Introduction

Malaria is the most important parasitic disease that affects human today. Malaria is caused by protozoan parasites of the genus *Plasmodium*, and the disease is characterized by fever, chills, headache, nausea and vomiting. Human can be infected with the five species of malaria parasites, namely [1] *Plasmodium vivax*, *Plasmodium ovale*, *Plasmodium malariae*, *Plasmodium falciparum* and lastly *Plasmodium knowlesi*, which was initially reported to infect primates until it was recently found in humans [1]. However, mosquitoes–human transmission of *Plasmodium knowlesi* has not been reported [1].

The spread of human immunodeficiency virus (HIV) is high within sub-Sahara Africa. HIV infection shows insidious processes that can take years to deplete immunological crucial white blood cells [2,3]. HIV infection is known to affect virtually all the organs in the body, causing different metabolic dysfunctions in addition to the compromise of the immune system [4,5].

ABSTRACT

This study determined the effects of malaria parasite and HIV infection on malondialdehyde (MDA), serum iron (Fe) and some enzymes activities of pregnant women in Abeokuta, Ogun State. A total of 251 pregnant women were enrolled for the study. Blood samples were collected from each consented pregnant women during ante-natal clinic for malaria test, HIV screening, MDA, Fe, glutathione-S-transferases (GST), superoxide-dismutase (SOD) and peroxidase (PERO). The prevalence of malaria parasite infection and HIV in the study was 28.3% and 16.4%, respectively, while co-infection occurred in 8% of the population. Malaria prevalence increased with decrease in CD4 count. Though, HIV and malaria as single infection increased MDA and reduced serum iron values in the pregnant women (p < 0.05), MDA values were significantly higher (p < 0.05) in pregnant women with HIV and malaria co-infection. Reduction in SOD value was recorded in those with malaria and HIV co-infection but increased in other groups (p < 0.05). Serum PERO titer value in pregnant women with HIV and malaria co-infection was significantly lower (p < 0.05) compared with pregnant women infected with either HIV or Malaria. These results showed varying degrees of HIV and malaria-related oxidative stress in pregnant women.
The high prevalence of HIV and malaria in sub-Saharan Africa makes co-infections to be common in this region, and this has important implications since both HIV and malaria are among the leading causes of morbidity in pregnancy in Africa. Co-infection of HIV with malaria can amount to a substantial negative impact on the health of pregnant women and their developing fetus [6,7]. HIV and malaria in pregnancy have been incriminated in increase in peripheral and placenta parasitemia, parasite densities, severe clinical malaria, anemia and risks of adverse birth outcome [6–8]. HIV in multigravid women appeared to impair a pregnant women’s ability to control malaria parasitemia, resulting in more frequent and high-density parasitemia than in HIV-uninfected pregnant women [6,8].

The blood is an important tissue in man; biochemical parameters are useful in making diagnosis of diseases and also help in the antenatal assessment of women in pregnancy [9]. Hemoglobin degradation by malaria parasite produces the redox active by-products, free heme and $\text{H}_2\text{O}_2$, conferring oxidative stress and damages on the host cell [10]. Apart from hemoglobin degradation, malaria parasitization has been reported to increase oxidative stress through the release of reactive oxygen species (ROS) in patients [11]. In the presence of active malaria parasite infection, phagocytic cells such as polymorphonuclear leukocytes and macrophages usually engage in a respiratory burst as a host cell-mediated immune response. This consequently promotes free radical productions that react to yield ROS. The increase in lipid peroxidation (oxidative stress) level in malaria patients and a decrease in ascorbic acid and GSH (antioxidants) have been observed to be accountable for the development of oxidative stress in malaria patients [12]. Hence, malaria parasite virulence seems to depend largely on the patients’ antioxidant capacities, which in turn is determined by the concentrations of antioxidant micronutrients [13].

Naturally, the body produces several antioxidants such as peroxidase (PERO), glutathione-S-transferases (GST), reduced glutathione (GSH), catalase (CAT), superoxide dismutase (SOD) etc., in neutralizing the effects of oxidative damages caused by the malaria parasites. However, several host factors can influence the supply of these antioxidants.

