

Original Research Article

Changes in blood counts, serum lactate dehydrogenase activity and haptoglobin level in malaria infected subjects in Nnewi, Anambra state, Nigeria

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ABSTRACT

Background: Malaria is a mosquito-borne public health problem which alters the blood counts, haptoglobin level and serum lactate dehydrogenase (sLDH) activity of the infected individuals. Some of the alterations are associated risk factors in malaria pathology. This study aims at elucidating changes in blood counts, sLDH activity and haptoglobin level in malaria infected subjects seen in a Tertiary Health Institution in Nnewi, as search for associated risk factors in malaria pathology.

Methods: This cross sectional study enrolled 270 age matched subjects between 18-65 years. The test group (200) who tested positive to *P. falciparum* was placed into two groups based on their parasite counts with cut-off of ≥ 1000 parasites $\times 10^9/L$. Group one (100) had counts above the cut-off and group two (100) below. The control (70) was aparasitemic. The demographic data were noted and 4mls of blood drawn. 2mls in K3EDTA was for FBC testing using Mythic 22 hematology analyzer, and remaining dispensed into plain tubes was for sLDH assay by kinetic method and haptoglobin by ELISA technique.

Results: The HCT, Hb, RBC and Platelet count of test were progressively significantly lowered ($p=0.001$) compared to control, with an intra-significant difference among the 3 groups ($p<0.05$), also the parameters were found to have an inverse significant relationship ($p=0.001$) to the parasite counts. This trend was also seen with haptoglobin while reverse was the case with LDH activity which rather increased significantly ($p = 0.000$) at opposite direction as parasite density increases.

Conclusions: This study show that the degree of intravascular haemolysis is directly influenced by the parasite density, this portends that high endemicity and perennial parasitemia in the study area could cause chronic anaemia and thrombocytopenia in the population studied.

Keywords: Blood counts, Haptoglobin, Lactate dehydrogenase, Malaria parasitemia

INTRODUCTION

Malaria is highly endemic in Nigeria and it remains one of the leading causes of childhood and maternal morbidity and mortality in the country.¹ Changes in blood

counts in affected individuals have been documented and appear to be implicated in malaria pathology and morbidity.²⁻⁸ These changes affects all the major cell lines, although environmental factors such as nutrition, malaria immunity, parasite density, presence of

haemoglobinopathy and other factors tends to modulate the effect.^{9,10} Since liver, spleen and red blood cells are the main organs and cells involved in malaria pathology, it is worthwhile that study of some proteins and or enzymes associated with red cells such as Haptoglobins (Hp) and Lactate dehydrogenase (LDH) could be of help in understanding the mechanisms in malaria pathology.⁵ Hp is acute phase protein with protective role in hemolytic disease. It binds irreversibly to hemoglobin and reduces the oxidative and peroxidative potential of free haemoglobin.¹¹ Studies show that changes in Hp levels are consistent with clinical malaria.¹² LDH on the other hand is an intracellular hydrogen transfer enzyme, that catalyses the readily reversible reaction involving the oxidation of lactate to pyruvate with nicotinamide adenine dinucleotide (NAD) serving as coenzyme.¹³ High levels of LDH are found in the liver, heart, erythrocytes, skeletal muscles and kidneys. Increase in its activity has been widely applied as diagnostic indices for such organ dysfunction.^{14,15} LDH is the most abundant enzyme expressed by *P. falciparum* which it requires for its carbohydrate metabolism during the intraerythrocytic cycle.¹

Despite efforts by different agencies in malaria control, it has remained a great menace and a public health issue due to its increasing rate of morbidity and mortality in the affected individuals.

The aim of this work is to search for additional tools that may aid in identifying associated risk factors in malaria pathology in the study area by determining the levels of Hp, LDH and blood counts in infected individuals.

METHODS

This study was carried out in the General out Patient Department (GOPD) of Nnamdi Azikiwe University Teaching Hospital (NAUTH), Nnewi, Anambra State. NAUTH is a tertiary institution located at Nnewi North Local Government Area of Anambra State, South East Nigeria. It is located at 6.02° North latitude, 6.915° East longitude and 149 meters elevation above the sea level with a population of 769,500 (according to 2006 National Population census). Nnewi falls within the tropical rain forest of Nigeria, the rainy season stretches from March to October and dry season from November to February. The town has bi-peak malaria transmission in March and November corresponding the onset and cessation of rain.¹⁷ The temperature of the region is between 20°C and 36.5°C. The climatic weather, poor sanitary conditions and the rain forest vegetation, create a favourable breeding site for vectors.

