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# Evaluating the Effect of Maternal Iron Deficiency Anemia on Fetal Hemodynamics: A Doppler Ultrasound Study of it's Impact on CPR.

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## Abstract

***Purpose:*** *The purpose of the study is to assess the impact and effects of maternal IDA on fetal hemodynamics by using the modality of Doppler ultrasound. In this research we are focusing on cerebral-placental ratio (CPR) and MCA-PSV to determine its association with fetal anemia, and overall outcomes that fetus has to face with mothers having maternal anemia. The reason of choosing this purpose was the contribution of maternal iron deficiency anemia IDA towards maternal and fetal morbidity and also it is important to study a major global health issue in rural area of Pakistan where its often neglected.*

***Methods:*** *It is a comparative case control study. This study was conducted with the help of Dr. Hareem khan (Co-Supervisor) at the radiology and obstetrics department of Ali children and surgical hospital Manga Mandi Lahore, Pakistan. The population that was included in the study was 100 woman which were between 20 to 40 weeks of pregnancy, in this population 50 of them cases i.e: anemic and 50 of them non-anemic controls. Under the supervision of trained doctors ultrasound was used to evaluate the indices of umbilical artery and middle cerebral artery, PI, RI, MCA-PSV and CPR were calculated. After analyzing the data using SPSS version 26, we applied distribution statistical tests, chi-Square test and correlation analysis. The results were prepared and $p< 0.05$ was considered significant.*

***Results:*** *After careful analysis of the collected data the results were as following: The population under study had 50% anemic cases and after ultrasound 40% of the fetuses showed signs of compromise. If we talk about anemia it was present in 19% of the cases and it was more frequently present in anemic mothers (p=0 .049). After careful calculations and statistical analysis it was concluded that the cerebral resistance was much reduced in anemic fetuses, the mean MCA-PI was much lower in cases (1.10± 0.33) as compared to controls (1.23±0.15), this ended up in reduce cerebral resistance and if we talk about correlation, a strong and*

*negative correlation was observed between fetal anemia and MCA-PI ($r = -0.900$, $p<0.001$). When it comes to outcomes and fetal condition on the current ultrasounds it was also noted that maternal anemia was associated with adverse fetal effects ($x^2 = 21.80$, $p<0.001$). All these results confirmed that there is a negative effect of maternal iron deficiency anemia on fetal hemodynamics.*

***Conclusion:*** *As the result shows, this study confirms the hypothesis that maternal iron deficiency anemia IDA does have a significant and negative impact on fetal Doppler indices MCA and UA, RI and PI. These results demonstrate alterations in fetal circulation resulting in increasing risk of fatal anemia and compromise in mothers with IDA and through this research we came to a conclusion that if we incorporate Doppler ultrasound particularly measurements like CPR and MCA-PSV into routine checkups of pregnant women suffering from maternal anemia, we could be able to detect any fetal compromise at early phase and it will also help us in timely management of pregnancies that are at high risk.*

## INTRODUCTION

Maternal Iron Deficiency Anemia (IDA) is the most common nutritional deficiency worldwide, defined as hemoglobin levels below 11 g/dL during pregnancy, indicating depleted iron stores (1). Pregnancy increases iron demand nearly twofold to support maternal blood production and fetal growth, and failure to meet this demand results in anemia, reducing oxygen delivery to maternal and placental tissues (1). According to WHO, over 30% of women are anemic, with rates reaching up to 50% in low- and middle-income countries lacking effective nutrition programs (2,3). In Pakistan, about two-thirds of pregnant women suffer from IDA due to poor nutrition, repeated pregnancies, infections, and limited supplementation access (4).

IDA causes fatigue, infection risk, and postpartum hemorrhage in mothers, and in fetuses can lead to intrauterine growth restriction, preterm birth, anemia, or stillbirth (5). It also affects early neurological development (6). Despite these risks, fetuses show compensatory adaptation called the "brain-sparing effect," where blood flow is redirected to vital organs like the brain, heart, and adrenals through cerebral vasodilation (7). Doppler ultrasound detects these hemodynamic changes non-invasively. The cerebroplacental ratio (CPR), calculated as MCA-PI divided by UA-PI, indicates fetal well-being (8). A CPR below 1.0 or under the 5th percentile suggests fetal compromise (9). Studies link low CPR values to fetal distress and poor neonatal outcomes (10).

The physiological pathway is: Maternal IDA → low hemoglobin → reduced placental perfusion → fetal hypoxia → brain-sparing effect → reduced MCA-RI and CPR (7,8). Another Doppler index, the Middle Cerebral Artery Peak Systolic Velocity (MCA-PSV), is the gold standard for detecting fetal anemia (11). Low blood viscosity and increased cardiac output in anemia raise MCA-PSV levels. An MCA-PSV exceeding 1.5 multiples of the median (MoM) for gestational age indicates moderate to severe fetal anemia with 100% sensitivity and 92% specificity (12,13). For example, at 30 weeks (median MCA-PSV = 40 cm/s), a reading of 65 cm/s equals 1.62 MoM, confirming anemia (14). This method has replaced invasive tests like amniocentesis or cordocentesis, which carry risks of bleeding, infection, or miscarriage (15).

Although MCA-PSV effectively identifies fetal anemia, it is less frequently used because factors like intrauterine growth restriction or placental insufficiency can also elevate its values, creating diagnostic uncertainty (16,17). Doppler ultrasound remains superior as it is non-invasive, affordable, real-time, and safe, unlike MRI (expensive), CT (contraindicated), or cardiotocography (detects late signs only) (18,19). Operator skill is the main factor influencing accuracy.

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CPR and MCA-PSV together provide complementary information, with CPR assessing vascular resistance and MCA-PSV reflecting cardiac output and blood viscosity (20). Despite evidence linking maternal anemia to decreased CPR and increased MCA-PSV, data remain inconsistent due to small sample sizes, non-standardized Doppler protocols, and operator variability. There is a clear need for larger, methodologically robust studies to confirm the relationship between maternal IDA, fetal Doppler parameters, and outcomesTherefore we have designed this study accordingly to address this specific gap. Pregnant women diagnosed with Iron Deficiency anemia; Hb level below 11g/dL calculated through their CBC or Hb tests will be compared with controls that are pregnant ladies with Hemoglobin levels above 11g/dL. Doppler indices like MCA PI and RI, UA PI and RI, CPR and MOM will be calculated and compared of fetuses between 28 to 40 weeks. These will be compared with neonatal outcomes and fetal anemia status (calculated by MCA-PSV). All is done to provide sufficient evidence about whether maternal IDA alone could be responsible to alter fetal hemodynamic and induce adverse effects in fetus or not.

If we talk about the rationale, in this specific investigation it could be twofold. In clinical practices this study will help us to determine whether Doppler should be integrated in routine checkup in obstetric settings in pregnancies complicated with IDA for early detection of fetal hemodynamic changes and their effect on fetus and will help us improve surveillance and guide in future intervention for better outcomes. If significant associations or found between altered indices in mothers with IDA, we'll be able to provide evidence to incorporate Doppler in routine protocols particularly in areas with higher prevalence of IDA in mothers. This will help in precise risk stratification and better management of adverse fetal or maternal outcomes. Scientifically this study will shed light on adaptive physiology of fetal response towards maternal iron deficiency anemia.

In summary, Maternal IDA is a prevalent condition in world and especially in Pakistan and it has many adverse fetal outcomes. While the laboratory checkups are main diagnostic procedures to detect IDA in mothers they do not provide with any information of its effect on the fetus. No lab test is usually able to show the hemodynamic effect t of IDA of mother on the growing fetus. Doppler ultrasound, through its revolutionary indices like CPR and MCA-PSV provide a safe and practical method to evaluate these effects and help the medical professionals to design better protocols to help with timely interventions. This study aims to fill the critical gap in literature and contribute as an evidence to improve clinical strategies for the betterment of fetal outcomes.

## OBJECTIVE

- To assess and evaluate the impact of maternal iron deficiency anemia on fetal doppler parameters especially focusing on the changes of Doppler indices like CPR and MCA-PSV (MOM), in ongoing pregnancies.
- To appraise the changes that are occurring in CPR and their effect on fetal well-being in pregnancies complicated with IDA.
- To highlight the importance of including doppler ultrasound in monitoring and management of high risk pregnancies to avoid fetal compromise.

