Doppler Study In High-Risk Pregnancy: An Observational Study

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Abstract

Background: The increased morbidity of high-risk pregnancies also affects the mother and the baby because of the placental insufficiency and compromised baby. The Doppler ultrasonography is a non-invasive tool to assess fetal and placental circulation and is an important tool for early detection of adverse perinatal outcome. The purpose of this study was to determine the predictive value of Doppler velocimetry of the umbilical artery (UA) and middle cerebral artery (MCA) in the evaluation of the mother and fetus outcome in high-risk pregnancies.

Objective: To carry out a prospective observational study in the Department of obstetrics and gynaecology in a tertiary care teaching hospital for high-risk pregnant women.

Methods: To undertake a prospective observational study in one of the departments of obstetrics and gynaecology in a tertiary care teaching hospital of 118 high risk pregnant women. The eligible pregnancies with singleton fetuses (34 weeks' gestation or greater) were subjected to Doppler ultrasonography of the umbilical artery and middle cerebral artery. The Doppler indices such as the Pulsatility Index (PI), Resistance Index (RI) and Systolic-to-Diastolic (S/D) ratio were obtained, and a correlation was made with the maternal and neonatal outcome. The data were analysed statistically by using SPSS software 26.0 and p value was set to be statistically significant at p value < 0.05.

Results: These results showed that, pregnancy-induced hypertension (35.6%), Intrauterine growth restriction (25.4%) and gestational diabetes mellitus (18.6%) were the most prevalent high-risk conditions. Almost one-third of the subjects had abnormal Doppler signals in their umbilical artery, which was significantly associated with cesarean delivery, low birth weight, low APGAR score, admission to a NICU and neonatal death ($p<0.05$). The abnormal Doppler indices of umbilical artery were independent risk factors for adverse perinatal outcome in logistic regression analysis. The pulsatility index of the umbilical artery showed the best diagnostic value (AUC = 0.89) when used as a predictor of adverse outcome of the newborn.

Conclusion: Doppler ultrasonography, especially umbilical artery velocimetry, can be used as an effective reliable method in high-risk pregnancies to identify those fetuses at high risk for poor perinatal outcome. This could be achieved through the routine use of Doppler assessment as part of antenatal surveillance which would aid in the early detection of abnormalities, timely obstetric intervention and better maternal and/or foetal outcomes.

Keywords High-risk pregnancy; Doppler ultrasonography; Umbilical artery Doppler; Middle cerebral artery Doppler; Placental insufficiency; Perinatal outcomes; Fetal surveillance; Pregnancy-induced hypertension; Intrauterine growth restriction; Neonatal outcomes.

1. Introduction

High risk pregnancy is a public health problem as it is related to the higher rate of maternal, fetal and neonatal mortality and morbidity in the world. The World Health Organization (Hettiarachchi et al., 2023) reports that pregnancy-related complications are one of the major causes of maternal deaths especially in the low- and middle-income countries. Maternal and fetal hypoxia, intrauterine growth restriction (IUGR), low birth weight, and neonatal mortality are significantly increased risk factors for high-risk pregnancies, which includes pregnancy-induced hypertension (PIH), gestational diabetes mellitus (GDM), maternal anaemia and adverse obstetric history (Zhang et al., 2025; Huang et al., 2025). Therefore, early detection of fetal compromise is crucial to improve perinatal outcomes and prevent the onset of any maternal and/or neonatal complications.

The other half of the care of higher risk pregnancies is fetal surveillance. There are conventional methods of monitoring like fetal movement counting, fetal cardiotocography (CTG) and fetal biophysical profile (BPP) that give useful information about fetal well-being but have the disadvantage of detecting fetal distress at a time when a significant degradation in the fetus' condition has already occurred (Chidiogo et al., 2024). For this reason, Doppler ultrasonography is increasingly important and useful non-invasive imaging tool that allows documentation of fetoplacental/utero-placental circulation to determine changes in circulation before any irreversible changes can occur to the foetus (Stampalija et al.,2025). Doppler ultrasound has become part of the care of women with high-risk pregnancies, due to its safety, repeatability and the fact that it allows for the immediate assessment of fetal circulation.

The umbilical artery (UA) and middle cerebral artery (MCA) are two fetal vessels that are thought to be the most important to be measured by Doppler ultrasonography. The Doppler interrogations of the umbilical artery reflect the placental vascular resistance, and they offer a lot of information about the function of the placenta. Placental vascular resistance is usually reduced during pregnancy leading to increased end-diastolic blood flow. In pregnancies which are complicated with placental insufficiency, the vascular resistance is increased, which results in high values of Pulsatility Index (PI), Resistance Index (RI) and Systolic-to-Diastolic (S/D) ratio. These abnormal findings are well established to be significantly related to fetal growth restriction, preterm delivery, cesarean section, low birth weight, admission to a neonatal intensive care unit (NICU) and perinatal death (Enginee& Kumar, 2010; Malhotra et al., 2019). Thus, the Doppler signal of the umbilical artery can be used as a good measure of the circulatory condition of the fetoplacental unit and fetal well-being.

