MSI Journal of
Medicine and Medical Research (MSIJMMR)

# ASSESSMENT OF THE IMPACT OF MALARIA ON VELOCIMETRY IN SECOND AND THIRD TRIMESTERS: A CASE OF PREGNANT WOMEN IN ONITSHA, ANAMBRA STATE, NIGERIA

Sharonrose Ogochukwu Nwadike[1*], Anthony. C. Ugwu[1], Michael Promise Ogolodom[2], Yusuf Mohammed Mohammed[3], Charity Ezinwanne Ofojebe[1]

[1*]Department of Radiography and Radiological Sciences, Nnewi Campus, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

[2]Department of Radiography, Faculty of Basic Medical Sciences, College of Medical Sciences, Rivers State University, Port Harcourt, Nigeria.

[3]Department of Medical Radiography, Ahmadu Bello University Zaria, Nigeria.

*** Correspondence:** Sharonrose Ogochukwu Nwadike.

*The authors declare that no funding was received for this work.*

OPEN ACCESS

Received: 10-April-2026

Accepted: 15-June-2025

Published: 20-June-2026



This article is published in the **MSI Journal of Medicine and Medical Research (MSIJMMR)**

**ISSN 3049-1401 (Online)**

The journal is managed and published by MSI Publishers.

**Volume 3, Issue 2 (May-Aug), 2026**

**ABSTRACT: Background:** Continuous monitoring and early detection of placental changes through imaging and Doppler studies can help in managing and improving pregnancy outcomes in malaria-endemic regions such as Nigeria. The aim of this study is to investigate the impact of malaria on placental velocimetry in the second and third trimester, among pregnant women in Onitsha metropolis.

**Materials and Methods:** The study design was a case control carried among pregnant women with malaria and comparing with apparently health controls. Both groups undergo laboratory test for malaria and Doppler ultrasound scan for placental pulsatile index and resistive index using standard protocols. Descriptive and inferential statistical tools were used for statistical analysis with level of statistical significance set at $p < 0.005$.

**Results:** The PI differs significantly between pregnancies affected by malaria and healthy controls, with a small to moderate effect size ($F(1, 396) = 11.831$, $p < 0.001$, partial $\eta^2 = 0.029$). The RI does not significantly differ between the second and third trimesters ($F(1, 396) = 1.016$, $p = 0.31$, partial $\eta^2 = 0.003$), the effect of malaria on RI does not vary across trimesters $F(1, 396) = 1.656$, $p = 0.19$, partial $\eta^2 = 0.004$).

**Conclusion:** The PI differs significantly between pregnancies affected by malaria and healthy controls, with a small to moderate effect size, suggesting some practical relevance. There was no statistically significant main effect of trimester, indicating that PI does not differ between the second and third trimesters. Importantly, the interaction effect between malaria status and trimester was statistically significant. This suggests that the effect of malaria on PI varies depending on the trimester. The RI differs significantly between pregnancies affected by malaria and healthy controls, although the effect size was small. However, there was no statistically significant main effect of trimester and RI does not significantly differ between the second and third trimesters.

**Keywords:** *Doppler indices, gestational age, malaria.*

## INTRODUCTION

Malaria is a life-threatening disease to gravid women caused by Plasmodium parasites, which are transmitted to people through the bites of infected female Anopheles mosquitoes [1]. Malaria can significantly affect the structure and function of the placenta, leading to changes in its thickness, morphology, and blood flow dynamics [1]. Malaria infection can disrupt placental development, contributing to miscarriage or early foetal loss, through systemic or local deficiencies in the immune response to malaria [2-4]. Placental malaria in the second trimester is associated with an increased risk of intrauterine growth restriction and preterm birth [5], while in the third trimester, sequestration of malaria parasites in the placenta can trigger inflammation and interstitial thickening, causing structural damage that raises placental thickness and compromises placental function [6]. This disrupts maternal-foetal nutrient and oxygen transfer, often resulting in maternal anaemia, intrauterine growth restriction, low birth weight, and heightened risks of infant mortality and morbidity [7].

According to Elphinstone *et al [8]*, their research revealed that Malaria alters blood flow patterns, leading to reduced uteroplacental perfusion and increased resistance in placental circulation. These changes can be detected through increased uterine artery resistive index and abnormal umbilical artery Doppler readings, which are associated with foetal growth restriction and other complications [9]. Understanding the impact of malaria on placental health across different trimesters is crucial for developing targeted interventions to mitigate the adverse outcomes associated with Pregnancy Associated Malaria [8-10]. Continuous monitoring and early detection of placental changes through imaging and Doppler studies can help in managing and improving pregnancy outcomes in malaria-endemic regions [11,12]. Notably, understanding velocimetry indices such as umbilical artery resistive index in malaria infected pregnancies could enhance risk stratification and prompt obstetric interventions to improve foetal growth and reduce mortality. Therefore, this study was designed to assess the impact of malaria on velocimetry in the second and third trimester, pregnant women in a selected diagnostic facility in Onitsha Anambra state.