## METHODOLOGY

This comparative case-control study evaluates the effect of iron deficiency anemia in pregnant women on fetal hemodynamics using Doppler ultrasound. The study included 100 pregnant women, divided into two groups, 50 anemic (cases) and 50 non-anemic (controls) presenting in the Radiology and Obstetrics departments of Ali Children Surgical Hospital, Manga Mandi, Lahore,

Pakistan, over six months from proposal approval to thesis submission. Based on calculations, 39 participants per group were required, rounded to 50 in each group for practicality.
Singleton pregnancies between 20 to 40 weeks with documented hemoglobin levels were included. Fetal structural or chromosomal abnormalities, multiple gestations, or placental insufficiency history were excluded. Data were recorded using a structured proforma and questionnaire. Participants were categorized into cases and controls based on lab-verified hemoglobin levels. Using a Sonimage 613 (Konica Minolta) with a 2.5–5 MHz convex probe, Doppler ultrasound was performed in a supine or left lateral position. The umbilical artery and middle cerebral artery (MCA) were evaluated for Pulsatility Index (PI), Resistance Index (RI), and Systolic/Diastolic ratio. The cerebroplacental ratio (CPR) was calculated as MCA PI divided by UA PI. Fetal anemia was assessed using MCA-PSV compared to reference values.

**All Doppler indices and clinical data were documented on standardized sheets for analysis.**

**RESULTS**

It detected a strong correlation between fetal outcomes, maternal anemia, and fetal Doppler indices. In 100 cases, 40% of fetuses had evidence of compromise and 60% were normal. In 19% of cases, fetal anemia was identified, while in 43% of women, maternal anemia was seen, showing its prevalence and impact on pregnancy outcomes. Maternal anemia was found to be significantly associated with unfavorable fetal outcomes ($p < 0.001$), implying that anemic mothers were at a greater risk of fetal distress compared to non-anemic mothers.
Doppler examinations identified a reduced Middle Cerebral Artery Pulsatility Index (MCAPI) with fetal anemia, suggesting a "brain-sparing effect" due to hypoxia. Analysis by the Chi-square test ($p < 0.001$) and correlation analysis ($r = -0.900$) also demonstrated an inverse significant relationship between MCA PI and fetal anemia. In addition, maternal and fetal MCA PI levels had a good correlation, signifying a physiological correlation of maternal and fetal circulation patterns. These results indicate the significance of Doppler ultrasonography, that is, MCA PI and CPR, as sensitive methods for the detection of early fetal impairment in anemic pregnancies.
Mean Doppler index comparisons demonstrated that healthy fetuses and non-anemic women possessed greater MCAPI and CPR, suggesting better oxygenation and perfusion of the fetus. On the contrary, anemic mothers and impaired fetuses possessed lesser MCAPI but greater UAPI and UARI, suggesting greater placental resistance and reduced blood supply. Although some of the indices showed small changes not proven statistically, overall data confirm that maternal anemia adversely affects fetoplacental perfusion and fetal well-being. Doppler monitoring on a regular basis and proper treatment of maternal anemia are therefore essential for avoiding fetal hypoxia and favorable neonatal outcome.

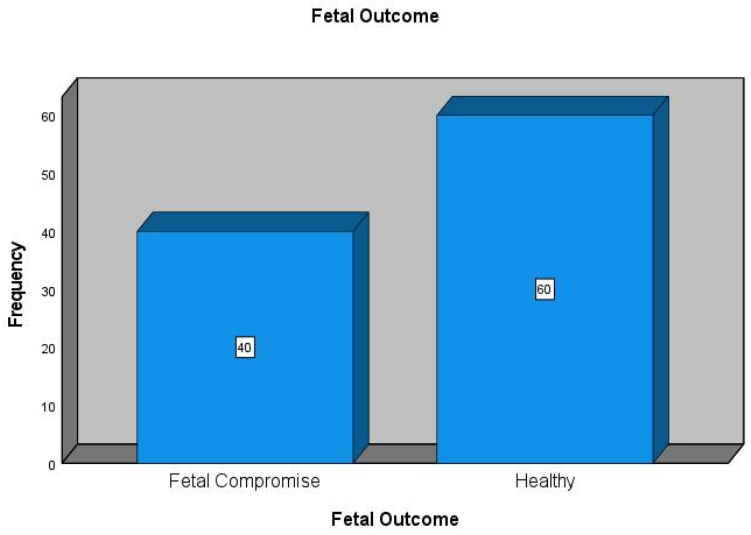


**Figure 4.1 graphical representation of fetal outcome**

**Table 4.1: Frequency distribution of fetal outcome**

| Fetal outcome | Frequency (n) | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Healthy | 60 | 60.0 | 60.0 | 60.0 |
| Fetal compromise | 40 | 40.0 | 40.0 | 100.0 |
| Total | 100 | | 100.0 | |

The distribution of fetal outcomes across the 100 cases under study is shown in the above table. Forty (40%) of the total fetuses had indications of fetal compromise, whereas 60 (60%) were determined to be healthy. This suggests that while a considerable percentage of pregnancies ended in fetal discomfort or problems, the majority of pregnancies had a normal completion. The results emphasize how crucial early discovery and observation are to enhancing fetal health outcomes.

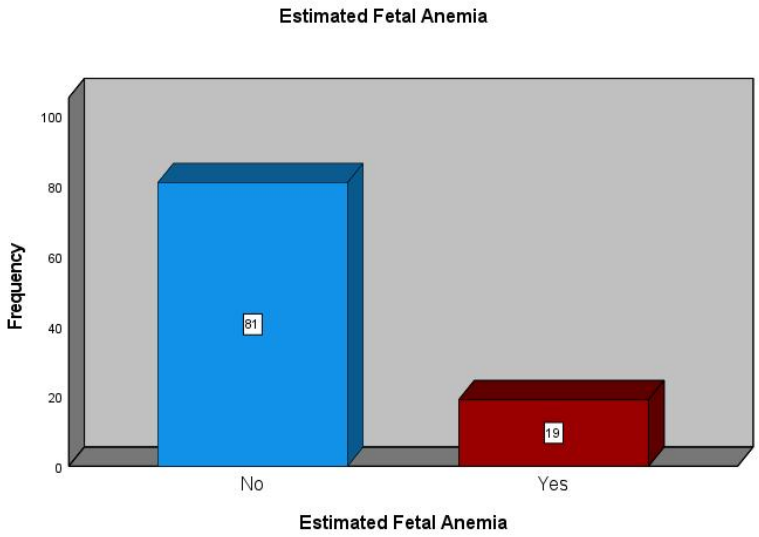


**Figure 4.2 Graphical representation of estimated fetal anemia**

**Table 4.2 : Frequency distribution of estimated fetal anemia**

| Estimated fetal anemia | Frequency (n) | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Yes | 19 | 19.0 | 19.0 | 19.0 |
| No | 81 | 81.0 | 81.0 | 100.0 |
| Total | 100 | 100 | 100.0 | |

The table shows data on the predicted fetal anemia in 100 cases. It indicates that 19 (19%) fetuses had fetal anemia, while the majority, 81 (81%), showed no indications of anemia. This suggests that fetal anemia occurred in a relatively small part of the studied sample, suggesting that most fetuses maintained normal hemoglobin levels during the examination.

**Table4.3: Frequency distribution of Anemic status**

| Anemic status | Frequency (n) | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| True | 50 | 50.0 | 50.0 | 50.0 |
| False | 50 | 50 | 50 | 100.0 |
| Total | 100 | 100 | 100.0 | |

The table shows the distribution of anemic status among 100 study participants. It indicates that 50 (50%) of the participants were actually anemic, whereas the remaining 50 (50%) were not anemic (false). This

reveals an equal distribution of anemia among the research population, suggesting that anemia is a fairly common illness in this group that requires additional investigation into its cause and clinical consequences.

