International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Predictive Value of Umbilical Artery, Middle Cerebral Artery and Cerebroplacental Ratio Doppler in Late-Onset Fetal Growth Restriction: A Prospective Observational Study from a Tertiary Care Radiology Practice

Dr. Archana Verma[1], Dr. Pradeep Kumar Nayak[2], Dr. Manish Kumar[3]

[1]Associate Professor, Department of Radiodiagnosis, Katihar Medical College and Hospital, Katihar, Bihar, India.
[2]Professor, Department of Radiodiagnosis, Katihar Medical College and Hospital, Katihar, Bihar, India.
[3]Physician and Cardiologist, Arc Hospital, Bhagalpur, Bihar, India.

OPEN ACCESS

Corresponding Author:

Dr. Manish Kumar
Physician and Cardiologist, Arc Hospital, Bhagalpur, Bihar, India.

Received: 15-04-2026
Accepted: 24-05-2026
Available online: 11-06-2026

ABSTRACT

Background: Late-onset fetal growth restriction (FGR) is an important obstetric condition associated with increased perinatal morbidity and mortality. It commonly manifests after 32 weeks of gestation and is frequently associated with placental insufficiency leading to chronic fetal hypoxia. Doppler velocimetry of fetal vessels, particularly the Umbilical Artery (UA), Middle Cerebral Artery (MCA), and Cerebroplacental Ratio (CPR), has emerged as an essential non-invasive tool for fetal surveillance and assessment of hemodynamic adaptation in compromised fetuses. Among these Doppler indices, CPR has gained increasing importance as a sensitive marker of fetal compromise and adverse neonatal outcome.

Aim and Objectives: To evaluate the predictive value of Umbilical Artery Doppler, Middle Cerebral Artery Doppler, and Cerebroplacental Ratio in predicting adverse perinatal outcomes in pregnancies complicated by late-onset fetal growth restriction.

Materials and Methods: This prospective observational study was conducted in the Department of Radiodiagnosis at a tertiary care center over a period of 18 months. A total of 85 pregnant women diagnosed with late-onset fetal growth restriction after 32 weeks of gestation were included in the study. Detailed obstetric ultrasonography and Doppler evaluation of the Umbilical Artery, Middle Cerebral Artery, and Cerebroplacental Ratio were performed. Maternal demographic profile, Doppler indices, mode of delivery, birth weight, APGAR score, NICU admission, and neonatal complications were recorded and analyzed.

Results: The majority of women belonged to the age group of 21–25 years (36.5%), and 57.6% were primigravida. Abnormal Umbilical Artery Doppler was observed in 43.5% cases, reduced MCA pulsatility index in 54.1%, and abnormal CPR in 61.2% cases. Caesarean delivery was required in 63.5% pregnancies. NICU admission was observed in 40% neonates, while low APGAR score was present in 31.8% neonates. Abnormal CPR showed statistically significant association with adverse perinatal outcomes including low birth weight, low APGAR score, NICU admission, and increased caesarean section rate ($p<0.05$). CPR demonstrated the highest sensitivity (86.3%) and specificity (82.5%) in predicting adverse perinatal outcome.

Conclusion: Cerebroplacental Ratio is a superior predictor of adverse perinatal outcome in late-onset fetal growth restriction when compared with isolated Umbilical Artery and Middle Cerebral Artery Doppler parameters. Combined Doppler assessment provides valuable information regarding fetal compromise and helps in timely obstetric intervention for improving neonatal outcome.

Keywords: *Late-onset fetal growth restriction; Umbilical artery Doppler; Middle cerebral artery Doppler; Cerebroplacental ratio; Perinatal outcome; Doppler velocimetry.*

INTRODUCTION

Fetal growth restriction (FGR) remains one of the most challenging and clinically significant conditions encountered in modern obstetric practice. It is associated with increased fetal morbidity, neonatal complications, long-term neurodevelopmental impairment, and perinatal mortality.[1,2] FGR refers to the inability of the fetus to attain its genetically predetermined growth potential and is commonly associated with placental insufficiency, maternal vascular disorders, and impaired uteroplacental circulation.[3] Despite significant advances in prenatal diagnosis and fetal surveillance, fetal growth restriction continues to contribute substantially to adverse perinatal outcomes worldwide.[4]

Late-onset fetal growth restriction is defined as fetal growth restriction diagnosed after 32 weeks of gestation and constitutes nearly 70–80% of all FGR cases.[1,5] Unlike early-onset FGR, late-onset FGR often presents with subtle placental dysfunction and relatively preserved umbilical artery blood flow, making diagnosis difficult.[6] These fetuses may appear clinically stable until sudden fetal compromise occurs. Therefore, accurate antenatal surveillance becomes extremely important in identifying fetuses at risk and optimizing the timing of delivery.[4,5]

