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Original Research Article

Assessment of Third Trimester Fetal Doppler Parameters in Prediction of Adverse Perinatal Outcomes in High-Risk Pregnancies

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Abstract

Introduction: High-risk pregnancies are associated with increased risk of fetal compromise and adverse perinatal outcomes. Doppler velocimetry provides valuable information regarding fetoplacental circulation and may assist in early identification of pregnancies requiring intensified surveillance. This study was conducted to assess the role of third-trimester fetal Doppler parameters in predicting adverse perinatal outcomes among high-risk pregnancies.

Materials and Methods: A prospective observational study was conducted among 100 high-risk pregnant women undergoing third-trimester Doppler assessment between 28 and 40 weeks of gestation. Doppler parameters including umbilical artery (UA) pulsatility index (PI), middle cerebral artery (MCA) PI, cerebroplacental ratio (CPR), and uterine artery PI were evaluated. Participants were followed until delivery, and neonatal outcomes including birth weight, Apgar score, NICU admission, respiratory distress, and perinatal mortality were recorded. The association between Doppler abnormalities and adverse perinatal outcomes was analyzed. ROC curve analysis was performed to evaluate predictive accuracy.

Results: Adverse perinatal outcomes were observed in 37% of pregnancies. Abnormal UA Doppler was present in 26%, abnormal MCA Doppler in 21%, reduced CPR in 28%, and abnormal uterine artery PI in 19% of cases. Abnormal UA Doppler, MCA Doppler, and reduced CPR were significantly associated with adverse outcomes ($p<0.001$). CPR demonstrated the highest predictive performance with an AUC of 0.84, sensitivity of 78.4%, and specificity of 82.5%, followed by UA PI (AUC 0.78), MCA PI (AUC 0.76), and uterine artery PI (AUC 0.71).

Conclusion: Third-trimester fetal Doppler evaluation is an effective method for predicting adverse perinatal outcomes in high-risk pregnancies. Cerebroplacental ratio showed superior predictive ability compared with individual Doppler parameters and may serve as a useful marker for fetal compromise. Incorporation of Doppler surveillance can aid in timely decision-making and improve neonatal outcomes.

Keywords: Fetal Doppler, High-risk pregnancy, Umbilical artery Doppler, Middle cerebral artery, Cerebroplacental ratio, perinatal outcome, Placental insufficiency.

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Introduction

Identification of pregnancies at increased risk for adverse maternal and perinatal outcomes remains a key objective of obstetric care, as early recognition of fetal compromise allows timely surveillance, appropriate delivery planning, and improved neonatal outcomes [1]. High-risk pregnancies are associated with complications such as fetal growth restriction (FGR), hypertensive disorders, placental insufficiency, preterm birth, and increased perinatal morbidity and mortality. Despite advances in antenatal monitoring, accurate prediction of fetal compromise remains challenging, highlighting the need for reliable non-invasive assessment methods [2].Placental insufficiency is a major contributor to adverse perinatal outcomes. Impaired placental vascular development and reduced uteroplacental perfusion lead to increased vascular resistance, decreased oxygen transfer, and progressive fetal hypoxia. In response, the fetus develops adaptive circulatory redistribution, characterized by

preferential blood flow to vital organs, particularly the brain, known as the "brain-sparing effect" [3]. Detection of these hemodynamic changes provides important information regarding fetal well-being and impending compromise. Doppler velocimetry of fetal and placental circulation is an established non-invasive technique for evaluating fetal hemodynamics and predicting adverse outcomes in high-risk pregnancies [4].

Doppler parameters such as pulsatility index (PI), resistive index (RI), and systolic/diastolic ratio provide quantitative assessment of vascular resistance within the uteroplacental and fetoplacental circulation [5]. Umbilical artery (UA) Doppler reflects placental resistance, and abnormal findings including increased impedance, absent end-diastolic flow, or reversed end-diastolic flow are associated with placental dysfunction and increased risk of fetal morbidity and mortality [6].Middle cerebral artery (MCA) Doppler evaluates fetal adaptive responses to hypoxia.