The Doppler of middle cerebral artery has been used to complement the assessment of placental function by assessing cerebral circulation of the fetus. In chronic hypoxia (placental insufficiency) the fetus makes a compensation by redirecting blood flow to the vital organs – mainly to the brain, named brain-sparing effect. This adaptive mechanism results in a reduction of the MCA vascular resistance and a reduction of the pulsatility index of the MCA resulting in an increased cerebral perfusion.This is an adaptive mechanism that leads to lower MCA vascular resistance and lower pulsatility index of the MCA which in turn leads to an increase in cerebral perfusion.This adaptive mechanism leads to a decreased vascular resistance and the decrease in pulsatility index in MCA which means there is a greater cerebral perfusion (Shah et al., 2026). Although it can have a protective effect in the short term, cerebral redistribution in the long term is a sign of increased fetal compromise and has been associated with poor neonatal outcomes, including asphyxia at birth, low APGAR scores, admission to the NICU, and death of the baby (Beacom et al., 2025). Thus, analysis of both the Doppler of the umbilical artery and of MCA will give a better picture of the hemodynamic of the fetus, than the analysis of either of these arteries.

The Doppler velocimetry is known to be an important technique for employing in 'high risk' pregnancy monitoring according to International clinical guidelines. Doppler assessment has been used to optimise timing of obstetric interventions and reduce the adverse perinatal findings and it is recommended in women with complicated pregnancies (fetal growth restriction and/or placental insufficiency) by the International Society of Ultrasound in Obstetrics and Gynaecology (Bhide et al., 2021), the American College of Obstetricians and Gynaecologists (Restriction, 2021) and the Royal College of Obstetricians and Gynaecologists (Hanton et al., 2025). The role of Doppler indices in prediction of various conditions of high-risk pregnancy is still debatable especially in developing countries with varying disease burden from one state to another and across countries, and varying quality of health service and obstetric care across the states (Ali et al., 2021). The use of Doppler ultrasonography in various clinical settings needs to be further studied and substantiated with prospective studies.

This study aimed to assess the utility of umbilical artery (UA) and middle cerebral artery (MCA) Doppler velocimetry for prediction of maternal and infant outcomes in high-risk pregnancies in a prospective observational study. The relationship between Doppler findings and the major perinatal outcomes, such as mode of delivery, birth weight, APGAR score, NICU admission and neonatal survival are evaluated. Also, the study will be designed to look at the common risk factors in mothers and associated adverse fetal outcome. The results will be useful for the validation of the use of Doppler ultrasonography as both a reliable and non-invasive fetal surveillance tool and a clinically useful and effective method of fetal risk stratification and timely obstetric intervention in high-risk pregnancies.

2. Materials and Methods

This study was conducted as a hospital-based prospective observational study in the Department of Obstetrics and Gynaecology, Malda Medical College and Hospital, Malda, West Bengal, India. The study was carried out over a period of 12 months following approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment, and the study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

2.1 Study Population

The study population consisted of pregnant women with high-risk pregnancies receiving antenatal care and/or labour and delivery services in the Department of Obstetrics and Gynaecology at both outpatient and inpatient services between 2010-2016. A total of 118 women who were eligible in the study were consecutively recruited for the study. High risk pregnancies were those with pregnancy-induced hypertension (PIH),

gestational diabetes mellitus (GDM), intrauterine growth restriction (IUGR) and the women who had a history of poor obstetric history.

2.2 Eligibility Criteria

Women were included if they were diagnosed with a high-risk obstetric condition, such as pregnancy-induced hypertension, diabetes mellitus complicating pregnancy, intrauterine growth restriction, and/or had an adverse obstetric history, and had a singleton pregnancy and gestational age of 34 weeks or more. To avoid the influence of potential confounding conditions that may affect Doppler measurements in fetuses and influence the outcomes of the neonates, women who had multiple gestations, fetuses with congenital anomalies were excluded from the study and women with confirmed genetic abnormalities (Kim et al., 2023).

2.3 Sample Size

A total of 118 patients of high-risk pregnant women who met the criteria during study period were included in the study. As this was a prospective observational study carried out in a tertiary care teaching hospital, all participants that met the inclusion/exclusion criteria who came to the hospital during the study period were included in the study until the required sample size was obtained.

2.4 Clinical Assessment

Detailed information regarding demography and clinical data were obtained after enrolment through a case record form. The maternal characteristics were recorded, such as age, gravidity, parity, gestational age, obstetric history, medical disorders and pregnancy complications. A detailed obstetric evaluation was done on all of them which included blood pressure measurement, abdominal examination, fundal height measurement, presentation and fetal heart rate evaluation. The medical records were also reviewed to confirm the diagnosis of high-risk pregnancy (Padoan, 2020) and the following laboratory tests were reviewed if available:The following laboratory tests were reviewed if available.

2.5 Doppler Ultrasonography

The obstetric ultrasonography and Doppler velocimetry were performed by experienced radiologists/obstetricians using a standardized ultrasonography protocol for all the participants. Once the routine fetal biometric evaluation was performed, Doppler was performed with the mother in the semi-recumbent position to decrease compression of the inferior vena cava (Kametas, 2020).

