0.912
Potassium vs age	0.045	0.133
Potassium vs BMI	0.092	0.156
Ca vs age	0.134-	0.038
Ca vs BMI	0.115-	0.075
Ca vs Ph.	0.196	0.002
Ph vs age	0.279-	0.00
Ph vs BMI	0.445-	0.00

#### 4. DISCUSSION

The severity of malaria infection is recognised by acute renal failure and hepatic malfunction, characterised by renal failure, as indicated by the presence of oliguria and an increased level of creatinine in the blood (16).

The present results showed a significantly increased level of plasma creatinine, creatinine clearance, and Proteinuria among individuals with severe MalariaMalaria compared to non-malaria individuals (P-value = 0.000, P-value = 0.000, and P-value = 0.000, respectively). In MalariaMalaria, kidney impairment is due to hemodynamic instability and immune response (17).

Our results agree with previous studies that reported a significant increase in plasma creatinine levels in severe malaria patients. (12, 18-21).

A positive correlation was found between Proteinuria and the number of malaria parasites. The present results agree with a previous study by Lubis M et al. (22) and Tobón-Castaño A. et al. (8), which shows Proteinuria in patients with MalariaMalaria; it also agrees with the study by Naqvi R et al. (2015) (23), which reports that Proteinuria of 1+ to 3+ was found in 43 of the malaria cases.

Our study results also showed a significant decrease in creatinine clearance; this result agrees with the study by Sowunmi A et al. (24), which reports a reduction in creatinine clearance during acute illness.

The result showed a significant increase in the level of plasma urea (p Value= 0.000), a finding supported by Obisike et al. (25), who found that the increase in urea levels in malaria-infected could be due to dehydration because of fever

from the malaria parasite infection and because of parasite sequestration into the renal microvasculature. (25) Our result disagrees with Onyeneke et al. (26), who reported a significant decrease in urea levels in severe MalariaMalaria compared to control subjects.

Our results showed a significant increase in plasma uric acid in the case study compared with the control group (P Value = 0.000), likely due to an increase in inflammatory cytokines. (8) This finding is supported by Debarup Das et al.2022) (27), who found an increase in uric acid. Many studies (1, 27, 28, 29) have shown that the serum uric acid level is significantly higher in complicated MalariaMalaria compared to uncomplicated MalariaMalaria.

A decrease in plasma sodium and potassium levels was observed among cases compared to controls (p-value = 0.000). The exact cause of hyponatremia in MalariaMalaria is not known. We hypothesise that it may be due to dehydration, vomiting, or renal failure. Hyponatremia could be due to increased secretion of anti-diuretic hormones in response to hypovolemia in severe malaria infection. There is also a significant association between the severity of hyponatremia and the severity of MalariaMalaria (30). Similarly, hyponatremia was also found in a study reported by Jasmin H. et al. (31) and Asima Rani. et al. (32)

We found hypokalemia in cases of *P. falciparum* only. It was also associated with the severity of the *P. falciparum* infections. During an attack of *P. falciparum* malaria, the host cell loses a significant amount of potassium ions as *P. falciparum* resides within the cells, which may contribute to hypokalemia. (33)

Increased excretion of the potassium ion from the kidney and excess vomiting in *P. falciparum* malaria infection may also cause hypokalemia. Severe hypokalemia suggests the severity of *P. falciparum* malaria infection. (34) Similarly, hypokalemia was also found in a study reported by Yoel C. (35)

There was a significant decrease in plasma phosphorus levels among patients with severe MalariaMalaria compared with the control group (P Value = 0.021), due to increased uptake of phosphorus by infected red cells, increased renal excretion resulting from tubular dysfunction, redistribution of phosphate, and cellular shifts in severe malaria patients. Our study findings align

with those of Ayoola OO et al. (36) and Haber R et al. (37), who reported a decrease in plasma phosphorus and calcium levels in patients with malaria.

## **5. CONCLUSION**

Altogether, the study findings highlighted the link between plasma Creatinine, urea, uric acid, and Proteinuria, which are increased, and electrolytes, which are decreased, in severe malaria. These findings reinforce the importance of closely monitoring renal parameters and electrolyte levels in patients suffering from severe malaria, as they are essential for early detection and management of nephropathy.

**Limitation of the study:** it is a one center study

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