A reduced MCA PI indicates cerebral vasodilatation due to redistribution of blood flow toward the fetal brain and suggests fetal compromise [7]. The cerebroplacental ratio (CPR), calculated as MCA PI divided by UA PI, combines information from fetal cerebral circulation and placental resistance and has been proposed as a useful predictor of adverse outcomes, particularly in late-onset FGR and high-risk pregnancies [8]. Uterine artery Doppler provides information regarding maternal placental perfusion and has been widely studied in pregnancies complicated by preeclampsia, FGR, and abnormal placentation. Increased uterine artery resistance and persistent diastolic notching indicate impaired trophoblastic invasion and increased risk of placental insufficiency [9,10]. Sciscione and Hayes reported that combining uterine artery PI with diastolic notching improves prediction of adverse pregnancy outcomes compared with individual parameters alone [11].

Although individual Doppler parameters demonstrate significant associations with adverse neonatal outcomes, their predictive value may vary according to gestational age, maternal risk factors, and underlying pathology [12].

Third-trimester Doppler assessment is particularly important because fetal deterioration may progress rapidly, and early detection of circulatory changes can assist in balancing risks of continued pregnancy against premature delivery. Compared with conventional surveillance methods, Doppler studies may identify fetal compromise before irreversible deterioration occurs [13]. Abnormal Doppler findings have been associated with increased risks of low birth weight, low Apgar scores, NICU admission, respiratory distress, and perinatal mortality [14]. Therefore, the present study, titled "Assessment of Third Trimester Fetal Doppler Parameters in Prediction of Adverse Perinatal Outcomes in High-Risk Pregnancies," was conducted to evaluate the association between Doppler abnormalities and adverse neonatal outcomes and to determine the predictive value of UA, MCA, CPR, and other Doppler indices for antenatal risk stratification and timely obstetric intervention.

Materials and Methods

The present study was conducted as a prospective observational study to assess the role of third-trimester fetal Doppler parameters in predicting adverse perinatal outcomes among high-risk pregnancies. The study was carried out in the Department of Obstetrics and Gynaecology at tertiary care centre

Study Setting and Duration: The study was conducted in the Department of Obstetrics and Gynaecology, ESIC Medical College, PGIMSR and Hospital, Kalaburagi, Karnataka, from February 2025 to December 2025.

Study Population: The study included pregnant women with high-risk pregnancies attending the antenatal outpatient department or admitted to the obstetric unit during the study period.

Eligible participants underwent third-trimester fetal Doppler assessment and were followed until delivery to evaluate maternal and neonatal outcomes.

Inclusion Criteria: Pregnant women fulfilling the following criteria were included:

- Singleton pregnancies with gestational age between 28 and 40 weeks.
- Pregnancies classified as high-risk due to maternal, fetal, or placental risk factors.
- Women willing to participate in the study and providing written informed consent.
- Pregnancies undergoing antenatal evaluation with fetal Doppler ultrasonography.

High-risk factors included hypertensive disorders of pregnancy, diabetes mellitus, fetal growth restriction, oligohydramnios, previous adverse obstetric history, maternal anemia, advanced maternal age, and other conditions associated with increased risk of adverse perinatal outcomes.

Exclusion Criteria: Pregnant women with the following conditions were excluded:

- Multiple gestation pregnancies.
- Major fetal congenital anomalies detected on ultrasonography.
- Intrauterine fetal demise at the time of recruitment.
- Pregnancies with uncertain gestational age.

- Women unwilling to participate or unable to complete follow-up.
- Cases with incomplete Doppler or perinatal outcome data.

Data Collection and Clinical Assessment: After obtaining written informed consent, detailed demographic and clinical information was recorded for each participant. Maternal characteristics including age, parity, gestational age, and associated high-risk factors were documented.