Study population/Study protocol

The study subjects comprised of individuals who presented with history of fever, headache, and / or with axillary temperature of $\geq 37.50^{\circ}\text{C}$ in the last 24 hours and who hadn't taken any anti- malaria drug, and in whom

test for malaria parasite had been requested by the attending Clinician. These had drops of blood collected for RDT and thick PBF. The thick PBF stained with 10% Giemsa stain was considered negative if after examining 100 high power fields, no malaria parasite was encountered.¹⁸

The positives were enrolled into the study. A total of 200 subjects formed the test group. These were further subdivided into 2 groups based on the present cut-off parasite density of 1000 parasites $\times 10^9/\text{l}$. Thus group one comprised of 100 subjects with malaria parasite count ≥ 1000 parasites $\times 10^9/\text{l}$, and group two (100) with malaria parasite count < 1000 parasites $\times 10^9/\text{l}$. Controls were 70 apparently healthy individuals who were parasitological negative, selected from staff and students of the same hospital. All the subjects were within the ages of 18-65 years and demographic data collected through questionnaire. Ethical approval was sought and obtained from the institutional ethics committee and informed consent also obtained.

Sampling method

Sampling was in 2 stages. At the first stage, all the subjects with defining criteria were screened. Then, 4mls of blood sample was collected, 2mls into EDTA for FBC determination using Mythic 22Haematology Analyzer-a 5 part differential counter. The remaining 2mls was dispensed into plain tube and expressed serum used for LDH assay by kinetic method using Agappe Diagnostic Kit manufactured in Switzerland following the manufacturer's instruction. The remaining fraction was stored at -20°C for batch testing for Haptoglobin using Quantikine ELISA test kit manufactured in USA following manufacturer's instruction. Parasite screening by RDT was done using Carestart test kit and quantification was done according to method of Chessborough (2005).¹⁸

Statistical analysis

Data generated was analyzed using SPSS version 20. The descriptive results were expressed as mean \pm S.D. Inferential statistics was by Student t-tests for comparison of 2 means, ANOVA for more than 2 variables and Turkey Post Hoc tests for intra- mean comparison. Pearson's correlation was used to correlate the parameters. p-values of ≤ 0.05 were considered significant.

RESULTS

The mean value of Hp, HCT, RBC Hb and platelets presented in Table 1 showed a significant decrease between the two test groups and between the control ($p \leq 0.00$), while in the reverse direction, an increase was observed for LDH across the two and when compared with control ($p \leq 0.000$). The turkey post-hoc multiple comparative analyses showed a significant decrease

($p \leq 0.000$) in Hp between all the groups. Intra group difference was noted between group one and two ($p \leq 0.000$) and between one and control ($p \leq 0.000$) but no difference ($p \geq 0.005$) was seen between group two and control in HCT, Hb, and RBC values. However, a significant increase ($p \leq 0.000$) was observed for LDH across the groups. The mean value of TWBC,

Neutrophils and Lymphocytes, Eosinophil and Monocyte was significantly higher in group one compared to group two and control subjects ($p \leq 0.000$), a post-hoc test showed a significant increase between the three groups ($p \leq 0.000$) for TWBC, Neutrophils and Lymphocytes but none between Eosinophil and Monocyte ($p \geq 0.05$) as seen in Table 2.

Table 1: The mean age, HCT, Hb, RBC, red cell indices, LDH and Hp of test subjects and controls using ANOVA.

Parameters	Group one n=100	Group two n=100	Control n=70	F- value	p- value	Group one vs. two	Group one vs. control	Group two vs. control
Age (years) Mean±SD	38.06±11.71	38.64±12.08	38.20±12.12	0.063	0.939	1.000	1.000	1.000
Hct (%) Mean±SD	35.03±4.12	40.20±3.56	41.13±3.77	67.34	0.000*	0.000**	0.000*	0.363
Hb (g/dl) Mean±SD	11.85±1.30	13.54±1.18	13.82±1.23	67.62	0.000*	0.000**	0.000*	0.476
RBC ($\times 10^{12}$) Mean±SD	4.02 ±0.64	4.72±0.54	4.76±0.51	48.79	0.000*	0.000**	0.000*	1.000
MCV (fl) Mean±SD	87.78±7.86	86.07±6.93	87.17±5.54	1.54	0.216	0.251	1.000	0.929
MCH (pg) Mean±SD	29.61±2.84	28.89±2.32	29.20±1.89	2.22	0.111	0.110	0.827	1.000
Hp (ng/l) Mean±SD	19.89±3.77	22.06±5.88	25.45±5.24	25.28	0.000*	0.007**	0.000*	0.000*
LDH (U/l) Mean±SD	348.59±49.49	318.90±56.55	282.69±46.24	33.87	0.000*	0.000**	0.000*	0.000*

*values differ significantly from control ($p < 0.05$).