The umbilical artery (UA) was assessed by putting the Doppler sample gate in a free-floating loop of the umbilical cord. The Doppler indices that were observed were:

- Pulsatility Index (PI)
- Resistance Index (RI)
- Systolic/Diastolic (S/D) ratio

Using colour Doppler imaging the middle cerebral artery (MCA) was then located in the transverse plane in the fetal head at the level of the sphenoid bones. Doppler measurements were recorded from the proximal 1/3 of the artery and an insonation angle of 0° as close as possible to it was maintained. The following indexes were taken:

- Pulsatility Index (PI)
- Resistance Index (RI)

All Doppler measurements were recorded at fetal quiet times, and three consecutive waveforms of a similar type were recorded for an average value. The Doppler results were normal or abnormal based on Doppler reference values for each gestational age.

2.6 Outcome Assessment

After Doppler examination, all the cases were followed prospectively till the delivery time. The mode of delivery (vaginal delivery or cesarean section) was included as a maternal outcome. Immediate neonatal outcomes evaluated included birth weight, APGAR score, need for neonatal intensive care unit (NICU) admission, neonatal complications and neonatal survival (Gebrehea&Teame, 2022). The Doppler velocimetry in high-risk pregnancies was compared with the outcome measures to know whether Doppler is a good predictor in high risk pregnancies.

2.7 Study Variables

The main independent variables were the Doppler indices for the umbilical artery (UA) and middle cerebral artery (MCA), such as Pulsatility Index (PI), Resistance Index (RI) and the ratio of Umbilical Artery Systolic/Diastolic (S/D) ratio.

The main outcome measures were:

- Mode of delivery
- Birth weight
- APGAR score
- NICU admission
- Neonatal morbidity
- Neonatal mortality

Secondary variables included mother's demographic characteristics, and obstetric risk factors (previous poor obstetric history, intrauterine growth restriction, gestational diabetes mellitus, pregnancy induced hypertension).

2.8 Statistical Analysis

All the collected data were then entered into the Microsoft Excel then analysed using IBM SPSS Statistics software (Version 26.0, IBM Corp., Armonk, NY, USA). The results of continuous variables were presented as mean ± standard deviation (SD) and the results of categorical variables were presented as frequencies and percentages.

Chi-square test or Fisher's exact test was used to assess the relationship between Doppler findings and the maternal and/or neonatal outcomes, depending on the data type. Data were tested for normality and the independent samples t-test used for comparing continuous variables. Logistic regression analysis was used to determine the independent risk factors for adverse perinatal outcomes and odds ratios (ORs) with 95% confidence intervals (CIs) were used to present the results. Throughout this analysis a two-sided p-value of < 0.05 was used as the cut-off for statistical significance.

2.9 Ethical Considerations

Before the start of the study the study protocol was approved by the Institutional Ethics Committee, Malda Medical College and Hospital. Before entering the study, all the participants gave informed consent, which was both oral and in writing. The information of participants was kept anonymous throughout the study, and all data were anonymised prior to the statistical analysis. The study respected the ethical principles of Declaration of Helsinki (2013 revision) and followed the guidelines for institutional research ethics.

3. Results

3.1 Baseline Characteristics of the Study Population

In the current, prospective observational study 118 high-risk pregnant women were recruited. The mean maternal age was 27.8 ± 4.6 years, and majority (67.8%) of the patients were in the age group of 20-30 years. Most women had multiple pregnancies (61.0%) while 39.0% had their first pregnancy. The mean gestation age at the time of Doppler examination was 36.9 ± 1.8 weeks and over half of the Doppler exams (50.8%) were performed at 37-40 weeks of pregnancy. The demographic and obstetric data of the subjects of the study are shown in table 1.

Table 1. Baseline Demographic and Obstetric Characteristics of the Study Population (n = 118)

Variable	Frequency (n)	Percentage (%)
Age (years)		
<20	8	6.8
20–25	36	30.5
26–30	44	37.3
31–35	22	18.6
>35	8	6.8
Gravidity		
Primigravida	46	39.0
Multigravida	72	61.0

Gestational Age (weeks)		
34–36	52	44.1
37–40	60	50.8
>40	6	5.1
Mean Maternal Age (years)	27.8 ± 4.6	—
Mean Gestational Age (weeks)	36.9 ± 1.8	—

Most of the participants were in the age of 20-30 years (67.8%) which is the common age group for reproduction. Most women were multigravida (61.0%) suggesting that past pregnancy was the norm among the women studied. The Doppler assessment was mainly conducted with the late 3rd trimester, more than half of women (50.8%) assessed at gestation weeks 37-40; a time where routine fetal surveillance is carried out in high-risk pregnancies.

3.2 Distribution of High-Risk Pregnancy Conditions

Data on distribution of maternal high risk pregnancy conditions is presented in Table 2. The most common obstetric complications encountered were pregnancy induced hypertension (PIH) (35.6%), intrauterine growth restriction (IUGR) (25.4%) and gestational diabetes mellitus (GDM) (18.6%). A few participants had multiple risk factors, so the frequency of the risk factors was totalled and thus surpassed the number of participants in the study.