Antioxidants are molecules that can easily react with free radicals to terminate the chain reaction before vital molecules are destroyed. Excess free radicals and low antioxidant give rise to a phenomenon known as oxidative stress; this is a harmful process that can negatively affect several cellular structures such as membrane lipids, proteins, lipoproteins and deoxyribonucleic acid. Antioxidants such as GSH, GPx, GST, SOD and catalase are known to play a major role in keeping the level of ROS in check during malaria infection.

Just like malaria parasites, HIV is also capable of causing oxidative stress due to an increase in plasma metabolites of lipid peroxidation [10]. This makes both HIV and malaria co-infection pose serious negative consequences on the oxidative–antioxidant balance in infected host. The resultant of co-infection is presumed to be severe and to cause high mortality among pregnant women [8]. This is due to the fact that antioxidant activities are very low during pregnancy in order to protect and nourish the developing baby. This condition naturally puts pregnant women in a state of oxidative stress [7]. The implication of this phenomenon is that any infection in pregnancy may exert more oxidative stress to the already existing ones since the current antioxidants levels might not be enough to detoxify the pregnant woman from infection-related oxidative stress metabolites. However, studies documenting the effect of combination of factors (HIV infection, malaria and pregnancy) on oxidative stress and antioxidant profiles of pregnant women are lacking. It is against this background that the present study was undertaken to investigate the impact
of HIV and malaria co-infection on lipid peroxidation and antioxidant responses among pregnant women in Abeokuta Ogun State.

Methods

Description of the study location

The study was carried out in Federal Medical Center, Idi Aba Abeokuta (7°14′399″N, 3°38′045″E) and Ogun State General Hospital Abeokuta (7°10′20.8″N, 3°2′29.6″E).

Ethical approval

Ethical clearance were obtained from both hospitals before the study commencement. Purpose of the study was explained to the pregnant women prior to enrollment; as many as consented to be part of the study was enrolled after signing the consent form.

Criteria for selection and study population

Pregnant women at the Obstetrics Departments of Federal Medical Center, Abeokuta, and Ogun State General Hospital, Abeokuta, Nigeria, participated in the study. A total of 251 pregnant women were randomly selected from the two hospitals. The sample population was selected irrespective of age, educational background, marital status and occupation. Patients with more serious health issues such as diabetes and kidney problem were not selected for this study. Also, patients currently treating malaria or in the last 3 weeks, as well as those with hematological disorders were excluded (all participants were newly diagnosed for malaria).

The formula used in calculating the sample size in this study (presented below) is a simplified formula for measuring a proportion within a specified margin of error sample according to [14];

\[ n = \frac{N}{1 + Ne^2} \]

Where;
- \( n \) = the required sample size
- \( N \) = total number of pregnant women on register for 3 months (674)
- \( e \) = 5% margin of error

Applying the above formula, the sample size was determined as presented below;

\[ n = \frac{674}{1 + 674(0.05^2)} \]

Therefore, \( n = 251 \).

Thus, a total of 251 patients were randomly chosen irrespective of age, social class, marital status and cultural or religious affiliations.

Collection of blood samples and questionnaire administration

Finger-pricked blood samples were collected for parasitemia determination, while venous blood samples were collected into labeled plain bottles for evaluation of oxidative stress and antioxidant levels as described by [15]. Relevant clinical characteristics, age, gravidity, HIV status and CD4 count were recorded with the aid of a questionnaire.

Laboratory procedures

Malaria parasite, HIV and CD 4 count test

Malaria parasite test was examined by using Quantitative Buffy Coat (QBC) method following the procedure of Pinto et al. [16]. CD4 count was estimated by BD FACS Count machine. HIV status was determined by the use of HIV rapid test kit: HIV 1/2 START-PAK(R) DIPSTICK Assay and HIV –1/2 DETERMINE(R) Kit. The sample that was positive with HIV 1/2 START-PAK was re-run with HIV 1/2 Determine kit following the manufacturer procedure. The CD4 absolute counts was reported as the CD4+ CD3+ lymphocyte counts.

