

EVALUATION OF UMBILICAL ARTERY DOPPLER INDICES IN THIRD TRIMESTER MATERNAL ANEMIA AND ASSOCIATION WITH FETAL GROWTH RESTRICTION

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Abstract

Background: Maternal anemia is a common pregnancy complication that affects placental oxygen delivery and can disrupted fetoplacental circulation thereby exposing the fetus to the risk of fetal growth restriction. The Umbilical artery Doppler assessment is used to detect a change in the placental resistance during the third trimester because at that time the fetus is at its maximum oxygen demand. The correlation between the severity of anemia and changes observed in Doppler is significant in order to enhance fetal monitoring and determine the way interventions can be given in time.

Objective: To assess umbilical artery Doppler indices (PI, RI, S/D ratio) and EDF in third trimester anemic pregnancy and determine their correlation with fetal growth restriction.

Methods: Descriptive cross-sectional study was done to 111 anemic third-trimester pregnant women with non-probability purposive sampling technique. Maternal demographics, level of anemia, umbilical artery Doppler parameters, and fetal biometry were taken and anonymized according to proper ethical standards. The statistical analysis was conducted with SPSS 26.

Results: The participants had 31.5% mild, 66.7% moderate, and 1.8% severe cases of anemia. The severity of anemia was positively correlated with Doppler indices. Mild anemia recorded nearly normal mean values (PI 0.917, RI 0.568, S/D ratio 2.287), moderate anemia recorded slightly high mean values (PI 0.918, RI 0.59, S/D ratio 2.572), whereas severe anemia recorded high mean values (PI 1.440, RI 0.790, S/D ratio 4.740). In all the cases, end-diastolic flow was maintained. Severe anemia was related with high Doppler indices and fetal growth restriction.

Conclusion: Doppler indices increase with the severity of anemia, indicating that there is an increase in placental resistance. Extreme anemia is the primary manifestation in fetal growth restriction. Umbilical artery Doppler measurement is an effective screening method that may be applicable in the detection of at-risk pregnancy to utilize the method to conduct monitoring and take measures that

could lead to a better outcome.

INTRODUCTION

The health of the mother is very critical in the development of a fetus, given the fact that pregnancy requires a lot of physiological changes to accommodate the increasing metabolic and oxygen requirements. The fetus needs adequate maternal hemoglobin, cardiac output and uteroplacental perfusion to ensure proper oxygen and nutrient delivery [1]. The impaired functioning of these mechanisms disrupts the well-being of the fetus, predisposing them to preterm birth, low birth weight and fetal growth restriction [2]. Maternal anemia which is among the most common and preventable during the pregnancy is one of the leading causes of fetoplacental dysfunction [3].

Anemia in pregnancy is caused by a decrease of the red blood cell mass, a disruption of hemoglobin

production, nutritional deficiency or chronic illness. Reduction of hemoglobin decreases oxygen supply and changes the oxygen gradient between the mother and fetus [4]. The severity of anemia is commonly characterized as mild (10-10.9 g/dL), moderate (7.1-9.9 g/dL) and severe (less than 7 g/dL). Although mild anemia can be corrected by increased cardiac output and applicant vasodilation, gradual depletion of hemoglobin imposes physiological consequences on the fetoplacental block [5]. Moderate anemia causes an early placental hypoxia and an increase in vascular resistance, whereas severe anemia results in oxidative stress, endothelial dysfunction and microvascular stasis which results in providing inadequate nutrient supply to the placental tissue, which can greatly worsen the placental perfusion [6].