## MATERIALS AND METHODS

**Study Design:** The study design is a case control study. Because the study involves identifying individuals with malaria and comparing them to apparently health controls.

**Study Area:** The study was conducted at the Radiology department Federal Medical Centre, Onitsha Anambra State Nigeria. The diagnostic centre is located in Anambra metropolitan area in the eastern region of Nigeria. Licensed and registered with the Anambra State Ministry of Health.

**Population of the study:** The study population consist of pregnant women for ultrasound scan diagnosed to be infected with malaria in their second and third trimesters and attends antenatal clinic at Federal Medical Centre, Onitsha Anambra State Nigeria, whose records was assessed at the antenatal unit, within the age range of 18 to 45 years, who attends obstetric clinics and or undergoing obstetric scans in the diagnostic facility (Radiology Department, Federal Medical Centre Onitsha). Similarly, apparently healthy pregnant women in their second and third trimester were also studied as control.

**Ethical Consideration:** Ethical approval with protocol number: **FHST/REC/024/1054** was obtained from Research Ethics Committee of Faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University Nnewi campus, Anambra state, Nigeria. A corresponding approval was obtained from Radiology Department, Federal Medical Centre Onitsha, finally each volunteered participant was ensured to sign an informed consent form before enrolment in the study.

**Sample Size Determination:** The sample size was calculated using Yamane's formula for finite population [13].

$n= N/1+N\ (e)\ 2$

Where: n = the desired sample size, N = the finite population,

1= unity (a constant) e = the level of significance (limit of tolerable error).

A total of 250 gravid women were diagnosed with malaria in their 2nd and 3rd trimesters between 2021 and 2024, at the ante-natal clinic of Federal Medical Centre Onitsha Anambra State.

Therefore n= 250/1+250 (0.01)2

= 250/1+250 x 0.001

= 250/1+0.25

= 250/1.25

= 200. Therefore, the sample sizes of 200 was considered for this study, for the malarial affected gravid patients and matched same sample sizes of 200 of apparently healthy participants were recruited for the control group.

**Sampling Technique**

A purposive sampling technique was adopted for the adult gravid patients with positive malaria blood test at second and third trimester of pregnancy. Convenience sampling method was employed for patients with negative malaria blood test at second and third trimester of pregnancy control group. A convenient sampling method involves recruiting participants who are readily available, willing and convenient to participate in the study. Purposive sampling, also known as judgmental

sampling, is a non-probability sampling technique where participants are selected based on the researcher's judgment and expertise. The goal is to select a sample that is representative of the population of the research interest. Purposive sampling was efficient in this research as it allows the researcher to quickly identify and select participants with specific characteristics.

**Inclusion criteria:** These include; gravid women who are willing to participate, pregnant mothers between ages 18-45 years, only second and third trimester pregnancies was inclusive, viable singleton gestation confirmed through ultrasound scan, pregnant women with recent positive malarial laboratory test result seen in the antenatal folder, apparently healthy pregnant women, who are matched in maternal age, foetal gestational age, body mass index (BMI), with the case group was included until the projected sample size was reached.

**Exclusion criteria: These include but not limited to;** multiple gestations, foetus with developmental malformation, maternal medical history of diabetes mellitus, this is because diabetes mellitus in pregnancy crosses the placenta and triggers the foetal pancreas to produce excess insulin; this can cause the foetus to grow too large (macrosomia)[14] and pregnancy-related with IUGR, as it readily affects the foetal biometry [15].

**Instrument for data collection:** The ultrasound machine used is a GE Medical System SCS, Monitor Display, model name: 21.5 Inch Display Module R2, GPN: 5880738 Rev. 7, P/N 301010552, serial number: 2321552267, GE. Equipped with a 3.5MHz curvilinear transducer and electronic callipers. Last calibrated in 17$^{th}$ February 2025 this is of great importance to ensure reliability of the measured data.

Plate 1 GE Medical System SCS


Plate 2: Curvilinear transducer

**Validation and reliability of the equipment**

GE Medical System SCS monitor display, model name: 21.5 Inch display Module R2, GPN: 5880738 Rev. 7, P/N 301010552, serial number: 2321552267, GE, the Placenta Blood Flow (PBF) results that was obtained matched a clinical measurement that stands as the reference value to the study, with a percentage difference in measurement of between 10% and 15%. The measurement of Doppler and Anthropometric parameters was linked to the model following the fact that by definition, **Placenta Blood Flow (PBF)** = Cross-sectional area of the umbilical vein (CSAuv) × Mean flow velocity integral (FVIuv) **/s** ×60 (CSAuv) is calculated from the diameter of the umbilical vein and FVIuv is the integrated blood flow velocity measured through the umbilical vein.

Doppler ultrasound scanners is generally considered to be highly reliable when used appropriately by a professional, with studies showing good accuracy in measuring blood flow, when considering the right settings and angel of approach; however, its reliability can be affected by factors like operator skill, patient positioning and the complexity of the blood vessel being examined. The reliability of the equipment is dependent on; Operator dependence, Limitations due to anatomy and different Doppler modes, the researcher will pay detailed attention to these three.