Assay of oxidative stress biomarker

Lipid peroxidation was estimated colorimetrically by thiobarbituric acid reactive substance (T BARS) method of [17]. Serum iron was determined
colorimetrically following manufacturer instruction as described by the manufacturer of the kit (Chromatest, Barcelona, Spain) following the methods of [18]. The test works on the principle that transferrin-bound iron is released at an acid PH and reduced from ferric to ferrous ions. These ions react with ferrozine to form a violet-colored complex, which is measured spectrophotometrically at 560 nm. The absorbance measured at this wavelength is proportional to serum iron concentration. The assay of SOD (ECI 15.1.1) was carried out according to the procedure describe by Winterbrom et al. [19]. The activity of peroxidase was determined as reported by Walsh and Wang [20]. The activity of glutathione-s-transferase was determined according to the procedure described by Habig et al. [21]. Detailed procedures for the determination of oxidative stress biomarker has been described elsewhere in our previous study [22].

Statistical analysis

Differences in prevalence with respect to CD4 count were tested using chi-square tests. Differences in MDA and antioxidants levels between groups of pregnant women were tested using the one way analysis of variance (ANOVA) and the control (those who tested negative to both malaria and HIV). Values were presented as mean ± standard error of the mean. Relationships between iron and antioxidant levels were tested using linear regression. A probability value of P < 0.05 was regarded as statistically significant, using SPSS version 20.0. Venn diagram was also used to present part of the result.

Results

Characteristics of the pregnant women

The demographic characteristics of the pregnant women are described in Table 1. A very high proportion of the pregnant women 235 (93.6%) were within the age brackets of 31–40 years, while virtually all of the pregnant women 248 (98.8%) were in their second trimester. Furthermore, a very high proportion 237 (94.4%) of the respondents were primigravid, while none of the pregnant women recruited in this study were on iron supplementation. Majority of the respondents 211 (84.1%) were married at the time of the study (Table 1).

Malaria and HIV infection profile of the pregnant women

The malaria and HIV infection profile of the pregnant women are presented in Figure 1. A total of 251 pregnant women participated in this study. Ninety-two (92) of the pregnant women were positive for either malaria, HIV or both. Generally, malaria and HIV prevalence of 28.3% (71 of 251) and 16.4% (41 of 251) were recorded, respectively, among the pregnant women who participated in this study. While malaria and HIV co-infection occurred in 20 (8.0%) of the pregnant women, 51 (20.3%) and 21 (8.4%) were positive for malaria and HIV, respectively, as a single infection (Figure 1).

| Variable                        | Frequency N = 251 | Percentage (%) |
|---------------------------------|-------------------|----------------|
| **Age**                         |                   |                |
| 21–30                           | 15                | 6.0            |
| 31–40                           | 235               | 93.6           |
| Above 40                        | 1                 | 0.4            |
| **Trimester**                   |                   |                |
| First                           | 3                 | 1.2            |
| Second                          | 248               | 98.8           |
| Third                           | 0                 | 0.0            |
| **Gravidity**                   |                   |                |
| Prim   | 237              | 94.4           |
| Secund | 11               | 4.4            |
| Multi                          | 3                 | 1.2            |
| **On iron supplementation**     |                   |                |
| Yes                             | 0                 | 0.0            |
| No                              | 251               | 100.0          |
| **Marital status**              |                   |                |
| Single                          | 36                | 14.3           |
| Married                         | 211               | 84.1           |
| Divorced                        | 4                 | 1.6            |
**Figure 1.** Malaria and HIV infection profile of the pregnant women.

**Figure 2.** Prevalence of malaria by CD4 count among the HIV positive pregnant women.
Prevalence of malaria with respect to CD4 count

Malaria prevalence increased with decrease in CD4 count. The prevalence of malaria was higher among pregnant women with CD4 counts below 200 cells/µl (AIDS group) (68.4%) compared to other groups with higher CD4 counts (Figure 2).

Impact of malaria and HIV on malondialdehyde (MDA) and iron (Fe) concentration among the pregnant women

Generally, HIV infection was significantly associated with higher MDA values in this study. Furthermore, MDA mean value was higher among the pregnant women with HIV and malaria co-infections (5.919 x 10^{-8}) compared to pregnant women with HIV alone (4.484 x 10^{-8}). An elevation of mean MDA values was also recorded in pregnant women infected with only malaria when compared with the control (Table 2).

Generally, a reduction in mean Fe concentrations was recorded in HIV-infected pregnant women compared with those who had only malaria infection and the control. The least mean Fe concentration was recorded among pregnant women with HIV and malaria co-infection. Malaria infection also resulted in reduction of mean Fe concentration among the pregnant women but not as severe as those with HIV infection (Table 2).

