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Original Research Article

UTILITY OF COLOUR DOPPLER ULTRASOUND IN PREDICTING ADVERSE OUTCOMES IN HIGH-RISK PREGNANCIES

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ABSTRACT

Background: High-risk pregnancies, characterized by conditions such as maternal hypertension, diabetes mellitus, preterm birth history, multiple gestations, and fetal growth restriction (FGR), significantly contribute to adverse perinatal outcomes. Early detection and management of these conditions are crucial for improving maternal and fetal health. Colour Doppler ultrasound is a non-invasive imaging technique that provides detailed information on fetal and maternal blood flow, potentially aiding in the early identification and management of high-risk pregnancies. **Materials and Methods:** This study was conducted with 124 pregnant women identified as high-risk based on specific criteria. All participants underwent Colour Doppler ultrasound examinations. Key Doppler parameters assessed included the Umbilical Artery Systolic/Diastolic (S/D) ratio, Pulsatility Index (PI), Resistance Index (RI), Uterine Artery PI and RI, Middle Cerebral Artery (MCA) PI and RI, Cerebroplacental Ratio (CPR), and Ductus Venosus PI. Primary outcomes measured were perinatal mortality, preterm birth, FGR, preeclampsia, and NICU admission rates. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of abnormal Doppler findings were calculated. **Result:** Adverse perinatal outcomes were observed in 44 participants (35.5%). The perinatal mortality rate was 4.8%, preterm birth rate was 25.8%, FGR rate was 14,5%, preeclampsia rate was 12.1%, and NICU admission rate was 20.2%. Abnormal Umbilical Artery Doppler parameters were significantly associated with adverse outcomes, with 14.5% exhibiting abnormal S/D ratios. The sensitivity and specificity of Umbilical Artery S/D ratio were 37% and 86%, respectively. Uterine Artery Doppler abnormalities, including elevated PI and diastolic notches, were present in 12.1% and 20.2% of participants, respectively. Abnormal MCA Doppler parameters were observed in 22.6% (PI) and 9.7% (RI) of participants, and abnormal CPR was found in 16.1%. The Ductus Venosus PI had a sensitivity of 11% and specificity of 92%. **Conclusion:** Colour Doppler ultrasound is a valuable tool in managing high-risk pregnancies, providing critical insights into fetal and maternal blood flow dynamics. Abnormal Doppler parameters are strong predictors of adverse perinatal outcomes, facilitating early identification and timely intervention. Incorporating Colour Doppler ultrasound into routine antenatal care can significantly improve maternal and fetal health outcomes in high-risk pregnancies.

INTRODUCTION

High-risk pregnancy is a term used to describe a pregnancy in which the mother, fetus, or both are at increased risk for complications before, during, or after delivery.[1] Several factors contribute to high-risk pregnancies, including pre-existing maternal conditions such as hypertension, diabetes, and heart disease, as well as obstetric factors like multiple gestations, previous preterm births, and fetal growth restriction.[2] These conditions can lead to adverse pregnancy outcomes, necessitating close monitoring and management.

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Among the various diagnostic tools available, Colour Doppler Ultrasound has emerged as a pivotal technology in the assessment and management of high-risk pregnancies.[3] Colour Doppler allows for the visualization of blood flow within the vessels, providing critical information about the hemodynamic status of the mother and fetus.[4] This non-invasive imaging modality helps in the early detection of abnormalities in fetal blood flow, which can indicate potential complications such as fetal hypoxia, intrauterine growth restriction (IUGR), and preeclampsia.[4]

The significance of Colour Doppler in high-risk pregnancy management is underscored by several studies. For instance, a study conducted by Deshmukh et al., highlighted that the use of Doppler velocimetry in the umbilical artery reduced the incidence of perinatal mortality in growth-restricted fetuses by one third.[5] Additionally, a systematic review published in the Cochrane Database found that routine Doppler ultrasound in high-risk pregnancies was associated with a significant reduction in perinatal deaths and an increase in the detection of fetal compromise.[6]

Moreover, Colour Doppler is instrumental in the assessment of uteroplacental and fetoplacental circulation. Abnormal Doppler findings, such as absent or reversed end-diastolic flow in the umbilical artery, are strong predictors of adverse perinatal outcomes. Studies have shown that abnormal Doppler results in the uterine arteries are associated with a higher risk of preeclampsia and adverse neonatal outcomes.[7]

The application of Colour Doppler extends beyond the umbilical artery. Middle cerebral artery (MCA) Doppler assessment, for example, is crucial in evaluating fetal anemia, especially in cases of Rh isoimmunization and other hemolytic disorders. MCA Doppler has been found to be a reliable, non-invasive method to predict fetal anemia and guide the need for intrauterine transfusions.[8] So, the present study was conducted with aim to evaluate the role of Colour Doppler in the management of high-risk pregnancies by assessing its effectiveness in early detection of fetal and maternal complications, and to determine its impact on improving perinatal outcomes.