Relevant obstetric history, previous pregnancy outcomes, and medical disorders complicating pregnancy were noted. All participants underwent routine antenatal evaluation, including general physical examination, obstetric examination, and relevant laboratory investigations as per institutional protocol. Gestational age was confirmed using the last menstrual period and/or early pregnancy ultrasound records.

Ultrasound and Fetal Doppler Assessment: Third-trimester ultrasound and Doppler examinations were performed using a standardized protocol by trained radiologists/sonologists. Doppler assessment was performed with the mother in a semi-recumbent position to avoid vena caval compression.

The following Doppler parameters were assessed:

Umbilical Artery Doppler

Umbilical artery blood flow was evaluated by measuring:

- Pulsatility index (PI)
- Resistive index (RI)
- Systolic/diastolic (S/D) ratio
- Presence or absence of end-diastolic flow

Abnormal umbilical artery Doppler was defined as increased resistance indices, absent end-diastolic flow, or reversed end-diastolic flow according to gestational age-specific reference values.

Middle Cerebral Artery Doppler: Middle cerebral artery Doppler assessment was performed by measuring:

- MCA pulsatility index (PI)
- MCA resistive index (RI)
- Peak systolic velocity (when applicable)

Reduced MCA PI suggestive of cerebral redistribution was considered abnormal.

Cerebroplacental Ratio: The cerebroplacental ratio (CPR) was calculated as:

CPR = Middle cerebral artery PI / Umbilical artery PI

A reduced CPR below the recommended gestational age-specific cutoff was considered indicative of increased fetal risk.

Uterine Artery Doppler

Uterine artery Doppler parameters were assessed, including:

- Pulsatility index (PI)
- Resistive index (RI)
- Presence of early diastolic notch

Abnormal uterine artery Doppler findings were recorded as evidence of impaired uteroplacental circulation.

Follow-Up and Assessment of Perinatal Outcomes: All enrolled women were followed until delivery. Mode and timing of delivery were documented based on obstetric indications and fetal condition. Neonatal outcomes were assessed after delivery, including:

- Birth weight
- Apgar score at 1 and 5 minutes
- Admission to neonatal intensive care unit (NICU)
- Requirement of respiratory support
- Perinatal morbidity and mortality

Adverse perinatal outcome was defined as the occurrence of one or more unfavorable neonatal outcomes, including low birth weight, low Apgar score, NICU admission, respiratory distress, or perinatal death.

Outcome Measures: The primary outcome of the study was to determine the association between abnormal third-trimester fetal Doppler parameters and adverse perinatal outcomes.

Secondary outcomes included evaluation of the predictive ability of individual Doppler parameters, including:

- Umbilical artery PI, RI, and S/D ratio
- Middle cerebral artery PI
- Cerebroplacental ratio
- Uterine artery Doppler indices

Statistical Analysis: Data collected were entered into a Microsoft Excel sheet and analyzed using SPSS, 27. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range, while categorical variables were presented as frequency and percentage. The association between Doppler parameters and adverse perinatal outcomes was assessed using appropriate statistical tests. The chi-square test or Fisher's exact test was applied for categorical variables, and Student's t-test or Mann–Whitney U test was used for continuous variables as appropriate. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive accuracy of Doppler parameters for adverse perinatal outcomes.

Sensitivity, specificity, positive predictive value, negative predictive value, and area under the curve (AUC) were calculated wherever applicable. A p-value of <0.05 was considered statistically significant.

Results

A total of 100 high-risk pregnant women undergoing third-trimester fetal Doppler assessment were included in the present study. The demographic profile, maternal risk factors, Doppler findings, and neonatal outcomes were analyzed to determine the predictive value of Doppler parameters for adverse perinatal outcomes.

The mean maternal age of the study participants was 28.6 ± 4.7 years. The majority of women belonged to the age group of 21–30 years (68%), followed by women aged >30 years (24%) and ≤20 years (8%).

