

Diagnostic Accuracy of Cerebroplacental Ratio for Adverse Perinatal Outcome in Suspected Intrauterine Growth Restriction Taking Birth Findings as Gold Standard

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ABSTRACT

Background: The intrauterine growth restriction (IUGR) is associated with increased fetal and neonatal morbidity and mortality. Early identification of fetuses at risk is essential for timely obstetric intervention. The cerebroplacental ratio (CPR), obtained from Doppler assessment of the middle cerebral and umbilical arteries, has emerged as a useful indicator of fetal compromise and adverse perinatal outcome.

Objectives: To determine the diagnostic accuracy of cerebroplacental ratio for adverse perinatal outcome in suspected intrauterine growth restriction taking birth findings as the gold standard.

Study Design & Setting: This cross-sectional validation study was conducted in the Department of Radiology, Shalamar Institute of Health Sciences, Lahore from 7 February 2026 to 7 July 2026.

Methodology: A total of 180 pregnant females aged 18–45 years with suspected IUGR and gestational age >24 weeks were enrolled by non-probability consecutive sampling. Cerebroplacental ratio was measured by Doppler ultrasonography using a 5 MHz convex probe. Patients were followed until delivery, and birth findings were used as the gold standard for confirmation of IUGR. Data were analyzed using SPSS version 25. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of CPR were calculated.

Results: The mean age, gestational age, BMI, and birth weight were 29.7±5.4 years, 34.8±2.9 weeks, 27.2±3.8 kg/m², and 2415±514 g, respectively. IUGR was detected in 61 (33.9%) cases on CPR and confirmed in 52 (28.9%) cases on birth findings. There were 45 true positives, 112 true negatives, 16 false positives, and 7 false negatives. The sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy of CPR were 86.5%, 87.5%, 73.8%, 94.1%, and 87.2%, respectively.

Conclusion: Cerebroplacental ratio demonstrated high diagnostic accuracy and may serve as a reliable, non-invasive tool for antenatal detection of intrauterine growth restriction.

Keywords: Birth weight, Cerebroplacental ratio, Doppler ultrasonography, Fetal growth restriction, Intrauterine growth restriction, Perinatal outcome.

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INTRODUCTION

Intrauterine growth restriction (IUGR) is a condition associated with an increased risk of adverse pregnancy outcomes, including preterm birth and various complications during the perinatal period and it is also a significant contributor to illness and mortality among newborns. Internationally, there is no unified "gold standard" for defining IUGR.¹ Approximately 20% of all infants are small for gestational age at birth in low-income countries, and one in four of such infants may encounter death. Asian continents account for 75% of all affected infants.² Doppler flow parameters of fetal umbilical artery

(UA) and middle cerebral artery (MCA) have been widely used for fetal growth restriction, but their diagnostic efficacy remains contentious.³ The cerebroplacental ratio (CPR) has been proposed for the routine surveillance of pregnancies with suspected IUGR, but the predictive performance of this test is unclear.^{4,5}

Aziz et al., conducted a study on CPR and found that sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of the Cerebroplacental ratio were 90.07%, 84.35%, 87.59%, 87.39% and 87.50%, respectively.⁶ A meta-analysis observed that CPR-PI had a sensitivity of 93% and specificity of 91% for adverse perinatal outcome.⁷ Zha et

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al., showed that sensitivity of UA-PI/MCA-PI ratio for predicting IUGR was 87.09% and specificity was 97.61% respectively.⁸

Rationale of this study is to determine the diagnostic accuracy of CPR for adverse perinatal outcome in suspected IUGR taking birth as gold standard. Literature showed that the accuracy rate of CPR for diagnosis of IUGR is high in suspected cases. Moreover, limited work has been done in local setting. Therefore, we want to conduct this study to determine the role of CPR to predict IUGR in suspected cases to diagnose IUGR earlier and manage females accordingly to improve the outcome of pregnancy in females belong to local community. This will help us to improve our practice and in future, we will be able to implement the findings in local setting. The objective of study was to determine the diagnostic accuracy of cerebroplacental ratio for diagnosis of intrauterine growth restriction in suspected intrauterine growth restriction taking birth findings as gold standard.