**Method of data collection**

The overview of the ultrasound scanning technique for gravid women in the second and third trimester, focusing on placenta thickness, morphology, and velocimetry.

**Ultrasound scanning procedures**

The patient details were inputted to the scanner and confirmed with the patient

Brief explanation and indication of the scan which is for academic research

The patient lies supine on the couch and was properly covered with a protective cloth. Ultrasound gel was applied at the lower abdomen and the trans-abdominal probe (3.5MHs) was selected for gestational scan. The probe was first placed transverse position at the lower abdomen with the marker as a reference. The placental location was localized, by keeping the image orientation correct as the probe was rotated in clockwise direction when changing from a transverse plan to longitudinal plan and anti-clock wise from longitudinal to transverse. Sliding, rotation, Deeping and angling technique was adopted to determine the location of the umbilical cord insertion, for correct measurement of the placental thickness, maintaining a longitudinal orientation staring at the right funds the probe was slide down towards the sympisis keeping the probe perpendicular to the floor. Sliding was done along the three tracks located to determine the location of the umbilical cord insertion. Fundal, anterior, posterior and anterior and posterior fundal placental positions were determined from the scans.

Velocimetry measurements was gotten on the placenta, specifically focusing on umbilical artery blood flow, typically taken at the point where the umbilical cord inserts into the foetus at the abdominal region This allows for the assessment of the foetal umbilical artery's resistance to blood flow, providing insights into placental function and foetal well-being.

Placenta velocimetry; using Doppler ultrasound in measurement and to evaluate the blood flow in the; (1) umbilical artery (2) middle cerebral artery, and (3) ducts venous was done. Pulsatility Index (PI): Calculating the PI, which reflects the resistance to blood flow in the placenta were done. It is the difference between the peak systolic flow and the minimum diastolic flow velocity. Resistance Index (RI): Calculating the RI, which reflects the resistance to blood flow in the placenta. S/D Ratio: Calculation of the S/D ratio, which reflects the ratio of systolic to diastolic blood flow in the umbilical artery, was considered. Finally Doppler analysis: The

researchers used the Doppler function to analyze the blood flow within the umbilical cord and placenta, measuring parameters including peak systolic velocity and resistance index. The Doppler waveforms was interpreted and compared to normal ranges to assess placental function and detailed documentation of parameters and ranges was well noted for the research findings. The images and videos of the collected data was documented; measurements and any notable findings was saved for time management and later assessed. Report that generates details of the ultrasound findings, including measurements, observations, and recommendations for further evaluation or follow-up were properly guarded.

**Laboratory methodology for the test findings**

The study population comprised pregnant adult women who attended routine antenatal visits during the study period. Participants who gave their consent where recruited and if they either presented with fever, had a recent history of fever, or showed malaria-related symptoms such as chills, headache, or anaemia. Before each procedure, the purpose of the study was explained to the participants in simple, clear language. Informed consent was obtained from all participants, and great care was taken to maintain confidentiality. Standard infection control practices were strictly followed during every stage of blood collection and laboratory analysis.

**Blood Sample Collection**

For every participant, venous blood was collected. This method was chosen because it allowed for a larger volume of blood to be obtained, which was useful for preparing both thick and thin smears as well as for any additional confirmatory laboratory tests that were required [16].

During venipuncture, the participant was comfortably seated, and a tourniquet was applied to the upper arm to make the veins more prominent. The chosen puncture site, usually the antecubital fossa, was cleaned with 70% alcohol and allowed to air dry. A sterile syringe and needle were then used to withdraw approximately 2–3 mL of blood. Once the blood was collected, the tourniquet was released and the needle was carefully removed. Pressure was applied with sterile cotton wool until bleeding stopped, and a small plaster was applied. The collected blood was immediately

transferred into an EDTA anticoagulant tube, mixed gently by inversion to prevent clotting, and promptly transported to the laboratory.

**Preparation of Blood Smears**

From each venous blood sample, both thick and thin smears were prepared according to WHO recommendations [17].

For the thick film, a larger drop of blood was placed on a clean slide and spread gently in a circular motion to form a circle of about one centimetre in diameter. The smear was prepared to be thick enough that printed text beneath the slide could only just be seen. The film was then left to air dry naturally without the use of fixatives.

For the thin film, a smaller drop of blood was placed near the frosted edge of a slide. Using another spreader slide held at a 45° angle, the drop was pulled back and then pushed smoothly forward to produce a thin smear with a feathered edge. This thin film was air-dried completely before being fixed with absolute methanol for about thirty seconds and then allowed to dry again.

**Staining of Smears**

Both the thick and thin blood films were stained using the Giemsa staining technique, which is considered the gold standard for malaria microscopy [17,18]. A 10% Giemsa solution was prepared using buffered water at pH 7.2, and slides were immersed in the solution for ten minutes. For quality control, some slides were stained using 3% Giemsa for thirty to forty-five minutes. After staining, the slides were rinsed gently with buffered water and placed vertically on a drying rack to air dry completely before examination.