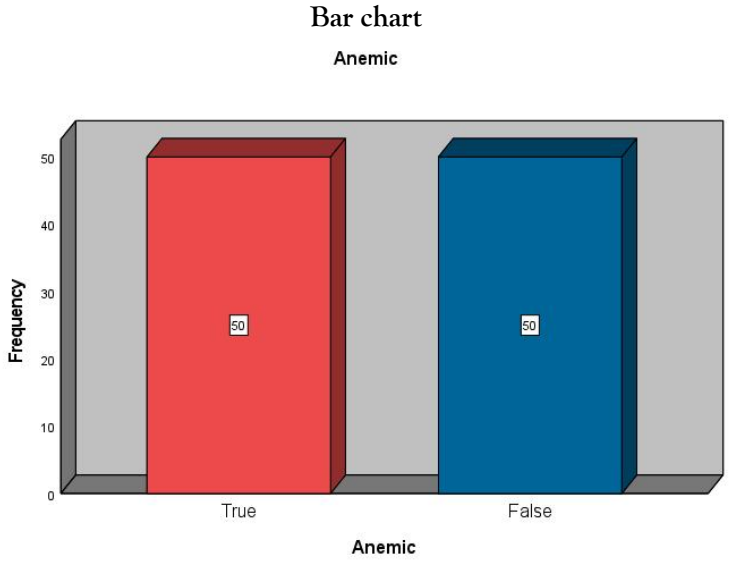


Figure 4.3 Graphical representation of anemic status of patients

Table 4.4 : Middle Cerebral Artery PI – Frequency Distribution

| PI Value | Frequency | Percent (%) | Valid Percent (%) | Cumulative Percent (%) |
|---|---|---|---|---|
| 0.50 | 01 | 1.0 | 1.0 | 1.0 |
| 0.51 | 01 | 1.0 | 1.0 | 2.0 |
| 0.52 | 02 | 2.0 | 2.0 | 4.0 |
| 0.53 | 01 | 1.0 | 1.0 | 5.0 |
| 0.58 | 01 | 1.0 | 1.0 | 6.0 |
| 0.59 | 01 | 1.0 | 1.0 | 7.0 |
| 0.60 | 01 | 1.0 | 1.0 | 8.0 |
| 0.65 | 01 | 1.0 | 1.0 | 9.0 |
| 0.68 | 01 | 1.0 | 1.0 | 10.0 |
| 0.73 | 01 | 1.0 | 1.0 | 11.0 |
| 0.75 | 01 | 1.0 | 1.0 | 12.0 |
| 0.79 | 02 | 2.0 | 2.0 | 14.0 |
| 1.10 | 03 | 3.0 | 3.0 | 17.0 |
| 1.11 | 03 | 3.0 | 3.0 | 20.0 |

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| | | | | |
|---|---|---|---|---|
| 1.12 | 04 | 4.0 | 4.0 | 24.0 |
| 1.14 | 07 | 7.0 | 7.0 | 31.0 |
| 1.15 | 01 | 1.0 | 1.0 | 32.0 |
| 1.16 | 02 | 2.0 | 2.0 | 34.0 |
| 1.17 | 03 | 3.0 | 3.0 | 37.0 |
| 1.18 | 03 | 3.0 | 3.0 | 40.0 |
| 1.20 | 02 | 2.0 | 2.0 | 42.0 |
| 1.21 | 02 | 2.0 | 2.0 | 44.0 |
| 1.22 | 01 | 1.0 | 1.0 | 45.0 |
| 1.23 | 05 | 5.0 | 5.0 | 50.0 |
| 1.24 | 04 | 4.0 | 4.0 | 54.0 |
| 1.25 | 04 | 4.0 | 4.0 | 58.0 |
| 1.26 | 01 | 1.0 | 1.0 | 59.0 |
| 1.27 | 01 | 1.0 | 1.0 | 60.0 |
| 1.28 | 02 | 2.0 | 2.0 | 62.0 |
| 1.29 | 03 | 3.0 | 3.0 | 65.0 |
| 1.31 | 03 | 3.0 | 3.0 | 68.0 |
| 1.32 | 02 | 2.0 | 2.0 | 70.0 |
| 1.33 | 05 | 5.0 | 5.0 | 75.0 |
| 1.34 | 01 | 1.0 | 1.0 | 76.0 |
| 1.35 | 02 | 2.0 | 2.0 | 78.0 |
| 1.36 | 01 | 1.0 | 1.0 | 79.0 |
| 1.37 | 05 | 5.0 | 5.0 | 84.0 |
| 1.38 | 04 | 4.0 | 4.0 | 88.0 |
| 1.39 | 01 | 1.0 | 1.0 | 89.0 |
| 1.40 | 01 | 1.0 | 1.0 | 90.0 |
| 1.42 | 02 | 2.0 | 2.0 | 92.0 |
| 1.44 | 02 | 2.0 | 2.0 | 94.0 |
| 1.45 | 01 | 1.0 | 1.0 | 95.0 |
| 1.46 | 02 | 2.0 | 2.0 | 97.0 |
| 1.47 | 01 | 1.0 | 1.0 | 98.0 |
| 1.49 | 02 | 2.0 | 2.0 | 100.0 |
| **Total** | **100** | **100.0** | **100.0** | |

The table shows the distribution of Pulsatility Index (PI) values among the 100 study participants. The PI values vary from 0.50 to 1.49, indicating variation among the group. Lower PI values (less than 1.0) were found in only a few of participants, indicating lower arterial resistance in a few cases. Most individuals had PI levels ranging from 1.10 to 1.49, indicating that the majority of cases are within the normal physiological

range. The most common PI readings were 1.14 (7%), 1.23 (5%), 1.33 (5%), and 1.37 (5%), showing that these values were typical across the study population. Overall, the data show an evident grouping of PI values around 1.1-1.4, which indicates essentially typical Doppler flow characteristics.

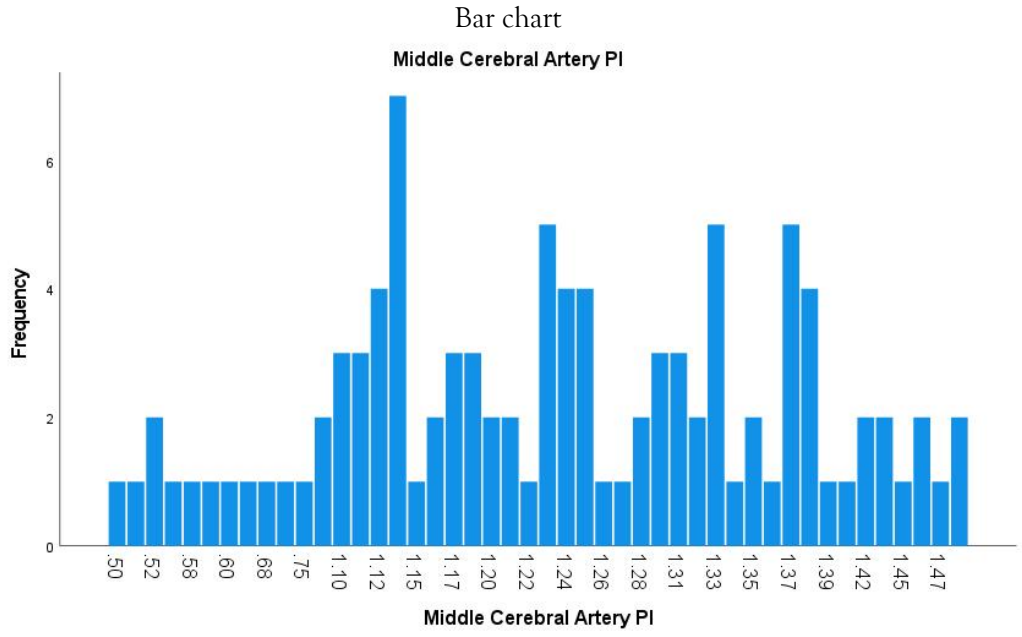


**Figure 4.4 Graphical representation of middle cerebral artery PI**

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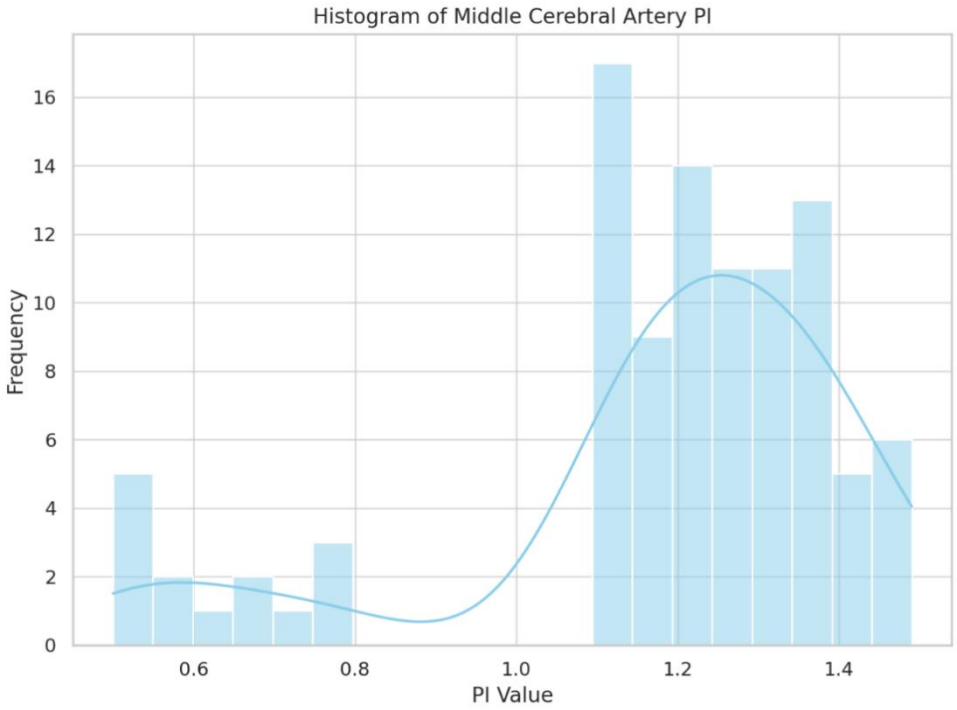


