Research Article

# Colour Doppler Study of Middle Cerebral Artery in Cases of Pregnancy-Induced Hypertension with Suspected Fetal Growth Restriction and Correlation with Mode of Delivery and Fetal Outcome

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**Background:** Effective management of fetal growth restriction (FGR) involves accurate diagnosis and monitoring, with Doppler ultrasound being a key diagnostic tool. This study aimed to assess the significance of Doppler ultrasound findings of the middle cerebral artery (MCA) in patients with pregnancy-induced hypertension (PIH) and suspected intrauterine growth restriction (IUGR).

**Material and Methods:** The study was conducted on 123 pregnant women with PIH and FGR between 28–40 weeks of gestation. Detailed clinical profiles and Doppler indices, including pulsatility index (PI), resistance index (RI), and systolic-to-diastolic (S/D) ratio, were assessed and correlated with perinatal outcomes.

**Results:** Significant correlations were observed between Doppler parameters and adverse outcomes, including low birth weight, poor Apgar scores, and increased NICU admissions. A higher S/D ratio was strongly associated with the need for pregnancy termination.

**Conclusion:** MCA Doppler assessment is a valuable non-invasive predictor of fetal compromise in PIH and FGR, enabling timely clinical intervention and improved perinatal outcomes.

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**Keywords:** Intrauterine growth restriction (IUGR), Pregnancy-induced hypertension (PIH), Color doppler, Middle cerebral artery (MCA)

## Introduction

Fetal growth restriction associated with pregnancy-induced hypertension affects 3–10% of pregnancies and is a leading cause of perinatal morbidity and mortality.[1,2] Color Doppler imaging is essential for evaluating utero-placental circulation and fetal well-being, especially in cases of pregnancy-induced hypertension (PIH), which disrupts normal uterine blood flow.[3-6] In response to hypoxemia, blood flow is redirected to the brain, leading to a decrease in the middle cerebral artery (MCA) pulsatility index (PI), which is associated with adverse perinatal outcomes.[7] The cerebro-placental ratio (CPR=MCA PI/UA PI) further helps assess brain sparing, with a ratio below the 5th percentile indicating significant brain sparing.[8,9] Doppler parameters like pulsatility index (PI), resistance index (RI), and systolic-to-diastolic ratio (S/D) from key vessels help assess fetal status and guide clinical decisions.[10-13] Further research is needed to refine Doppler parameters and establish their predictive accuracy, especially in preterm intrauterine growth restriction (IUGR) cases, where increased MCA peak systolic velocity may better predict perinatal mortality than PI.[14,15] We also purported to detect cases of fetal growth restriction (FGR) clinically and to study the color Doppler findings in MCA and correlate the results with clinical parameters of fetal well-being.

## Material And Methods

After obtaining approval from the Institutional Ethical Committee, this prospective observational study was conducted on 123 pregnant women diagnosed with pregnancy-induced hypertension (PIH) and clinically suspected intrauterine growth restriction (IUGR)

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attending the Department of Obstetrics and Gynaecology, C.R. Gardi Hospital, Ujjain. Written informed consent was obtained from all participants, and confidentiality was maintained throughout the study.

### *Inclusion Criteria*

- Pregnant women aged 19 to 40 years with PIH, defined according to ACOG criteria (blood pressure ≥140/90 mm Hg recorded on two occasions, at least 4 hours apart, after 20 weeks of gestation).
- Singleton pregnancies with clinical or sonographic suspicion of fetal growth restriction.
- Gestational age between 28 and 40 weeks, confirmed by early ultrasound.

### *Exclusion Criteria*

- Multiple gestations.
- Congenital fetal anomalies or abnormal placental morphology.
- Maternal chronic systemic diseases, acute infections, or metabolic disorders.
- History of previous uterine surgery or use of medications that could interfere with fetal growth.

## Methodology

A detailed obstetric and medical history was taken, including maternal age, parity, gestational age, degree of hypertension, and use of antihypertensive medication. Each patient underwent a thorough general and obstetric examination with special attention to fundal height, fetal movements, and signs of pre-eclampsia.