Globally, fetal growth restriction affects approximately 5–10% of all pregnancies and remains one of the leading contributors to perinatal morbidity and mortality, particularly in developing countries.[2,7] The burden of FGR is especially high in South Asian countries including India due to high prevalence of maternal anemia, hypertensive disorders, malnutrition, and inadequate antenatal care.[8] Neonates affected by fetal growth restriction are at increased risk of birth asphyxia, meconium aspiration syndrome, respiratory distress syndrome, necrotizing enterocolitis, hypoglycemia, sepsis, and long-term cardiovascular and metabolic disorders.[9,10]

The pathophysiology of fetal growth restriction is complex and multifactorial. Placental insufficiency plays a central role in most cases and results in impaired transfer of oxygen and nutrients to the fetus.[3,11] As placental resistance increases, compensatory fetal hemodynamic changes occur in an attempt to preserve oxygen supply to vital organs such as the brain, heart, and adrenal glands.[12] This adaptive phenomenon is commonly referred to as the "brain-sparing effect." Doppler velocimetry allows assessment of these circulatory adaptations and provides valuable information regarding fetal well-being.[13]

Umbilical Artery Doppler is one of the most extensively studied parameters in fetal surveillance.[14] It reflects placental vascular resistance and fetoplacental circulation. Increased pulsatility index, elevated systolic-diastolic ratio, absent end-diastolic flow, and reversed end-diastolic flow indicate progressive placental insufficiency and worsening fetal compromise.[15] However, in late-onset fetal growth restriction, umbilical artery Doppler may remain normal despite significant fetal hypoxia due to milder placental abnormalities.[6,16]

Middle Cerebral Artery Doppler evaluation has emerged as an important marker of fetal adaptation to hypoxia.[12,17] Under hypoxic conditions, cerebral vasodilatation occurs resulting in reduced vascular resistance and decreased MCA pulsatility index. This redistribution of blood flow toward the fetal brain forms the basis of the brain-sparing phenomenon.[18] Several studies have demonstrated that abnormal MCA Doppler is associated with adverse neonatal outcome, intrapartum fetal distress, and emergency caesarean section.[6,19]

The Cerebroplacental Ratio (CPR), calculated as the ratio of MCA pulsatility index to Umbilical Artery pulsatility index, combines information regarding placental resistance and fetal cerebral adaptation.[8,16] CPR has gained increasing recognition as a superior predictor of fetal compromise compared to isolated Doppler parameters.[20] Reduced CPR indicates both increased placental resistance and cerebral redistribution and has been shown to correlate strongly with intrapartum fetal distress, low APGAR score, NICU admission, operative delivery, and neonatal morbidity.[21,22]

Several international guidelines now recommend incorporation of Doppler velocimetry in the surveillance of pregnancies complicated by fetal growth restriction. The International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) recommends the use of UA Doppler and CPR in evaluation of suspected fetal growth restriction.[4] Similarly, the Royal College of Obstetricians and Gynaecologists (RCOG) emphasizes the importance of Doppler surveillance in reducing adverse perinatal outcomes.[5]

Recent studies have highlighted the limitations of relying solely on estimated fetal weight for diagnosing late-onset fetal growth restriction.[13,20] Many fetuses with apparently normal biometric parameters may still have placental insufficiency and abnormal hemodynamic adaptation detectable only through Doppler studies.[23] Therefore, Doppler evaluation has become an indispensable component of fetal surveillance in high-risk pregnancies.[18]

The importance of identifying fetal compromise before the onset of irreversible hypoxic injury cannot be overstated.[24] Delayed recognition may lead to intrauterine fetal demise or severe neonatal complications, whereas unnecessary early delivery may expose the neonate to prematurity-related complications.[3,25] Hence, a balance between prolonging

pregnancy and timely intervention is essential. Doppler velocimetry provides an objective method for monitoring fetal status and assists clinicians in decision-making regarding delivery.[4]

Late-onset fetal growth restriction poses unique diagnostic challenges because conventional fetal monitoring techniques such as cardiotocography and biophysical profile may remain normal until late stages of fetal compromise.[11,19] In contrast, Doppler abnormalities may precede clinical deterioration and provide early warning signs of fetal hypoxia. Consequently, Doppler indices such as MCA and CPR are increasingly being evaluated for their ability to predict adverse perinatal outcome.[20]

Several investigators have compared the predictive accuracy of Umbilical Artery Doppler, Middle Cerebral Artery Doppler, and CPR in fetal growth restriction.[6,8,16] While Umbilical Artery Doppler reflects placental pathology, MCA Doppler reflects fetal adaptation. CPR integrates both placental and fetal circulatory changes and may therefore provide superior diagnostic accuracy.[22] However, the relative predictive value of these parameters in late-onset fetal growth restriction remains an area of ongoing research.