Figure 4.5 Histogram with mean and SD of middle cerebral artery PI

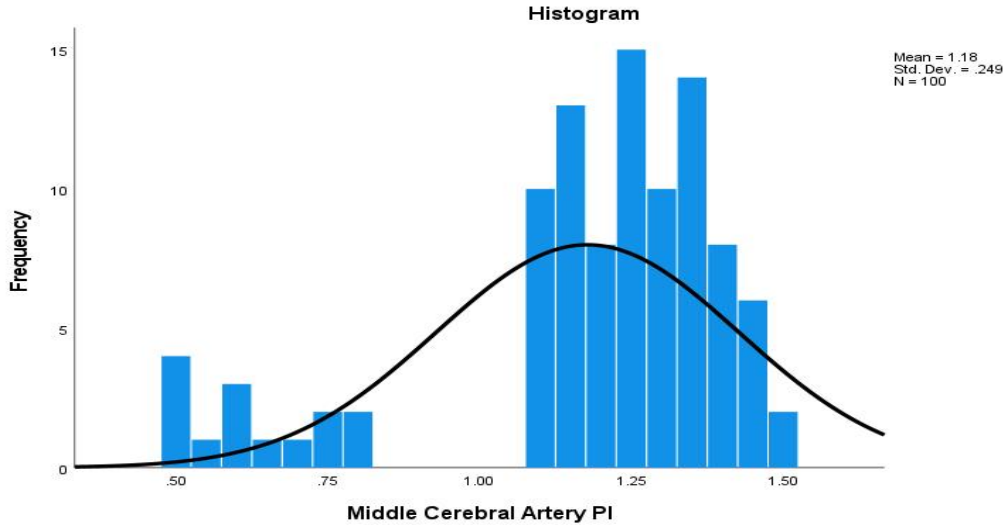


Figure 4.6 Graphical representation of MCA PI Mother

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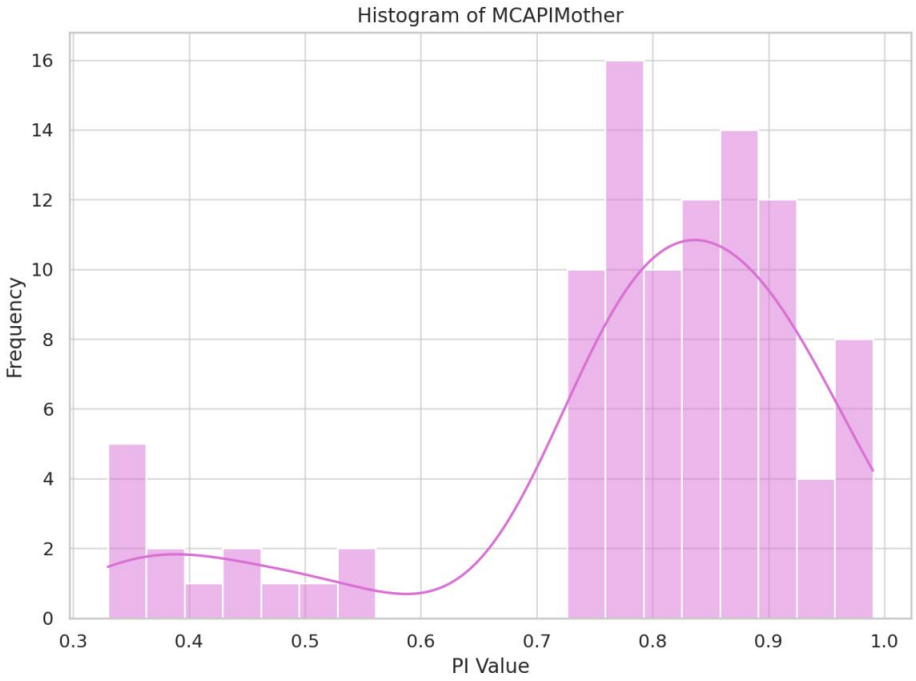
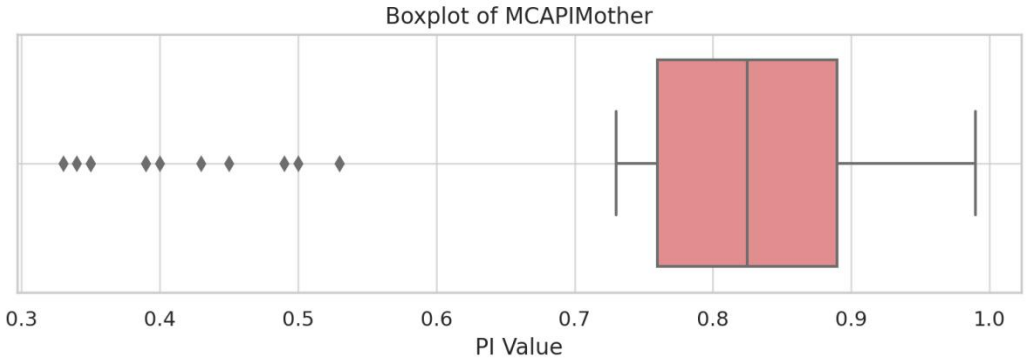



Boxplot



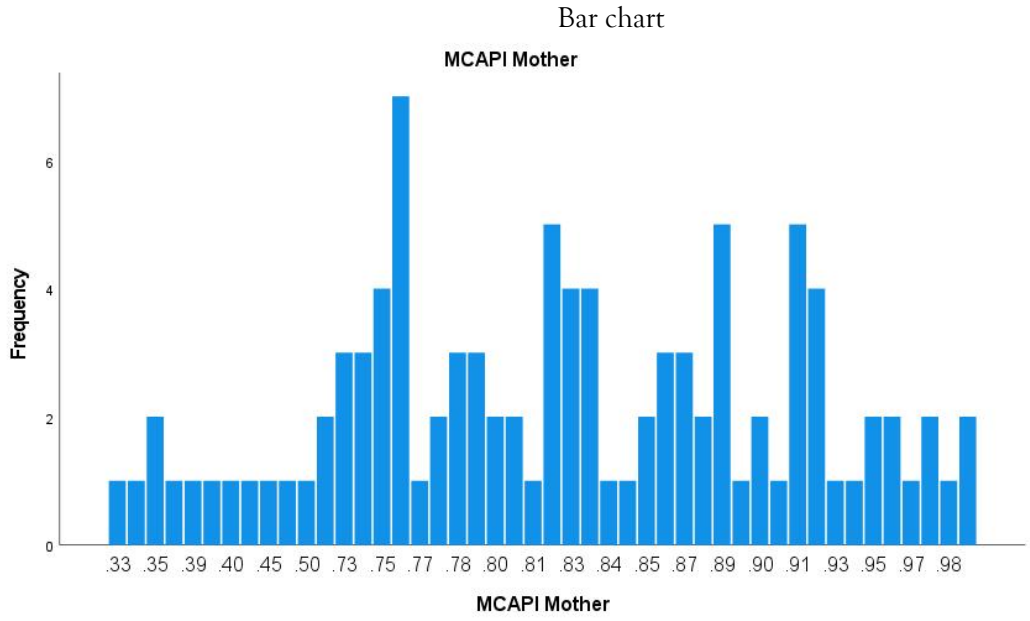



Figure 4.7 Graphical representation of histogram of MCA PI mother

Table 4.5 : MCAPI Mother – Frequency Distribution

| PI Value | Frequency | Percent (%) | Valid Percent (%) | Cumulative Percent (%) |
|---|---|---|---|---|
| 0.33 | 01 | 1.0 | 1.0 | 1.0 |
| 0.34 | 01 | 1.0 | 1.0 | 2.0 |
| 0.35 | 03 | 3.0 | 3.0 | 5.0 |
| 0.39 | 02 | 2.0 | 2.0 | 7.0 |
| 0.40 | 01 | 1.0 | 1.0 | 8.0 |
| 0.43 | 01 | 1.0 | 1.0 | 9.0 |
| 0.45 | 01 | 1.0 | 1.0 | 10.0 |
| 0.49 | 01 | 1.0 | 1.0 | 11.0 |
| 0.50 | 01 | 1.0 | 1.0 | 12.0 |
| 0.53 | 02 | 2.0 | 2.0 | 14.0 |
| 0.73 | 03 | 3.0 | 3.0 | 17.0 |
| 0.74 | 03 | 3.0 | 3.0 | 20.0 |
| 0.75 | 04 | 4.0 | 4.0 | 24.0 |
| 0.76 | 07 | 7.0 | 7.0 | 31.0 |
| 0.77 | 03 | 3.0 | 3.0 | 34.0 |