Antioxidant level among the malaria and HIV-infected pregnant women

Serum superoxide dismutase (SOD) titer values (67.7) in pregnant women with only HIV infection was significantly higher (P < 0.05) compared to all other categories. This was followed by those with only malaria infection, while SOD values were lower in pregnant women with both HIV and malaria (co-infection) compared with the control (Table 2).

On the other hand, there was no significant difference (P > 0.05) in GSH titer values across the different categories of pregnant women. However, GSH values were slightly elevated in pregnant women with HIV as a single infection. Furthermore, GSH value was slightly down-regulated in pregnant women with malaria and HIV co-infection (Table 2).

Serum PERO titer value in pregnant women with HIV and malaria co-infection was significantly lower compared to all other groups. On the other hand, serum PERO was elevated in pregnant women with either HIV or malaria as a single infection when compared with the control group.

Relationship between the level of iron and concentration of oxidative enzymes

A very strong, inverse and significant relationship (r = −0.891, P< 0.05) existed between serum iron concentration and MDA in this study. On the other hand, serum iron concentration showed no significant relationship (r = values <

Table 2. Mean distribution of MDA, Fe and some antioxidants among the selected pregnant women.

| Variables | Different categories of pregnant women based on infection status |
|-----------|-------------------------------------------------------------|
|           | HIV and malaria | HIV alone | Malaria alone | control |
| MDA (mg/ml) | 5.919 x 10^{-8a} | 4.484 x 10^{-8a} | 2.586 x 10^{-8b} | 1.136 x 10^{-8b} |
| Fe (mg/ml) | 16.6 c | 19.8 c | 29.8 c | 67.1 c |
| SOD       | 25.5 a | 67.7 a | 48.8 b | 35.5 c |
| GSH       | 4.23 a | 6.94 a | 5.76 a | 5.56 a |
| PERO      | 1.08 a | 4.94 a | 2.52 b | 1.92 c |

Key: abc Mean values in row with different super script are significantly different from each other (P< 0.05).
MDA- Malondialdehyde, Fe- Iron, SOD- Superoxide dismutase, PERO- Peroxidase, GSH- Reduced glutathione.
Table 3. Relationship between the level of iron and concentration of oxidative enzymes.

|        | MDA | Fe (mg/ml) | SOD | GSH | PERO |
|--------|-----|------------|-----|-----|------|
| MDA    | 1   |            |     |     |      |
| Fe (mg/ml) | −0.891* | 1          |     |     |      |
| SOD    | −0.050 | −0.248 1   |     |     |      |
| GSH    | −0.293 | 0.037 0.957* | 1   |     |      |
| PERO   | 0.0291 | −0.250 0.980* | 0.947* | 1   |

Values with asterisk connotes significance at 95% confidence interval (P< 0.05).

0.300, P> 0.05) with SOD, GSH and PERO. However, a significant, direct and very strong relationship (r values >0.8, P < 0.05) existed between the three antioxidants (GSH, SOD and PERO) (Table 3).

Discussion

Pregnant women and infant protection is a priority in the health field because these population groups are the most exposed to sickness and death [23]. Both HIV and malaria are known to cause maternal anemia and increase in lipid peroxidation, as well as increase in oxidative stress [24–26].

The overall prevalence of malaria and HIV among the pregnant women in this study was 28.3% and 16.4%, respectively. The malaria prevalence observed in this study is lower than the ones reported in previous studies (>50%) from the same area [27,28]. One major factor that may be responsible for these discrepancies is the timing of investigations. The studies that reported higher prevalence were from pregnant women who were attending antenatal care for the first time unlike this current study, which involved those who were already receiving adequate antenatal care for some time. This further buttress the effectiveness of focus antenatal care in the reduction of pregnancy-associated malaria in the study area.

Prevalence of malaria increased with decrease in CD4 count and occurred more among those who has progressed to AIDS. It has been established that decline in CD4+ T cell number to a level of 200 cells per μl (AIDS) will lead to loss of cell-mediated immunity. Hence, variety of opportunistic infections including malaria will easily set in [29].