The present study was conducted to evaluate the predictive role of Umbilical Artery Doppler, Middle Cerebral Artery Doppler, and Cerebroplacental Ratio in pregnancies complicated by late-onset fetal growth restriction and to correlate these Doppler findings with neonatal outcome.

MATERIAL AND METHODS

This prospective observational study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Obstetrics and Gynecology at a tertiary care teaching hospital over a period of 18 months. A total of 85 pregnant women diagnosed with late-onset fetal growth restriction after 32 weeks of gestation were included in the study after obtaining informed consent.

Detailed obstetric ultrasonography and Doppler evaluation were performed using a high-resolution ultrasound machine with color Doppler facility. Umbilical Artery (UA) Doppler, Middle Cerebral Artery (MCA) Doppler, and Cerebroplacental Ratio (CPR) were assessed in all patients. Maternal demographic profile, gestational age, associated risk factors, mode of delivery, birth weight, APGAR score, and NICU admission were recorded and analyzed.

Statistical analysis was performed using SPSS software version 25. Quantitative data were expressed as mean ± standard deviation and qualitative variables as percentages. Chi-square test and Student's t-test were applied wherever appropriate. A p-value <0.05 was considered statistically significant.

INCLUSION CRITERIA

1. Singleton pregnancy
2. Gestational age >32 weeks
3. Sonographically diagnosed fetal growth restriction
4. Estimated fetal weight below the 10th percentile
5. Patients willing to participate in the study

EXCLUSION CRITERIA

1. Multiple pregnancy
2. Major congenital fetal anomalies
3. Chromosomal abnormalities
4. Intrauterine fetal demise
5. Severe maternal systemic illness
6. Uncertain gestational age
7. Patients unwilling to participate

RESULTS

A total of **85 pregnant women diagnosed with late-onset fetal growth restriction (FGR)** were included in the present prospective observational study. Detailed maternal demographic characteristics, Doppler findings, and neonatal outcomes were analyzed.

Table 1: Maternal Age Distribution of Study Participants (n=85)

Maternal Age Group (Years)	Number of Cases	Percentage (%)
18–20	12	14.1
21–25	31	36.5
26–30	28	32.9

31–35	10	11.8
>35	4	4.7
Total	**85**	**100**

The majority of pregnant women belonged to the age group of **21–25 years (36.5%)**, followed by **26–30 years (32.9%)**. Only 4.7% of women were older than 35 years. The mean maternal age was **26.2 ± 4.3 years**, indicating that late-onset FGR was more commonly observed among women in the younger reproductive age group.

Table 2: Gravidity Distribution among Study Participants

Gravidity	Number of Cases	Percentage (%)
Primigravida	49	57.6
Multigravida	36	42.4
Total	**85**	**100**

Among the 85 cases, **57.6% were primigravida**, while 42.4% were multigravida. This suggests that late-onset fetal growth restriction was more commonly encountered in first pregnancies.

Table 3: Gestational Age at Diagnosis

Gestational Age (Weeks)	Number of Cases	Percentage (%)
32–34 weeks	24	28.2
35–37 weeks	46	54.1
>37 weeks	15	17.7
Total	**85**	**100**