**Microscopy**

Examination of the stained slides was carried out using a light microscope fitted with a 100x oil immersion objective lens. The thick films were used for parasite detection and density estimation. Each slide was first scanned under the 10x objective to identify suitable fields, and then carefully examined using the oil immersion lens. At least 100 high-power fields were studied before a slide was declared negative. The

thin films, on the other hand, were used primarily for parasite species identification. Morphological characteristics such as the size and shape of the parasites, chromatin patterns, and stippling were observed to differentiate between species. Mixed infections were also recorded whenever present.

**Parasite Density Estimation**

Parasite density was estimated using the WHO semi-quantitative method [17]. The grading was done as follows:

1. (+): 1–10 parasites per 100 high-power fields
2. (++): 11–100 parasites per 100 fields
3. (+++): 1–10 parasites per field
4. (++++): More than 10 parasites per field

This method was adopted because it is widely used in clinical and epidemiological studies, and it provided a reliable way of categorizing the parasite burden among participants [16].

**Interpretation of Results**

Slides were declared positive when malaria parasites were detected and the species identified. A slide was declared negative only after at least 100 high-power fields had been thoroughly examined with no parasites seen. For pregnant women, even very low levels of parasitemia were considered important, since malaria infection during pregnancy is associated with adverse outcomes such as maternal anaemia, placental malaria, and poor pregnancy outcomes [19].

**Duration of the study**

The research was carried out from May 2025 to March 2026.

**Method of Data Analysis**

Data was analyses using the statistical package for social science-SPSS software version 20.0, in line with the research objectives:

1. To determine the difference in umbilical Pulsatility index (PI) in the second and third trimester between the pregnancy affected by malaria and healthy controls. A two-way ANOVA was done in table 2, to examine the difference in umbilical Pulsatility index (PI) in the second and third trimester between the pregnancy affected by malaria and healthy controls.
2. To determine the difference in umbilical RI in the second and third trimester between the pregnancy affected by malaria and healthy controls. A two-way ANOVA was assessed in table 3 to evaluate the effects of malaria status and trimester on umbilical Resistance Index (RI). A descriptive and inferential statistical tool was adopted for statistical analysis with level of statistical significance set at $p < 0.005$.

**RESULTS**

The descriptive analysis shown in table 1, Gestational Age**:** The gestational age ranged from 20.45 to 40.00 weeks, with a mean of 31.19 ± 5.55 weeks, indicating that the majority were in the second and third trimesters. Placenta Thickness**:** Placental thickness varied between 2.43 mm/s and 4.78 mm/s, with a mean of 3.65 ± 0.53 mm/s, reflecting the normal variability in placental growth across gestation. Resistance Index (RI): The RI ranged from 0.06 to 0.79, with a mean of 0.59 ± 0.10, suggesting mostly normal uteroplacental blood flow patterns. Pulsatility Index (PI): The PI values ranged from 0.11 to 3.45, with a mean of 1.59 ± 0.53, indicating variability in placental vascular resistance among participants. Distance (mm/s): Measured values ranged from 0.20 to 3.20, with a mean of 0.89 ± 0.49, representing variations in measured vascular or anatomical parameters. Amniotic Fluid Index (AFI): AFI ranged from 4.00 to 73.00 cm, with a mean of 10.98 ± 3.98 cm, showing that most participants had normal fluid levels, although there were a few extreme values. Maternal Age**:** Ages ranged from 18 to 45 years, with a mean of 29.53 ± 6.89 years, confirming that most participants were within the prime reproductive age (TABLE 1).

A two-way ANOVA was done in table 2, to examine the difference in umbilical Pulsatility index (PI) in the second and third trimester between the pregnancy affected by malaria and healthy controls. The analysis revealed a statistically

significant main effect of malaria status on PI ($F(1, 396) = 11.831$, $p < 0.001$, partial $\eta^2 = 0.029$). This indicates that PI differs significantly between pregnancies affected by malaria and healthy controls, with a small to moderate effect size, suggesting some practical relevance. There was no statistically significant main effect of trimester ($F(1, 396) = 0.002$, $p = 0.97$, partial $\eta^2 = 0.000$), indicating that PI does not differ between the second and third trimesters. Importantly, the interaction effect between malaria status and trimester was statistically significant ($F(1, 396) = 5.033$, $p = 0.03$, partial $\eta^2 = 0.013$). This suggests that the effect of malaria on PI varies depending on the trimester (Table 2).