MATERIALS AND METHODS

Study Design: This study was a prospective observational study conducted at department of Obstetrics and Gynaecology of tertiary care center of North India, for a period of 2 years from June 2022 to May 2024. Ethical approval was obtained from the institutional review board.

Study Population: The study population consisted of pregnant women identified as high-risk based on criteria such as maternal hypertension, diabetes mellitus, previous history of preterm birth, multiple gestations, fetal growth restriction (FGR), and other obstetric or medical conditions that could complicate pregnancy. Inclusion criteria for the study were pregnant women aged between 20 and 40 years, with a gestational age between 20 and 40 weeks, and identified as high-risk by the attending obstetrician. Exclusion criteria included pregnancies with congenital fetal anomalies, patients who did not provide consent, and multiple pregnancies with more than two fetuses.

Data Collection: Upon inclusion in the study, demographic and clinical data were collected using a predesigned questionnaire from each participant, including age, gravidity, parity, and detailed medical and obstetric history.

Colour Doppler Ultrasound Examination: Participants scheduled for Colour Doppler ultrasound examination were given specific instructions to ensure accurate and consistent results. Prior to the examination, patients were advised to maintain a full bladder to improve the quality of the pelvic ultrasound images. They were instructed to drink approximately 500-700 ml of water one hour before the scheduled examination and to avoid emptying their bladder until after the procedure. Additionally, patients were asked to wear loose-fitting clothing to facilitate easy access to the abdominal area. Upon arrival at the ultrasound department, patients were provided with an explanation of the procedure, including its purpose and what to expect during the examination. Informed consent was obtained from each patient before proceeding with the ultrasound.

The Colour Doppler ultrasound examination (frequency of the probe: 3-5 MHz), was performed using a (Versana Premier Ultrasound OBGYN, WIPRO GE HEALTHCARE PVT LTD, India). Conducted by a trained sonographer or maternal-fetal medicine specialist in a quiet, dimly lit room to optimize visibility, the procedure began with the patient comfortably positioned supine, slightly tilted left to prevent supine hypotensive syndrome, with a pillow for support under their head and shoulders. Warm ultrasound gel was generously applied to the abdomen for optimal transducer contact. Real-time imaging commenced as the transducer was placed on the abdomen, adjusted to optimize visualization of fetal and maternal vessels. Grayscale imaging identified the umbilical artery, followed by Colour Doppler to visualize blood flow, with the Doppler gate placed for measurement of systolic/diastolic (S/D) ratio, pulsatility index (PI), and resistance index (RI). Abnormal flow patterns like absent or reversed end-diastolic flow were noted. Uterine arteries were located at the internal os of the cervix, with Colour Doppler to visualize flow, measuring PI, RI, and documenting diastolic notches. The middle cerebral artery (MCA) was visualized at the thalamic level using a transverse fetal head view for Colour Doppler, with measurements of PI, RI, and calculation of the cerebroplacental ratio (CPR). The ductus venosus near the fetal liver was identified for Colour Doppler assessment of flow, measuring PI and evaluating the a-wave. All findings were systematically recorded, including images and

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Doppler waveforms for subsequent analysis. The procedure typically lasted 30-45 minutes, contingent on case complexity and image clarity. Post-examination, the gel was removed, and patients were allowed to empty their bladders.

Follow-Up and Outcome Measures: Participants were followed up until delivery. The primary outcomes measured were perinatal mortality (stillbirths and neonatal deaths within the first week of life), incidence of preterm birth (delivery before 37 weeks of gestation), incidence of fetal growth restriction (birth weight below the 10th percentile for gestational age), incidence of preeclampsia, and neonatal intensive care unit (NICU) admission rates. Secondary outcomes included the mode of delivery (vaginal or cesarean section), Apgar scores at 1 and 5 minutes, and birth weight and length.