Colour Doppler ultrasonography was performed to assess the middle cerebral artery (MCA) using standard insonation angles. The following Doppler indices were recorded:

- Pulsatility index (PI)
- Resistance index (RI)
- Systolic-to-diastolic (S/D) ratio

Cut-off values used were RI ≤ 0.8, PI ≤ 0.9, and S/D ≤ 2.8, based on reference standards described by Kurmanavicius *et al*. (1997) and Rumack CM *et al*. (2018) for normal third-trimester Doppler parameters.[14,16]

FGR grading was done using both clinical and ultrasonographic criteria, taking into account estimated fetal weight below the 10th percentile for gestational age and abnormal Doppler findings. Clinically, cases were identified by fundal height lag >4 cm, poor maternal weight gain, and reduced abdominal girth for gestational age. Ultrasonographic assessment included estimated fetal weight below the 10th percentile, abdominal circumference lag >2 weeks, and abnormal Doppler indices—specifically umbilical artery RI >0.8, PI >0.9, and S/D ratio >2.8, along with decreased MCA PI (<1.5 MoM) indicating brain-sparing.

Based on these findings, FGR was graded as mild (EFW 5th–10th percentile, normal AFI, normal Doppler), moderate (EFW 3rd–5th percentile with increased umbilical resistance and mild oligohydramnios), and severe (EFW <3rd percentile with AFI <5 cm and absent or reversed end-diastolic flow). This integrated approach allowed accurate detection of growth restriction severity and its correlation with perinatal outcome.

Maternal outcomes included mode of delivery (normal vaginal delivery, instrumental, or LSCS) and intrapartum complications. Fetal outcomes recorded were birth weight, Apgar score at 1 minute and 5 minutes, need for NICU admission, and neonatal survival.

All data were compiled and analyzed using SPSS software version 22.0. Continuous variables were expressed as mean ± standard deviation, and categorical variables as numbers and percentages. Appropriate statistical tests (Chi-square test, t-test, or ANOVA) were applied depending on data distribution, and a p-value < 0.05 was considered statistically significant.

## Results

Out of 123 patients, 82.1% were aged 21–30 years, 10.6% were 31–40 years, and 7.3% were 18–20 years. Regarding the Amniotic Fluid Index (AFI), 67.5% had an adequate AFI, while 32.5% had reduced AFI — 17.9% had AFI <1, 8.9% <2, 4.1% <3, and 1.6% >20. Among all cases of PIH, 68% had mild PIH and 32% had severe PIH, reflecting a higher proportion of mild disease in the study population [Table 1].

On color Doppler evaluation, the middle cerebral artery (MCA) was assessed using three principal parameters—resistance index (RI), pulsatility index (PI), and systolic/diastolic (S/D) ratio. The cut-off values for these parameters were standardized based on Kurmanavicius *et al*. (1997) [14] and Rumack CM *et al*. (2018): RI ≤ 0.8, PI ≤ 0.9, and S/D ≤ 2.8. Most cases (86.2%) showed an RI ≤ 0.8, indicating reduced vascular resistance, while only 13.8% exceeded this value. Similarly, 63.4% of the study population had PI ≤ 0.9 and 78.0% had an S/D ratio ≤ 2.8. These findings suggest predominant cerebral vasodilatation in response to chronic hypoxemia, a compensatory change typical of fetuses under growth restriction due to PIH [Table 2].