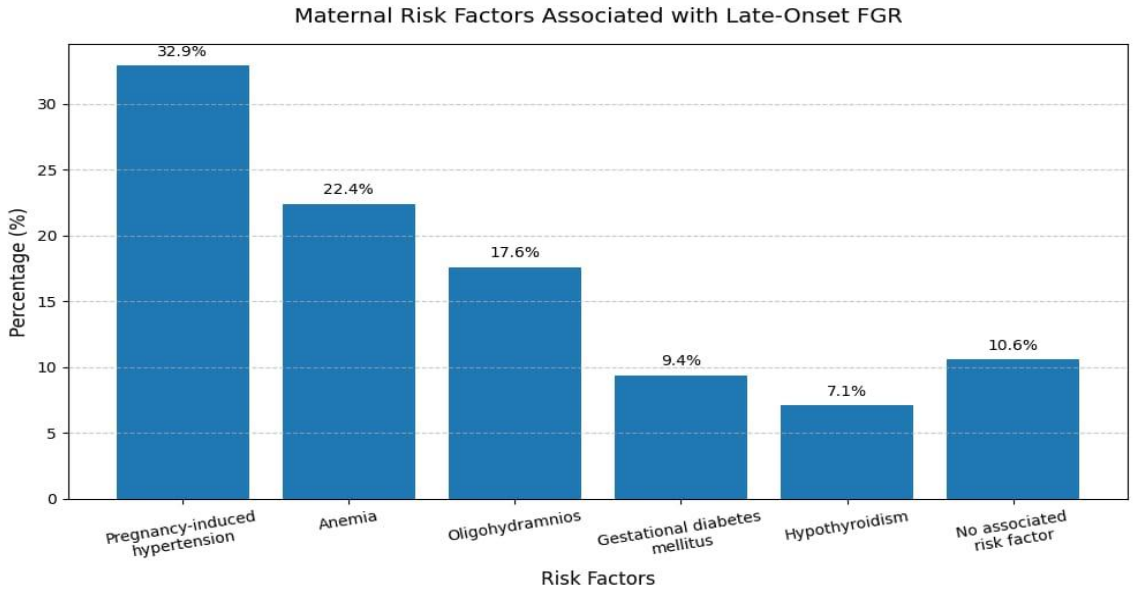
Interpretation

More than half of the cases (**54.1%**) were diagnosed between **35–37 weeks of gestation**, while 28.2% were diagnosed between 32–34 weeks. The findings indicate that most late-onset FGR cases were detected during the late third trimester.

Table 4: Maternal Risk Factors Associated with Late-Onset FGR

Risk Factor	Number of Cases	Percentage (%)
Pregnancy-induced hypertension	28	32.9
Anemia	19	22.4
Oligohydramnios	15	17.6
Gestational diabetes mellitus	8	9.4
Hypothyroidism	6	7.1
No associated risk factor	9	10.6

Pregnancy-induced hypertension was the most common associated maternal risk factor, present in **32.9%** of cases, followed by anemia (22.4%). Oligohydramnios was observed in 17.6% of pregnancies. These findings indicate a strong association between maternal vascular disorders and late-onset FGR.



Graph 1:Risk factors

Table 5: Umbilical Artery Doppler Findings

Umbilical Artery Doppler	Number of Cases	Percentage (%)
Normal	48	56.5
Abnormal PI/S-D ratio	37	43.5
Total	**85**	**100**

Abnormal umbilical artery Doppler findings were noted in **43.5%** of fetuses, indicating increased placental resistance. However, more than half of the cases showed normal umbilical artery Doppler despite growth restriction, emphasizing the limitation of isolated umbilical artery assessment in late-onset FGR.

Table 6: Middle Cerebral Artery Doppler Findings

MCA Doppler Findings	Number of Cases	Percentage (%)
Normal MCA PI	39	45.9
Reduced MCA PI	46	54.1
Total	**85**	**100**

Reduced middle cerebral artery pulsatility index was observed in **54.1%** of fetuses, suggestive of the "brain-sparing effect" secondary to fetal hypoxia. MCA abnormalities were more frequent than umbilical artery abnormalities in late-onset FGR.

Table 7: Cerebroplacental Ratio (CPR) Findings

CPR Findings	Number of Cases	Percentage (%)
Normal CPR	33	38.8
Abnormal CPR (<1.08)	52	61.2
Total	**85**	**100**

An abnormal cerebroplacental ratio was observed in **61.2%** of cases, making it the most frequently deranged Doppler parameter in the present study. This indicates that CPR may be a more sensitive marker for identifying fetal compromise in late-onset FGR.

Table 8: Mode of Delivery among Study Participants

Mode of Delivery	Number of Cases	Percentage (%)
Vaginal delivery	31	36.5
Caesarean section	54	63.5
Total	**85**	**100**

The majority of pregnancies (**63.5%**) required caesarean section, primarily due to fetal distress and abnormal Doppler findings. This reflects the increased obstetric intervention associated with late-onset FGR.

Table 9: Birth Weight Distribution

Birth Weight	Number of Cases	Percentage (%)
<1.5 kg	14	16.5
1.5–2.0 kg	39	45.9
2.1–2.5 kg	24	28.2
>2.5 kg	8	9.4
Total	**85**	**100**

Nearly half of the neonates (**45.9%**) had a birth weight between 1.5–2.0 kg, while 16.5% weighed less than 1.5 kg. The mean birth weight was **1.94 ± 0.42 kg**, indicating significant fetal growth compromise.

Table 10: APGAR Score at 5 Minutes

APGAR Score	Number of Cases	Percentage (%)
<7	27	31.8
≥7	58	68.2
Total	**85**	**100**

Low APGAR score (<7 at 5 minutes) was observed in **31.8%** of neonates, indicating increased neonatal compromise among fetuses with abnormal Doppler findings.