| | | | | |
|---|---|---|---|---|
| 0.78 | 03 | 3.0 | 3.0 | 37.0 |
| 0.79 | 03 | 3.0 | 3.0 | 40.0 |
| 0.80 | 02 | 2.0 | 2.0 | 42.0 |
| 0.81 | 03 | 3.0 | 3.0 | 45.0 |
| 0.82 | 05 | 5.0 | 5.0 | 50.0 |
| 0.83 | 08 | 8.0 | 8.0 | 58.0 |
| 0.84 | 01 | 1.0 | 1.0 | 59.0 |
| 0.85 | 03 | 3.0 | 3.0 | 62.0 |
| 0.86 | 03 | 3.0 | 3.0 | 65.0 |
| 0.87 | 03 | 3.0 | 3.0 | 68.0 |
| 0.88 | 02 | 2.0 | 2.0 | 70.0 |
| 0.89 | 06 | 6.0 | 6.0 | 76.0 |
| 0.90 | 02 | 2.0 | 2.0 | 78.0 |
| 0.91 | 06 | 6.0 | 6.0 | 84.0 |
| 0.92 | 04 | 4.0 | 4.0 | 88.0 |
| 0.93 | 02 | 2.0 | 2.0 | 90.0 |
| 0.95 | 02 | 2.0 | 2.0 | 92.0 |
| 0.96 | 02 | 2.0 | 2.0 | 94.0 |
| 0.97 | 03 | 3.0 | 3.0 | 97.0 |
| 0.98 | 01 | 1.0 | 1.0 | 98.0 |
| 0.99 | 02 | 2.0 | 2.0 | 100.0 |
| **Total** | **100** | **100.0** | **100.0** | |

The table shows the distribution of Pulsatility Index (PI) values among 100 study participants. The PI values range from 0.33 to 0.99, indicating variation in vascular resistance across the population. Most participants had PI values clustered between 0.70 and 0.95, suggesting that the majority fall within a normal range. The most frequently recorded PI value was 0.83 (8%), followed by 0.76 (7%), 0.89 (6%), and 0.91 (6%), showing a concentration around mid to higher normal limits. Only a few participants showed very low PI values below 0.50, indicating rare cases of reduced resistance. Overall, the data demonstrate a predominantly normal distribution of PI values, with mild variations among individuals.

**Table 4.6: Fetal anemia (MCAPI)**

| Fetal anemia (MCAPI) | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| No | 86 | 86.0% | 86.0% | 86.0% |
| Yes | 14 | 14.0% | 14.0% | 100.0% |
| **Total** | **100** | **100.0%** | **100.0%** | |

The table shows the distribution of fetal anemia (based on MCA PI levels) among 100 study participants. Out of the total, 86 (86%) fetuses had no signs of anemia, whereas 14 (14%) had fetal anemia. This shows

that the majority of fetuses had normal MCA PI levels, indicating adequate blood flow and oxygenation, whereas a smaller minority showed anemia. These findings highlight the value of MCA Doppler indicators for detecting fetuses at risk of anemia and providing appropriate medical treatment.

Pie chart

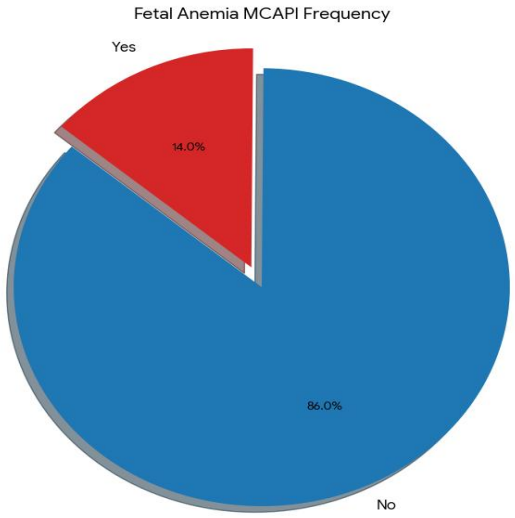



**Figure 4.8 Graphical representation of fetal anemia MCA PI**

Bar chart

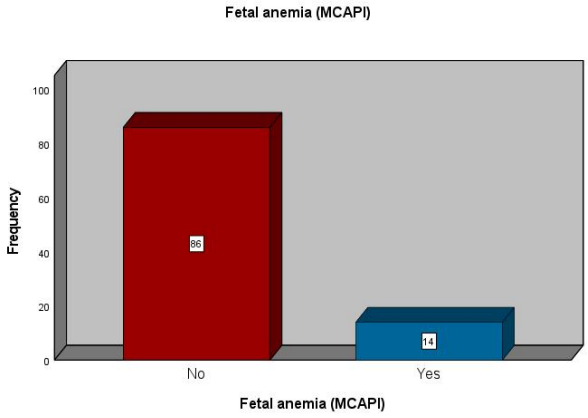



**Figure 4.9 Graphical representation of fetal anemia MCA PI**

Table 4.7 Cross tabulation b/w maternal anemia and fetal outcome

| Maternal Anemia | | | |
|---|---|---|---|
| **Fetal Outcome** | **Yes** | **No** | **Total** |
| **Healthy** | 14 | 45 | 59 |
| **Compromise** | 29 | 12 | 41 |
| **Total** | 43 | 57 | 100 |

The table shows the relationship between maternal anemia and fetal outcome for 100 study participants. Out of 43 anemic mothers, 14 (32.6%) had healthy babies, and 29 (67.4%) experienced fetal compromise. In comparison, of the 57 non-anemic moms, 45 (78.9%) had healthy babies, whereas only 12 (21.1%) suffered fetal impairment. These findings indicate a strong association between maternal anemia and poor fetal outcomes, indicating that anemia during pregnancy may considerably raise the likelihood of fetal distress or problems.

Bar chart

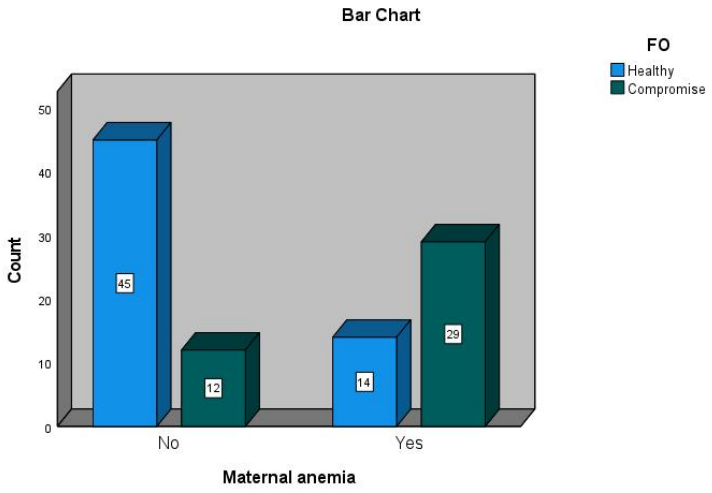



**Figure 4.10 Graphical representation of maternal anemia of patients**

**Table 4.8 Chi square test for fetal outcome and maternal anemia**

| Chi-Square Tests | | | |
|---|---|---|---|
| | **Value** | **df** | **Sig. (2-sided)** |
| Pearson Chi-Square | 21.804[a] | 1 | <0.001 |
| Likelihood Ratio | 22.435 | 1 | <0.001 |
| No. of Valid Cases | 100 | | |

The table shows the outcomes of Chi-square test to establish the relationship between maternal anemia and fetal outcome in 100 subjects. The Pearson Chi-square is 21.804, and the degree of freedom is 1, and the p-value (<0.001) value is highly significant value of the relationship between the two variables. This implies that maternal anemia plays a very important role in fetal outcome. This is to say that anemic mothers have a high likelihood of fetal compromise as opposed to non-anemic mothers. The outcome validates that maternal anemia is statistically significant in its negative influence on the health outcomes of the fetus.