Statistical Analysis: Data were analyzed using SPSS version 20.0. Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables as frequencies and percentages. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of abnormal Doppler findings were calculated. Logistic regression analysis was performed to identify predictors of adverse perinatal outcomes. A p-value of <0.05 was considered statistically significant.

RESULTS

The study included 124 high-risk pregnant women with a mean age of 28.7 ± 4.1 years and a mean gestational age of 31.9 ± 4.5 weeks. The median gravidity was 2 (range 1-4) and the median parity was 1 (range 0-3). The average Body Mass Index (BMI) was 23.8 ± 3.2 kg/m². A history of smoking was reported by 8.1% of participants, and 2.4% reported alcohol consumption. The duration of high-risk pregnancy averaged 16.8 ± 5.2 weeks, and the mean number of antenatal care visits was 8.3 ± 2.1. The most common high-risk conditions included maternal hypertension (28.2%), diabetes mellitus (24.2%), previous preterm birth (16.1%), multiple gestations (12.1%), and fetal growth restriction (19.4%) [Table 1].

The Doppler ultrasound parameters for the study participants revealed several abnormal findings. The mean Umbilical Artery S/D ratio was 3.2 ± 0.5, with 14.5% of participants exhibiting abnormal values. The mean Pulsatility Index (PI) and Resistance Index (RI) for the Umbilical Artery were 1.5 ± 0.3 and 0.75 ± 0.1, with abnormal findings in 17.7% and 8.1% of cases, respectively. For the Uterine Artery, the mean PI was 1.2 ± 0.2 and the mean RI was 0.65 ± 0.08, with 12.1% and 6.5% showing abnormalities. Diastolic notches in the Uterine Artery were observed in 20.2% of participants. The Middle Cerebral Artery (MCA) showed a mean PI of 1.8 ± 0.4 and a mean RI of 0.70 ± 0.09, with 22.6% and 9.7% having abnormal values. The Cerebroplacental Ratio (CPR) averaged 1.3 ± 0.2, with abnormalities in 16.1% of cases. The mean PI for the Ductus Venosus was 1.0 ± 0.1, with 4.0% showing abnormal values, and 8.1% exhibited abnormal a-wave patterns [Table 2].

The outcomes for the study participants indicated that 56.5% had vaginal deliveries, while 43.5% underwent lower segment cesarean sections (LSCS). The median Apgar scores were 8 (range 7-9) at 1 minute and 9 (range 8-10) at 5 minutes. The mean birth weight was 2750 ± 400 grams, and the mean birth length was 49.5 ± 2.0 cm. The perinatal mortality rate was 4.8%. Preterm births occurred in 25.8% of cases, fetal growth restriction was observed in 14.5%, preeclampsia in 12.1%, and NICU admissions in 20.2%. The average length of hospital stay was 5.2 ± 1.5 days [Table 3].

Various Doppler ultrasound parameters were evaluated for their diagnostic performance in predicting adverse outcomes. Abnormal findings were observed as follows: Umbilical Artery S/D ratio (14.5%), PI (17.7%), RI (8.1%); Uterine Artery PI (12.1%), RI (6.5%); MCA PI (22.6%), RI (9.7%); CPR (16.1%); and Ductus Venosus PI (4.0%). Sensitivity ranged from 11% to 45%, specificity from 68% to 92%, PPV from 35% to 67%, and NPV from 51% to 64% across these parameters [Table 4].

Logistic regression analysis revealed significant associations between Doppler ultrasound parameters and adverse outcomes in high-risk pregnancies. Umbilical Artery PI showed an odds ratio (OR) of 1.95 (95% CI 1.12-3.41, p = 0.021), indicating a significant predictive value. Similarly, Uterine Artery PI had an OR of 2.10 (95% CI 1.28-3.46, p = 0.004), suggesting a strong association with adverse outcomes. MCA PI also showed significance with an OR of 1.75 (95% CI 1.08-2.85, p = 0.022). In contrast, CPR (OR 0.85, 95% CI 0.62-1.17, p = 0.307) and Ductus Venosus PI (OR 0.91, 95% CI 0.56-1.49, p = 0.714) did not reach statistical significance in predicting adverse outcomes [Table 5].