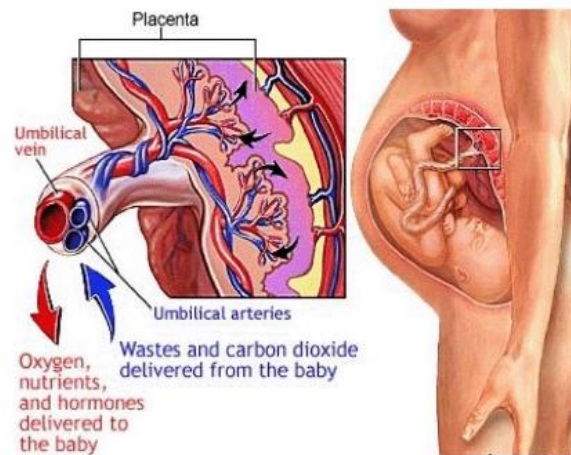


Illustration of Fetal Circulation Showing the Placenta, Umbilical Cord and Major Fetal Vessels [24]

Fetal Growth Restriction (FGR) is a condition in which a fetus fails to reach its genetic growth potential because of insufficient oxygen or nutrient supply and is characterized as the fetus with an estimated fetal weight below the 10th percentile of its gestational age [7]. Maternal anemia is also known to cause FGR because when there is chronic fetal hypoxia, the compensatory placental remodeling can overcome the impact of the hypoxia by temporarily supplying fetal perfusion. However, as the process of persistent hypoxia continues, placental resistance is

more likely to increase, due to this blood redistribution takes place and fetal development becomes more limited which eventually results in asymmetric FGR [8].

These hemodynamic changes need to be detected early on in order to avoid adverse effects. One of the important tools used in measuring fetoplacental hemodynamics is umbilical artery Doppler velocimetry [9]. Doppler imaging gives quantitative information on downstream placental resistance by measuring systolic/diastolic (S/D) ratio, resistive

index (RI), pulsatility index (PI) and end-diastolic flow (EDF). With the emergence of placenta insufficiency, PI, RI, and S/D ratios increase, and EDF might subside or revert with severe compromise. Such abnormalities may also be observed before FGR clinical manifestations, which makes Doppler especially important in pregnancies with maternal anemia [10]. Doppler monitoring is most important in the third trimester where fetal oxygen requirements are maximum and placenta reserves are decreasing [11]. Early warning of high resistance indices at this stage can help in intervention and possibly alleviate chances of severe growth retardation, preterm distress and still birth. Considering the overwhelming impact of maternal anemia, and its association with placental dysfunction, it is imperative that umbilical artery Doppler pattern may be examined to identify that fetoplacental compromises at an early stage [12].

The aim of this study is to determine the umbilical artery Doppler indices during the third trimester pregnancy with maternal anemia and its relation with fetal growth restriction. The evaluation of these parameters will give objective evidence on how anemia changes fetoplacental circulation and leads to a poor growth of the fetus. The results will not only help to overcome the issue of at-risk pregnancies but will be used to implement necessary interventions like closer monitoring, corticosteroid usage, or preplanned delivery. This study can eventually improve the practice of diagnosis, decrease adverse perinatal outcomes, and facilitate improved maternal and fetal health.

METHODOLOGY

The study was a descriptive cross-sectional study undertaken in the course of four months in Fatima Memorial Hospital, Lahore and involved 111 third trimester anemic pregnant mothers using non-probability purposive sampling. The inclusion criteria were 18-40 years old mothers who were in their third trimester with singleton pregnancies and with hemoglobin level <11 g/dL whereas those with multiple pregnancies, fetal defects, maternal chronic illnesses, and placental pathologies were excluded. Ethical approval and informed consent were used in the process of data collection. The maternal demographics, severity of anemia in the mothers,

umbilical Doppler parameters and fetal biometry were determined using a structured proforma. Doppler measurements were taken from a free-floating loop of umbilical cord, and the estimated weight of the fetus was computed based on the standard growth measurements. An EFW which was below the 10th percentile was considered fetal growth restriction. The analysis of data was conducted with the help of SPSS version 26. Clinical and Doppler variables were summarized using descriptive statistics. Two-way ANOVA and chi-square tests were applied to compare groups of anemia whereas Pearson correlation was used to measure association between Doppler indices and estimated fetal weight. A p-value of less than 0.05 was taken to indicate significance.