Table 11: NICU Admission among Neonates

NICU Admission	Number of Cases	Percentage (%)
Required	34	40.0
Not Required	51	60.0
Total	**85**	**100**

A total of **40%** of neonates required NICU admission due to complications such as respiratory distress, prematurity, low birth weight, and fetal distress. NICU admission was significantly higher among fetuses with abnormal CPR.

Table 12: Association of Abnormal CPR with Adverse Perinatal Outcome

Adverse Outcome	Abnormal CPR (n=52)	Normal CPR (n=33)	p-value
NICU admission	28	6	0.001
Low APGAR score	22	5	0.003
Caesarean delivery	39	15	0.002
Birth weight <2 kg	35	9	0.001

Abnormal cerebroplacental ratio showed a statistically significant association with adverse perinatal outcomes including NICU admission, low APGAR score, low birth weight, and increased caesarean delivery rate ($p<0.05$). These findings support the role of CPR as an important predictor of fetal compromise in late-onset FGR.

Table 13: Diagnostic Performance of Doppler Parameters in Predicting Adverse Perinatal Outcome

Doppler Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Umbilical artery Doppler	68.4	71.2	66.1	73.0
MCA Doppler	74.5	76.4	72.8	77.9
Cerebroplacental ratio	86.3	82.5	84.1	85.0

Among all Doppler parameters, the cerebroplacental ratio demonstrated the highest sensitivity (86.3%) and specificity (82.5%) for predicting adverse perinatal outcomes. CPR was found to be superior to isolated MCA and umbilical artery Doppler indices in identifying fetuses at risk.

DISCUSSION

Fetal growth restriction (FGR) remains one of the most important contributors to adverse perinatal outcome and neonatal morbidity worldwide. Late-onset fetal growth restriction, diagnosed after 32 weeks of gestation, represents nearly 70–80% of all FGR cases and is often associated with subtle placental insufficiency and progressive fetal hypoxia. Because late-onset FGR may present with apparently normal fetal biometry and relatively preserved umbilical artery blood flow, Doppler velocimetry has become an essential modality for fetal surveillance and prediction of adverse neonatal outcome.[1,2] In the present study, the predictive role of Umbilical Artery Doppler, Middle Cerebral Artery Doppler, and Cerebroplacental Ratio was evaluated in 85 pregnancies complicated by late-onset fetal growth restriction.

In the present study, the majority of pregnant women belonged to the age group of 21–25 years, followed by 26–30 years. Similar demographic findings were reported by Hertting et al. in a 2025 study evaluating antenatal identification of late-onset fetal growth restriction, where the mean maternal age was approximately 27 years.[3] Younger maternal age distribution in developing countries may reflect early marriage, nutritional deficiencies, and increased prevalence of maternal anemia. Primigravida women constituted 57.6% of the study population. Previous studies by Khalil et al. and Gramellini et al. also observed increased incidence of fetal growth restriction among primigravid women due to abnormal placentation and inadequate uteroplacental vascular remodeling.[4,5]

The majority of cases in the present study were diagnosed between 35–37 weeks of gestation, emphasizing the importance of third-trimester surveillance. Similar observations were reported in the Delphi consensus-based study on late-onset fetal growth restriction published in 2024, where most pregnancies were diagnosed in late third trimester and were associated with abnormal Doppler findings and increased obstetric intervention.[6] Early recognition of late-onset fetal growth restriction is clinically important because delayed diagnosis may lead to sudden fetal compromise and stillbirth.

Pregnancy-induced hypertension emerged as the most common maternal risk factor associated with late-onset fetal growth restriction in the present study. Maternal vascular disorders are known to impair trophoblastic invasion and placental perfusion, resulting in chronic uteroplacental insufficiency.[7] Maternal anemia was another major associated condition observed in the study. Similar findings have been reported in Indian and international studies where maternal anemia significantly contributed to placental hypoxia and low birth weight.[8]

Abnormal Umbilical Artery Doppler findings were observed in 43.5% of fetuses in the present study. Umbilical artery Doppler reflects placental vascular resistance and fetoplacental circulation. Elevated systolic-diastolic ratio and increased pulsatility index indicate progressive placental insufficiency.[9] However, more than half of the fetuses in the present study demonstrated normal Umbilical Artery Doppler findings despite evidence of fetal growth restriction. Similar findings were reported by Figueras et al. and Cruz-Martinez et al., who observed that isolated Umbilical Artery Doppler has limited sensitivity in late-onset fetal growth restriction because placental lesions are often less severe compared with early-onset disease.[10,11]