**values differ significantly between Group one and group two subjects ($p < 0.05$)

Table 2: The mean total and differential WBC and platelet count in subjects and control using ANOVA.

Groups	Group one n=100	Group two n=100	Control n=70	F-value	p- value	Group one vs. two	Group one vs. control	Group two vs. control
TWBC($\times 10^9/L$) Mean±SD	7.76±2.62	6.50±2.50	4.44±1.27	42.89	0.000*	0.000**	0.000*	0.000*
Neutrophil(%) Mean±SD	58.24±9.18	37.0±8.16	49.4±8.38	143.0	0.000*	0.000**	0.000*	0.000*
Lymphocyte (%) Mean±SD	33.54±8.61	53.18±9.15	43.94±7.93	129.10	0.000*	0.000**	0.000*	0.000*
Eosinophil (%) Mean±SD	3.46±3.28	3.80±2.64	2.30±1.30	4.56	0.012*	1.000	0.072	0.010*
Monocyte (%) Mean±SD	5.42±2.95	3.80±2.64	5.26±2.63	3.71	0.026*	0.074	1.000	0.057
Platelet($\times 10^9/l$) Mean±SD	140.0±28.77	201.42±41.08	264.36±49.20	206.44	0.000*	0.000**	0.000*	0.000*

*values differ significantly from control ($p < 0.05$).

**values differ significantly between Group one and group two subjects ($p < 0.05$)

Table 3 is Pearson's correlation of studied parameters in group one subjects with parasite count. A strong negative correlation exist between MP and Hp (-0.807), HCT (-

0.814), Hb (-0.821), RBC (-0.674), and PLT (-0.973) ($p \leq 0.000$ respectively) indicating an inverse relationship exist between them, were increasing count results in decrease in values of these parameters. In a similar

relation, a strong positive correlation was observed between parasite count and LDH (0.903) ($p \leq 0.000$). This implies that increase in parasite count increases the LDH activity in the subjects. Table 4 is the Pearson's

correlation of studied parameters and parasite count in group two. The same pattern of result as seen in group one also applied.

Table 3: Pearson's correlation of studied parameters in subjects with malaria parasite count ≥ 1000 parasites $\times 10^9/l$.

Parameters	N	R	p-value
Mp($\times 10^9/l$) vs. HCT (%)	100	-0.814	0.000*
Mp($\times 10^9/l$) vs. Hb (g/dl)	100	-0.821	0.000*
Mp($\times 10^9/l$) vs. RBC ($\times 10^{12}/l$)	100	-0.674	0.000*
Mp($\times 10^9/l$) vs. Platelets ($\times 10^9/l$)	100	-0.873	0.000*
Mp($\times 10^9/l$) vs. Hp (ng/ml)	100	-0.807	0.000*
Mp($\times 10^9/l$) vs. LDH (U/l)	100	0.903	0.000*

*Values differ significantly ($p < 0.05$); R= correlation coefficient

Table 4: Pearson's correlation of studied parameters in subjects with malaria parasite count < 1000 parasites $\times 10^9/l$.

Parameters	N	R	p-value
Mp ($\times 10^9/l$) vs. HCT%	100	-0.903	0.000*
Mp ($\times 10^9/l$) vs. Hb (g/dl)	100	-0.885	0.000*
Mp ($\times 10^9/l$) vs. RBC ($\times 10^{12}/l$)	100	-0.552	0.000*
Mp ($\times 10^9/l$) vs. TWBC ($\times 10^9/l$)	100	-0.954	0.000*
Mp ($\times 10^9/l$) vs. Platelets ($\times 10^9/l$)	100	-0.970	0.000*
Mp ($\times 10^9/l$) vs. Hp (ng/ml)	100	-0.964	0.000*
Mp ($\times 10^9/l$) vs. LDH (U/L)	100	0.980	0.000*