Regarding parity, 54% were multigravida, while 46% were primigravida. The mean gestational age at the time of Doppler assessment was 33.8 ± 2.6 weeks, with most participants undergoing assessment between 33–36 weeks of gestation (48%), followed by 28–32 weeks (34%) and ≥37 weeks (18%) (Table 1).

Among the various high-risk conditions, hypertensive disorders of pregnancy were the most common risk factor observed in 32% of cases, followed by fetal growth restriction (FGR) in 28% and maternal anemia in 22%.

Oligohydramnios was present in 18% of women, while previous adverse obstetric history and gestational diabetes mellitus were observed in 15% and 12% of cases, respectively. Advanced maternal age (>35 years) was present in 9% of participants. Multiple high-risk factors were present in 36% of pregnancies (Table 2). The distribution of different high-risk factors among study participants is illustrated in Figure 1.

Assessment of third-trimester Doppler parameters revealed abnormal umbilical artery pulsatility index (PI) in 24% of cases, while abnormal umbilical artery resistance index (RI) and S/D ratio were observed in 22% and 26%, respectively. Absent or reversed end-diastolic flow was detected in 6% of pregnancies. Abnormal middle cerebral artery (MCA) PI was observed in 21% of cases. Reduced cerebroplacental ratio (CPR), indicating impaired fetal hemodynamic adaptation, was present in 28% of pregnancies. Abnormal uterine artery PI and persistent diastolic notch were noted in 19% and 16% of participants, respectively (Table 3). The distribution of normal and abnormal Doppler parameters is presented in Figure 2.

The relationship between abnormal Doppler findings and adverse perinatal outcomes was evaluated. Among women with abnormal umbilical artery Doppler findings, 19 out of 26 cases (73.1%) developed adverse perinatal outcomes compared with 18 out of 74 cases (24.3%) with normal umbilical artery Doppler findings (p<0.001).

Similarly, adverse outcomes were significantly higher among pregnancies with abnormal MCA Doppler (71.4% vs 27.8%, p<0.001). Reduced CPR was strongly associated with adverse outcomes, with 75.0% of women with reduced CPR developing adverse outcomes compared with 22.2% among those with normal CPR values (p<0.001) (Table 4).

The mean birth weight among neonates was 2540 ± 520 g. Low birth weight (<2500 g) was observed in 42% of neonates. An Apgar score <7 at 5 minutes was recorded in 14% of cases. NICU admission was required in 32% of neonates, while respiratory distress requiring support occurred in 18%. Neonatal sepsis was observed in 9%, and perinatal mortality occurred in 4% of cases. Overall, 37% of pregnancies resulted in adverse perinatal outcomes (Table 5).

ROC curve analysis was performed to assess the predictive ability of individual Doppler parameters for adverse perinatal outcomes.

Among all parameters, the cerebroplacental ratio demonstrated the highest predictive performance, with an area under the curve (AUC) of 0.84, sensitivity of 78.4%, specificity of 82.5%, PPV of 73.7%, and NPV of 85.7%.

Umbilical artery PI showed an AUC of 0.78, with sensitivity and specificity of 73.0% and 76.2%, respectively. MCA PI demonstrated an AUC of 0.76, whereas uterine artery PI showed comparatively lower predictive accuracy with an AUC of 0.71 (Table 6).

The comparative ROC curve demonstrating the predictive performance of different Doppler parameters is shown in Figure 3.

Overall, reduced CPR and abnormal fetoplacental Doppler parameters demonstrated significant association with adverse perinatal outcomes, highlighting their clinical utility in antenatal risk assessment among high-risk pregnancies.