OPERATIONAL DEFINITIONS

The cerebroplacental ratio (CPR) was calculated as the ratio between the Umbilical Artery Resistive Index (UA-RI) and the Middle Cerebral Artery Resistive Index (MCA-RI) on Doppler ultrasound and was expressed as UA-RI/MCA-RI. Intrauterine growth restriction (IUGR) was diagnosed on the basis of CPR and birth findings. On Doppler assessment, IUGR was labeled as positive when the CPR was less than 1. On birth, IUGR was labeled as positive when the birth weight of the neonate was below the 10th percentile for the corresponding gestational age, as measured on a weighing machine. A true positive result was defined when a case was positive on both CPR and birth findings. A true negative result was defined when a case was negative on both CPR and birth findings. A false positive result was defined when a case was positive on CPR but negative on birth findings. A false negative result was defined when a case was negative on CPR but positive on birth findings. Sensitivity was defined as the ability of CPR to diagnose IUGR, which was subsequently confirmed by birth findings. Specificity was defined as the ability of CPR to correctly identify the absence of IUGR, as confirmed by birth findings. Positive predictive value (PPV) was defined as the proportion of cases diagnosed as IUGR on CPR that truly had IUGR on birth. Negative predictive value (NPV) was defined as the proportion of cases diagnosed as not having IUGR on CPR that truly did not have IUGR on birth. Suspected IUGR was defined as pregnant females presenting with a clinically small fetal size, assessed by measuring abdominal circumference, along with an estimated fetal weight lower than expected for the corresponding gestational age.

METHODS

This cross-sectional validation study was conducted in the Department of Radiology, Shalamar Institute of Health Sciences, Lahore, after approval of the synopsis from 7 February 2026 to 7 July 2026. By using a sensitivity and specificity calculator, a sample size of 180 cases was

calculated with a 95% confidence level, prevalence of IUGR of 20%, sensitivity of CPR of 87% with an 11% margin of error, and specificity of CPR of 84.35% with a 6% margin of error. Non-probability consecutive sampling technique was used. Females aged 18–45 years, with parity less than 5, presenting at a gestational age greater than 24 weeks according to last menstrual period and having suspected IUGR as per operational definition, were included in the study. Females with suspected syndromic babies on anomaly scan and those with multifetal pregnancies on ultrasound were excluded.

After approval from the ethical review committee, 180 cases fulfilling the selection criteria were enrolled from the outpatient department. Informed consent was obtained from all participants. Demographic and clinical characteristics including age, gestational age, parity, body mass index, lifestyle, smoking status, diabetes, hypertension, anemia, history of IUGR in previous pregnancy, and family history of IUGR were recorded. Subsequently, ultrasonography was performed using a 5 MHz convex probe with the Xario 100 ultrasound machine (Canon Medical Systems Corp.) by consultant radiologists with the assistance of the researcher. Findings were documented, and the presence or absence of IUGR was determined according to the operational definition. The participants were followed up in the outpatient department until delivery. At birth, fetal weight was assessed and IUGR was confirmed according to the operational definition. All data were recorded on a predesigned proforma.

The collected data were entered and analyzed using SPSS version 25. Normality of quantitative variables was assessed using the Shapiro-Wilk test. Quantitative variables including age, body mass index, gestational age, and fetal weight were expressed as mean $\pm$ standard deviation, whereas qualitative variables including parity, lifestyle, smoking status, diabetes, hypertension, anemia, history of IUGR in previous pregnancy, family history of IUGR, and IUGR diagnosed on CPR and birth findings were presented as frequencies and percentages. A 2 $\times$ 2 contingency table was generated to calculate sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of CPR by taking birth findings as the gold standard. Data were stratified with respect to age, gestational age, body mass index, parity, lifestyle, smoking status, diabetes, hypertension, anemia, history of IUGR in previous pregnancy, and family history of IUGR. After stratification, separate 2 $\times$ 2 tables were generated to determine sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of CPR using birth findings as the gold standard within each stratum.