A two-way ANOVA was assessed in table 3 to evaluate the effects of malaria status and trimester on umbilical Resistance Index (RI). The analysis revealed a statistically significant main effect of malaria status on RI ($F(1, 396) = 4.472$, $p = 0.04$, partial $\eta^2 = 0.011$), indicating that RI differs significantly between pregnancies affected by malaria and healthy controls, although the effect size was small. However, there was no statistically significant main effect of trimester ($F(1, 396) = 1.016$, $p = 0.31$, partial $\eta^2 = 0.003$), suggesting that RI does not significantly differ between the second and third trimesters. Additionally, the interaction effect between malaria status and trimester was not statistically significant ($F(1, 396) = 1.656$, $p = 0.19$, partial $\eta^2 = 0.004$), indicating that the effect of malaria on RI does not vary across trimesters. Overall, these findings suggest that while malaria status has a statistically significant influence on RI, this effect is consistent across both trimesters, and trimester alone does not significantly affect RI (Table 3).

Table 1: Descriptive statistics of selected maternal and obstetric parameters

| Variables | N | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|
| Gestational Age (Weeks) | | 20.45 | 40.00 | 31.19 | 5.55 |
| Placenta Thickness (mm/s) | | 2.43 | 4.78 | 3.65 | 0.53 |
| Resistance Index | 400 | 0.06 | 0.79 | 0.59 | 0.10 |
| Pulsatility Index | | 0.11 | 3.49 | 1.59 | 0.53 |
| Distance (mm/s) | | 0.20 | 3.20 | 0.89 | 0.49 |
| Amniotic Fluid Index (cm) | | 4.00 | 73.00 | 10.98 | 3.98 |
| Maternal Age | | 18 | 45 | 29.53 | 6.89 |

Table 2: Differences in umbilical pulsatility index (PI) in the second and third trimester between the pregnancies affected by malaria and healthy control

| Source of Variation | Type III Sum of Squares | Df | Mean Square | F-value | p-value | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Malaria status | 3.187 | 1 | 3.187 | 11.831 | 0.00 | 0.029 |
| Trimester | 0.001 | 1 | .001 | 0.002 | 0.97 | 0.000 |
| Malaria × Trimester | 1.356 | 1 | 1.356 | 5.033 | 0.03 | 0.013 |
| Error | 106.400 | 396 | .269 | | | |
| Total | 1098.848 | 400 | | | | |

Table 3: Difference in umbilical RI in the second and third trimester between the pregnancies affected by malaria and healthy controls

| Source of Variation | Type III Sum of Squares | Df | Mean Square | F-value | p-value | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Malaria status | 0.046 | 1 | 0.046 | 4.472 | 0.04 | 0.011 |
| Trimester | 0.010 | 1 | 0.010 | 1.016 | 0.31 | 0.003 |
| Malaria × Trimester | 0.017 | 1 | 0.017 | 1.656 | 0.19 | 0.004 |
| Error | 4.032 | 396 | 0.010 | | | |
| Total | 140.997 | 400 | | | | |

## DISCUSSIONS

The result on the difference in umbilical Pulsatility index (PI) in the second and third trimester between the pregnancies affected by malaria and healthy controls shows that revealed a statistically significant main effect of malaria status**on** PI. This indicates that PI differs significantly between pregnancies affected by malaria and healthy controls**,** with a small to moderate effect size**,** suggesting some practical relevance. There was no statistically significant main effect of trimester, indicating that PI does not differ between the second and third trimesters. Importantly, the interaction effect between malaria status and trimester was statistically significant.

This suggests that the effect of malaria on PI varies depending on the trimester. This finding is consistent with the findings of previous studies conducted by Ferdous *et al [*20], Sonhaye *et al [*21] and Ademola *et al* [22].

In a study carried out by Ferdous *et al [20]* to provide normal value of pulsatility index of umbilical artery in second and third trimester of pregnancy which involved a cross sectional study on 60 pregnant Bangladeshi women in the department of Radiology and Imaging, BIRDEM for measurement of Pulsatility Index (PI) of umbilical artery of their foetuses by duplex colour Doppler sonography during 2nd and 3rd trimester of pregnancies. Considering total 2nd and 3rd trimesters the mean PI value of umbilical artery was 1.24 (SD±0.27). While considering the gestational in separate trimesters, study showed that the value of PI in 2nd trimester was 1.33 (SD±0.29) and in 3rd trimester PI was 1.18 (SD±0.25). Paired t test shows there was a highly significant (t= 35.79, df= 59, Level of significance= 0.001) difference between mean values of PI in different gestational ages. It was observed that there was gradual decrease of PI value with increase of gestational age (r=-0.207) but this decrease of PI was not statistically significant (p= 0.113). Regression analysis between dependent PI value and independent gestational age showed linear negative relationship but this was not statistically significant (p= 0.11). This study revealed that the Pulsatility index of umbilical artery was decreased with increase of gestational age from 2nd to 3rd trimester. Effect of asymptomatic malaria parasitemia on the uterine and umbilical artery blood flow impedance in third trimester singleton South-western Nigerian pregnant women. In a study by Sonhaye *et al[21]* to evaluate the role of umbilical artery Doppler ultrasound in the surveillance of pregnancies at risk of vascular disorders in Lomé which involved a cross-sectional analytical study carried out in the department of radiology of Campus teaching hospital over a period of 6 months. This study was based on the measurement of the resistance index of the umbilical artery in pregnant women presenting vascular risk and other pregnant women without vascular risk. The correlation between the pathological index and the at-risk pregnancies was assessed by the Odds Ratio as well as the correlation between the resistance index and the Apgar score at birth. The resistance index was measured in 209 at-risk pregnant women and in 425 pregnant women without vascular risk. The average age of