**Table 4.9 Corelation analysis of fetal outcome and fetal anemia**

| | Value | Asymp. Std. Error[a] | Approx. T[b] | Approx. Sig. |
|---|---|---|---|---|
| Pearson's R | 0.467 | 0.089 | 5.227 | <0.001[c] |
| Spearman Correlation | 0.467 | 0.089 | 5.227 | <0.001[c] |
| N of Valid Cases | 100 | | | |

The table shows findings of a correlation study of fetal outcome and fetal anemia across 100 cases. The Pearson's correlation coefficient (r = 0.467) and Spearman correlation coefficient (r = 0.467) show a moderate positive association between the two variables. The correlation is statistically significant (p-value < 0.001). It shows that as the extent or occurrence of fetal anemia develops, so does the chance of a poor or fatal fetal outcome. In conclusion, the findings indicate that prenatal anemia is strongly associated with poor fetal outcomes.

**Symmetric Measures**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Interval by Interval | Pearson's R | .467 | .089 | 5.227 | <.001[c] |
| Ordinal by Ordinal | Spearman Correlation | .467 | .089 | 5.227 | <.001[c] |
| N of Valid Cases | | 100 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | 21.804[a] | 1 | <.001 | | |
| Continuity Correction[b] | 19.929 | 1 | <.001 | | |
| Likelihood Ratio | 22.435 | 1 | <.001 | | |
| Fisher's Exact Test | | | | <.001 | <.001 |
| Linear-by-Linear Association | 21.586 | 1 | <.001 | | |
| N of Valid Cases | 100 | | | | |

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.63.

b. Computed only for a 2x2 table

The table shows the outcomes of Chi-square test to establish the relationship between maternal anemia and fetal outcome in 100 subjects. The Pearson Chi-square is 21.804, and the degree of freedom is 1, and the p-value (<0.001) value is highly significant value of the relationship between the two variables. This implies that maternal anemia plays a very important role in fetal outcome. This is to say that anemic mothers have a high likelihood of fetal compromise as opposed to non-anemic mothers. The outcome validates that maternal anemia is statistically significant in its negative influence on the health outcomes of the fetus.

**Table 4.10: Cross tabulation between fetal anemia and maternal anemia**

| | | Maternal anemia | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Fetal anemia | Yes | 12 | 31 | 43 |
| | No | 07 | 50 | 57 |
| Total | | 43 | 57 | 100 |

The table shows the cross-tabulation of fetal and maternal anemia among 100 study participants. Of the 43 anemic mothers, 12 (27.9%) had fetuses with anemia, whereas 31 (72.1%) did not. In comparison, only 7 (12.3%) of 57 non-anemic mothers' fetuses had anemia, whereas 50 (87.7%) did not. These findings indicate that fetal anemia occurs more commonly when the mother is anemic, indicating a link between maternal anemia and fetal hematological condition. This highlights the significance of monitoring and controlling maternal anemia in order to minimize the risk of fetal anemia and associated problems.

**Maternalanemia * fetalanemia Crosstabulation**

Count

| | | fetalanemia | | |
|---|---|---|---|---|
| | | No | Yes | Total |
| Maternalanemia | No | 50 | 7 | 57 |
| | Yes | 31 | 12 | 43 |
| Total | | 81 | 19 | 100 |

Bar chart

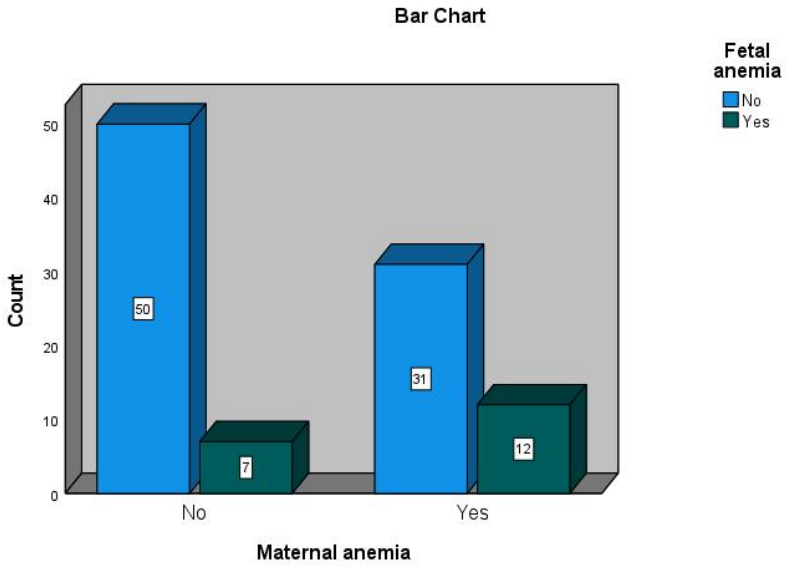



**Figure 4.10 Graphical representation of fetal anemia MCA PI**

**Chi square test for fetal anemia and maternal anemia**

| Chi-Square Tests | | | |
|---|---|---|---|
| | Value | df | Sig. (2-sided) |
| Pearson Chi-Square | 3.889[a] | 1 | 0.049 |
| Likelihood Ratio | 3.864 | 1 | 0.049 |
| No. of Valid Cases | 100 | | |

The following table shows the findings of the Chi-square test that was conducted to determine the relationship between maternal anemia and fetal anemia in 100 respondents. Pearson Chi-square= 3.889 and the degree of freedom=1 and p-value=0.049 which is below the 0.05 level. This means that there is a high correlation between maternal and fetal anemia. That is, fetuses of anemic mothers have a high probability of getting anemia than non-anemic mothers. These results indicate that maternal anemia can be a contributor or contributor to the occurrence of fetal anemia and hence the need to ensure that the levels of maternal hemoglobin levels are managed during pregnancy.

**Corelation analysis of fetal anemia and maternal anemia**

| | Value | Asymp. Std. Error[a] | Approx. T[b] | Approx. Sig. |
|---|---|---|---|---|
| Pearson's R | 0.197 | 0.099 | 1.991 | 0.049[c] |
| Spearman Correlation | 0.869 | 0.045 | 17.349 | 0.049[c] |
| N of Valid Cases | 100 | | | |

**Symmetric Measures**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Interval by Interval | Pearson's R | .197 | .099 | 1.991 | .049[c] |
| Ordinal by Ordinal | Spearman Correlation | .197 | .099 | 1.991 | .049[c] |
| N of Valid Cases | | 100 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | 3.889[a] | 1 | .049 | | |
| Continuity Correction[b] | 2.940 | 1 | .086 | | |
| Likelihood Ratio | 3.864 | 1 | .049 | | |
| Fisher's Exact Test | | | | .071 | .044 |
| Linear-by-Linear Association | 3.850 | 1 | .050 | | |
| N of Valid Cases | 100 | | | | |

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.17.