RESULTS

The study included 111 third-trimester anemic pregnant women. The maternal age was 21-40 years with a mean maternal age of 27.92 ± 4.45 years and mean gestational age of 32.70 ± 3.08 weeks at assessment. The majority of the participants were in the early-to-mid third trimester. In terms of anemia severity, 31.5% (n = 35) were mildly anemic, 66.7% (n = 74) were moderately anemic, and 1.8% (n = 2) were severely anemic. The weight of the fetus (EFW) was normal in 95.5% (106 fetuses) with mean value of 2167.71 ± 628.55 g whereas 4.5% (5 fetuses) had fetal weight below the 3rd percentile with mean value of 1349.40 ± 111.72 g, which represents severe fetal growth restriction (FGR). There are no fetuses with EFW below the 10th percentile. Among the participants, umbilical artery pulsatility index (PI) mean value is 0.927 ± 0.204 , umbilical artery resistive index (RI) mean value is 0.592 ± 0.078 and the mean value of umbilical artery systolic/diastolic (S/D) is 2.52 ± 0.53 . End-diastolic flow (EDF) in the umbilical artery was present in 100% of cases. There was a strong correlation between the severity of anemia and the fetal growth outcome (Pearson Chi-Square = 44.086, df = 2, p < 0.001). There was normal fetal growth in all the mildly anemic women. In moderate anemia, severe FGR was found in 3 of 74 fetuses (4.1%), but in both severe anemic women (100%), fetuses were found to have EFW below 3rd percentile. Doppler indices of umbilical arteries increased progressively with the severity of the

anemia. The average PI, RI and S/D ratio of mild anemia were 0.917 ± 0.239 , 0.568 ± 0.075 and 2.287 ± 0.309 respectively. Moderate anemia had slight enhancements in the values; PI 0.918 ± 0.170 , RI 0.597 ± 0.072 and S/D 2.572 ± 0.460 . There was a significant rise in severe anemia, where PI is 1.440, RI is 0.790 and S/D ratio is 4.740. In all cases, end-diastolic flow was maintained. One-way ANOVA supported statistical significance of the differences in Doppler indices between anemia groups; PI ($F = 7.152$, $df = 2$, 108 , $p = 0.001$), RI ($F = 9.432$, $df = 2$, 108 , $p < 0.001$), and S / D ratio ($F = 34.540$, $df = 2$, 108 , $p < 0.001$). The post-hoc test revealed that severe anemia compared with mild and moderate was significant in all Doppler parameters ($p < 0.001$), whereas, mild and moderate anemia were not significant in PI and RI but in S/D ratio ($p = 0.001$). The Pearson correlation analysis showed weak positive relationships between Doppler indices and

EFW in PI ($r = 0.215$, $p = 0.024$) and RI ($r = 0.241$, $p = 0.011$), and moderate correlation in S/D ratio ($r = 0.378$, $p < 0.001$). There were also high internal correlations between PI with RI ($r = 0.746$, $p < 0.001$) and PI with S/D ($r = 0.733$, $p < 0.001$), and between PI and RI with S/D ($r = 0.899$, $p < 0.001$). The fetuses were compared with normal growth and severe FGR in which the Doppler indices were high in the FGR group. In severe FGR, there was elevated PI (1.128 vs. 0.918; $p = 0.024$), RI (0.678 vs. 0.588; $p = 0.011$) and S/D ratio (3.436 vs. 2.478; $p < 0.001$), indicating raised fetoplacental resistance. On the whole, the results prove that as maternal anemia severity increases, the umbilical artery Doppler indices are significantly higher as well as the probability of severe fetal growth restriction. All results are shown in these tables.