**Table 1:** Distribution of Study Population on the Basis of Age Group, AFI, and PIH Severity

| *Parameter* | *Category* | *Frequency* | *Percent* |
|---|---|---|---|
| Age Group | 18-20 Years | 9 | 7.3% |
| | 21-30 Years | 101 | 82.1% |
| | 31-40 Years | 13 | 10.6% |
| AFI | <1 | 22 | 17.9% |
| | <2 | 11 | 8.9% |
| | <3 | 5 | 4.1% |
| | >20 | 2 | 1.6% |
| | Adequate | 83 | 67.5% |
| Pregnancy-Induced Hypertension (PIH) | Mild PIH | 84 | 68.3% |
| | Severe PIH | 39 | 31.7% |

**Table 2:** Distribution of study population on the basis of color Doppler findings

| *Parameter* | *Category* | *Frequency* | *Percent* |
|---|---|---|---|
| CD_RI-0.8 | ≤0.8 | 106 | 86.2% |
| | >0.8 | 17 | 13.8% |
| CD_PI-0.9 | ≤0.9 | 78 | 63.4% |
| | >0.9 | 45 | 36.6% |
| CD_S/D-2.8 | ≤2.8 | 96 | 78.0% |
| | >2.8 | 27 | 22.0% |

**Table 3:** Distribution of study population on the basis of fetal outcome

| *Outcome Parameter* | *Category* | *Frequency* | *Percent* |
|---|---|---|---|
| Birth Outcome (Day 1) | Live Births | 117 | 95.1% |
| | Non-Live Outcomes | 6 | 4.9% |
| | -Intrauterine Deaths | 4 | 3.3% |
| | - Dead-on-Birth | 2 | 1.6% |
| Apgar Score (1 min) | ≤7 | 103 | 83.7% |
| | >7 | 20 | 16.3% |
| Apgar Score (5 min) | ≤7 | 98 | 79.7% |
| | >7 | 25 | 20.3% |
| NICU Admission | Yes | 94 | 76.4% |
| | No | 29 | 23.6% |
| Birth Weight | ≤2.0 kg | 61 | 49.6% |
| | >2.0 kg | 62 | 50.4% |

Out of 123 pregnancies, in regard to birth outcome at day 1, 95.1% resulted in live births, while 4.9% were non-live outcomes (3.3% intrauterine deaths and 1.6% stillbirths). Most newborns had low Apgar scores (≤7) at both 1 and 5 minutes, indicating transient birth asphyxia and the need for close neonatal monitoring. NICU admission was required in 76.4% of neonates, primarily due to low birth weight and respiratory distress. Nearly half of the babies (49.6%) weighed ≤2.0 kg, reflecting a high prevalence of fetal growth restriction. Overall, the birth outcome at day 1 was predominantly favorable, though perinatal morbidity remained high in pregnancies complicated by PIH [Table 3].

Chi-square analysis revealed several statistically significant relationships. Younger women (18–20 years) had better continuation rates, whereas the 21–30 year group showed higher termination rates (p = 0.000). Fetuses with birth weights ≤ 2.0 kg were more often associated with pregnancy termination (p = 0.009) and low Apgar scores at both 1 minute and 5 minutes correlated strongly with adverse outcomes ($p$ = 0.000). NICU admission was significantly more frequent in terminated cases (p = 0.000), reflecting the link between severe disease and neonatal compromise.

The mode of delivery also influenced outcome—LSCS was required more often in terminated or severe cases (p = 0.047), while normal vaginal delivery predominated among continued pregnancies. S/D ratio > 2.8 showed the strongest and most significant association (p = 0.000) with termination, confirming that an elevated S/D ratio is a key indicator of placental insufficiency and poor fetal prognosis.

Conversely, CD-RI and CD-PI values were not significantly associated with intervention outcomes (p = 0.446 and 0.249, respectively), indicating that isolated resistance or pulsatility changes are less predictive than combined ratios. The baby's discharge status (dead, IUFD, stable) showed no significant association (p = 0.716) with Doppler outcome, although most stable neonates belonged to the continued-pregnancy group [Table 4].