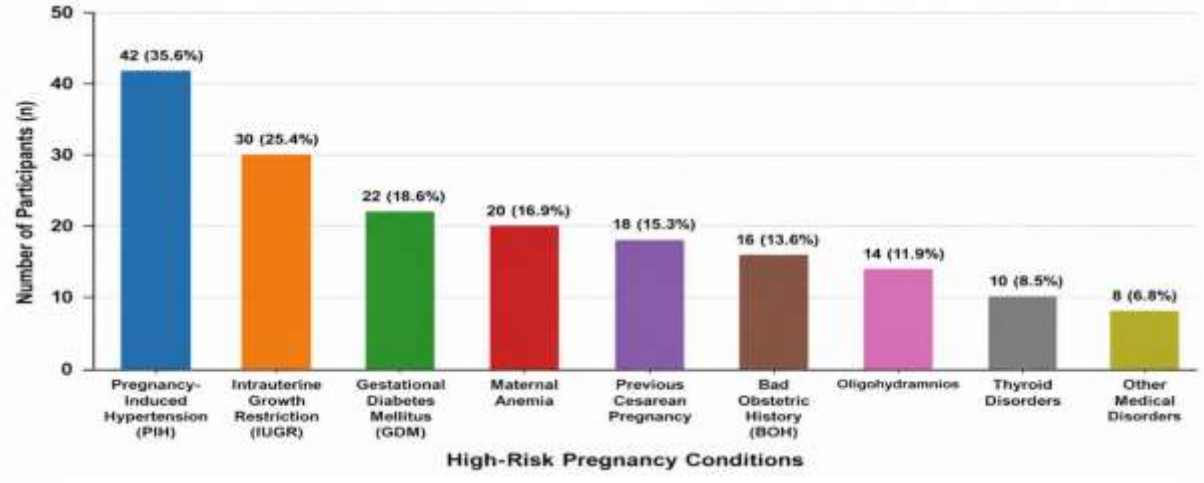
Table 2. Distribution of High-Risk Pregnancy Conditions (n = 118)

High-Risk Pregnancy Condition	Frequency (n)	Percentage (%)
Pregnancy-Induced Hypertension (PIH)	42	35.6
Intrauterine Growth Restriction (IUGR)	30	25.4
Gestational Diabetes Mellitus (GDM)	22	18.6
Bad Obstetric History (BOH)	16	13.6
Oligohydramnios	14	11.9
Maternal Anaemia	20	16.9
Other High-Risk Conditions*	10	8.5

*Other high-risk conditions included hypothyroidism, chronic hypertension, and autoimmune disorders.

The most prevalent high-risk condition was pregnancy induced hypertension (PIH) (35.6%) followed by intrauterine growth restriction (IUGR) (25.4%) and gestational diabetes mellitus (GDM) (18.6%). Bad obstetric history was also common; as was maternal anaemia. These results indicate that placental dysfunction-related disorders were the primary indications for Doppler velocimetry and emphasize the need for fetal vascular assessment in pregnancies with a high risk for adverse maternal and fetal outcomes.

Figure 1. Distribution of High-Risk Pregnancy Conditions among the Study Participants (Illustrative Example, n = 118).



A bar chart showing the number of times the 'big' high risk pregnancy conditions occurred for the enrolled participants. The most common complications were pregnancy induced hypertension, intrauterine growth restriction and gestational diabetes mellitus. A few participants presented with more than one high-risk condition so the total number of participants in the study exceeded the number of High Risk conditions.

3.3 Doppler Velocimetry Findings

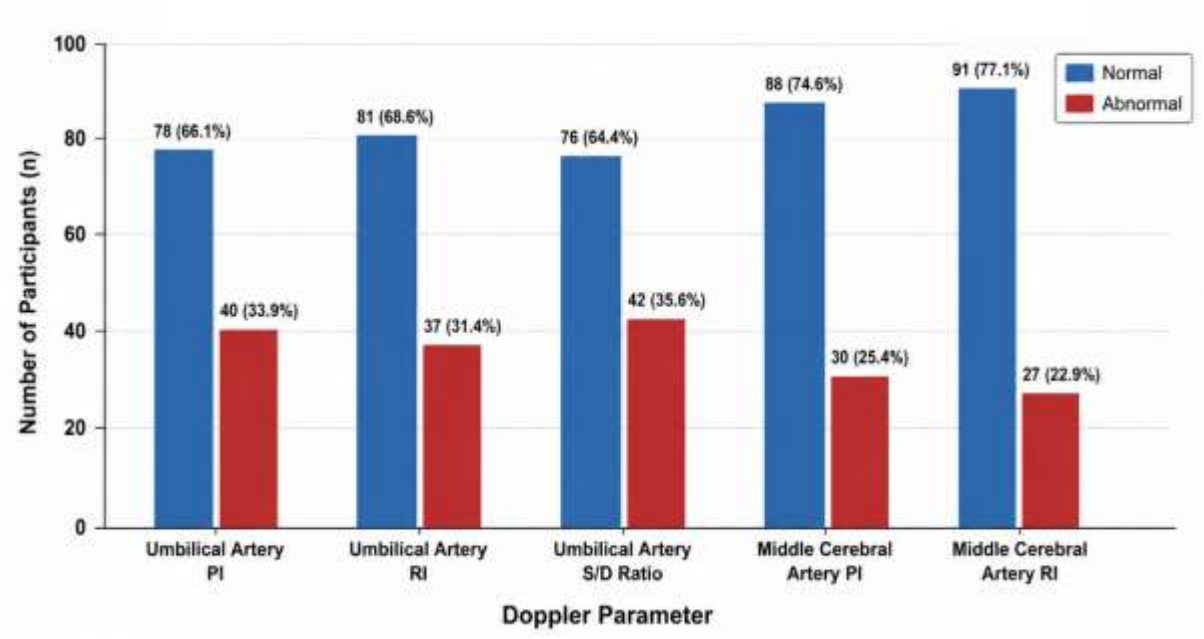
All 118 participants had successful Doppler examination of the umbilical artery (Ua) and middle cerebral artery (MCA). The abnormalities of Doppler were more common in umbilical artery than in middle cerebral artery. The number of Doppler abnormalities were presented in Table 3.