Lipid peroxidation is the main manifestation of oxidative stress. MDA is the by-product of non-enzymatic degradation of polyunsaturated fatty acids, and it is mostly found in cell membrane [30]. Naturally, pregnant women are always in a state of oxidative stress due to high demand and elevated requirements for tissue oxygen [31]. Malaria-related oxidative stress and antioxidant responses is highly dependent on peripheral blood parasite density [22], which may be unavailable in the maternal peripheral blood due to ability of malaria parasite to sequester in the placenta [7], hence explaining why SOD, PERO and GSH were higher in pregnant women infected with only malaria. Nonetheless, HIV and malaria co-infection in pregnancy significantly increased the level of oxidative stress in the pregnant women compared with all other groups. Studies have indicated that a special kind of mutual relationship exists between mMalaria and HIV, in which both helps in proliferation of one another hereby increasing both viral load and parasite density [32–34]. To further explain this, malaria parasites have been reported to stimulate increased expression of CC chemokine receptor 5 on dendritic cells in interstitial tissues. This receptor mediates the attachment of HIV virions to macrophages, facilitating infection and virus multiplication [35]. On the other hand, HIV has been reported to increase malaria parasites density in pregnant women by inducing the down-regulation of some cytokines of the cellular immune response, such as IL-12 and IFN-Ƴ, and causes destruction of memory T cells, leading to reduced ability to clear the parasite [35]. One of the resultant effects of this relationship is the abnormal increase in generation of ROS, leading to oxidative stress. This is possible due to the fact that both HIV and malaria are capable of generating ROS independently in infected person...
This was evident in the fact that MDA values were higher in HIV-infected pregnant women compared with those having malaria alone in this study.

The high lipid peroxidation observed among the HIV-infected persons could be traced to the abnormalities in lipid metabolism potentially induced by both the virus itself and medication used for the treatment, thereby resulting in high level of oxidative stress [36]. This involved series of reactions; first, HIV infection affects the way the body deals with lipids. The disease caused a rise in total cholesterol, triglycerides, low density lipoprotein (LDL) and a decrease in the level of high density lipoprotein (HDL) [37]. This action resulted in lipid peroxidation, which is linked with free radicals produced during peroxide formation from fatty acid containing methylene interrupted double bonds. Apart from this, several HIV proteins have been proven to enhance ROS production by different mechanisms. These viral proteins include among others the envelope protein Gp120, Tat, Nef, Vpr and RT. The envelope protein Gp120 enhances ROS production via upregulation of cytochrome P450 2E1 (CYP2E1), proline oxidase (POX) and activation of NOX2 and NOX4 [10].

Increase in lipid peroxidation has been associated with various tissue damages in pregnant women. Pregnancy-associated malaria-induced lipid peroxidation has also been incriminated in human placental damages [30]. Hence, careful consideration should be given toward HIV-infected pregnant women in accessing and utilizing malaria prevention tools.

Iron is required by the enzymes involved in antioxidant activities [38]. Iron augmentation in pregnant women has been associated with decrease in serum MDA [39]. As a result, the significant reduction of iron among pregnant women with HIV and malaria co-infection is not unexpected. This is an implication that the iron store in the body is being used up to fight against the generated ROS. This was also emphasized in the very strong, inverse and significant relationship ($r = -0.891$) that existed between MDA and Fe concentrations.

The same antioxidant response with respect to SOD was observed among the pregnant women. A significant reduction of SOD values among pregnant women with HIV and malaria co-infection was observed. Studies have indicated that antioxidants such as SOD also play crucial role in detoxifying the system from lipid peroxidation. However, SOD was not significantly correlated with MDA in this study.

While GSH values in infected pregnant women were not significantly different from that of control, serum PERO titer value in pregnant women with HIV and malaria co-infection was significantly lower compared to all other groups. Serum PERO was also elevated in pregnant women with either HIV or malaria as a single infection when compared with the control groups. This implies that HIV and malaria co-infection may trigger the response of peroxidase alongside with iron and SOD to combat the generated oxidative stress.