*Values differ significantly ($p < 0.05$); R= correlation coefficient

DISCUSSION

Haematological changes are common complications in malaria infected individuals. This study observed that subjects infected with *P. falciparum* had significantly lower HCT, Hb, and RBC compared with control subjects. This is consistent with several earlier reports, while the mechanism of anaemia can simply be said to be multifactorial, several possible mechanisms ranging from haemolysis of parasitized and non-parasitized erythrocytes, reduced erythropoiesis and dyserythropoiesis, phagocytosis of uninfected red blood cells to auto immune destruction of red blood cells are manifest.^{2,3,6,7} This study believes that one or more of these mechanisms may be the underlining pathological mechanism because the degree of red cell crash was disproportional to the parasite density implying that several may be involved in bringing about anaemia.

White blood cells play a vital role in the body's immune defense against diseases. The TWBC in this study was seen to be significantly higher in malaria infected subjects compared to control subjects. While there are conflicting results on TWBC count, our result tends to be in consonant with works done in geographical area

sharing similarity with ours, namely the work of Ifeanyichukwu and Esan in Nnewi Anambra State Kotepui et al, Garba and coworkers in Sokoto and Auta et al, Dustin- Ma North West Nigeria but differs with those outside of our environmental similarity, the works of McKenzie et al, Chandra and Chandra in Uttarakhand State India and Al-Salahy et al, in North West Yemen.^{2,5,6,19-22} This therefore strengthens the belief that environmental factors have strong effect on blood counts.¹⁰ One could explain the raise in TWBC as suggested by Eharhor et al, to be due to increase in release from marginal pool into the peripheral blood in inflammatory response or due to exaggerated immune response during infestation as proposed by Chandra and Chandra.^{2,3}

Significantly lower platelet count in test subjects compared to control subjects was also noted and in addition, the platelet count had an inverse relationship to the parasite count; the higher the parasite count, the lower the platelet count. This finding is consistent with independent reports, notably that of Guptal and coworkers Joera and colleagues and Kotepui at all who also in addition observed thrombocytopenia in malaria. The studies of Dash and Padhy, Joshi and Gamit, and

that of Hamid and coworkers collaborated thrombocytopenia as a feature in malaria.²³⁻²⁸ Although these authors proposed varied mechanisms to explain the low counts seen in *P. falciparum* infestation, while Gupta and coworkers Joera and colleagues suggested oxidative stress damage as the mechanism involved, Joshi and Gamit reported the mechanism to be immune mediated, and Metanat and harifi-Mood posited that splenic sequestration was responsible.^{23,24,27,29} de Mast in their work proposed glycoprotein 1b (GP1b) shedding especially in early infection and when systemic platelet activation and consumptive coagulopathy could not be established as the mechanism involved.³⁰

The serum Haptoglobin (Hp) on the other hand was significantly lower in test group compared to control group. Several works collaborates this finding notably that of Fowkes et al, Imrie et al and Alfred and Gwakisa, also a clear inverse relationship between serum haptoglobin level and malaria density was noted, as the parasite density increases, the serum haptoglobin level drops. It is important to recall that Hp functions to mop up free haemoglobin.³¹⁻³³ So invariably in malaria parasitemia where increased haemolysis is a feature, Hp level is significantly reduced.^{11,12} The serum lactate Dehydrogenase (LDH) in another development was significantly higher in test subjects compared to control subjects, and the parasite count in addition has a direct relationship with LDH. Dabadghao and colleagues, in their work collaborate this present report and in addition affirms that sLDH correlates with disease severity, while Kumar and Keerthana, in addition to reporting a relation between the two also posited it as a diagnostic biomarker of malaria. Mtove et al, and Kumar similarly hold that sLDH could serve as point of care in acute febrile illness in differentiating malaria from other febrile illness.³⁴⁻³⁷

CONCLUSION

The present study demonstrated that significant haematological alteration occurs in malaria across all cell lines and the degree of intravascular haemolysis (evidenced by increase in Hp level and LDH activity) is directly influenced by the parasite density. This portends that high endemicity and perennial parasitemia in the study area could cause chronic anaemia and thrombocytopenia in the population studied.