Table 3. Distribution of Doppler Velocimetry Findings (Illustrative Example, n = 118)

Doppler Parameter	Normal n (%)	Abnormal n (%)
Umbilical Artery PI	78 (66.1)	40 (33.9)
Umbilical Artery RI	81 (68.6)	37 (31.4)
Umbilical Artery S/D Ratio	76 (64.4)	42 (35.6)
Middle Cerebral Artery PI	88 (74.6)	30 (25.4)
Middle Cerebral Artery RI	91 (77.1)	27 (22.9)

Nearly one-third of the participants had abnormal umbilical artery Doppler indices, while 25% of participants had abnormal MCA Doppler indices. Increased umbilical artery vascular resistance may have been common among women with high-risk pregnancies as evidenced by the higher prevalence of abnormal Doppler findings.

Figure 2. Distribution of Normal and Abnormal Doppler Findings



3.4 Maternal Outcomes

The outcomes of newborns and mothers are summarized in Table 4.

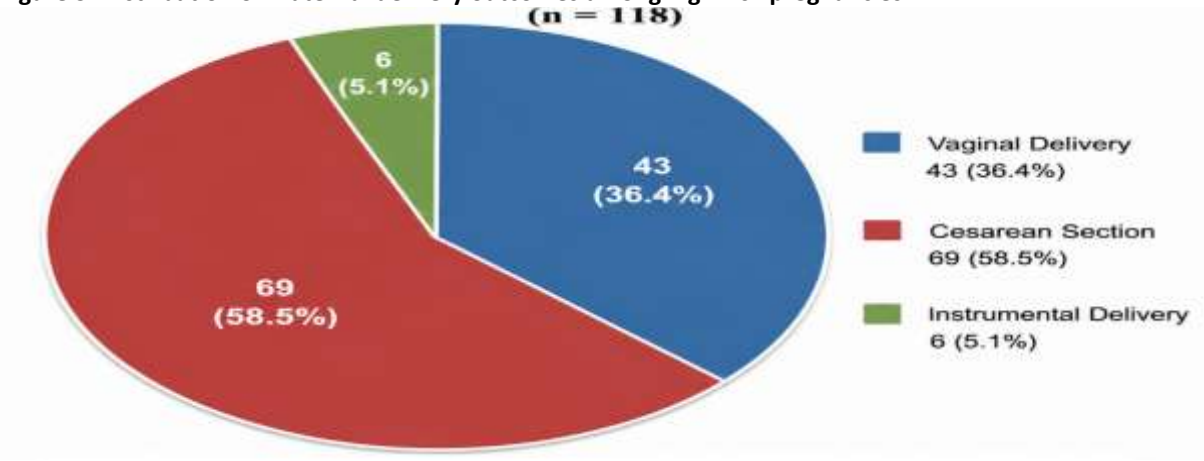
Table 4. Maternal Outcomes (Illustrative Example, n = 118)

Outcome	Frequency (n)	Percentage (%)
Vaginal Delivery	43	36.4
Cesarean Section	69	58.5
Instrumental Delivery	6	5.1
Maternal Complications*	18	15.3

*****Maternal complications were: postpartum haemorrhage, severe hypertension and prolonged labour.

Cesarean section delivery method was the highest (58.5%) method of delivery. This indicates that the proportion of pregnancies with abnormal fetal surveillance and maternal risk factors which require obstetric intervention has increased.

Figure 3. Distribution of maternal delivery outcomes among high-risk pregnancies.