b. Computed only for a 2x2 table

Table 4.11 Cross tabulation between MCAPI and fetal anemia (MCAPI)

| Fetal Anemia (MCAPI) | | | |
|---|---|---|---|
| MCA PI | No | Yes | Total |
| 0.50 | 00 | 01 | 01 |
| 0.51 | 00 | 01 | 01 |
| 0.52 | 00 | 02 | 02 |
| 0.53 | 00 | 01 | 01 |
| 0.58 | 00 | 01 | 01 |
| 0.59 | 00 | 01 | 01 |
| 0.60 | 00 | 01 | 01 |
| 0.65 | 00 | 01 | 01 |
| 0.68 | 00 | 01 | 01 |
| 0.73 | 00 | 01 | 01 |
| 0.75 | 00 | 01 | 01 |
| 0.79 | 00 | 02 | 02 |
| 1.10 | 03 | 00 | 03 |
| 1.11 | 03 | 00 | 03 |
| 1.12 | 04 | 00 | 04 |
| 1.14 | 07 | 00 | 07 |
| 1.15 | 01 | 00 | 01 |
| 1.16 | 02 | 00 | 02 |

| | | | |
|---|---|---|---|
| 1.17 | 03 | 00 | 03 |
| 1.18 | 03 | 00 | 03 |
| 1.20 | 02 | 00 | 02 |
| 1.21 | 02 | 00 | 02 |
| 1.22 | 01 | 00 | 01 |
| 1.23 | 05 | 00 | 05 |
| 1.24 | 04 | 00 | 04 |
| 1.25 | 04 | 00 | 04 |
| 1.26 | 01 | 00 | 01 |
| 1.27 | 01 | 00 | 01 |
| 1.28 | 02 | 00 | 02 |
| 1.29 | 03 | 00 | 03 |
| 1.31 | 03 | 00 | 03 |
| 1.32 | 02 | 00 | 02 |
| 1.33 | 05 | 00 | 05 |
| 1.34 | 01 | 00 | 01 |
| 1.35 | 02 | 00 | 02 |
| 1.36 | 01 | 00 | 01 |
| 1.37 | 05 | 00 | 05 |
| 1.38 | 04 | 00 | 04 |
| 1.39 | 01 | 00 | 01 |
| 1.40 | 01 | 00 | 01 |
| 1.42 | 02 | 00 | 02 |
| 1.44 | 02 | 00 | 02 |
| 1.45 | 01 | 00 | 01 |
| 1.46 | 02 | 00 | 02 |
| 1.47 | 01 | 00 | 01 |
| 1.49 | 02 | 00 | 02 |
| **Total** | **86** | **14** | **100** |

The table shows a cross-tabulation of MCA PI levels and fetal anemia (based on MCA PI) in 100 study participants. It shows that lower MCA PI levels are primarily associated with cases of fetal anemia, whereas higher MCA PI values are seen in non-anemic fetuses. Fetuses with anemia had MCA PI values less than 0.80, but non-anemic fetuses often had values more than 1.0, indicating normal cerebral blood flow restriction. This inverse relationship indicates a drop in MCA PI value correlates to fetal anemia, indicating compensatory vasodilation in response to decreased oxygen-carrying capacity. Overall, the findings highlight the diagnostic utility of MCA Doppler indices (particularly PI values) for diagnosing and monitoring fetal anemia.

**Table 4.12: Chi square test for MCAPI and fetal anemia (MCAPI)**

| Test | Value | df | p-value (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 100.00[a] | 45 | <0.001 |
| Likelihood Ratio | 80.993 | 45 | <0.001 |
| Number of Valid Cases | 100 | | |

The table shows the results of the Chi-square test, which studied the association between MCA PI levels and fetal anemia (based on MCA PI) in 100 cases. The Pearson Chi-square value is 100.00 with 45 degrees of freedom, and the p-value (<0.001) shows a significant relationship between the two variables. This suggests that differences in MCA PI levels are highly related to the presence or absence of fetal anemia. Lower MCA PI levels correspond to anemic fetuses, whereas higher values are associated with non-anemic ones. These data show the MCA PI is a valid Doppler measure for diagnosing fetal anemia and may be utilized successfully in clinical monitoring of at-risk pregnancies.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 100.000[a] | 45 | <.001 |
| Likelihood Ratio | 80.993 | 45 | <.001 |
| Linear-by-Linear Association | 80.130 | 1 | <.001 |
| N of Valid Cases | 100 | | |

a. 91 cells (98.9%) have expected count less than 5. The minimum expected count is .14.

**Table 4.13 Corelation analysis of fetal anemia (MCAPI) and MCAPI**

| | Value | Asymp. Std. Error[a] | Approx. T[b] | Approx. Sig. |
|---|---|---|---|---|
| Pearson's R | -0.900 | 0.022 | -20.399 | <0.001[c] |
| Spearman Correlation | -0.601 | 0.062 | -7.451 | <0.001[c] |
| N of Valid Cases | 100 | | | |

The table shows the findings of a correlation study of fetal anemia (based on MCA PI) and MCA PI levels in 100 cases. The Pearson's correlation coefficient (r = -0.900) shows a strong negative connection, and the

p-value (<0.001) validates its statistical significance. Similarly, the Spearman correlation (r = -0.601) indicates a substantial negative relationship.

This indicates that when MCA PI levels fall, the likelihood and severity of fetal anemia rises. The significant inverse correlation reflects the physiological process of cerebral vasodilation in anemic fetuses, which reduces MCA PI levels by reducing vascular resistance. As a result, our data show that MCA PI is a very sensitive indication of fetal anemia in Doppler ultrasonography examinations.

**Symmetric Measures**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Interval by Interval | Pearson's R | -.900 | .022 | -20.399 | <.001[c] |
| Ordinal by Ordinal | Spearman Correlation | -.601 | .062 | -7.451 | <.001[c] |
| N of Valid Cases | | 100 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

**Table 4.14: Chi square test for MCAPI and MCAPI mother**

| Test | Value | df | p-value (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 4500.000[a] | 2025 | **<0.001** |
| Likelihood Ratio | 728.326 | 2025 | **1.000** |
| Number of Valid Cases | 100 | | |

The table shows the results of the Chi-square test, which investigated the relationship between fetal MCA PI and maternal MCA PI in 100 cases. The Pearson Chi-square value is 4500.000 with 2025 degrees of freedom, and the p-value (<0.001) shows a significant association between the two variables. This implies that variations in maternal MCA PI values are highly associated with changes in fetal MCA PI values, suggesting a potential physiological relationship between maternal and fetal circulatory dynamics.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 4500.000[a] | 2025 | <.001 |
| Likelihood Ratio | 728.326 | 2025 | 1.000 |
| Linear-by-Linear Association | 99.000 | 1 | <.001 |
| N of Valid Cases | 100 | | |

a. 2116 cells (100.0%) have expected count less than 5. The minimum expected count is .01.

Corelation analysis of mother MCAPI and MCAPI

| | Value | Asymp. Std. Error[a] | Approx. T[b] | Approx. Sig. |
|---|---|---|---|---|
| Pearson's R | 1.000 | 0.000 | 664,343 ,859.37 0 | <0.001[c] |
| Spearman Correlation | 1.000 | | | 0.000[c] |
| N of Valid Cases | 100 | | | |

**Symmetric Measures**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Interval by Interval | Pearson's R | 1.000 | .000 | 664343859.4 | .000[c] |
| Ordinal by Ordinal | Spearman Correlation | 1.000 | .000[c] | | |
| N of Valid Cases | | 100 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Table4.15: Mean comparison of maternal anemia and all doppler indices

| Doppler indices | | | | | |
|---|---|---|---|---|---|
| Maternal anemia | CPR | MCARI | MCAPI | UARI | UAPI |

| | | | | | | |
|---|---|---|---|---|---|---|
| No | Mean | 3.0000 | 2.2807 | 1.2346 | 2.7193 | 3.0000 |
| | SD | 1.4392 | 1.1611 | 0.1512 | 1.1611 | 1.4392 |
| | N | 57 | | | | |
| Yes | Mean | 3.0000 | 2.7907 | 1.1026 | 2.2093 | 3.0000 |
| | SD | 1.4142 | 1.0132 | 0.3256 | 1.0132 | 1.4142 |
| | N | 43 | | | | |
| Total | Mean | 3.0000 | 2.5000 | 1.1778 | 2.5000 | 3.0000 |
| | SD | 1.4213 | 1.1236 | 0.2494 | 1.1236 | 1.4213 |
| | N | 100 | | | | |

Mothers with anemia had a lower mean MCA PI (1.10 ± 0.33) than non-anemic mothers (1.23 ± 0.15), according to the mean Doppler index values. This suggests that fetuses of anemic mothers have less cerebral resistance. similarly, the anemic group's UARI (2.21 ± 1.01) was lower than that of the non-anemic group (2.72 ± 1.16), indicating that maternal anemia may be related to altered uterine artery flow. Other indices, such UAPI, MCARI, and CPR, however, revealed slight differences between the two groups. All things considered, our results suggest that maternal anemia may have a significant effect on fetal and uteroplacental blood flow, as seen by reduced MCA PI and UARI values.