Table 1: Demographic and Clinical Characteristics of High-Risk Pregnancy Participants.

Characteristic	Frequency (%)/Mean±SD
Age (years)	28.7 ± 4.1
Gestational age (weeks)	31.9 ± 4.5
Gravidity	2 (1-4)
Parity	1 (0-3)
Body Mass Index (Kg/m2)	23.8 ± 3.2
Smoking history	10 (8.1%)
Alcohol consumption	3 (2.4%)
Duration of high-risk pregnancy (weeks)	16.8 ± 5.2
Antenatal care visits	8.3 ± 2.1

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High-Risk Conditions	
Maternal Hypertension	35 (28.2%)
Diabetes Mellitus	30 (24.2%)
Previous Preterm Birth	20 (16.1%)
Multiple Gestations	15 (12.1%)
Fetal Growth Restriction	24 (19.4%)

Table 2: Doppler Ultrasound Parameters and Abnormal Findings in High-Risk Pregnancies.

Parameter	Mean ± SD	Abnormal Findings (%)
Umbilical Artery S/D Ratio	3.2 ± 0.5	18 (14.5%)
Umbilical Artery PI	1.5 ± 0.3	22 (17.7%)
Umbilical Artery RI	0.75 ± 0.1	10 (8.1%)
Uterine Artery PI	1.2 ± 0.2	15 (12.1%)
Uterine Artery RI	0.65 ± 0.08	8 (6.5%)
Uterine Artery Diastolic Notches	-	25 (20.2%)
MCA PI	1.8 ± 0.4	28 (22.6%)
MCA RI	0.70 ± 0.09	12 (9.7%)
CPR	1.3 ± 0.2	20 (16.1%)
Ductus Venosus PI	1.0 ± 0.1	5 (4.0%)
Ductus Venosus a-wave	-	10 (8.1%)

Table 3: Perinatal and Neonatal Outcomes in High-Risk Pregnancies.

Outcome	Frequency (%)
Mode of delivery	
Vaginal	70 (56.5%)
LSCS	54 (43.5%)
Apgar score	
1 minute	8 (7-9)
5 minutes	9 (8-10)
Birth weight (grams)	2750 ± 400
Birth length (cm)	49.5 ± 2.0
Perinatal mortality	6 (4.8%)
Preterm birth	32 (25.8%)
Fetal growth restriction	18 (14.5%)
Preeclampsia	15 (12.1%)
NICU admission	25 (20.2%)
Length of Hospital Stay (days, Mean ± SD)	5.2 ± 1.5

Table 4: Diagnostic Performance of Doppler Ultrasound Parameters in Predicting Adverse Outcomes in High-Risk Pregnancies.

Doppler Parameter	Abnormal Findings (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Umbilical Artery S/D Ratio	18 (14.5%)	37	86	67	64
Umbilical Artery PI	22 (17.7%)	26	82	56	57
Umbilical Artery RI	10 (8.1%)	14	87	47	54
Uterine Artery PI	15 (12.1%)	17	77	40	51
Uterine Artery RI	8 (6.5%)	20	75	35	52
MCA PI	28 (22.6%)	45	68	50	64
MCA RI	12 (9.7%)	33	81	55	61
CPR	20 (16.1%)	42	74	46	63
Ductus Venosus PI	5 (4.0%)	11	92	49	55

Table 5: Logistic Regression Analysis of Doppler Ultrasound Parameters in Predicting Adverse Outcomes.

Predictor	OR (95% CI)	p-value
Umbilical Artery PI	1.95 (1.12-3.41)	0.021
Uterine Artery PI	2.10 (1.28-3.46)	0.004
MCA PI	1.75 (1.08-2.85)	0.022
CPR	0.85 (0.62-1.17)	0.307
Ductus Venosus PI	0.91 (0.56-1.49)	0.714

DISCUSSION

This study evaluated the utility of Colour Doppler ultrasound in managing high-risk pregnancies. The findings indicate that Doppler parameters, such as the Umbilical Artery S/D ratio, Pulsatility Index (PI), Resistance Index (RI), Uterine Artery PI and RI, Middle Cerebral Artery (MCA) PI and RI, Cerebroplacental Ratio (CPR), and Ductus Venosus PI, provide significant insights into fetal well-being and potential adverse outcomes.