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REFERENCES

1. World Health Organization. world malaria report, 20 avenue Appia CH-1211 Geneva27 Available at: www.who.int/malariahttp://www.who.int/malaria/publications/world_malaria_report_2008/en/index.html, 2008, Accessed 1st November 2016.
2. Chandra S, Chandra H. Role of haematological parameters as an indicator of acute malarial infection in Uttarakhand state of India. Mediterranean J Hematol and Infe Dis. 2013;5(1)9-16.
3. Erhabor O, Mohammad HJ, Onuigwe FU, Abdulrahman Y, Ezimah AC. Anaemia and Thrombocytopenia among Malaria Parasitized Children in Sokoto, North Western Nigeria. J Hematol and Transfusion. 2014;2(2):1020.
4. Garba N, Danladi SB, Muhammad A. Determination of some haematological parameters in malaria infected subjects in Usmanu Danfodiyo University Teaching Hospital (UDUTH) Sokoto, Nigeria. Bayero J Pure Applied Sci. 2015;8(1):80-3.
5. Al-Salahy M, Shnawa B, Abed G, Mandour A, Al-Ezzi A. Parasitaemia and Its Relation to Hematological Parameters and Liver Function among Patients Malaria in Abs, Hajjah, Northwest Yemen. Interdisciplinary Perspectives on Inf Dis. 2016:1-5.
6. Auta T, Runka JY, Bawa JA, Sa'adatu SK. Haemoprevalence of malaria and haematological parameters of febrile patients in a hospital in Dutsin-Ma town, North Western Nigeria. Biosciences Research in Today's World. 2016:2:8-14.
7. Ani OC, Ani EG, Ogamdi SO, Okafor FC. Haematological indices of malaria infected residents of Isu community, Onicha local government area, Ebonyi state, Nigeria. Animal Res Interna. 2016;13(1):2321-7.
8. Ali HA, Abdulla MU, Nadeem JY, Ahmed SA, Dujana AH, Ahmed AS. Malaria and Hematological changes. Pakistan J Med Sci. 2008;24(2):287-91.
9. Maina RN, Walsh D, Gaddy C, Hongo G, Waitumb J, Otieno L, et al. Impact of Plasmodium falciparum infection on haematological parameters in children living in Western Kenya malaria J. 2008;9(3):1-11.
10. Erhart LM, Yingyuen K, Chuanak N, Buathong N, Laoboonchai A, Miller RS, Meshnick SR, Gasser Jr RA, Wongsrichanalai C. Hematologic and clinical indices of malaria in a semi-immune population of western Thailand. Am J Tropical Med Hygiene. 2004 Jan 1;70(1):8-14.
11. Lim SK, Ferraro B, Moore K, Halliwell B. Role of haptoglobin in free hemoglobin metabolism. Redox Report. 2001 Aug 1;6(4):219-27.
12. Schaer DJ, Buehler PW, Alayash AI, Belcher JD, Vercellotti GM. Hemolysis and free hemoglobin revisited: exploring hemoglobin and heme scavengers as a novel class of therapeutic proteins.