pregnant women was 26.31 years for “the at-risk pregnant” versus 25.38 years for the “pregnant- witnesses”. The association between the pathological resistance index (RI) and the gestational pathologies studied, had been positive and significant with an odds ratio of 1.57 for a 95% confidence interval of (1.07 - 2.20). A pathological RI is a risk factor for the occurrence of a pathological Apgar score at birth because this association was positive and significant for “pregnant-cases” as for “pregnant-witnesses”. This study revealed that measuring the index of resistance is not a common practice in our communities. However, it could be an important tool in the surveillance of at-risk pregnancies for diseases such as malaria, pre-eclampsia, and maternal anaemia. In a study by Ademola *et al*[22], to assess the utility of uterine and umbilical artery Doppler in the second and third-trimester in predicting adverse pregnancy outcomes which involved a prospective longitudinal study, the demographic, clinical, Doppler ultrasound parameters of the uterine and umbilical arteries of 84 consecutive women attending the antenatal clinic at 22–24 weeks and 116 women at 30–34 weeks gestation and pregnancy outcomes were documented and analyzed. Pregnant women with adverse pregnancy outcomes had significantly higher second-trimester mean uterine systolic/diastolic (S/D) ratio ($p = 0.001$), pulsatility index (PI; $p = 0.003$), umbilical artery S/D ($p = 0.016$), and resistivity index (RI; $p = 0.041$) as well as higher third-trimester uterine S/D and PI. While pregnancies with adverse foetal outcomes showed significantly higher uterine artery S/D and PI at the second trimester, third-trimester uterine showed higher S/D, RI, and PI and umbilical artery PI than in women with normal foetal outcomes. The combination of uterine PI and early diastolic notch were predictors of maternal outcomes and correctly predicted 73% ($p < 0.001$) in the second trimester. By the third trimester, the uterine PI alone was the best predictor and accurately predicted about 62% of maternal outcomes ($p = 0.028$). In addition, the second-trimester uterine S/D and early diastolic notch and uterine PI in the third trimester correctly predicted 79% and 78% of foetal outcomes, respectively. This study revealed that among unselected pregnant women population, the second-trimester Doppler parameters are better predictors of maternal adverse pregnancy outcomes, while adverse foetal outcome prediction by uterine and umbilical Doppler at the second- and the third-trimester parameters are comparable.

This is also consistent with a Doppler velocimetry studies, which measure blood flow in the umbilical artery and foetal circulation, have also provided insights into the impact of malaria on placental function. Comparative evaluations indicate that malaria-infected women often exhibit abnormal Doppler indices, which correlate with poor foetal outcomes such as growth restriction [23,24]. Significant differences in blood flow velocities and resistance were observed, indicating that malaria negatively impacts placental perfusion. These findings highlight the value of Doppler ultrasound as a non-invasive tool for assessing placental function in pregnancies affected by malaria.

Finding on the difference in umbilical RI in the second and third trimester between the pregnancy affected by malaria and healthy controls, revealed a statistically significant main effect of malaria status on RI, indicating that RI differs significantly between pregnancies affected by malaria and healthy controls, although the effect size was small. However, there was no statistically significant main effect of trimesters, suggesting that RI does not significantly differ between the second and third trimesters. Additionally, the interaction effect between malaria status and trimester was not statistically significant, indicating that the effect of malaria on RI does not vary across trimesters. Overall, these findings suggest that while malaria status has a statistically significant influence on RI, this effect is consistent across both trimesters, and trimester alone does not significantly affect RI.

This is consistent with the findings reported by some authors in their previous studies. In a study conducted by Adetayo *et al [25]* to determine the effect of asymptomatic malaria parasitemia on the uterine and umbilical artery blood flow impedance in third trimester singleton South-western Nigerian pregnant women. A comparative cross-sectional study was conducted between June 2016 and January 2017 to assess and compare the vascular flow of the uterine and umbilical arteries in healthy pregnant women with AMP and those without malaria parasitemia in the third trimester of singleton pregnancy using Doppler ultrasound. The mean uterine arteries Doppler indices were significantly higher in AMP than controls. The mean Doppler indices values for pulsatility index (PI), resistive index (RI), and systolic to diastolic ratio (SDR) were 0.85±0.16, 0.59±0.11, and 2.12±0.17 for the subjects and