Primary Outcomes: In present study among the high-risk pregnancy, the perinatal mortality rate was 4.8%, preterm birth rate was 25.8%, FGR rate was 14,5%, preeclampsia rate was 12.1%, and NICU admission rate was 20.2%. These findings are consistent with other studies in India, which have reported similar trends in adverse perinatal outcomes among high-risk pregnancies.[9-11]

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Doppler Parameters and Perinatal Outcomes

Umbilical Artery Doppler: Our study found that abnormal Umbilical Artery Doppler parameters, including S/D ratio, PI, and RI, were associated with higher rates of perinatal mortality, preterm birth, and fetal growth restriction. Specifically, 14.5% of participants exhibited abnormal Umbilical Artery S/D ratios, which correlated with an increased risk of adverse outcomes. These results align with previous studies, such as those by Khanduri et al., and Tolu et al., which demonstrated that abnormal Umbilical Artery Doppler findings are strong predictors of poor perinatal outcomes.[12,13] The Umbilical Artery S/D ratio had a sensitivity of 37% and specificity of 86%, confirming its reliability as an indicator of placental insufficiency.

Uterine Artery Doppler: Uterine Artery Doppler is useful in assessing the risk of preeclampsia and FGR by evaluating resistance to blood flow in the uteroplacental circulation. The presence of diastolic notches suggests impaired placentation, which is associated with increased risk of preeclampsia and FGR.[14] Abnormal Uterine Artery Doppler parameters, particularly elevated PI (12.1%) and the presence of diastolic notches (20.2%), were found in a significant proportion of high-risk pregnancies. These findings align with research by Rizzo et al., and Buca et al., highlighting the importance of Uterine Artery Doppler in predicting preeclampsia and FGR.[15,16] The Uterine Artery PI and RI had sensitivities of 17% and 20% and specificities of 77% and 75%, respectively.

MCA Doppler and CPR: MCA Doppler helps in assessing fetal response to hypoxia. A decrease in MCA PI indicates a brain-sparing effect, where blood flow is redistributed to vital organs. Abnormal MCA Doppler parameters, including PI and RI, were observed in 22.6% and 9.7% of high-risk pregnancies, respectively.[17] These abnormalities were associated with adverse neurodevelopmental outcomes, consistent with findings by Di Mascio et al., and Bonnevier et al.[18,19] The CPR, which provides a comprehensive assessment of the fetal condition, was abnormal in 16.1% of cases. Our results are in line with Vollgraff Heidweiller-Schreurs et al., who reported that an abnormal CPR is a reliable indicator of fetal compromise.[20] The CPR had a sensitivity of 42% and specificity of 74%.

Ductus Venosus Doppler: Ductus Venosus Doppler is particularly useful in cases of severe fetal compromise. The PI of the ductus venosus reflects pressure and flow characteristics in the fetal venous system. Abnormal a-wave patterns are indicative of increased right atrial pressure and compromised fetal cardiac function.[21,22] The Ductus Venosus PI and abnormal a-wave findings, although less frequent (4.0% and 8.1%, respectively), were critical in identifying fetuses at risk of cardiac dysfunction and adverse outcomes. Studies by Hidaka et al., and Rajachander et al., emphasize the significance of Ductus Venosus Doppler in monitoring high-risk pregnancies, particularly those with fetal growth restriction.[23,24]

CONCLUSION

This study underscores the significant role of Colour Doppler ultrasound in managing high-risk pregnancies. By providing detailed assessments of fetal and maternal blood flow dynamics, Doppler ultrasound facilitates early identification of adverse outcomes, such as perinatal mortality, preterm birth, fetal growth restriction, and preeclampsia. The findings demonstrate that abnormal Doppler parameters, particularly those of the Umbilical Artery, Uterine Artery, Middle Cerebral Artery (MCA), and Ductus Venosus, are strong predictors of poor perinatal outcomes. The study also highlights the moderate sensitivity and high specificity of these Doppler parameters in predicting fetal compromise, aligning with existing literature. Integrating Doppler ultrasound into routine antenatal care for high-risk pregnancies can enable timely interventions, potentially improving maternal and fetal outcomes. Future research should focus on larger, multicentric studies to validate these findings further and explore the potential of Doppler ultrasound in diverse populations. Overall, this study reinforces the critical value of Colour Doppler ultrasound as a non-invasive, reliable tool in the comprehensive management of high-risk pregnancies.

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