- Blood, *J Am Society of Hematol.* 2013 Feb 21;121(8):1276-84.
13. Burtis CA, Ashwood ER, Bruns DE. *Tietz fundamentals of clinical chemistry.* Saunders, an imprint of Elsevier Inc, Philadelphia. 2008;321-322.
 14. Huijgen HJ, Sanders GT, Koster RW, Vreeken J, Bossuyt PM. The Clinical Value of Lactate Dehydrogenase in Serum: A Quantitative Review. *European J Clin Chemistry Clin Biochem.* 1997 Aug 1;35(8):569-80.
 15. Burns ER, Kale A, Murthy VV. Diagnosis of the hemolytic state using serum levels of erythrocyte adenylate kinase. *Am J Hematol.* 2000 Jul;64(3):180-3.
 16. Vander JD, Hunsaker LA, Campos NM, Baack BR. D-lactate production in erythrocytes infected with *Plasmodium falciparum*. *Molecular and Biochemical Parasitol.* 1990;42:277-84.
 17. Okocha EC, Ibeh CC, Ele PU, Ibeh NC. The Prevalence of Malaria Parasitaemia in Blood Donors in Nigeria Teaching Hospital. *J Vect Borne Dis.* 2005;42(1):21-6.
 18. Monica C. Examination of Blood for Malaria Parasite. In: *District Laboratory Practice in Tropical Countries Part1* Cambridge University Press 2nd ed; 2009:201-258.
 19. McKenzie FE, Prudhomme WA, Magill AJ, Forney JR, Permpnich B, Lucas C, Gasser RA. Jr., Wongsrichanal C. White Blood Cell Counts and Malaria. *J Inf Dis.* 2005;192(2):323-30.
 20. Ifeanyichukwu MO, Esan AJ. Evaluation of Blood Cells and Platelets in *Plasmodium Falciparum* Malaria Infected Individuals. *Inter J Hematol Dis.* 2014;1(1):49-54.
 21. Kotepui M, Piwkham D, PhunPhuech B, Phiwklam N, Chupeerach C, Duangmano S. Effects of malaria parasite density on blood cell parameters. *PLoS One.* 2015;10(3).
 22. Garba N, Danladi SB, Muhammad A. Determination of some haematological parameters in malaria infected subjects in Usmanu Danfodiyo University Teaching Hospital (Uduth) Sokoto, Nigeria. *Bayero J Pure Applied Scien.* 2015;8(1):80-3.
 23. Gupta NK, Bansal SB, Jain UC, Sahare K. Study of thrombocytopenia in patients of malaria. *Tropical Parasitol.* 2013 Jan;3(1):58.
 24. Jojera AS, Hathila RN, Patel PR, Tailor HJ. Changes in WBC and platelet count in patients with malaria: a hospital based comparative study. *Int J Res Med Sci.* 2013 Oct;1(4):401-3.
 25. Kotepui M, Phunphuech B, Phiwklam N, Chupeerach C, Duangmano S. Effect of malarial infection on haematological parameters in population near Thailand-Myanmar border. *Malaria J.* 2014 Dec 1;13(1):218.
 26. Dash HS, Padhy S. Study of Clinical and Laboratory Profile in Malaria. *Indian J Applied Res.* 2015;5(12):218-22.
 27. Joshi G, Gamit D. Platelet profile and its correlation to paediatric patients with acute malaria in a tertiary care hospital. *Sri Lanka J Child Health.* 2016;45(2):107-10.
 28. Hamid TA, Eldin FA, Elnasri HA. Effect of Malaria Parasite Infection on Platelet Parameters (Platelets count, mean platelets volume and platelets distribution width) among Malaria Patients in Khartoum State. *Annals of Bio Res.* 2016;7(5):18-23.
 29. Metanat M, Sharifi-Mood B. Malaria vivax and severe thrombocytopenia in Iran. *Iranian J Parasitol.* 2010:69-70.
 30. De Mast Q, De Groot PG, Van Heerde WL, Roestenberg M, Van Velzen JF, et al. Thrombocytopenia in early malaria is associated with GP1b shedding in absence of systemic platelet activation and consumptive coagulopathy. *British J Haematol.* 2010 Dec;151(5):495-503.
 31. Fowkes FJ, Imrie H, Migot-Nabias F, Michon P, Justice A, Deloron P, Luty AJ, Day KP. Association of haptoglobin levels with age, parasite density, and haptoglobin genotype in a malaria-endemic area of Gabon. *Am J Tropical Med Hygiene.* 2006 Jan 1;74(1):26-30.
 32. Imrie H, Fowkes FJ, Michon P, Tavul L, Hume JC, Piper KP, et al. Haptoglobin levels are associated with haptoglobin genotype and α^+ -thalassemia in a malaria-endemic area. *The American journal of tropical medicine and hygiene.* 2006 Jun 1;74(6):965-71.
 33. Alfred B, Gwakisa P. Haptoglobin gene polymorphism influences the effect of malaria infection on host haptoglobin plasma level but not susceptibility to the disease. *African J Biotechnol.* 2013;12(10):1115-20.
 34. Dabadghao V, Singh VB, Sharma D, Meena BL. Serum lactate levels in malaria and its correlation with disease severity. *Intern J Adv Med Health Res.* 2015;2:28-32.
 35. Kumar TA, Keerthana BL. Serum enzyme levels as biomarkers in malaria. *Scholars J Applied Medical Sciences.* 2016;4:89-92.
 36. Mtove G, Nadjm B, Hendriksen IC, Amos B, Muro F, Todd J, et al. Point-of-care measurement of blood lactate in children admitted with febrile illness to an African District Hospital. *Clin Infect Diseases.* 2011 Sep 15;53(6):548-54.
 37. Kumar IH, Kirti S, Kumar PH, Vipul S, Kumudini B. Serum total LDH activity a useful tool in aiding differential diagnosis of malaria. *J Advance Res Biol Sci.* 2013;5(1):25-7.

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