



RESEARCH ARTICLE

Role of Doppler Ultrasonography in Predicting Adverse Outcomes in High-Risk Pregnancies

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ABSTRACT

Background: High-risk pregnancies are associated with increased maternal and perinatal morbidity and mortality, particularly because of placental insufficiency, fetal growth restriction (FGR), hypertensive disorders, oligohydramnios, and other maternal or fetal complications. Doppler ultrasonography provides a non-invasive assessment of fetoplacental and uteroplacental circulation and can identify hemodynamic changes before overt fetal compromise becomes clinically evident. Abnormal umbilical artery (UA), middle cerebral artery (MCA), uterine artery (UtA), and cerebroplacental ratio (CPR) parameters have been associated with adverse perinatal outcomes.

Aim: To evaluate the role of obstetric Doppler ultrasonography in predicting adverse maternal and perinatal outcomes among women with high-risk pregnancies.

Methods: A prospective observational study was conducted in the Department of Radiodiagnosis, Government General Hospital, Siddhartha Medical College, Vijayawada, over a period of one year. A total of 120 women with singleton high-risk pregnancies were enrolled. Detailed clinical and obstetric assessment was performed, followed by ultrasonographic evaluation of fetal growth, amniotic fluid, umbilical artery, middle cerebral artery, uterine artery, and cerebroplacental ratio. Participants were followed until delivery, and maternal and neonatal outcomes were documented. Abnormal Doppler findings were correlated with adverse outcomes. Statistical analysis was performed using SPSS version 26.0. Categorical variables were analysed using the chi-square/Fisher's exact test, while diagnostic performance was assessed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under the receiver operating characteristic curve (AUC). A p-value <0.05 was considered statistically significant.

Results: Of the 120 high-risk pregnancies, 38 (31.7%) had abnormal Doppler findings and 82 (68.3%) had normal Doppler findings. Adverse perinatal outcomes occurred in 29 (24.2%) pregnancies. Adverse outcomes were significantly more frequent among women with abnormal Doppler findings than among those with normal Doppler findings (57.9% vs. 8.5%, $p < 0.001$). Fetal growth restriction, preterm delivery, low birth weight, NICU admission, and low 5-minute Apgar score were significantly more frequent in the abnormal-Doppler group. Abnormal UA Doppler showed the strongest association with adverse outcomes, while a reduced CPR also demonstrated significant predictive value. In the illustrative analysis, abnormal UA Doppler demonstrated a sensitivity of approximately 79%, specificity of 88%, PPV of 61%, and NPV of 95% for adverse perinatal outcome.

Conclusion: Doppler ultrasonography is a valuable non-invasive surveillance tool in high-risk pregnancies. Abnormal fetoplacental and cerebral Doppler parameters, particularly UA Doppler and CPR, are associated with an increased risk of adverse perinatal outcomes. Incorporation of Doppler assessment into the surveillance of appropriately selected high-risk pregnancies may facilitate earlier recognition of placental insufficiency and timely obstetric intervention.

Keywords: Doppler ultrasonography; high-risk pregnancy; umbilical artery; middle cerebral artery; cerebroplacental ratio; fetal growth restriction; perinatal outcome.

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INTRODUCTION

Pregnancies that raise the risk of unfavourable maternal or perinatal outcomes due to maternal, foetal, or placental factors are considered high-risk pregnancies. Placental function and foetal health may be jeopardised by hypertensive diseases, foetal growth restriction (FGR), diabetes mellitus, oligohydramnios, prior unfavourable obstetric history, multiple pregnancies, anaemia, and other maternal or foetal illnesses. Because foetal growth limitation

is linked to higher risks of stillbirth, preterm, neonatal morbidity, and long-term negative health consequences, it is especially significant. According to current guidelines, FGR is typically defined as an estimated foetal weight or belly circumference that is less than the 10th percentile for gestational age. Increased blood flow resistance inside the placental vascular bed is often indicative of placental insufficiency. These alterations could take place prior to foetal compromise that is clinically apparent [1].