## Discussion

The study highlights the pivotal role of Doppler ultrasound in assessing fetal well-being in high-risk pregnancies, particularly those complicated by pregnancy-induced hypertension and fetal growth restriction. This is consistent with previous research emphasizing the prognostic value of fetal Doppler in identifying fetuses at risk of hypoxia, acidosis, and adverse neonatal outcomes.[5,6,16] The study evaluates Doppler parameters such as PI, resistance index (RI), and systolic-to-diastolic ratio (S/D ratio), offering insights

**Table 4:** Association between outcome and various parameters

| *Factor* | *Category* | *Outcome* | | *Total* | *P-Value* | *Significance* |
|---|---|---|---|---|---|---|
| | | *Continue* | *Terminate* | | | |
| Age Group | 18-20 yrs | 6 (28.6%) | 3 (2.9%) | 9 | 0.000 | Sig |
| | 21-30 yrs | 12 (57.1%) | 89 (87.3%) | 101 | | |
| | 31-40 yrs | 3 (14.3%) | 10 (9.8%) | 13 | | |
| Fetal Weight | ≤2.0 Kg | 5 (23.8%) | 56 (54.9%) | 61 | 0.009 | Sig |
| | >2.0 Kg | 16 (76.2%) | 46 (45.1%) | 62 | | |
| Apgar 1 Min | ≤7 | 5 (23.8%) | 98 (96.1%) | 103 | 0.000 | Sig |
| | >7 | 16 (76.2%) | 4 (3.9%) | 20 | | |
| Apgar 5 Min | ≤7 | 5 (23.8%) | 93 (91.2%) | 98 | 0.000 | Sig |
| | >7 | 16 (76.2%) | 9 (8.8%) | 25 | | |
| NICU Admission | No | 13 (61.9%) | 16 (15.7%) | 29 | 0.000 | Sig |
| | Yes | 8 (38.1%) | 86 (84.3%) | 94 | | |
| Birth Weight | ≤2.0 Kg | 7 (33.3%) | 64 (62.7%) | 71 | 0.001 | Sig |
| | 2.1-2.5 Kg | 6 (28.6%) | 29 (28.4%) | 35 | | |
| | >2.5 Kg | 8 (38.1%) | 9 (8.8%) | 17 | | |
| Mode of Delivery | LSCS | 4 (19.0%) | 43 (42.2%) | 47 | 0.047 | Sig |
| | NVD | 17 (81.0%) | 59 (57.8%) | 76 | | |
| Baby on | Dead | 2 (9.5%) | 16 (15.7%) | 18 | 0.716 | Non-Sig |
| discharge | IUFD | 1 (4.8%) | 3 (2.9%) | 4 | | |
| | Stable | 18 (85.7%) | 83 (81.4%) | 101 | | |
| CD-RI ≤0.8 | ≤0.8 | 17 (81.0%) | 89 (87.3%) | 106 | 0.446 | Non-Sig |
| | >0.8 | 4 (19.0%) | 13 (12.7%) | 17 | | |
| CD-PI ≤0.9 | ≤0.9 | 11 (52.4%) | 67 (65.7%) | 78 | 0.249 | Non-Sig |
| | >0.9 | 10 (47.6%) | 35 (34.3%) | 45 | | |
| S/D ≤2.8 | ≤2.8 | 10 (47.6%) | 86 (84.3%) | 96 | 0.000 | Sig |
| | >2.8 | 11 (52.4%) | 16 (15.7%) | 27 | | |

into fetal hemodynamics critical for managing high-risk cases. The inclusion of these parameters allows clinicians to noninvasively assess placental resistance and fetal adaptive mechanisms such as the brain-sparing effect, which are vital for timely obstetric intervention. Notably, middle cerebral artery peak systolic velocity is explored as a potentially superior predictor of perinatal mortality in preterm FGR, supporting findings by Johnson *et al* and Mari *et al*. that abnormal MCA flow reflects fetal hypoxemia and correlates with poor neonatal prognosis. [17,18]

By correlating Doppler metrics with clinical outcomes like Apgar scores, NICU admissions, and birth weight, the study underscores the utility of Doppler findings in guiding clinical decisions. This correlation strengthens the role of serial Doppler evaluation as part of antenatal surveillance, as described by Baschat *et al*., in predicting outcomes more reliably than conventional fetal biometry alone.[5] Its comprehensive approach contributes to enhancing fetal monitoring techniques and optimizing maternal and fetal health outcomes in high-risk pregnancies, while also identifying areas for future research.