Table 1: Demographic and Obstetric Characteristics of Study Participants (n=100)

Parameter	Findings
Maternal age (years), Mean ± SD	28.6 ± 4.7
Age group, n (%)	
≤20 years	8 (8%)
21–30 years	68 (68%)
>30 years	24 (24%)
Parity, n (%)	
Primigravida	46 (46%)
Multigravida	54 (54%)
Gestational age at Doppler assessment (weeks), Mean ± SD	33.8 ± 2.6
28–32 weeks	34 (34%)
33–36 weeks	48 (48%)
≥37 weeks	18 (18%)

Table 2: Distribution of High-Risk Factors among Study Participants (n=100)

High-risk factor	n (%)
Hypertensive disorders of pregnancy	32 (32%)
Fetal growth restriction (FGR)	28 (28%)
Oligohydramnios	18 (18%)
Gestational diabetes mellitus	12 (12%)
Previous adverse obstetric history	15 (15%)
Maternal anemia	22 (22%)
Advanced maternal age (>35 years)	9 (9%)
Multiple risk factors present	36 (36%)

Note: Some participants had more than one high-risk factor.

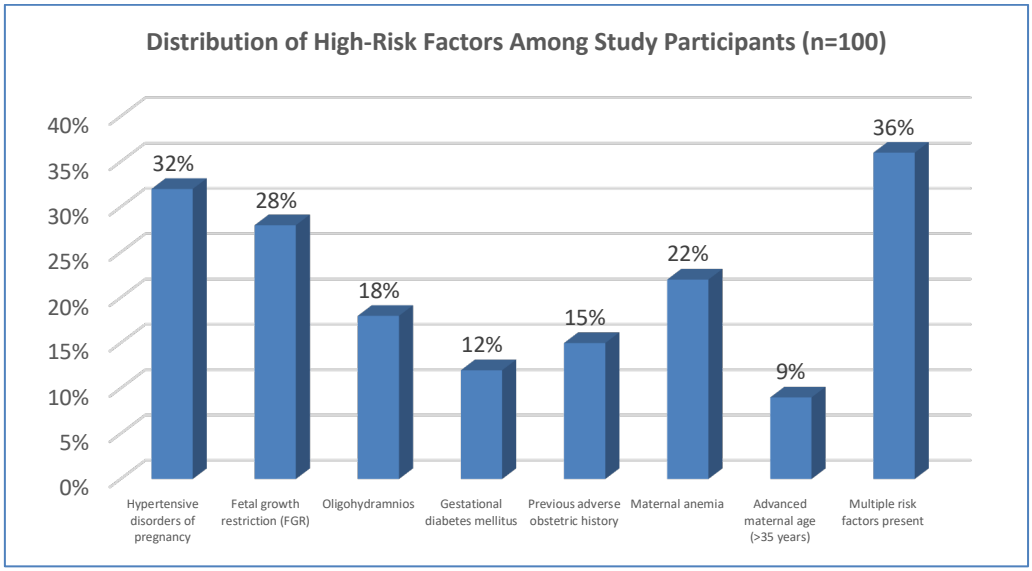

Figure 1: Distribution of High-Risk Factors among Study Participants (n=100)

Table 3: Third Trimester Fetal Doppler Findings among Study Participants (n=100)

Doppler parameter	Normal n (%)	Abnormal n (%)
Umbilical artery PI	76 (76%)	24 (24%)
Umbilical artery RI	78 (78%)	22 (22%)
Umbilical artery S/D ratio	74 (74%)	26 (26%)
Absent/reversed end-diastolic flow	94 (94%)	6 (6%)
Middle cerebral artery PI	79 (79%)	21 (21%)
Cerebroplacental ratio (CPR)	72 (72%)	28 (28%)
Uterine artery PI	81 (81%)	19 (19%)
Uterine artery diastolic notch	84 (84%)	16 (16%)