**Table 4.16: Mean comparison of fetal anemia and all doppler indices**

| Doppler indices | | | | | | |
|---|---|---|---|---|---|---|
| Fetal anemia | | CPR | MCARI | MCAPI | UARI | UAPI |
| No | Mean | 3.0000 | 2.4600 | 1.1743 | 2.5400 | 3.0000 |
| | SD | 1.4285 | 1.1286 | 0.2386 | 1.1286 | 1.4286 |
| | N | 81 | | | | |
| Yes | Mean | 3.0000 | 2.5400 | 1.1926 | 2.4600 | 3.0000 |
| | SD | 1.4285 | 1.1286 | 0.2980 | 1.1286 | 1.4286 |
| | N | 19 | | | | |
| Total | Mean | 3.0000 | 2.5000 | 1.1778 | 2.5000 | 3.0000 |
| | SD | 1.4213 | 1.1236 | 0.2494 | 1.1236 | 1.4213 |
| | N | 100 | | | | |

The table shows the mean Doppler indices of fetuses with and without anemia in 100 study participants. The findings indicate that the mean values of the Cerebroplacental Ratio (CPR), Middle Cerebral Artery Resistance Index (MCARI), Middle Cerebral Artery Pulsatility Index (MCAPI), Uterine Artery Resistance Index (UARI), and Umbilical Artery Pulsatility Index (UAPI) are almost the same in both groups. The average MCAPI for fetuses without anemia was 1.17 ± 0.24, however those with anemia had 1.19 ± 0.30, indicating no significant difference. Other Doppler parameters, such as CPR (3.0) and UARI (2.54 vs. 2.46), remained comparable across the two groups.

**Table 4.17 : Mean comparison of fetal outcome and all doppler indices**

| Doppler indices | | | | | | |
|---|---|---|---|---|---|---|
| Fetal outcome | | CPR | MCARI | MCAPI | UARI | UAPI |
| Healthy | Mean | 3.7143 | 2.5000 | 1.1269 | 2.5000 | 2.286 |
| | SD | 1.0376 | 1.1131 | 0.1893 | 1.1131 | 1.0376 |
| | N | 59 | | | | |
| Compromise | Mean | 1.3333 | 2.5000 | 1.1215 | 2.5000 | 4.667 |
| | SD | 0.4794 | 1.1670 | 0.3107 | 1.1670 | 0.4795 |
| | N | 41 | | | | |
| Total | Mean | 3.0000 | 2.5000 | 1.1778 | 2.5000 | 3.0000 |
| | SD | 1.4213 | 1.1236 | 0.2494 | 1.1236 | 1.4213 |
| | N | 100 | | | | |

The study found that healthy fetuses had a greater mean Cerebroplacental Ratio (CPR = 3.71 ± 1.04) than those with poor outcomes (CPR = 1.33 ± 0.48). The mean MCAPI values were similar across healthy (1.13 ± 0.19) and impaired groups (1.12 ± 0.31), with no significant differences. Similarly, MCARI and UARI were comparable for both outcomes. However, the UAPI indicated a considerable difference lower in healthy babies (2.29) and much greater in impaired ones (4.67), showing increased umbilical artery resistance in fetuses with bad outcomes.

**Table 4.18 One sample t test**

| Group | Mean (MCAPI) | SD | N | t | df | Sig. (2-tailed) | Mean Difference | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|---|---|---|---|---|
| Maternal anemia – Yes | 1.1026 | 0.3256 | 43 | -1.525 | 42 | 0.135 | -0.0752 | -0.1756 | 0.0252 |
| Maternal anemia – No | 1.2346 | 0.1512 | 57 | 2.663 | 56 | 0.010* | 0.0568 | 0.0136 | 0.1000 |
| Fetal anemia – Yes | 1.1926 | 0.2980 | 19 | 0.218 | 18 | 0.830 | 0.0148 | -0.1241 | 0.1537 |
| Fetal anemia – No | 1.1743 | 0.2386 | 81 | -0.126 | 80 | 0.900 | -0.0035 | -0.0594 | 0.0524 |
| Fetal outcome – Healthy | 1.1269 | 0.1893 | 59 | -2.037 | 58 | 0.046* | -0.0509 | -0.1007 | -0.0010 |
| Fetal outcome – Compromise | 1.1215 | 0.3107 | 41 | -1.145 | 40 | 0.259 | -0.0563 | -0.1556 | 0.0430 |

Non-anemic women showed a significant difference ($p = 0.010$), with their mean MCAPI (1.23) being significantly higher than the reference value, indicating greater fetal cerebral circulation than predicted. The mean MCAPI (1.10) among anemic moms did not change significantly ($p = 0.135$), indicating a little decrease without statistical significance. For fetal anemia, neither anemic nor non-anemic groups varied significantly from the reference ($p > 0.05$), indicating that MCAPI remained mainly stable despite fetal anemia status. In terms of fetal outcome, healthy babies showed a significant drop in MCAPI ($p = 0.046$), showing that lower MCAPI levels were within normal physiological adaptation limits, but impaired fetuses showed no significant change ($p = 0.259$).

## DISCUSSION

This study evaluated the relationship between maternal anemia and fetal Doppler indices, including the middle cerebral artery pulsatility index (MCAPI), umbilical artery indices, and cerebroplacental ratio (CPR). Results showed a significant effect of maternal anemia on fetal Doppler values. Reduced MCAPI in anemic mothers reflected compensatory cerebral vasodilation to maintain fetal brain oxygenation. Maternal anemia was also linked to fetal anemia and adverse outcomes, such as fetal compromise.

The findings aligned with previous studies by Stefanović et al. (2005), Abdel-Megeed et al. (2019), and Abdel Samie et al. (2021), which all reported similar hemodynamic changes in fetuses of anemic mothers. These studies found increased umbilical artery resistance (UARI, UAPI) and decreased MCA indices (MCARI, MCAPI), indicating higher placental resistance and brain-sparing effects. The current research confirmed the same trend, showing a strong negative correlation between MCAPI and fetal anemia ($r = -0.900$, $p = 0.001$).

Compared to earlier studies, this research differed slightly in sample size, gestational age range, and scanning intervals, which may explain variations in findings such as amniotic fluid index changes or umbilical artery ratios. However, all studies consistently showed that maternal anemia reduces fetal oxygen supply, leading to compensatory changes in blood flow and influencing fetal well-being.

This study also demonstrated that non-anemic mothers had higher MCAPI values ($1.23 \pm 0.15$) than anemic mothers ($1.10 \pm 0.32$), supporting earlier results. Fetuses with higher MCAPI values had better outcomes, and the association between maternal anemia and poor fetal outcome was statistically significant ($\chi^2 = 21.804$, $p < 0.001$).

Overall, the research reinforces that Doppler ultrasound, particularly MCA and UA indices, serves as a reliable tool for detecting fetal adaptation to maternal anemia and predicting adverse outcomes.

## CONCLUSION:

The research finds that maternal iron deficiency anemia significantly influences fetal hemodynamics through altering Doppler indices. Decrease in MCAPI and CPR in anemic mothers indicates fetal cerebral vasodilation and a compensatory "brain-sparing effect" due to hypoxia. Elevated UAPI and UARI levels signify heightened placental resistance, and this means worse fetoplacental circulation. The diagnostic usefulness of MCA Doppler is evidenced by its strong association between fetal compromise and maternal anemia ($p < 0.001$) and negative correlation between MCAPI and fetal anemia ($r = -0.900$, $p < 0.001$). In general, Doppler assessment of CPR and MCA indices is a reliable, non-invasive tool for the diagnosis of fetal hypoxia, and early intervention of maternal anemia can improve perinatal outcomes.

## LIMITATIONS:

- The research employed a limited sample size (n = 100), which could prevent generalizability to larger populations.
- Since it was a cross-sectional study, serial Doppler alterations in pregnancy were not feasible to investigate.
- The study did not evaluate the severity or duration of maternal anemia, which could have influenced fetal hemodynamic responses.
- Follow-up after correction of anemia (e.g., post-treatment Doppler changes) was not considered, and this precluded estimation of reversibility.
- Those confounding factors like maternal diet, co-morbidities, and altitude were not fully accounted for.
- The majority of the study was based on ultrasound Doppler measurements, which did not have direct correlation with neonatal hematological findings after delivery.
- Inconsistent operator technique and equipment calibration may have affected Doppler measurements.

**RECOMMENDATIONS:**

- Regular screening for maternal iron deficiency anemia must be embraced under prenatal care to allow for early treatment and detection.
- Routine Doppler ultrasound scans, especially of the MCA, UA, and CPR, should be performed in anemic pregnancy to assess fetal well-being.
- Pregnant women must be advised on a healthy diet, iron intake, and strict iron treatment.
- Abnormal Doppler findings in high-risk pregnancies must be referred to specialist obstetric monitoring and immediate management.
- In order to reduce the risk of fetal complications, health-care programs must enhance maternal education and preventive anemia measures.
- Additional long-term trials are necessary to define reversibility of Doppler changes following maternal anemia correction and their effect on newborn outcomes.

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