**Conclusion**

This results showed that parameters such as MDA and Fe could be an excellent indicator for HIV- and malaria-related oxidative stress in pregnant women. HIV-infected pregnant women should also strive to take substances that will boost their antioxidant capacity to prevent oxidative stress-related damages.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Ayodele S. Babalola http://orcid.org/0000-0003-0540-5675

References

[1] WHO. International travel and health; 2020 [cited 2020 Aug 22]. Available from: https://www.who.int/ith/diseases/malaria/en

[2] Onyenek Ej, Ofoha PC, Anyanwu GO, et al. Evaluation of nitric oxide and antioxidant status of plasmodium falciparum infected pregnant Nigerian women with Malaria. Int Digital Organ Sci Res. 2018;3(3):56–68

[3] Luo L, Wang N, Yue Y, et al. The effects of antiretroviral therapy on HIV reservoir size in Chinese chronically HIV infected patients: a prospective, multi-site cohort study. BMC Infect Dis. 2019;19(1):257.

[4] Shenghan L. HIV and coronary atherosclerosis: research separates association from causATION. Radiology. 2021;299(3):581–582.

[5] WHO. HIV/AIDS. Global health sector strategy on HIV, 2016-2021; 2020b [cited 2020 Aug 22]. Available from: https://www.who.int/news-room/fact-sheets/detail/hiv-aids

[6] Mbabu II, Eijkunle SD, Anolle F, et al. Relationship between placenta malaria and mother to child transmission of HIV infection in pregnant women in South East Nigeria. Malar J. 2020;19(1):97.

[7] Babalola AS, Idowu OA, Sam-Wobo SO, et al. Malaria infection at parturition in Aboeckota, Nigeria: current status and Pregnancy outcome. Malar World J. 2017;8. 12.

[8] Ssentongo P, Ba DM, Ssentongo AE, et al. Associations of malaria, HIV, and co-infection, with anemia in pregnancy in sub-Saharan Africa: a population-based cross-sectional study. BMC Pregnancy Childbirth. 2020;20(1):379.

[9] Abele A, Abebe M, Biadgo B, et al. Biochemical profiles of pregnant and non-pregnant women attending at the University of Gondar Hospital, Northwest Ethiopia: a comparative cross-sectional study. Ethiop J Health Sci. 2018;28(3):447–456.

[10] Ivanov AV, Valuev-Elliston VT, Ivanova ON, et al. Oxidative stress during HIV infection: mechanisms and consequences. Oxid Med Cell Longev. 2016;Article ID 8910396 | . DOI:10.1155/2016/8910396.

[11] Eze MO, Hunting DJ, Organ AU. Reactive oxygen production against malaria – a potential cancer risk factor. Med Hypothesis. 1990;32(2):121–123

[12] Atiku SM, Louise N, Kasozi DM. Severe oxidative stress in sickle cell disease patients with uncomplicated Plasmodium falciparum malaria in Kampala, Uganda. BMC Infect Dis. 2019;19(1):600.

[13] Ogbodo SO, Okaka ANC, Nwagha UI. Oxidative stress in symptomatic malaria parasitemic pregnant women from malaria endemic area of Nigeria. Am J Med Med Sci. 2014;4(5):168–174.

[14] Yamane T. Statistics, an introductory analysis. 2nd ed. New York: Harper and Row; 1967.

[15] Cheesbrough M. Medical laboratory manual for tropical countries. 3rd ed. Borough Green London: Butterworths and Co (Publishers) Limited; 2006. p. 35–42.

[16] Pinto ET, Hubner CA, Stremmel W, et al. Diagnosis of malaria parasite, resistance and susceptibility. Clin Infect Dis. 2001;40:694–698.

[17] Kharb S, Gulati N, Singh V, et al. Lipid peroxidation and vitamin E Levels in preeclampsia. Gynecol Obstet Invest. 1998;46(4):238–240.

[18] Jeremiah ZA, Uko EK, Buseri FI, et al. Baseline iron status of apparently healthy children in port Harcourt Nigeria. Eur J Gen Med. 2009;6(1):38–41.

[19] Winterborn AJ, Okado-Matsumoto A, Fridovich I. Enzymatic activity. J Biol Chem. 1979;274:38388.

[20] Walsh SW, Wang Y. Deficient glutathione peroxidase activity in pre eclampsia is associated with increased placental production of thymoxane and lipid peroxides. Am J Obstet Gynecol. 1993;169(6):1456–1461.

[21] Habig WH, Jakob WB. Glutathione-S-transferase in rat and human. Methods Enzymol. 1981;77:283–284

[22] Babalola AS, Jonathan J, Michael BE. Oxidative stress and anti-oxidants in asymptomatic malaria-positive patients: a hospital-based cross-sectional Nigerian study. Egypt J internal med. 2020;32(23):1–8.