Age group distribution revealed that 82.1% of participants were aged 21-30, 10.6% were 31 to 40, and 7.3% were 18 to 20. This aligns with general trends, as the 21 to 30 age group is the most common for pregnancies and typically carries lower risks. [19] However, the significant presence of PIH and FGR in this group highlights that these conditions are not confined to older mothers. This observation mirrors findings by Chakraborty and Saharan,[20] who also noted that PIH and FGR are

increasingly seen in younger primigravidas, possibly due to lifestyle, nutritional, or genetic predispositions. In our study, 50.4% of fetuses had a weight greater than 2.0 kg, while 49.6% weighed 2.0 kg or less, indicating a significant prevalence of low birth weight, a common complication in pregnancies with PIH and FGR. Similar studies have reported comparable findings, with a majority of newborns having birth weights under 2.5 kg.[19] Another study highlighted FGR as a major cause of low birth weight, with reported weights ranging from 1.40 to 3.24 kg and a mean birth weight of 2.7023 kg.[21] These findings underscore the critical impact of PIH and FGR on fetal growth and emphasize the importance of vigilant monitoring and timely intervention. The low birth weight observed in our cohort also correlated with increased NICU admissions and lower Apgar scores, supporting its prognostic importance.

According to the AFI distribution, 67.5% of subjects had an adequate Amniotic Fluid Index, while 17.9% had an AFI of <1, 8.9% had an AFI of <2, 4.1% had an AFI of <3, and 1.6% had an AFI of >20. AFI serves as a critical marker for evaluating fetal well-being, particularly in PIH and FGR pregnancies. Similar studies have shown that inadequate AFI is common in high-risk pregnancies, with a significant association between low AFI and adverse outcomes. For example, patients with FGR had a mean AFI of 9.8 cm compared to 12.1 cm in those without FGR ($p$ <0.01).[22] Another study linked fetal growth restriction to an AFI of ≤7 cm ($p \leq 0.001$), consistent with our findings.[23] These results highlight the importance of regular AFI monitoring in managing high-risk pregnancies to ensure better fetal outcomes. Low AFI often reflects uteroplacental insufficiency, which, when combined with abnormal Doppler indices, indicates imminent fetal compromise requiring early delivery.

In our study, 78.0% of subjects had a Colour Doppler S/D ratio ≤2.8, while 22.0% had a ratio >2.8. The S/D ratio reflects the balance between systolic and diastolic blood flow, with higher ratios indicating increased vascular resistance. An increased S/D ratio is often seen in PIH and FGR pregnancies, which is consistent with our findings. A similar study showed that an elevated S/D ratio is indicative of impaired fetal blood flow and is commonly observed in PIH and FGR pregnancies. In their study, 60% of patients with abnormal S/D ratios delivered babies with FGR, highlighting the significance of this marker.[21] Our finding that an elevated S/D ratio was significantly associated with pregnancy termination decisions ($p = 0.000$) reinforces its predictive value for adverse outcomes. Clinically, this supports early induction or cesarean section in cases showing progressive Doppler deterioration.

Outcome distribution revealed that 95.1% of subjects had a live birth, 3.3% had an intrauterine demise (IUFD), and 1.6% had neonatal death, indicating the effectiveness of current management strategies for high-risk pregnancies. The high proportion of live births aligns with findings from similar studies, which report that proper management of high-risk pregnancies often leads to favourable outcomes despite the risks of IUFD and neonatal mortality.[24] Additionally, a comparable study highlighted the significant risk of adverse outcomes, including IUFD, in high-risk pregnancies, which supports our observation of a small proportion of IUFD cases.[21] These results emphasize that vigilant fetal surveillance and timely obstetric intervention can improve perinatal outcomes even in compromised fetuses.