Middle Cerebral Artery Doppler abnormalities were observed in 54.1% of cases in the present study. Reduced MCA pulsatility index reflects cerebral vasodilatation secondary to chronic fetal hypoxia and redistribution of blood flow toward the fetal brain, commonly known as the brain-sparing effect.[12] Mari and Deter demonstrated that decreased MCA pulsatility index is associated with fetal hypoxia and adverse neonatal outcome.[13] Similar observations were also reported in a 2025 study by Karabay et al., which demonstrated significant correlation between abnormal fetal MCA Doppler parameters and adverse neonatal outcomes in pregnancies complicated by late fetal growth restriction.[14]

The most important finding of the present study was the high prevalence of abnormal cerebroplacental ratio. Abnormal CPR was observed in 61.2% of pregnancies and represented the most sensitive Doppler parameter in detecting fetal compromise. Cerebroplacental Ratio combines both placental resistance and fetal cerebral redistribution and therefore provides a comprehensive assessment of fetal hemodynamic adaptation.[5]

Several previous investigators have reported the superiority of CPR over isolated Umbilical Artery and MCA Doppler indices. Khalil et al. demonstrated that abnormal CPR was significantly associated with intrapartum fetal distress, operative delivery, and NICU admission.[4] Odibo et al. also observed that reduced CPR is an independent predictor of adverse perinatal outcome in pregnancies complicated by fetal growth restriction.[15]

Recent studies published during 2024–2026 further support the importance of cerebroplacental ratio in fetal surveillance. Kumar et al. in a 2024 study concluded that CPR is a reliable marker of placental insufficiency and fetal maladaptation and demonstrated significant association between reduced CPR and low APGAR score, NICU admission, and fetal distress.[16] Similarly, Zheng et al. in 2024 compared CPR and umbilicocerebral ratio in fetal growth restriction and reported superior diagnostic efficacy of CPR in predicting fetal compromise.[17]

A 2025 review by Danciu et al. emphasized that in late-onset fetal growth restriction, cerebroplacental ratio should be integrated with fetal surveillance protocols because conventional fetal monitoring methods may fail to detect early fetal compromise.[18] Hertting et al. in 2025 further demonstrated that mandatory assessment of CPR significantly improved antenatal identification of late-onset fetal growth restriction and contributed to better neonatal outcome.[3]

Another important study published in 2025 by Seravalli et al. highlighted that CPR and related Doppler indices play a crucial role in risk stratification of late-onset fetal growth restriction and may improve timing of delivery decisions.[19] Similarly, Arya et al. in 2025 reported strong association between pathological CPR and adverse neonatal outcome in fetuses with abnormal growth patterns.[20]

In 2026, Asghar et al. evaluated the diagnostic accuracy of cerebroplacental ratio in pregnancies complicated by intrauterine growth restriction and concluded that CPR is a non-invasive and highly reliable predictor of adverse perinatal outcome.[21] Another 2026 prospective observational study by Kaya et al. demonstrated that abnormal CPR was significantly associated with intrapartum fetal compromise and emergency caesarean delivery in late-onset fetal growth restriction.[22]

The present study also demonstrated statistically significant association between abnormal CPR and adverse neonatal outcomes including low birth weight, low APGAR score, increased NICU admission, and increased caesarean section rate. Similar findings were observed in a 2025 study by Tewari et al., which showed that abnormal cerebroplacental ratio was associated with increased NICU admission and operative delivery.[23]

The rate of caesarean section observed in the present study was 63.5%. Increased operative delivery in pregnancies complicated by fetal growth restriction has also been reported by Novillo-Del Álamo et al. in a 2024 systematic review evaluating the predictive role of CPR in emergency caesarean section due to intrapartum fetal compromise.[24] Reduced placental reserve and impaired fetal tolerance to labor stress are important contributing factors responsible for increased operative intervention in these pregnancies.

Low birth weight was another major adverse neonatal outcome observed in the present study. Nearly half of the neonates weighed between 1.5–2.0 kg. Chronic placental insufficiency results in reduced transfer of oxygen and nutrients leading

to impaired fetal growth and neonatal morbidity.[25] Low APGAR score at 5 minutes was observed in nearly one-third of neonates. Similar findings were reported by Morales-Rosello et al., who demonstrated significant association between abnormal CPR and poor neonatal acid-base status.[26]

NICU admission was required in 40% of neonates included in the present study. Respiratory distress, birth asphyxia, prematurity, and low birth weight were among the common indications for intensive neonatal care. Similar increased NICU admission rates were reported by Flood et al. and Prior et al., who concluded that abnormal CPR strongly correlates with neonatal morbidity.[27,28]

The diagnostic performance analysis performed in the present study demonstrated that CPR had the highest sensitivity and specificity for predicting adverse perinatal outcome compared with isolated Umbilical Artery and MCA Doppler indices. These findings are in agreement with the 2026 study by Asghar et al., which also demonstrated superior predictive accuracy of CPR in fetal growth restriction pregnancies.[21] The findings strongly support incorporation of cerebroplacental ratio into routine third-trimester fetal surveillance protocols.