[23] Galang RR, Newton SM, Woodworth KR, et al. Risk factors for illness severity among pregnant women with confirmed severe acute respiratory syndrome Coronavirus 2 infection—Surveillance for emerging threats to mothers and babies.
network, 22 state, local, and territorial health departments, 29 March 2020–5 March 2021. Clin Infect Dis. 2021;73(1):17–23.

[24] Rabiu OR, Dada-Adegbola H, Kosoko AM, et al. Contributions of malaria, helminths, HIV and iron deficiency to anaemia in pregnant women attending ante-natal clinic in SouthWest Nigeria. Afr Health Sci. 2020;20(3):1035–1044.

[25] Brickley EB, Spottiswoode N, Kabyemela E, et al. Cord blood hepcidin: cross-sectional correlates and associations with anemia, malaria, and mortality in a Tanzanian birth cohort study. Am J Tropical Med Hygiene. 2016;95(4):817–826.

[26] González R, Rupeârez M, Sevène E, et al. Effects of HIV infection on maternal and neonatal health in southern Mozambique: a prospective cohort study after a decade of antiretroviral drugs roll out. PLoS One. 2017;12(6):e0178134.

[27] Idowu OA, Sokunbi OA, Babalola AS. Prevalence of Malaria at booking among antenatal clients in a secondary health care facility in Abeokuta, Nigeria. Clin Mother Child Health. 2015;12(2). DOI:10.4172/2090-7214.1000177.

[28] Morgan G, Lecessiee B, Shulman CE. Malaria in pregnancy: its relevance to safe-motherhood programmes. Ann Trop Med Parasitol. 2002;96(1):559–566.

[29] Megnekou R, Djontu JC, Bigoga JD, et al. Impact of placental plasmodium falciparum Malaria on the profile of some oxidative stress biomarkers in women living in Yaoundé, Cameroon. PLoS ONE. 2015;10(8):e0134633.

[30] Yang H, Zhou M, Li H, et al. Effects of low-level lipid peroxidation on the permeability of nitroaromatic molecules across a membrane: a computational study. ACS Omega. 2020;5(10):4798–4806.

[31] Samir D, Noura DA. Study of Oxidative Stress during Pregnancy. Global J Pharm Pharm Sci. 2018; 4(5):GJPPS.MS.ID.555646 (2018). DOI: 10.19080/GJPPS.2018.04.555646.

[32] Chandramohan D, Greenwood BM. Is there an interaction between human immunodeficiency virus and Plasmodium falciparum?. Int J Epidemiol. 1991;27(2):296–301.

[33] Di Gennaro F, Marotta C, Locantore P, et al. Malaria and COVID-19: common and different findings. Trop Med Infect Dis. 2020;5(141):1–10.

[34] Hogan AB, Jewell BL, Sherrard-Smith E, et al. Potential impact of the COVID-19 pandemic on HIV, tuberculosis, and malaria in low-income and middle-income countries: a modelling study. Lancet Glob Health. 2020;8(9):1132–1141.

[35] Ned RM, Moore JM, Chaisavaneyakorn S, et al. Modulation of immune responses during HIV-malaria co-infection in pregnancy. Trends Parasitol. 2005;21(6):284–291.

[36] Mebrat Y, Amogne W, Mekasha A, et al. Lipid peroxidation and altered antioxidant profiles with pediatric HIV infection and antiretroviral therapy in Addis Ababa, Ethiopia. J Trop Pediatr. 2017;63:196–202.

[37] David D, Waters MD, Priscilla YHD, et al. Lipid abnormalities in persons living with HIV infection. Can J Cardiol. 2019;35(3):249–259.

[38] Flieger J, Flieger W, Baj J, et al. Antioxidants: classification, natural sources, activity/capacity measurements, and usefulness for the synthesis of nanoparticle. Materials. 2021;14(4135):4135.

[39] Sanaa S, Alya HM, Fayeda SS, et al. Effects of oral iron (ferrous versus ferric) supplementation on oxidative stress and antioxidant status in pregnant women with iron deficiency: controlled trial. Egypt J Haematol. 2016. DOI:10.4103/1110-1067.186392