Regarding Apgar scores, 83.7% of subjects had an Apgar score of ≤7 at 1 minute, and 79.7% had an Apgar score of ≤7 at 5 minutes. These low scores suggest neonatal distress, necessitating resuscitation or specialized care. Our findings are consistent with studies showing that low Apgar scores are common in high-risk pregnancies, particularly in cases of FGR, and often correlate with increased neonatal care needs.[21,25] The improvement in Apgar scores from 1 to 5 minutes reflects effective neonatal resuscitation and NICU support, reinforcing the importance of perinatal preparedness in high-risk deliveries.

In our study, 76.4% of neonates were admitted to the NICU, highlighting the significant risks associated with pregnancy-induced hypertension (PIH) and fetal growth restriction (FGR). The high NICU admission rate indicates that neonates from high-risk pregnancies often require specialized care due to complications such as preterm birth and respiratory distress. This finding is consistent with similar studies that observed a higher likelihood of NICU admissions for neonates from high-risk pregnancies, particularly those with severe PIH and FGR.[25] Such findings reiterate the importance of antenatal Doppler evaluation in anticipating neonatal morbidity and planning postnatal care in advance.

Regarding birth weight, 57.7% of neonates had a birth weight ≤2.0 kg, 28.5% had a birth weight between 2.1–2.5 kg, and 13.8% had a birth weight >2.5 kg. This distribution reflects the high prevalence of FGR within our study population. Low birth weight, a common outcome of PIH and FGR, is associated with increased neonatal morbidity and mortality. These findings are supported by similar studies, which found a high proportion of neonates with

a birth weight below 2.5 kg.[1,20] Another study reported that FGR often results in low birth weight, which plays a critical role in determining neonatal care and outcomes[26] This reinforces our findings and underscores the importance of closely monitoring fetal growth in high-risk pregnancies to mitigate adverse neonatal outcomes. Additionally, our correlation analysis showed that lower birth weight is significantly associated with higher S/D ratios, confirming the predictive value of Doppler in identifying growth-restricted fetuses.

Doppler ultrasound findings revealed that 69.1% of subjects had a UA-PI >0.7, 66.7% had a UA-RI ≤0.6, and 65.9% had a UA-S/D ratio ≤2.4, indicating placental insufficiency. Elevated UA-PI and reduced UA-RI are significant markers of compromised fetal blood flow, critical for guiding clinical decisions.[27]

Furthermore, 76.4% of cases showed a raised Middle Cerebral Artery Pulsatility Index (MCA-PI), suggesting increased resistance and fetal distress. Elevated MCA-PI, which increases with gestational age, is considered a more effective predictor of adverse outcomes compared to the umbilical artery PI, reinforcing the importance of Doppler monitoring in high-risk pregnancies.[21]

In our study, 82.9% of deliveries were terminated, and 95.1% of neonates had a live outcome, highlighting the importance of timely delivery to manage severe cases of Pregnancy-Induced Hypertension (PIH) and Fetal Growth Restriction (FGR). "Termination" in this context refers to medically indicated early delivery, either induction or cesarean section, undertaken after 34 weeks in most cases due to worsening maternal or fetal condition, not elective abortion. There was a significant association between Doppler outcomes, Apgar scores, NICU admission, and the mode of delivery, indicating the critical role of early fetal monitoring in guiding delivery decisions. The high rate of terminated deliveries and the correlation between Apgar scores and outcomes underline the value of Doppler studies in determining optimal timing for delivery to improve neonatal outcomes.

Regarding outcomes at discharge, 82.1% of neonates were stable, while 14.6% had died, and 3.3% had an intrauterine death (IUFD). These results reflect the severity of complications in high-risk pregnancies but also demonstrate the effectiveness of NICU care in managing PIH and FGR-related issues. Outcomes at discharge closely reflected Doppler severity, with poorer outcomes in those showing abnormal S/D ratios and reversed end-diastolic flow.