0.77±0.09, 0.51±0.06 and 2.05±0.22 for the controls, respectively. These differences were statistically significant: PI was (P< 0.001; 95% confidence interval [CI]: − 0.11, − 0.051), RI was (P< 0.001; 95% CI: − 0.10, − 0.063) and SDR was (P= 0.01; 95% CI: − 0.11, − 0.015). However, the mean umbilical arteries PI and RI were not significantly different between subjects and the controls. This study revealed that there were statistically higher uterine artery impedance indices in the third trimester among singleton pregnant women with AMP than controls. This study also showed that the uterine artery impedance indices increased with the severity of malaria parasitemia. In a similar study carried out by Umeokafor *et al[26]* to determine the pulsatility index (PI), resistivity index (RI), systolic/diastolic ratio(S/D), end diastolic velocity (EDV), and peak systolic velocity (PSV) of the umbilical artery of normal singleton pregnancy during the second and third trimesters in Nnamdi Azikiwe University Teaching Hospital, Nnewi, Nigeria which involved a prospective longitudinal study of 141 patients that was conducted at 21–25 weeks (second trimester) and 31–35 weeks (third trimester) gestation. An ultrasound machine with Doppler capability fitted with a curvilinear transducer with a frequency of 3.5–5.0MHZ was used to measure the PI, RI, S/D ratio, EDV, and PSV of the participants. The second and third-trimester uterine artery Doppler indices of the participants were, respectively: PI = 1.29 ± 0.36, versus 0.94 ± 0.24 (P <0.001), RI = 0.73 ± 0.10, versus 0.60 ± 0.10 (P < 0.001), S/D ratio = 3.68 ± 2.36, versus 2.29 ± 0.63 (P < 0.001), PSV = 48.52 ± 18.28, versus 65.24 ± 24.01 (P < 0.001), and EDV = 315.23 ± 9.11, versus 0.58 ± 14.43 (P < 0.001). The PI, RI, and S/D ratio values decrease between the second to third trimesters while the PSV and EDV values increase between the second to third trimesters. This study established the baseline reference values for normal singleton pregnancies in the study population and the Doppler indices of women with high-risk pregnancies could be compared with them.

## CONCLUSION

The PI differs significantly between pregnancies affected by malaria and healthy controls, with a small to moderate effect size, suggesting some practical relevance. There was no statistically significant main effect of trimester, indicating that PI does

not differ between the second and third trimesters. Importantly, the interaction effect between malaria status and trimester was statistically significant. This suggests that the effect of malaria on PI varies depending on the trimester. The RI differs significantly between pregnancies affected by malaria and healthy controls, although the effect size was small. However, there was no statistically significant main effect of trimester and RI does not significantly differ between the second and third trimesters. Additionally, the interaction effect between malaria status and trimester was not statistically significant, indicating that the effect of malaria on RI does not vary across trimesters.

**Conflict of interest:** None declared among the authors

**REFERENCES**


1. Huynh, B. T., Fievet, N., Gbaguidi, G., Dechavanne, S., Borgella, S., Massougbodji, A., Cot, M.,and Deloron, P. (2011). Influence of the timing of malaria infection during pregnancy on birth weight and on maternal anemia in Benin. *American Journal of Tropical Medicine and Hygiene, 85*(2), 214–220. https://doi.org/10.4269/ajtmh.2011.11-0125
2. Duffy, P. E.,and Fried, M. (Eds.). (2001). *Malaria in pregnancy*. London/New York: Taylorand Francis.
3. Benirschke, K., Burton, G. J.,and Baergen, R. N. (2012). *Pathology of the human placenta* (6th ed.). Berlin, Heidelberg: Springer.
4. Conroy, A. L., Silver, K. L., Zhong, K., Rennie, M., Ward, P., and Kain, K. C. (2013). Complement activation and the resulting placental vascular insufficiency drives fetal growth restriction associated with placental malaria. *Cell Hostand Microbe*, 13(2), 215–226.
5. Desai, M., ter Kuile, F. O., Nosten, F., McGready, R., Asamoa, K., Brabin, B.,and Newman, R. D. (2007). Epidemiology and burden of malaria in pregnancy. *The Lancet Infectious Diseases*, 7(2), 93–104.
6. Rogerson, S. J., Hviid, L., Duffy, P. E., Leke, R. F.,and Taylor, D. W. (2003). Malaria in pregnancy: Pathogenesis and immunity. *The Lancet Infectious Diseases, 3*(2), 105–112. DOI: 10.1016/S1473-3099(03)00622-6