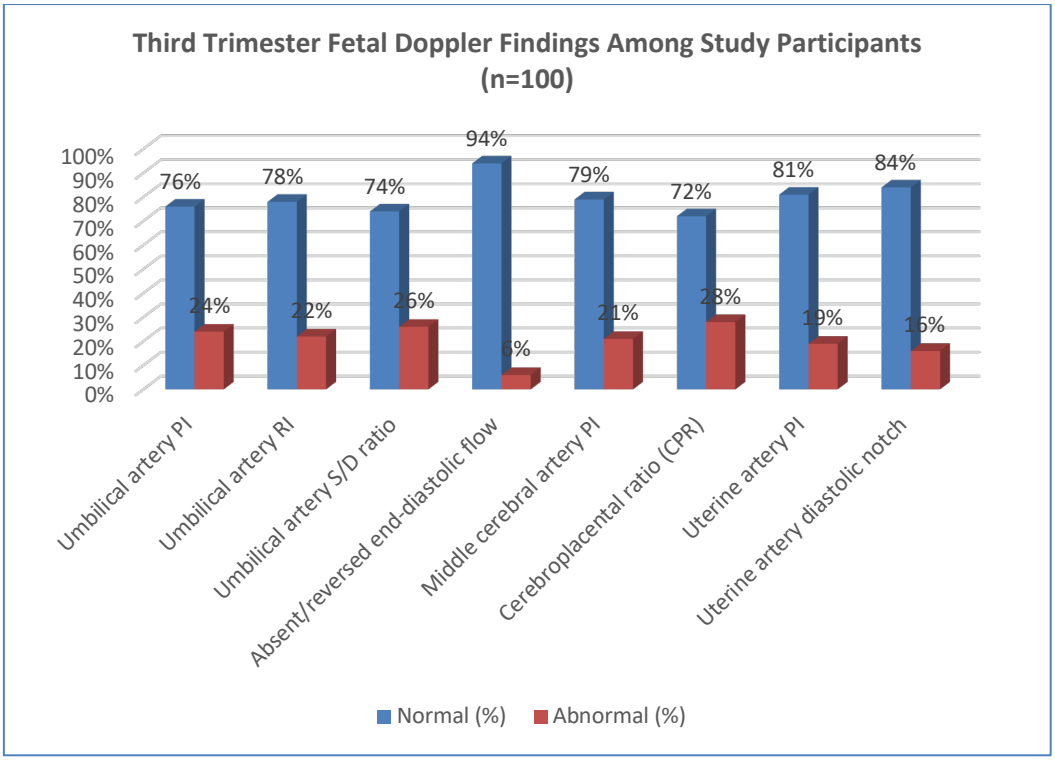

Figure 2: Third Trimester Fetal Doppler Findings among Study Participants (n=100)

Table 4: Association between Doppler Abnormalities and Adverse Perinatal Outcomes (n=100)

Doppler finding	Adverse outcome present n (%)	Adverse outcome absent n (%)	p-value
Abnormal Umbilical artery Doppler (n=26)	19 (73.1%)	7 (26.9%)	<0.001
Normal Umbilical artery Doppler (n=74)	18 (24.3%)	56 (75.7%)	
Abnormal MCA Doppler (n=21)	15 (71.4%)	6 (28.6%)	<0.001
Normal MCA Doppler (n=79)	22 (27.8%)	57 (72.2%)	
Reduced CPR (n=28)	21 (75.0%)	7 (25.0%)	<0.001
Normal CPR (n=72)	16 (22.2%)	56 (77.8%)	

Table 5: Neonatal Outcomes among Study Participants (n=100)

Neonatal outcome	n (%)
Birth weight (g), Mean ± SD	2540 ± 520
Low birth weight (<2500 g)	42 (42%)
Apgar score at 5 min <7	14 (14%)
NICU admission	32 (32%)
Respiratory distress requiring support	18 (18%)
Neonatal sepsis	9 (9%)
Perinatal mortality	4 (4%)
Overall adverse perinatal outcome	37 (37%)

Table 6: Predictive Performance of Doppler Parameters for Adverse Perinatal Outcomes