Table No: 1 Anemia Levels and Fetal Growth Outcomes

Variable	Category	Frequency(n)	Percentage (%)
Anemia Level	Mild	35	31.5
	Moderate	74	66.7
	Severe	2	1.8
Fetal Growth Outcome (EFW)	Normal	106	95.5
	Severe FGR (<3rd percentile)	5	4.5
End-Diastolic Flow (EDF)	Present	111	100
Anemia Level × FGR	Mild with Normal EFW	35	31.5
	Moderate with Normal EFW	71	64.0
	Moderate with Severe FGR	3	2.7
	Severe with Severe FGR	2	1.8

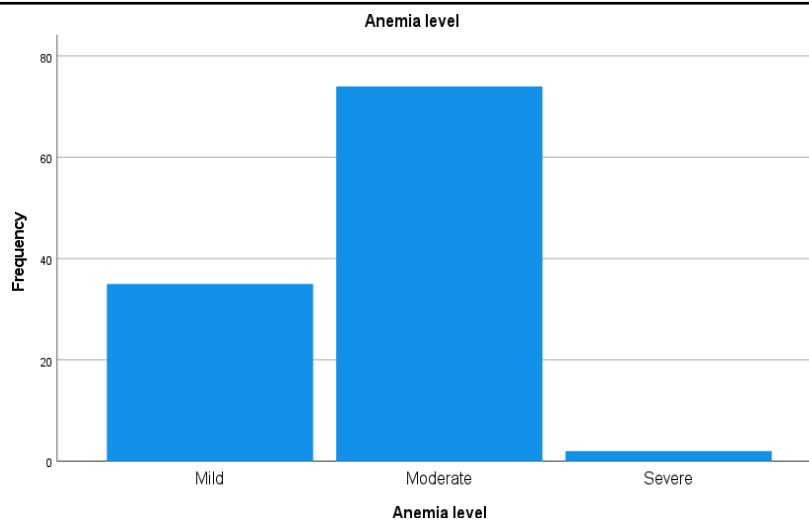


Figure No: 1 Anemia Levels Distribution Bar Graph

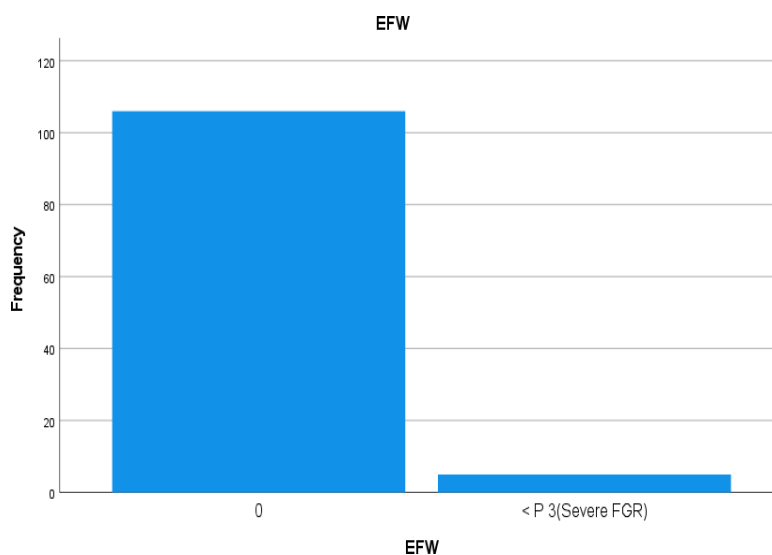


Figure No: 2 Estimated Fetal Weight Distribution Bar Graph

Table No 2: Chi-Square Tests between Anemia Level and Fetal Growth Outcome

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	44.086 ^a	2	.000
Likelihood Ratio	15.663	2	.000
N of Valid Cases	111		

Table No 3: Umbilical Artery Doppler Indices According to Maternal Anemia Severity

Variable	Anemia Severity	Mean	Standard Deviation
PI	Mild	0.9169	0.23885
	Moderate	0.9181	0.16984
	Severe	1.4400	0.00000
RI	Mild	0.5683	0.07528
	Moderate	0.5973	0.07221
	Severe	0.7900	0.00000
S/D Ratio	Mild	2.2871	0.30870
	Moderate	2.5719	0.46002
	Severe	4.7400	0.00000