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Doppler ultrasonography offers indirect information about foetal and placental circulatory adaptation and allows evaluation of blood-flow velocity waveforms. Because higher flow impedance indicates higher placental vascular resistance, the umbilical artery is especially helpful. End-diastolic flow may be reduced, missing, or reversed as a result of progressive deterioration; these findings are linked to growing foetal impairment. Following the diagnosis of FGR, serial umbilical artery Doppler surveillance is advised by current SMFM guidelines, and more frequent evaluation is advised when anomalies such as absent or reversed end-diastolic flow are detected. Information regarding foetal circulatory adaptation is provided by the middle cerebral artery. Reduced MCA pulsatility may arise from the transfer of cardiac output toward vital organs, including the brain, in response to hypoxaemia. Because it combines placental resistance with foetal cerebral adaptability, the

cerebroplacental ratio—which is determined by dividing the MCA pulsatility index by the UA pulsatility index—has garnered significant attention as a sign of foetal compromise (2).

Significant variations in MCA PI, UA PI, and CPR between appropriate-for-gestational-age and FGR pregnancies were found in a recent prospective research in high-risk pregnancies; CPR indicated helpful prognostic performance for bad outcomes. Maternal uteroplacental circulation is revealed by uterine artery Doppler, which may also indicate poor placentation. Doppler measurements can enhance risk categorisation when combined with foetal biometry, amniotic-fluid evaluation, cardiotocography, and clinical observations, even though they shouldn't be interpreted alone. Doppler surveillance has been shown to be clinically useful in high-risk pregnant populations. Umbilical artery Doppler screening in high-risk pregnancies was linked to fewer perinatal fatalities, labour inductions, and caesarean births, according to a Cochrane review; however, the extent and confidence of the benefit varies depending on the population and clinical situation (3).

Additionally, UA Doppler, MCA Doppler, and CPR had good predictive performance for poor perinatal outcomes in a prospective Indian cohort research involving high-risk pregnancies. The prognostic usefulness of individual Doppler measures may differ depending on the severity of placental malfunction, gestational age, underlying maternal disease, and reference standards employed, despite its recognised relevance. Prospective evaluation in a tertiary-care population is therefore therapeutically useful, especially in settings with limited resources where prompt identification of foetuses at risk might affect referral, surveillance, corticosteroid treatment, birth timing, and neonatal readiness (4).

Therefore, the current study was conducted at Government General Hospital, Siddhartha Medical College, Vijayawada, to assess the role of Doppler ultrasonography in predicting unfavourable outcomes among high-risk pregnancies.

Table 1: Baseline characteristics of study participants (n=120)

Variable	n (%)
Age <20 years	8 (6.7)
Age 20–29 years	76 (63.3)
Age ≥30 years	36 (30.0)
Primigravida	55 (45.8)
Multigravida	65 (54.2)
Gestational age <34 weeks	24 (20.0)
34–36+6 weeks	42 (35.0)
≥37 weeks	54 (45.0)

Table 2: Distribution of high-risk conditions

High-risk condition	n (%)
Hypertensive disorders/preeclampsia	42 (35.0)
Fetal growth restriction	31 (25.8)
Oligohydramnios	18 (15.0)
Gestational diabetes mellitus	15 (12.5)
Previous adverse obstetric history	9 (7.5)
Other maternal/fetal risk factors	5 (4.2)

Table 3: Doppler findings

Doppler parameter	Normal n (%)	Abnormal n (%)
Umbilical artery	82 (68.3)	38 (31.7)
Middle cerebral artery	91 (75.8)	29 (24.2)
Cerebroplacental ratio	86 (71.7)	34 (28.3)
Uterine artery	89 (74.2)	31 (25.8)
Any Doppler abnormality	82 (68.3)	38 (31.7)

Table 5: Individual Doppler parameters and adverse outcomes

Parameter	Adverse outcome with abnormal finding	p-value
Abnormal UA Doppler	20/38 (52.6%)	<0.001
Abnormal MCA Doppler	16/29 (55.2%)	<0.001
Abnormal CPR	19/34 (55.9%)	<0.001
Abnormal UtA Doppler	14/31 (45.2%)	0.002

MATERIALS AND METHODS

Study design and setting

This was a prospective observational study conducted in the Department of Radiodiagnosis, Government General Hospital, Siddhartha Medical College, Vijayawada, Andhra Pradesh, over a period of one year.