3.5 Neonatal Outcomes

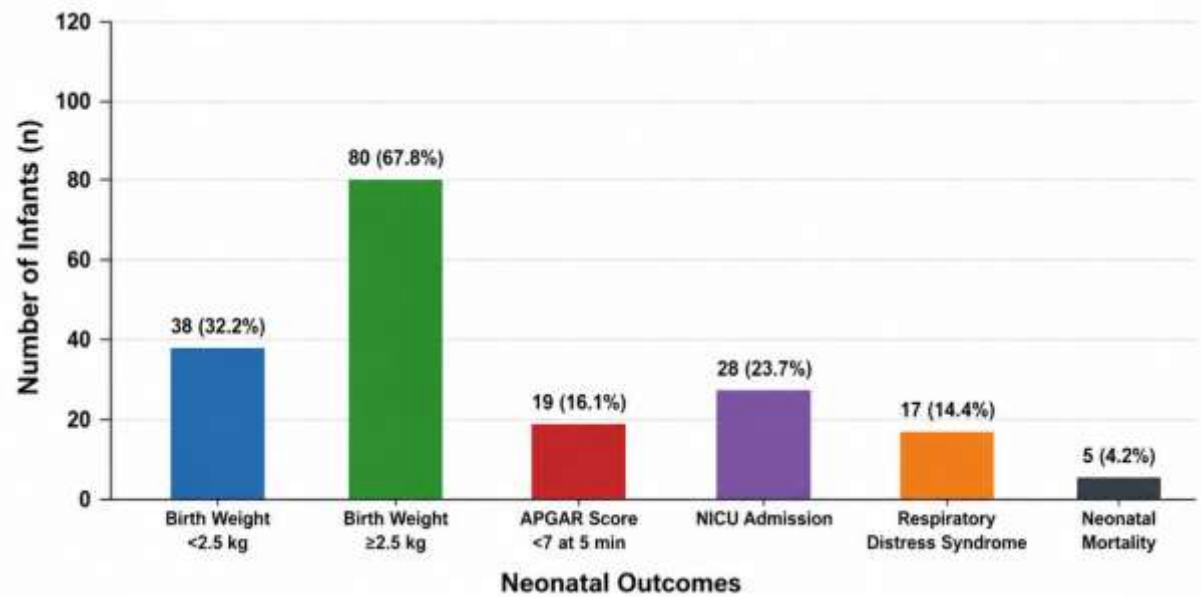
The summary of the outcomes of deliveries is summarized in Table 5.

Table 5. Neonatal Outcomes (Illustrative Example, n = 118)

Variable	Frequency (n)	Percentage (%)
Birth Weight <2.5 kg	38	32.2
Birth Weight ≥2.5 kg	80	67.8
APGAR Score <7 at 5 minutes	19	16.1
NICU Admission	28	23.7
Respiratory Distress Syndrome	17	14.4
Neonatal Mortality	5	4.2

Almost 30% of the neonates were of low birth weight and around 25% had to be admitted to NICU. Neonatal mortality was not a significant problem, and was mainly associated with severe Doppler abnormalities.

Figure 4. Distribution of neonatal outcomes among infants born to women with high-risk pregnancies.



3.6 Association Between Umbilical Artery Doppler Findings and Perinatal Outcomes

The Chi-square test was used to examine the correlation of abnormal Doppler results of the umbilical artery with problems during pregnancy or delivery.

Table 6. Association Between Umbilical Artery Doppler Findings and Perinatal Outcomes (Illustrative Example)

Outcome	Normal UA (n=78) n (%)	Abnormal UA (n=40) n (%)	χ^2	p-value
Cesarean Section	38 (48.7)	31 (77.5)	9.84	0.002
Low Birth Weight	16 (20.5)	22 (55.0)	15.27	<0.001
APGAR <7	8 (10.3)	11 (27.5)	5.78	0.016
NICU Admission	11 (14.1)	17 (42.5)	12.63	<0.001
Neonatal Mortality	1 (1.3)	4 (10.0)	5.12	0.024

The women who developed abnormal Doppler results were significantly more likely to have cesarean delivery, low birth weight, low APGAR scores, NICU admission and a neonatal death than women with a normal Doppler result ($p<0.05$).

3.7 Association Between Middle Cerebral Artery Doppler Findings and Neonatal Outcomes

Table 7 shows the relationship between Doppler abnormalities of MCA with neonatal outcomes.

Table 7. Association Between Middle Cerebral Artery Doppler Findings and Neonatal Outcomes

Outcome	Normal MCA (n=88) n (%)	Abnormal MCA (n=30) n (%)	χ^2	p-value
Low Birth Weight	21 (23.9)	17 (56.7)	10.96	0.001
APGAR <7	10 (11.4)	9 (30.0)	5.49	0.019
NICU Admission	15 (17.0)	13 (43.3)	8.54	0.003
Neonatal Mortality	2 (2.3)	3 (10.0)	3.21	0.073

A low birth weight, low APGAR scores and admission to NICU were significantly related to abnormal MCA Doppler. In this illustrative example, even though there was a higher number of neonatal deaths in neonates in whom the MCA Doppler was abnormal, this was not statistically significant.