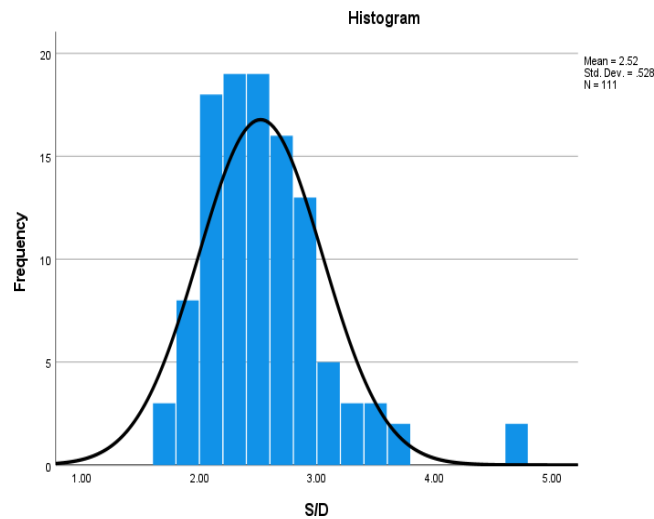


Figure No: 3 Umbilical Artery Systolic/Diastolic (S/D) Ratio Distribution Bar Graph

Table No 4: Maternal Anemia Severity in Relation to Umbilical Artery Doppler Indices and Fetal Growth Outcomes

Anemia Severity	PI (Mean)	RI (Mean)	S/D Ratio (Mean)	Normal EFW (n, %)	Severe FGR (n, %)
Mild (n = 35)	0.917	0.568	2.287	35 (100%)	0 (0%)
Moderate (n = 74)	0.918	0.597	2.572	71 (95.9%)	3 (4.1%)
Severe (n = 2)	1.440	0.790	4.740	0 (0%)	2 (100%)

DISCUSSION

Maternal anemia is one of the most common pregnancy complications and it affects the health of the mother and the fetus. Lowered hemoglobin levels restrict the supply of oxygen to the placenta

and fetus, which may change fetoplacental blood flow by compensatory or pathological processes. The Umbilical artery Doppler is a useful non-invasive method of assessing placental resistance, especially in the third trimester when fetal oxygen demand is maximum. The current research assessed the severity of anemia and its impact on umbilical artery Doppler

indices PI, RI, S/D ratio, and EDF and investigated their relationship with fetal growth restriction (FGR).

Participants were categorized into mild, moderate, and severe anemia groups. A progressive rise in Doppler indices across groups was observed, with significantly higher PI, RI, and S/D ratios in severe anemia. Only severe anemia was associated with FGR, suggesting that notable hemodynamic impairment must occur before growth restriction becomes evident. These findings align with Bosilah et al. (2021), who similarly demonstrated significant Doppler variations across anemia severity and corresponding changes in fetal biometry. Together, these results reinforce the concept that worsening anemia disrupts fetoplacental hemodynamics in a stepwise manner [13].

The near-normal Doppler values in mild and moderate anemia are consistent with studies by Agrawal et al. (2022) and Nawaz et al. (2025), which reported no significant deviations in PI, RI, or S/D ratios within these groups. Physiologically, mild and moderate anemia are often compensated through increased maternal cardiac output and placental vasodilation, thereby sustaining fetal oxygenation despite reduced hemoglobin. These mechanisms help to preserve the normal blood flow patterns, explaining the absence of FGR in these groups [14, 15]. A mild increase in the S/D ratio in moderate anemia, noted in this study, may indicate early vascular stress. This is parallel to the findings by Das et al. (2025), who described slight elevations in S/D ratio as an early adaptive response to declining oxygen tension. Such subtle changes suggest that moderate anemia represents a transitional phase, where compensatory mechanisms remain functional but may become strained as anemia progresses [16].

In contrast, severe anemia showed marked elevation of all these three Doppler indices, reflecting increased placental resistance. These results are consistent with Mostafa et al. (2023), who associated similar Doppler abnormalities with chronic hypoxia, endothelial dysfunction, and reduced villous perfusion [17]. Notably, EDF remained present in all cases, indicating partial rather than complete circulatory compromise. This aligns with Nazir et al. (2021), who emphasized that absent or reversed EDF appears only in advanced placental insufficiency [18].