The present study has several strengths. It prospectively evaluated Doppler findings in pregnancies complicated by late-onset fetal growth restriction and correlated them with clinically relevant neonatal outcomes. The study also compared the predictive role of multiple Doppler parameters and demonstrated the superiority of CPR in identifying fetuses at risk.

However, certain limitations should also be acknowledged. The study was conducted at a single tertiary care center with relatively limited sample size. Long-term neurodevelopmental follow-up of neonates was not performed. Future multicentric studies with larger sample sizes and long-term neonatal assessment are required to further validate the role of cerebroplacental ratio in management of late-onset fetal growth restriction.

Overall, the findings of the present study confirm that cerebroplacental ratio is a superior and clinically useful Doppler parameter for prediction of adverse perinatal outcome in pregnancies complicated by late-onset fetal growth restriction. Combined Doppler assessment enables early identification of fetal compromise and assists clinicians in timely obstetric intervention, thereby improving neonatal outcome

CONCLUSION

The present study concludes that Cerebroplacental Ratio is a superior predictor of adverse perinatal outcome in late-onset fetal growth restriction compared with isolated Umbilical Artery and Middle Cerebral Artery Doppler parameters. Abnormal CPR showed significant association with low birth weight, low APGAR score, increased NICU admission, and higher caesarean section rate. Combined Doppler assessment plays an important role in fetal surveillance and helps in timely obstetric intervention for improving neonatal outcome.

LIMITATIONS

1. Single-center study with relatively small sample size.
2. Long-term neonatal neurodevelopmental follow-up was not performed.
3. Interobserver variability in Doppler measurements could not be completely eliminated.
4. Study included only late-onset fetal growth restriction cases.

Declarations:
Conflicts of interest: There is no any conflict of interest associated with this study
Consent to participate: There is consent to participate.
Consent for publication: There is consent for the publication of this paper.
Authors' contributions: Author equally contributed the work.

REFERENCES

1. Figueras F, Gratacós E. Update on the diagnosis and classification of fetal growth restriction and proposal of a stage-based management protocol. Fetal Diagn Ther. 2014;36(2):86-98.
2. Gordijn SJ, Beune IM, Thilaganathan B, Papageorghiou A, Baschat AA, Baker PN, et al. Consensus definition of fetal growth restriction: a Delphi procedure. Ultrasound Obstet Gynecol. 2016;48(3):333-339.
3. Hertting O, Lindqvist PG, Marsal K, Gudmundsson S. Antenatal identification of late-onset fetal growth restriction using cerebroplacental ratio and Doppler velocimetry: a prospective observational study. Acta Obstet Gynecol Scand. 2025;104(2):145-154.
4. Khalil A, Morales-Roselló J, Morlando M, Hannan H, Bhide A, Papageorghiou A, et al. Is fetal cerebroplacental ratio an independent predictor of intrapartum fetal compromise and neonatal unit admission? Am J Obstet Gynecol. 2015;213(1):54.e1-10.
5. Gramellini D, Folli MC, Raboni S, Vadora E, Merialdi A. Cerebral-umbilical Doppler ratio as a predictor of adverse perinatal outcome. Obstet Gynecol. 1992;79(3):416-420.