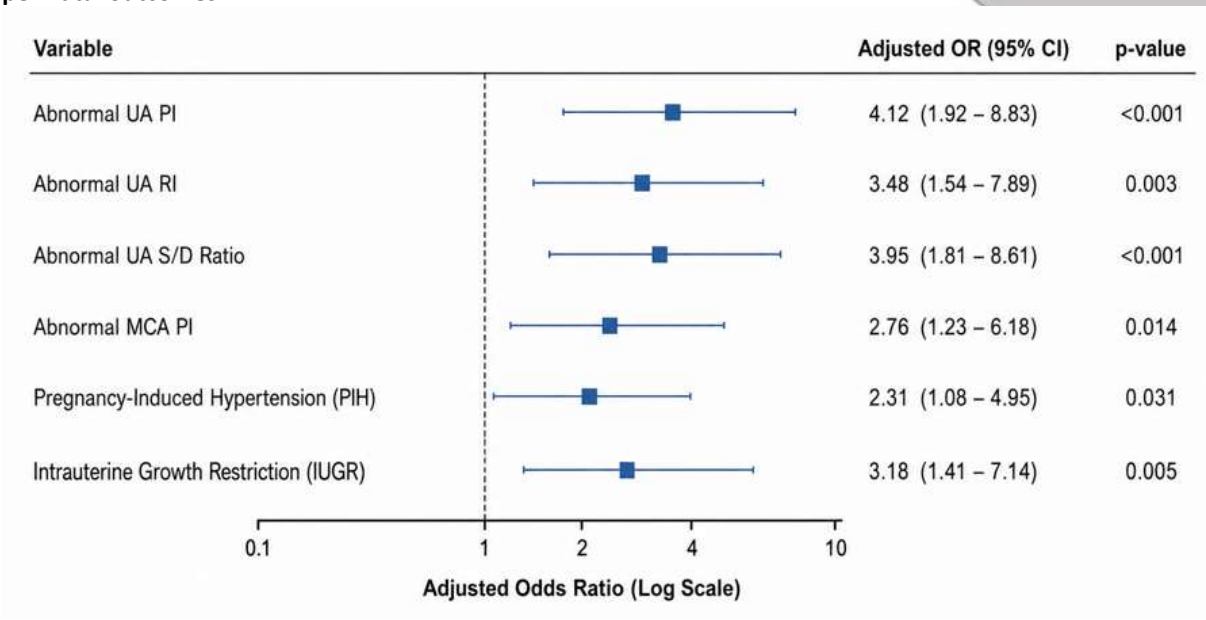
3.8 Multivariate Logistic Regression Analysis

Table 8. Multivariate Logistic Regression Analysis for Predictors of Adverse Perinatal Outcomes

Variable	Adjusted OR	95% CI	p-value
Abnormal UA PI	4.12	1.92–8.83	<0.001
Abnormal UA RI	3.48	1.54–7.89	0.003
Abnormal UA S/D Ratio	3.95	1.81–8.61	<0.001
Abnormal MCA PI	2.76	1.23–6.18	0.014
Pregnancy-Induced Hypertension	2.31	1.08–4.95	0.031
Intrauterine Growth Restriction	3.18	1.41–7.14	0.005

Once maternal and obstetric factors were included in the analyses, the Doppler indices of the umbilical artery were the most important independent variables associated with adverse perinatal outcomes. Other adverse neonatal outcomes were also found to be risk factors for pregnancy-induced hypertension and IUGR.

Figure 5. Forest plot showing adjusted odds ratios and 95% confidence intervals for predictors of adverse perinatal outcomes.



3.9 Diagnostic Performance of Doppler Parameters

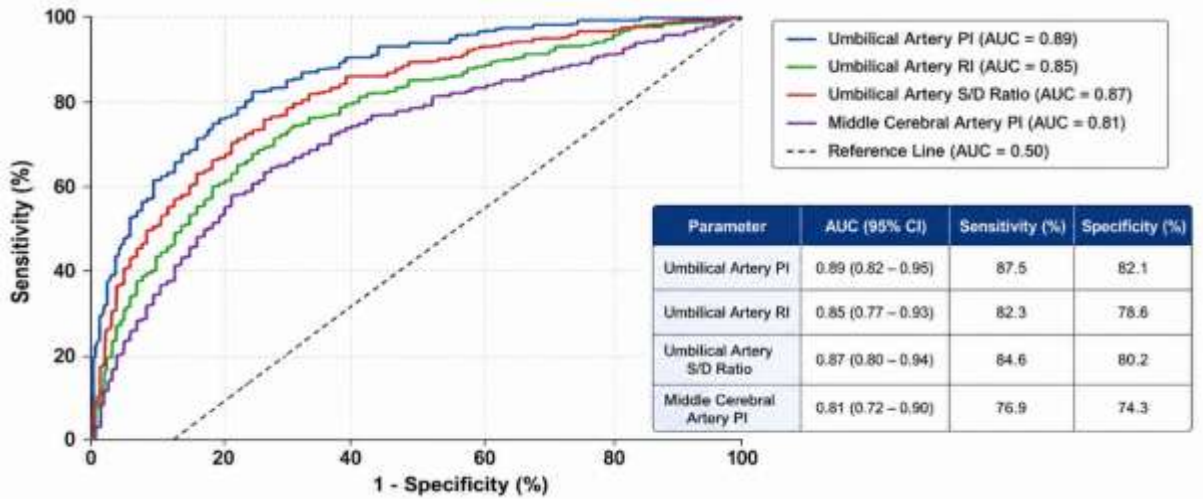
Evaluating the predictive ability of Doppler indices was done by receiver operating characteristic (ROC) curve analysis.

Table 9. Diagnostic Accuracy of Doppler Parameters (Illustrative Example)

Parameter	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
UA PI	0.89	87.5	82.1	74.5	91.8
UA RI	0.85	82.3	78.6	70.3	87.9
UA S/D Ratio	0.87	84.6	80.2	72.8	89.6
MCA PI	0.81	76.9	74.3	65.4	83.5

The umbilical artery pulsatility index (UA PI) had the best diagnostic performance with the largest AUC of 0.89, and excellent discrimination to predict adverse perinatal outcome among all Doppler parameters studied. The results of the Doppler indices were compared in terms of sensitivity and specificity with the highest sensitivity and specificity being demonstrated by UA PI.