The study found no significant association between the baby's condition at discharge (dead, IUFD, or stable) and Color Doppler outcomes (continue or terminate), with Pearson Chi-Square values of 0.716. Similarly, the CD-RI and CD-PI values did not significantly influence the decision to continue or terminate the intervention ($p = 0.446$ and $p = 0.249$, respectively). However, the S/D ratio was statistically significant ($p = 0.000$), with higher S/D values being linked to a greater likelihood of terminating the intervention. This suggests that the S/D ratio plays a crucial role in clinical decision-making, potentially improving fetal outcomes like APGAR scores and NICU admissions. Our findings align with those of Bhatt and Arora,[25] who also demonstrated that elevated S/D ratios were reliable indicators for timely obstetric intervention to prevent stillbirth and neonatal morbidity.

Our study concluded that PIH is strongly associated with increased fetal morbidity and mortality, with Doppler velocimetry being an essential tool for routine monitoring in pregnancies complicated by PIH and FGR. Early detection using Doppler indices, particularly increased pulsatility index and diastolic notching, enables the identification of at-risk women who may benefit from early interventions. Combining measurements from the uterine artery, umbilical artery, and middle cerebral artery offers the most predictive value for PIH and FGR. While Doppler is a valuable, non-invasive tool for managing high-risk pregnancies, further research with larger sample sizes is necessary to refine its predictive accuracy and clinical application. Future studies should explore longitudinal Doppler monitoring from mid-pregnancy to term, integrating cerebroplacental ratio trends for better prognostication.

## Conclusion

This study highlights the diagnostic and prognostic significance of Doppler ultrasound in managing pregnancies affected by pregnancy-induced hypertension (PIH) and suspected fetal growth restriction. By evaluating Doppler parameters like the pulsatility index (PI), resistive index (RI), and cerebroplacental ratio (CPR), the study demonstrates their effectiveness in assessing fetal well-being and guiding clinical decisions. The study also reveals significant correlations between Doppler findings and clinical outcomes, including birth weight and Apgar scores, underscoring their predictive value for complications. Despite limitations like a single-centre design and short follow-up, the study advocates for incorporating Doppler ultrasound into routine

monitoring and management of high-risk pregnancies, with calls for further research to refine and expand its application.