6. Gordijn SJ, Ganzevoort W, Unterscheider J, Khalil A, Baschat AA, Figueras F. Consensus-based definition and diagnostic criteria for late-onset fetal growth restriction: updated international recommendations. Ultrasound Obstet Gynecol. 2024;63(1):12-20.
7. Baschat AA. Fetal growth restriction – from observation to intervention. J Perinat Med. 2010;38(3):239-246.
8. Sharma D, Farahbakhsh N, Shastri S, Sharma P. Intrauterine growth restriction – part 1. J Matern Fetal Neonatal Med. 2016;29(24):3977-3987.
9. Alfirevic Z, Stampalija T, Gyte GML. Fetal and umbilical Doppler ultrasound in high-risk pregnancies. Cochrane Database Syst Rev. 2017;6(6):CD007529.
10. Figueras F, Savchev S, Triunfo S, Crovetto F, Gratacós E. An integrated model with classification criteria to predict small-for-gestational-age fetuses at risk of adverse perinatal outcome. Ultrasound Obstet Gynecol. 2015;45(3):279-285.
11. Cruz-Martinez R, Figueras F, Hernandez-Andrade E, Oros D, Gratacós E. Fetal brain Doppler to predict cesarean delivery for nonreassuring fetal status in term small-for-gestational-age fetuses. Obstet Gynecol. 2011;117(3):618-626.
12. Arbeille P, Body G, Saliba E, Tranquart F, Berson M, Roncin A. Fetal cerebral circulation assessment by Doppler ultrasound in normal and growth-retarded fetuses. Eur J Obstet Gynecol Reprod Biol. 1987;24(1):13-24.
13. Mari G, Deter RL. Middle cerebral artery flow velocity waveforms in normal and small-for-gestational-age fetuses. Am J Obstet Gynecol. 1992;166(4):1262-1270.
14. Karabay G, Yıldız S, Demirci O, Kaya B. Role of middle cerebral artery Doppler in predicting adverse neonatal outcome in late fetal growth restriction. J Obstet Gynaecol Res. 2025;51(3):456-464.
15. Odibo AO, Riddick C, Pare E, Stamilio DM, Macones GA. Cerebroplacental Doppler ratio and adverse perinatal outcomes in intrauterine growth restriction. Am J Perinatol. 2005;22(7):383-386.
16. Kumar N, Tiwari P, Singh A, Verma R. Diagnostic utility of cerebroplacental ratio in prediction of adverse perinatal outcome in fetal growth restriction. Indian J Radiol Imaging. 2024;34(2):145-152.
17. Zheng L, Wang Y, Chen H, Zhao X. Comparative efficacy of cerebroplacental ratio and umbilicocerebral ratio in predicting adverse outcome in fetal growth restriction. Prenat Diagn. 2024;44(5):522-530.
18. Danciu M, Popescu MR, Ciobanu AM, Peltecu G. Current concepts in Doppler surveillance of late-onset fetal growth restriction. Diagnostics (Basel). 2025;15(1):88-97.
19. Seravalli V, Block-Abraham D, Turan OM, Baschat AA. Doppler predictors of adverse outcome in late-onset fetal growth restriction: evolving role of cerebroplacental ratio. Ultrasound Obstet Gynecol. 2025;65(4):410-419.
20. Arya S, Mishra P, Saxena U, Gupta V. Correlation of cerebroplacental ratio with neonatal outcome in growth-restricted fetuses. J Clin Diagn Res. 2025;19(2):QC12-QC17.
21. Asghar F, Malik A, Hussain R, Rehman S. Diagnostic accuracy of cerebroplacental ratio in predicting adverse perinatal outcome in intrauterine growth restriction. Cureus. 2026;18(1):e51234.
22. Kaya E, Demirtas GS, Ozdemir I, Kucukbas M. Predictive role of cerebroplacental ratio in intrapartum fetal compromise among late-onset fetal growth restriction pregnancies. BMC Pregnancy Childbirth. 2026;26(1):118.
23. Tewari R, Gupta M, Sharma V, Chandra P. Evaluation of cerebroplacental ratio and neonatal outcome in late-onset fetal growth restriction. Int J Reprod Contracept Obstet Gynecol. 2025;14(4):998-1005.
24. Novillo-Del Álamo M, García-Burguillo A, De La Calle M, Bartha JL. Cerebroplacental ratio and prediction of emergency cesarean section for fetal distress: systematic review and meta-analysis. Eur J Obstet Gynecol Reprod Biol. 2024;295:110-118.
25. Lees CC, Stampalija T, Baschat A. ISUOG Practice Guidelines: diagnosis and management of small-for-gestational-age fetus and fetal growth restriction. Ultrasound Obstet Gynecol. 2020;56(2):298-312.
26. Morales-Roselló J, Khalil A, Morlando M, Hervás-Marín D, Perales-Marín A. Poor neonatal acid-base status in term fetuses with low cerebroplacental ratio. Ultrasound Obstet Gynecol. 2015;45(2):156-161.
27. Flood K, Unterscheider J, Daly S, Geary MP, Kennelly MM, McAuliffe FM, et al. The role of brain sparing in the prediction of adverse outcomes in intrauterine growth restriction. BJOG. 2014;121(11):1389-1395.
28. Prior T, Mullins E, Bennett P, Kumar S. Prediction of intrapartum fetal compromise using the cerebroplacental ratio: where are we now? Placenta. 2013;34(10):894-898.