Doppler parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC
Umbilical artery PI	73.0	76.2	61.5	84.2	0.78
Middle cerebral artery PI	70.3	78.1	66.7	81.0	0.76
Cerebroplacental ratio	78.4	82.5	73.7	85.7	0.84
Uterine artery PI	56.8	80.9	62.5	76.9	0.71

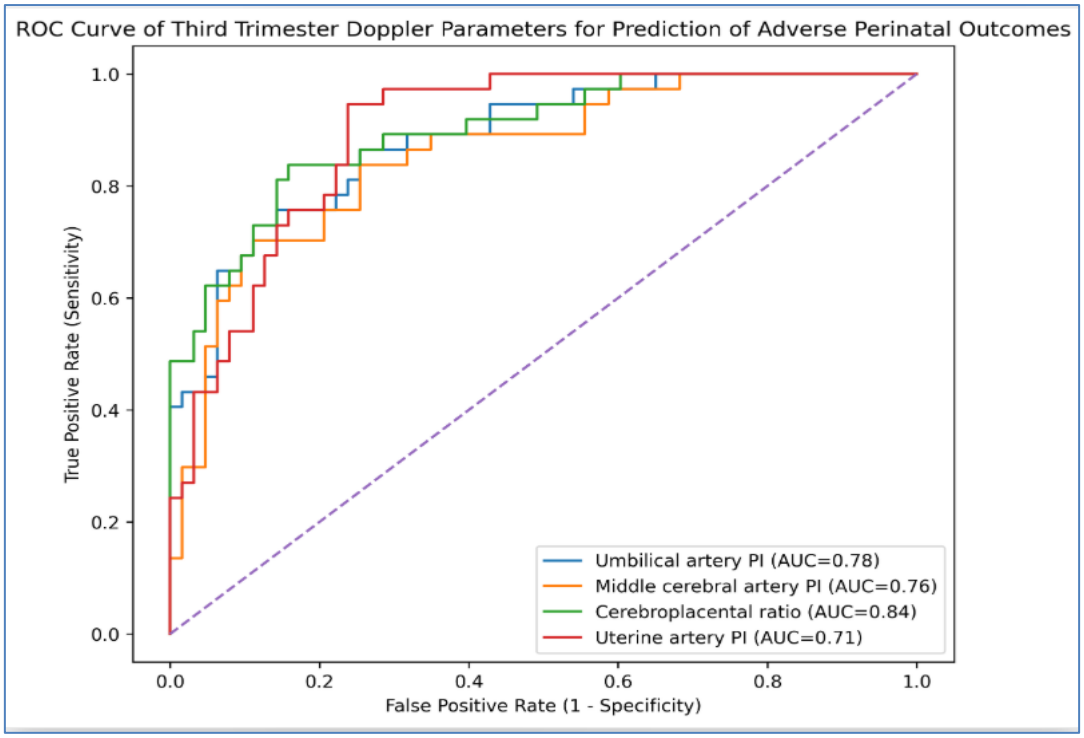

Figure 3: Predictive Performance of Doppler Parameters for Adverse Perinatal Outcomes

Discussion

The present prospective observational study evaluated the role of third-trimester fetal Doppler parameters in predicting adverse perinatal outcomes among 100 high-risk pregnancies. In this study, 37% of pregnancies developed adverse perinatal outcomes, and abnormal Doppler findings, particularly abnormal umbilical artery (UA) Doppler, middle cerebral artery (MCA) Doppler, and reduced cerebroplacental ratio (CPR), were significantly associated with poor neonatal outcomes. CPR showed the highest predictive performance with an AUC of 0.84, sensitivity of 78.4%, and specificity of 82.5%, followed by UA PI (AUC 0.78), MCA PI (AUC 0.76), and uterine artery PI (AUC 0.71).