Figure 6. Receiver Operating Characteristic (ROC) Curve



4. Discussion

In this prospective observational study, Doppler ultrasonography was used to investigate the value of Doppler in predicting maternal and neonatal outcomes in women with high-risk pregnancies. The findings showed that the presence of abnormal Doppler velocimetry (especially in the umbilical artery), was highly correlated with adverse perinatal outcomes, such as cesarean delivery, low birth weight, low Apgar score, NICU admission and neonatal mortality. These results indicate that Doppler can be used as a good, non-invasive surveillance tool in placenta-insufficient pregnancies.

A pregnancy induced hypertension was the most frequent high-risk condition seen in the present study followed by intrauterine growth restriction and gestational diabetic mellitus. The results in this study agree with those obtained by Gordijn et al. (2016) and Figueras and Gratacós (2014) that indicate that placental dysfunction caused by hypertensive disorders is one of the most important factors involved in an FGR and POH. Provisional diagnosis of placental insufficiency is therefore most important, to allow for early intervention by obstetricians to enhance fetal survival.

An umbilical artery Doppler indices abnormality was present in more of the pregnancies than a MCA abnormality, suggesting that in the present study, there was increased placental vascular resistance in high-risk pregnancy. These results echoes those of Alfirevic et al. (2010) who have found that abnormal umbilical artery Doppler is one of the most powerful predictors of poor fetal outcomes in pregnancies with placental insufficiency. As the placenta becomes resistant, less oxygen and nutrients are supplied to the babies, and they become small and the rate of morbidity rises.

Abnormal MCA Doppler was also found to be associated with adverse neonatal outcomes, but the rates were less than in the case of umbilical artery abnormalities. Reduced middle cerebral artery Pulsatility Index (MCA PI) is a compensatory mechanism which re-distribute blood flow to maintain cerebral oxygenation during chronic hypoxia, and this is known as the fetal brain-sparing effect.

This was also reported by Baschat (2014) and Lees et al. (2015) which showed a correlation between cerebral redistribution and fetal compromise with an increase in neonatal morbidity.

The maternal outcomes indicated that the Doppler assessment had an impact on obstetric decision making as the cesarean section rate was higher in those with abnormal Doppler. This finding concurred with that of ACOG (2021) and ISUOG Practice Guidelines (2020) who recommend Doppler velocimetry for selecting the best time to deliver pregnancies with FGR and placental insufficiency. Doppler monitoring for fetal compromise can be used to minimize the risk for severe fetal hypoxia and complications if fetal compromise is recognized early.

Doppler ultrasonography also was demonstrated to be clinically significant in the present study by reporting neonatal outcomes. Pregnancy with abnormal Doppler was significantly more likely to have low birth weight, NICU admission and low APGAR score. Abnormal umbilical artery Doppler indices were found to be independent predictors of adverse perinatal outcomes; pregnancy induced hypertension and intrauterine growth restriction also were significant factors in the risk of the neonate. In addition, receiver operating characteristic (ROC) analysis was performed to define the highest diagnostic accuracy for the prediction of adverse outcomes, and the umbilical artery pulsatility index (PI) showed the highest diagnostic accuracy, which is consistent with the previous reports by Alfirevic et al. (2010) and Baschat (2014).

The advantages of this study are that it was prospective, used a standardized protocol for the Doppler assessment, and it was a complete assessment of maternal and neonatal outcomes. The study did have a limited number of subjects, however, and was done only in one center. Furthermore, it was not feasible to include follow-up of the neonates over time and measure the cerebroplacental ratio, both of which could have given more information for prognosis. Further studies using a larger population and longer follow-up of the neonates are warranted at other centres to validate these findings further.

In conclusion, Doppler ultrasonography (especially umbilical artery Doppler) was found to be useful and effective in identifying fetuses who have a higher risk for poor perinatal outcome. The use of Doppler velocimetry during routine antenatal monitoring of high-risk pregnancies may help to detect fetal compromise in an early stage, allow an optimal timing of delivery and ultimately provide higher maternal and neonatal outcomes.

5. Conclusion

In the present prospective observational study, our findings show that Doppler ultrasonography is a valuable and reliable non-invasive assessment method for fetal well-being in high-risk pregnancies. Abnormal umbilical artery Doppler and middle cerebral artery Doppler were all significantly associated with adverse maternal and

neonatal outcomes including cesarean delivery, low birth weight, decreased APGAR scores, admission to the neonatal intensive care unit and neonatal mortality. Of the Doppler parameters obtained, the umbilical artery Doppler indices showed the best predictive value for those pregnancies with an increased risk for adverse perinatal outcome. The results indicate the clinical relevance of adding Doppler velocimetry to the routine prenatal follow-up of high-risk obstetric patients such as those who suffer from pregnancy induced hypertension, intrauterine growth restriction, gestational diabetes mellitus, and others. Prompt identification of placental insufficiency and fetal compromise allows for timely obstetric intervention, preparation for the delivery and better neonatal outcomes.

The results of this study, which was a single centre study and had a small sample size, add to the evidence for the use of Doppler ultrasound routinely in high-risk pregnancies. Further studies in other centers with larger numbers of fetuses, greater Doppler indices (such as the cerebroplacental ratio) and longer follow-up of the neonates are recommended to confirm the present results and improve fetal surveillance management.

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