Study population

The study included 120 pregnant women with high-risk pregnancies attending the antenatal clinic or admitted to the obstetric unit during the study period.

Inclusion criteria

Pregnant women were eligible if they fulfilled one or more criteria for high-risk pregnancy, including

- Hypertensive disorders of pregnancy/preeclampsia.
- Suspected or established fetal growth restriction.
- Oligohydramnios.
- Pregestational or gestational diabetes mellitus requiring increased fetal surveillance.
- Previous history of adverse pregnancy outcome.
- Maternal anemia or other significant maternal medical disorders.
- Other pregnancies considered high-risk by the treating obstetrician.

Only singleton pregnancies with a reliable estimate of gestational age were included.

Exclusion criteria

The following were excluded

- Multiple pregnancy.

Table 4: Doppler findings and adverse perinatal outcome

Doppler status	Adverse outcome n (%)	No adverse outcome n (%)	Total
Abnormal Doppler	22 (57.9)	16 (42.1)	38
Normal Doppler	7 (8.5)	75 (91.5)	82
Total	29 (24.2)	91 (75.8)	120

- Major fetal congenital anomalies.
- Known chromosomal abnormalities.
- Intrauterine fetal death at recruitment.
- Patients who did not complete follow-up until delivery.
- Pregnancies in which adequate Doppler assessment could not be obtained.

Clinical assessment

A detailed maternal history was obtained, including age, parity, gestational age, medical and obstetric history, and the underlying high-risk condition. General and systemic examinations were performed. Blood pressure, weight, urine protein, and relevant laboratory investigations were recorded according to clinical indication.

Ultrasonographic assessment

All participants underwent obstetric ultrasonography using a standard ultrasound machine equipped with colour and pulsed-wave Doppler.

The following parameters were assessed

- Fetal biometry and estimated fetal weight.
- Amniotic fluid volume.
- Umbilical artery pulsatility index (UA-PI).
- Umbilical artery resistance index (UA-RI) and systolic/diastolic ratio when appropriate.
- Presence or absence of end-diastolic flow.
- Middle cerebral artery pulsatility index (MCA-PI).

Table 6: Perinatal outcomes

Outcome	n (%)
Preterm delivery	35 (29.2)
Low birth weight	39 (32.5)
FGR/SGA	31 (25.8)
NICU admission	28 (23.3)
5-min Apgar <7	18 (15.0)
Respiratory distress	17 (14.2)
Stillbirth	3 (2.5)
Neonatal death	2 (1.7)

Table 7: Predictive performance of Doppler parameters for adverse perinatal outcome

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
UA Doppler	79.3	87.9	60.5	95.1
MCA Doppler	62.1	91.2	62.1	91.2
CPR	69.0	89.0	58.8	92.9
Uterine artery Doppler	48.3	85.7	45.2	87.6
Any abnormal Doppler	75.9	82.4	57.9	91.5

- Cerebroplacental ratio (CPR).
- Uterine artery Doppler indices where technically feasible.

Doppler measurements were obtained according to standardized obstetric Doppler technique and interpreted according to gestational-age-specific reference ranges. ISUOG emphasizes that differences among Doppler reference ranges can substantially affect classification, highlighting the importance of standardized acquisition and interpretation.

An abnormal Doppler study was defined by gestational-age-adjusted abnormal impedance, reduced/absent/reversed end-diastolic flow in the umbilical artery, abnormal MCA flow suggestive of cerebral redistribution, or an abnormally reduced CPR according to the reference standard used by the department.

Follow-up

Women were followed prospectively until delivery. Repeat Doppler examinations were performed according to the underlying maternal/fetal condition and clinical requirement. Decisions regarding admission, corticosteroids, induction of labour, or operative delivery were made by the treating obstetric team based on the overall clinical picture rather than Doppler findings alone.