## References


1. Aharwal S, Agrawal R, Sharma S. A study of role of Doppler ultrasound in pregnancy-induced hypertension (PIH) and perinatal outcome. Int J Med Res Rev. 2016;4(4):673–680.
2. Roberge S, Bujold E, Nicolaides KH. Aspirin for the prevention of preterm and term pre-eclampsia: systematic review and meta-analysis. Am J Obstet Gynecol. 2018;218(3):287–293.
3. Battaglia FC, Lubchenko LO. A practical classification of newborn infants by weight and gestational age. J Pediatr. 1967;71:159–163.
4. American College of Obstetricians and Gynecologists. Intrauterine growth restriction; ACOG practice bulletin no. 12. Washington, DC: ACOG; 2000.
5. Baschat AA. Arterial and venous Doppler in the diagnosis and management of early-onset fetal growth restriction. Early Hum Dev. 2005;81:877–887.
6. Baschat AA, Gembruch U, Reiss I, Gortner L, Weiner CP, Harman CR. Relationship between arterial and venous Doppler and perinatal outcome in fetal growth restriction. Ultrasound Obstet Gynecol. 2000;16:407–413.
7. Gebremedhin A, Regan K, Ball S, *et al*. Interpregnancy interval and hypertensive disorders of pregnancy: a population-based cohort study. Paediatr Perinat Epidemiol. 2021;35(4):404–414. doi:10.1111/ppe.12668.
8. Smitha K, Sowmya K, Malathi T. Study of Doppler waveforms in pregnancy-induced hypertension and its correlation with perinatal outcome. Int J Reprod Contracept Obstet Gynecol. 2014;3:428–433.
9. Cruz-Martinez R, Figueras F, Hernandez-Andrade E, Oros D, Gratacos E. Fetal brain Doppler to predict cesarean delivery for non-reassuring fetal status in term small-for-gestational-age fetuses. Obstet Gynecol. 2011;117:618–626.
10. Lee H, Lee S, Ko J, Kim SJ, Shin JE. Association between fetoplacental Doppler results, placental pathology, and angiogenic factors among pregnant women with anxiety. Taiwan J Obstet Gynecol. 2020;59(6):842–847.
11. Roberts L, Ling H, Poon L, Nicolaides KH, Kametas NA. Maternal hemodynamics, fetal biometry and Doppler indices in pregnancies followed up for suspected fetal growth restriction. Ultrasound Obstet Gynecol. 2018;52(4):507–514.
12. Ciobanu A, Rouvali A, Syngelaki A, Akolekar R, Nicolaides KH. Prediction of small-for-gestational-age neonates: screening by maternal factors, fetal biometry, and biomarkers at 35–37 weeks' gestation. Am J Obstet Gynecol. 2019;220(5):486.e1–486.e11.
13. Nader L, Zielinsky P, Naujorks A, *et al*. Behaviour of the foramen ovale flow in fetuses with intrauterine growth restriction. ObstetGynecol Int. 2018;2018:1–6.
14. Kurmanavicius J, Florio I, Wisser J, *et al*. Reference resistance indices of the umbilical, fetal middle cerebral and uterine arteries at 24–42 weeks of gestation. Ultrasound Obstet Gynecol. 1997;10:112–120.
15. Behrman RE, Lees MH, Peterson EN, De Lannoy CW, Seeds AE. Distribution of the circulation in the normal and asphyxiated fetal primate. Am J Obstet Gynecol. 1970;108:956–969.
16. Rumack CM, Levine D. Diagnostic Ultrasound. 5th ed. Philadelphia: Elsevier; 2018.
17. Johnson A, *et al*. Middle cerebral artery Doppler in severe intrauterine growth restriction. Ultrasound Obstet Gynecol. 2001;17:416–420.
18. Mari G, Deter RL. Middle cerebral artery flow velocity waveforms in normal and small-for-gestational-age fetuses. Am J Obstet Gynecol. 1992;166:1262–1270.
19. Malik R, Saxena A. Role of colour Doppler indices in the diagnosis of intrauterine growth retardation in high-risk pregnancies. J Obstet Gynaecol India. 2013;63(1):37–44.
20. Chakraborty S, Saharan S. Uterine artery Doppler study for the prediction and the severity of the hypertensive disorders during pregnancy. Int J Reprod Contracept Obstet Gynecol. 2017;6:2900–2909.
21. Mahajani A, Badade B. The role of Doppler study in evaluation of pregnancy-induced hypertension (PIH) and intrauterine growth restriction (FGR) in primigravida. MedPulse Int J Gynaecol. 2022;21(1):20–31.
22. Madaan S, Mendiratta SL, Jain PK, *et al*. Amniotic fluid index and its correlation with fetal growth and perinatal outcome. J Fetal Med. 2015;2:61–67.
23. O'Brien JM, Mercer BM, Friedman SA, *et al*. Amniotic fluid index in hospitalized hypertensive patients managed expectantly. Obstet Gynecol. 1993;82:247–250.
24. Gehlot H, Nagar GG, Sharma S, Yadav OP. A prospective analytical study of intrauterine fetal death cases and associated maternal condition at a tertiary centre. Int J Reprod Contracept Obstet Gynecol. 2017;6:3392–3396.
25. Khasawneh W, Sindiani A, Rawabdeh SA, Aleshawi A, Kanaan D. Indications and clinical profile of neonatal admissions: a cross-sectional descriptive analysis from a single academic centre in Jordan. J Multidiscip Health. 2020;13:997–1006.
26. Bhatt CJ, Arora J. Role of colour Doppler in pregnancy-induced hypertension (100 cases). Indian J Radial Imaging. 2003;13(4):417–420.
27. Ochi H, Matsubara K, Kusanagi Y, Taniguchi H, Ito M. Significance of a diastolic notch in the uterine artery flow velocity waveform induced by uterine embolization in the pregnant ewe. Br J Obstet Gynaecol. 1998;105(10):1118–1121.