7. Muehlenbachs A, Mutabingwa TK, Edmonds S, Fried M, Duffy PE (2006) Hypertension and maternal-fetal conflict during placental malaria. *PLoS Med* 3: e446.
8. Elphinstone, R. E., Weckman, A. M., McDonald, C. R., Tran, V., Zhong, K., Madanitsa, M., Kalilani-Phiri, L., Khairallah, C., Taylor, S. M., Meshnick, S. R., Mwapasa, V., Ter Kuile, F. O., Conroy, A. L.,and Kain, K. C. (2019). Early malaria infection, dysregulation of angiogenesis, metabolism and inflammation across pregnancy, and risk of preterm birth in Malawi: A cohort study. *PLoS medicine*, *16*(10), e1002914. https://doi.org/10.1371/journal.pmed.1002914
9. Guyatt, H. L., and Snow, R. W. (2001). Malaria in pregnancy as an indirect cause of infant mortality in sub-Saharan Africa. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, *95*(6), 569-576. https://doi.org/10.1016/S0035-9203(01)90082-3
10. Chua, C. L. L., Khoo, S. K. M., Ong, J. L. E., Ramireddi, G. K., Yeo, T. W., and Teo, A. (2021a). Malaria in pregnancy: From placental infection to its abnormal development and damage. *Frontiers in Microbiology, 12,* 777343. https://doi.org/10.3389/fmicb.2021.777343
11. Umbers, A. J., Aitken, E. H. and Rogerson, S. J. (2011). Malaria in pregnancy: small babies, big problem. *Trends in Parasitology*, volume-27(4), pp;168-175.
12. Berhe, A. D., Doritchamou, J. Y. A., and Duffy, P. E. (2023). Malaria in pregnancy: adverse pregnancy outcomes and the future of prevention. *Frontiers in Tropical Diseases*, 4, 1229735.
13. Yamane, T. (1967). *Statistics: An Introductory Analysis* (2nd ed.). New York: Harperand Row.
14. Farooq, U., Aya, A., Ali, A.,and Ahmad, S. (2007). Effect of maternal diabetes mellitus on fetal growth and development. *Journal of Ayub Medical College Abbottabad, 19*(4), 42–45. PMID: 18693628
15. Gardosi, J. (2002). Intrauterine growth restriction: New standards for assessing fetal growth. *Best Practiceand Research Clinical Obstetrics and Gynaecology, 16*(1), 1–12. DOI: 10.1053/beog.2001.0250
16. Cheesbrough, M. (2006). *District Laboratory Practice in Tropical Countries, Part 2* (2nd ed.). Cambridge: Cambridge University Press

17. World Health Organization. (2016). *WHO Malaria Microscopy Quality Assurance Manual – Version 2.* Geneva: World Health Organization. ISBN: 9789241549394
18. Ochei, J.,and Kolhatkar, A. (2008). *Medical Laboratory Science: Theory and Practice.* New Delhi: Tata McGraw-Hill Education.
19. Desai, M., Gutman, J., L'lanz, J.,and Ter Kuile, F. O. (2018). Intermittent preventive treatment for malaria in pregnancy: Updated evidence and new directions. *PLoS Medicine, 15*(9), e1002914. DOI: 10.1371/journal.pmed.1002914
20. Ferdous, J., Begum, S., Begum, R.,and Akhter, S. (2013). Normal values of pulsatility index of umbilical artery in second and third trimester of pregnancy in Bangladeshi women. *Bangladesh Journal of Radiology and Imaging, 21*(2), 63–67.
*21.* Sonhaye, L., Kolou, B., Boube, A.H., Bah, O.A., Amadou, A., Gbande P., Assih, K., Tchaou, M., Ntimon, B. and Adjenou, K. (2018). Umbilical Artery Resistance Index in the Surveillance of Pregnancies at Risk of Fetal-Maternal Hemodynamic Disorders in Lomé (Togo). *Open Journal of Radiology, doi: 10.4236/ojrad.2018.83018.*
22. Ademola, J.A., Adebola, R., Imran, O.M. and Abiodun, O.A. (2022). Utilization of Uterine and Umbilical Artery Doppler in the Second and Third Trimesters to Predict Adverse Pregnancy Outcomes: A Nigerian Experience. *Women's Health Reports (New Rochelle)* 3(1), 256–266.
23. Sruti, K. (2020). Comparative Evaluation of the Arterial and Venous Doppler in Predicting Perinatal Outcome in Fetus with IUGR. ProQuest Dissertations Publishing.Retrieved from; https://search.proquest.com/openview/111d590078a11527bdc0bf73a286034f/1?pq-origsite=gscholar&cbl=2026366&diss=y.
24. Gaccioli, F.,and Lager, S. (2016). Placental nutrient transport and intrauterine growth restriction. *Frontiers in Physiology, 7*, 40. DOI: 10.3389/fphys.2016.00040

25. Adetayo, M. A., Adekanmi, A. J., Roberts, A.,and Adeyinka, A. O. (2018). Effect of asymptomatic malaria parasitemia on the uterine and umbilical artery blood flow impedance in third-trimester singleton Southwestern Nigerian pregnant women. *Tropical Journal of Obstetrics and Gynaecology, 35*(3), 366–372. DOI: 10.4103/TJOG.TJOG_61_18

*26.* Umeokafor, C., Nwosu, C., Umeh, E., Okafor, C., Okafor, C., Nwammuo, B., Elendu, K. and Eze, K. (2024). Umbilical artery Doppler Indices in second and third trimesters in normal singleton pregnancy at nnamdiazikiwe university teaching hospital nnewi, Nigeria. *International Journal of Medicine and Health Development 29(1) 28-34.*