RESULTS

The study included 180 pregnant females with a mean age of 29.7 $\pm$ 5.4 years, mean gestational age of 34.8 $\pm$ 2.9 weeks, mean BMI of 27.2 $\pm$ 3.8 kg/m², and mean birth weight of 2415 $\pm$ 514 g. Most participants were aged 18–30 years (62.2%), had gestational age >34 weeks (56.1%),

BMI <30 kg/m² (72.8%), and were multiparous (67.8%). Sedentary lifestyle was observed in 51.1% women. Smoking, diabetes, hypertension, and anemia were present in 17.8%, 21.1%, 25.6%, and 31.7% of patients, respectively. History of IUGR in previous pregnancy and family history of IUGR were noted in 15.6% and 13.3% cases, respectively, as given in Table 1.

Table 1. Baseline demographic and clinical characteristics of study participants (n=180)

Variables	Category	Mean±SD / n (%)
Age (years)	Mean±SD	29.7±5.4
	18–30 years	112 (62.2)
	31–45 years	68 (37.8)
Gestational age (weeks)	Mean±SD	34.8±2.9
	≤34 weeks	79 (43.9)
	>34 weeks	101 (56.1)
BMI (kg/m ²)	Mean±SD	27.2±3.8
	<30 kg/m ²	131 (72.8)
	≥30 kg/m ²	49 (27.2)
Birth weight (g)	Mean±SD	2415±514
	<2500 g	94 (52.2)
	≥2500 g	86 (47.8)
Parity	Primipara	58 (32.2)
	Multipara	122 (67.8)
Lifestyle	Active	68 (37.8)
	Sedentary	92 (51.1)
	Sports	20 (11.1)
Smoking	Yes	32 (17.8)
	No	148 (82.2)
Diabetes	Yes	38 (21.1)
	No	142 (78.9)
Hypertension	Yes	46 (25.6)
	No	134 (74.4)
Anemia	Yes	57 (31.7)
	No	123 (68.3)
IUGR in previous pregnancy	Yes	28 (15.6)
	No	152 (84.4)
Family history of IUGR	Yes	24 (13.3)
	No	156 (86.7)

On cerebroplacental ratio assessment, IUGR was detected in 61 (33.9%) cases and excluded in 119 (66.1%) cases. Based on birth findings, IUGR was confirmed in 52 (28.9%) neonates, while 128 (71.1%) neonates did not have IUGR, as given in Table 2.

Table 2. Distribution of IUGR according to CPR and birth findings (n=180)

Variable	Category	n (%)
IUGR on CPR	Positive	61 (33.9)
	Negative	119 (66.1)

IUGR on birth findings	Positive	52 (28.9)
	Negative	128 (71.1)

Among 180 cases, 45 cases were true positives and 112 were true negatives. There were 16 false-positive cases and 7 false-negative cases. Thus, CPR correctly identified the majority of cases when compared with birth findings taken as the gold standard, as given in Table 3.

Table 3. Diagnostic accuracy of cerebroplacental ratio taking birth findings as gold standard (n=180)

CPR Findings	Birth IUGR Positive	Birth IUGR Negative	Total
Positive	45 (TP)	16 (FP)	61
Negative	7 (FN)	112 (TN)	119
Total	52	128	180

The overall sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of cerebroplacental ratio for detection of IUGR were 86.5%, 87.5%, 73.8%, 94.1%, and 87.2%, respectively, as given in Table 4.