Hypertensive disorders of pregnancy (32%) were the most common high-risk factor in the present study, followed by fetal growth restriction (28%) and maternal anemia (22%). These conditions are associated with abnormal placentation, increased fetoplacental vascular resistance, and impaired oxygen transfer, resulting in fetal adaptive changes detectable by Doppler velocimetry. Kant et al. (2016)[13] similarly demonstrated that abnormal Doppler indices in high-risk pregnancies were associated with increased adverse perinatal outcomes and highlighted the importance of CPR assessment in identifying compromised fetuses. Abnormal UA Doppler was observed in 26% of cases and showed a significant association with adverse outcomes (73.1% vs 24.3%, p<0.001). UA PI demonstrated an AUC of 0.78 with 73.0% sensitivity and 76.2% specificity, indicating its usefulness in detecting increased placental resistance. These findings are consistent with Heidweiller-Schreurs et al. (2018)[14], who reported that UA Doppler provides important prognostic information in fetal growth restriction and that combining placental and cerebral circulation parameters may improve prediction accuracy. MCA Doppler abnormalities were present in 21% of pregnancies and were significantly associated with adverse outcomes (71.4% vs 27.8%, p<0.001). MCA PI showed an AUC of 0.76, sensitivity of 70.3%, and specificity of 78.1%. Reduced MCA PI reflects cerebral vasodilatation due to fetal brain-sparing adaptation secondary to chronic hypoxia. Sharbaf et al. (2018)[15] similarly reported that abnormal MCA Doppler parameters were associated with adverse outcomes, particularly in growth-restricted pregnancies, and emphasized the benefit of combining MCA and UA measurements. Reduced CPR was observed in 28% of pregnancies and showed the strongest association with adverse outcomes (75.0% vs 22.2%, p<0.001). CPR demonstrated superior predictive ability with an AUC of 0.84, sensitivity of 78.4%, specificity of 82.5%, PPV of 73.7%, and NPV of 85.7%. This improved performance may be explained by its combined evaluation of placental resistance and fetal circulatory adaptation. Malik et al. (2023)[16] reported similar findings, demonstrating a significant association between abnormal CPR and adverse perinatal outcomes. Conde-Agudelo et al. (2018) [17] also concluded that CPR provides

clinically relevant predictive information, particularly in pregnancies complicated by placental insufficiency and fetal growth restriction. However, Heidweiller-Schreurs et al. (2020)[14] reported variable incremental value of CPR beyond UA Doppler, which may be due to differences in gestational age, population characteristics, and inclusion criteria.

Uterine artery PI abnormalities were observed in 19% of pregnancies and showed moderate predictive ability (AUC 0.71, sensitivity 56.8%, specificity 80.9%). Although less predictive than fetal Doppler parameters, uterine artery Doppler reflects impaired maternal placental circulation and abnormal placentation. Sciscione and Hayes reported that uterine artery Doppler provides better prediction when combined with other Doppler indices rather than used alone.

In the present study, low birth weight occurred in 42%, NICU admission in 32%, respiratory distress in 18%, and overall adverse perinatal outcomes in 37% of neonates, emphasizing the clinical importance of antenatal Doppler surveillance. Early identification of fetuses at risk allows timely interventions, including intensified monitoring, corticosteroid administration when indicated, neonatal care planning, and appropriate timing of delivery.

Conclusion

Third-trimester fetal Doppler assessment was found to be a valuable non-invasive tool for predicting adverse perinatal outcomes in high-risk pregnancies. Abnormal umbilical artery Doppler, middle cerebral artery Doppler, and reduced cerebroplacental ratio were significantly associated with increased neonatal morbidity. Among the evaluated parameters, the cerebroplacental ratio demonstrated the highest predictive accuracy with good sensitivity and specificity for adverse outcomes. Routine incorporation of Doppler assessment in high-risk pregnancies may facilitate early identification of fetal compromise, timely intervention, and improved perinatal outcomes.

Limitations: The study was limited by its single-centre design and relatively small sample size of 100 participants, which may restrict the generalizability of the findings. Long-term neonatal outcomes were not evaluated, and further multicentric studies with larger populations are required to validate the predictive role of individual Doppler parameters.

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