The association between abnormal Doppler indices and FGR found in this study is well-supported by literature. Saleem et al. (2025) observed abnormal PI in all growth-restricted fetuses [19], while Singh et al. (2025) linked elevated S/D ratios with fetal distress and low birth weight [20]. Similar conclusions by Yin et al. (2021) and Adekanmi et al. (2022) confirm that elevated PI, RI, and S/D ratios reliably indicate impaired placental function and adverse outcomes. In this study, normal Doppler values and normal fetal weights in mild and moderate anemia reaffirm that these levels rarely compromise fetal growth. Conversely, severe anemia was consistently associated with elevated Doppler indices and FGR, highlighting the direct relationship between hemodynamic compromise and restricted growth [21, 22].

Tawfik et al. (2021) similarly found FGR only in severe anemia and proposed a threshold effect where placental compensation fails once hemoglobin drops below a critical level. The present findings support this concept, suggesting that severe anemia represents the point at which oxygen and nutrient supply become inadequate for normal fetal growth [23].

In general, this research shows that there is an obvious, gradual influence of maternal anemia on fetal-placental circulation. The mild and moderate anemia has remained relatively compensated, but there was persistently Doppler worsening of severe anemia and co-occurring FGR. These findings confirm the applicability of umbilical artery Doppler as a sensitive method of detecting the presence of circulatory restriction in anemic pregnancies.

CONCLUSION

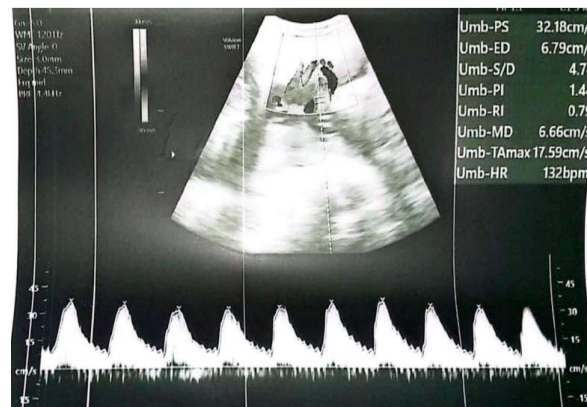
This research demonstrates that there is a severity dependent relationship between maternal anemia and fetoplacental circulation. Normal compensated Doppler values were observed in mild anemia and only minor increase in S/D ratio occurred in moderate anemia while severe anemia demonstrating the significantly increased PI, RI and S/D ratios although end-diastolic flow was normal and fetal growth restriction was only observed in severe anemia. This indicates that clinically significant placental resistance and growth retardation develop predominantly in the case of severe anemia. This reveals the importance of umbilical artery Doppler

indices as an early sign of hemodynamic distress during anemic pregnancies. It is suggested that further longitudinal and multi-center studies on the use of biochemical iron markers be done in the future to improve the accuracy of risk prediction and management.

Case 1:

There was a 25-year-old woman who came at 32 weeks of pregnancy with serious anemia (Hb 6.4 g/dL). The fetal weight was estimated at 1404 g by

ultrasound, which is below the 3rd percentile, which indicated severe fetal growth restriction. Umbilical artery Doppler showed significantly increased indices of PI 1.44, RI 0.79 and S/D 4.74 without impaired end-diastolic flow, which points to the increased placental resistance despite maintained forward flow. The given scan demonstrates the hemodynamic effect of severe anemia and the importance of Doppler in the process of identification of high-risk fetuses that need special attention.



Case 2:

The patient was a 21-year-old female had gestational age of 29 weeks with moderate anemia (Hb 9.2 g/dL) who had an estimated fetal weight of 1226g, which was within a normal range. Doppler assessment revealed a slight increase in the vascular indices; PI 1.1, RI 0.69, S/D 3.2), as well as maintained end-diastolic flow which signifies early stress of

vascularity but does not indicate any sharp stress within the fetoplacental compensation. This indicates that moderate anemia does not lead to growth impairment, but can have subtle Doppler changes which should be considered to use Doppler imaging to identify early changes of hemodynamics before clinical worsening.



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