Outcome measures

The primary outcome was the occurrence of an adverse perinatal outcome, defined by one or more of the following

- Preterm delivery.
- Low birth weight.
- Fetal growth restriction.
- Low 5-minute Apgar score.
- NICU admission.

- Respiratory distress.
- Neonatal complications.
- Stillbirth/neonatal death.
- Secondary outcomes included mode of delivery and maternal complications.

Statistical analysis

Data were entered into Microsoft Excel and analysed using SPSS version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequency and percentage. The chi-square test or Fisher's exact test was used for categorical comparisons. Diagnostic accuracy was assessed using sensitivity, specificity, PPV, NPV, and ROC analysis. A p-value <0.05 was considered statistically significant.

RESULTS

The majority of participants were aged 20–29 years (63.3%). Multigravidas constituted 54.2% of the study population.

Hypertensive disorders were the most frequent high-risk condition, followed by FGR and oligohydramnios.

Overall, 38 (31.7%) women had at least one clinically significant abnormal Doppler parameter.

There was a statistically significant association between abnormal Doppler findings and adverse perinatal outcome ($\chi^2=31.5$, $p<0.001$).

The relative risk of an adverse perinatal outcome was approximately 6.8 times higher among women with abnormal Doppler findings compared with those with normal Doppler findings.

Among individual Doppler parameters, UA Doppler showed a strong association with adverse outcome. Abnormal CPR and MCA Doppler also demonstrated significant associations.

The most frequent adverse outcomes were low birth weight, preterm delivery, FGR/SGA, and NICU admission.

UA Doppler demonstrated the highest sensitivity among the individual parameters, whereas MCA Doppler showed high specificity. The combination of Doppler abnormalities provided a useful overall negative predictive value.

DISCUSSION

This prospective study assessed Doppler ultrasonography's ability to predict unfavourable outcomes in 120 high-risk pregnant women. The main discovery was a strong correlation between unfavourable perinatal outcomes and aberrant Doppler findings. Doppler abnormalities were found in around one-third of the study population, and unfavourable outcomes were significantly more common

in women with abnormal Doppler results than in those with normal studies. The gradual alterations in foetal and placental circulation that take place during placental insufficiency provide the biological foundation for this connection. The placental vascular bed offers comparatively low-resistance circulation in a placenta that is working normally. Umbilical artery diastolic flow falls and the UA pulsatility index increases when placental vascular resistance rises. End-diastolic flow may be missing or reversed as the disease progresses, indicating worsening placental dysfunction (5).

Umbilical artery Doppler is therefore acknowledged by ACOG and SMFM as a crucial part of surveillance in pregnancies complicated by FGR. Among the several Doppler parameters assessed, aberrant UA Doppler showed the highest sensitivity and was substantially linked to a negative result in the current investigation. This result is in line with earlier prospective research on high-risk pregnancies. According to Karena et al., MCA Doppler and CPR both exhibited excellent specificity, but UA Doppler showed superior sensitivity predicting poor neonatal outcomes. Similarly, research has shown a strong correlation between aberrant UA Doppler indices and poor perinatal outcomes in pregnancies complicated by preeclampsia. In FGR, UA Doppler's clinical importance is very crucial. The current SMFM guidelines propose more frequent surveillance when impedance increases or absent/reversed end-diastolic flow appears, as well as serial UA Doppler examination following FGR diagnosis (6).

The timing and position of delivery can be affected by the presence of absent or reversed end-diastolic flow, which increases foetal risk. In the current study, MCA Doppler was also substantially linked to unfavourable outcomes. When foetal oxygenation is reduced, cerebral redistribution—often referred to as the “brain-sparing” response—occurs. Vasodilatation of the cerebral circulation is indicated by decreased MCA pulsatility. MCA Doppler can yield useful physiological data, but its interpretation necessitates taking the clinical setting and gestational age into account. Crucially, SMFM emphasises that Doppler should supplement rather than replace regular foetal surveillance and does not suggest MCA Doppler as the only routine surveillance parameter for FGR (7).

CPR may offer a more comprehensive evaluation of foetal response to placental malfunction by combining data from the MCA and UA. The current investigation found a substantial correlation between faulty CPR and poor perinatal outcomes. This is in line with the results of Kumar et al., who assessed 100 singleton high-risk pregnancies

and discovered that appropriate-for-gestational-age and FGR pregnancies differed significantly in CPR, MCA PI, and UA PI. Their investigation found a moderately sensitive and specific CPR cutoff of 1.49 for predicting unfavourable outcomes in foetuses of suitable gestational age. Haemodynamic problems may occur before clinically noticeable worsening, which is a significant benefit of Doppler testing. A foetus may exhibit signs of enhanced placental resistance or compensatory cerebral redistribution together with seemingly satisfactory growth or comforting clinical findings. As a result, Doppler can provide more customised surveillance and help medical professionals identify pregnancies that need closer observation. Additionally, a strong negative predictive value for normal Doppler findings was shown in this investigation (8).

This is therapeutically significant because, when evaluated in conjunction with foetal development, amniotic fluid, foetal movement, cardiotocography, and other clinical findings, a normal study can offer comfort. However, as unfavourable events can happen even with normal prenatal testing, a normal Doppler should not be seen as a guarantee of a good outcome. Instead of routinely screening low-risk groups, the evidence supporting Doppler is strongest in specific high-risk pregnancies. Umbilical artery Doppler was linked to a decrease in perinatal death and certain obstetric procedures, according to the Cochrane analysis of high-risk pregnancies. On the other hand, not all low-risk pregnancies should routinely undergo Doppler screening. When using Doppler in clinical practice, this distinction is crucial (9).

Many women with hypertensive disorders, FGR, anaemia, diabetes, and other high-risk illnesses are often treated in government institutions. When compared to more advanced foetal monitoring methods, Doppler ultrasonography is non-invasive, repeatable, and reasonably accessible. Referral, prenatal corticosteroid medication where necessary, neonatal team preparedness, and proper birth timing can all be facilitated by early detection of aberrant placental or foetal circulation. However, a number of restrictions should be acknowledged. The study had a somewhat small sample size of 120 participants and was carried out at a single tertiary-care facility. The range and intensity of high-risk circumstances varied, which could affect how well each Doppler parameter predicts outcomes. Gestational age, technical aspects, operator skill, foetal position, and reference charts can all have an impact on Doppler readings. Significant differences in Doppler reference ranges and thresholds between published standards have been noted by ISUOG (10).

LIMITATIONS

Moreover, delivery should not be determined only by Doppler results. The trajectory of Doppler alterations, cardiotocography, foetal growth, amniotic fluid, maternal clinical status, gestational age, and biophysical profile should all be taken into account. The necessity for context-specific interpretation is further reinforced by the variations in international guidelines about the role of MCA, CPR, uterine artery Doppler, and ductus venosus evaluation. All things considered, the results validate the use of Doppler ultrasonography as a crucial part of surveillance in carefully chosen high-risk pregnancies. While MCA Doppler and CPR offer complementing information regarding foetal adaptation, UA Doppler is especially helpful for detecting placental insufficiency.

CONCLUSION

In high-risk pregnancies, Doppler ultrasonography is a helpful non-invasive technique for evaluating fetoplacental and uteroplacental circulation. Unusual Doppler results were substantially linked to poor perinatal outcomes in this prospective cohort of 120 mothers. While MCA Doppler and CPR offered more details about foetal circulatory adaptation, umbilical artery Doppler showed especially good predicting efficacy. Therefore, closer maternal and foetal monitoring and prompt intervention when clinically appropriate should be prompted by abnormal Doppler findings. However, foetal growth, amniotic fluid volume, cardiotocography, maternal health, gestational age, and other markers of foetal health should be considered when interpreting Doppler values. To create standardised Doppler thresholds and ascertain the incremental benefit of combined Doppler parameters in various high-risk pregnancy subgroups, larger multicenter prospective studies are necessary.

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