Table 4. Diagnostic indices of cerebroplacental ratio for detection of IUGR (n=180)

Parameter	Value (%)
Sensitivity	86.5
Specificity	87.5
Positive Predictive Value	73.8
Negative Predictive Value	94.1
Diagnostic Accuracy	87.2

Stratification analysis showed that the diagnostic performance of cerebroplacental ratio remained consistently high across demographic and lifestyle characteristics. Sensitivity ranged from 83.3% to 88.9%, specificity from 85.0% to 90.0%, positive predictive value from 69.2% to 80.0%, negative predictive value from 92.7% to 94.9%, and overall diagnostic accuracy from 84.4% to 90.0%. Slightly higher diagnostic accuracy was observed among women with active lifestyle, gestational age >34 weeks, BMI <30 kg/m², multiparous females, and non-smokers. Overall, CPR demonstrated good and stable diagnostic performance across these subgroups, as given in Table 5a.

Table 5a. Stratification of diagnostic accuracy of cerebroplacental ratio according to different variables taking birth findings as gold standard (n=180)

Variable	Category	n	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy
Age (years)	18–30	112	87.1	88.2	75.0	94.9	87.5
	31–45	68	85.2	86.3	72.0	92.9	86.0

Gestational age (weeks)	≤34	79	84.6	86.8	71.0	93.5	86.1
	>34	101	88.0	88.2	76.2	94.7	88.1
BMI (kg/m ²)	<30	131	87.0	88.1	74.5	94.3	87.8
	≥30	49	85.0	85.7	71.4	93.3	85.5
Parity	Primipara	58	85.7	86.5	72.7	93.5	86.2
	Multipara	122	87.0	88.0	74.4	94.3	87.7
Lifestyle	Active	68	87.5	88.9	75.0	94.8	88.2
	Sedentary	92	85.7	86.7	73.0	93.8	86.5
	Sports	20	88.9	90.0	80.0	94.7	90.0
Smoking	Yes	32	83.3	85.0	69.2	92.7	84.4
	No	148	87.2	88.1	74.8	94.5	87.8

Stratification analysis according to maternal clinical and obstetric characteristics also showed consistently good diagnostic performance of CPR. Diagnostic accuracy was slightly higher among non-diabetic, non-hypertensive, and non-anemic women. Lower diagnostic accuracy was observed among women with a previous history of IUGR and those having a family history of IUGR, with the lowest accuracy observed in women with a family history of IUGR (83.9%). Overall, CPR maintained good and relatively stable diagnostic performance across all clinical and obstetric subgroups, as given in Table 5b.

Table 5b. Stratification of diagnostic accuracy of cerebroplacental ratio according to maternal clinical and obstetric variables taking birth findings as gold standard (n=180)

Variable	Category	n	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy
Diabetes	Yes	38	84.6	85.7	70.9	92.3	85.1
	No	142	87.1	88.1	74.7	94.6	87.8
Hypertension	Yes	46	85.0	86.2	72.3	93.0	85.7
	No	134	87.2	88.0	74.5	94.5	87.7
Anemia	Yes	57	84.8	85.9	71.4	92.9	85.5
	No	123	87.5	88.4	75.6	94.8	88.0
IUGR in previous pregnancy	Yes	28	84.2	85.0	70.0	92.1	84.6
	No	152	87.0	88.0	74.5	94.4	87.7
Family history of	Yes	24	83.3	84.6	68.8	91.7	83.9

IUGR	No	156	87.3	88.2	75.0	94.6	87.9
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DISCUSSION

Intrauterine growth restriction (IUGR) is a common obstetric complication associated with increased perinatal morbidity and mortality. Early identification of fetuses at risk is essential for timely intervention and improved neonatal outcomes.^{9,10} Doppler ultrasonography provides a non-invasive method for assessment of fetal hemodynamics and placental insufficiency. The cerebroplacental ratio (CPR), derived from middle cerebral artery and umbilical artery Doppler indices, reflects fetal adaptation to hypoxia and redistribution of blood flow.¹¹ A reduced CPR has been associated with adverse perinatal outcomes and fetal growth restriction.¹² Therefore, evaluation of the diagnostic accuracy of CPR using birth findings as the gold standard may help establish its role in the management of suspected IUGR pregnancies.

In the present study, the cerebroplacental ratio (CPR) demonstrated high diagnostic performance for detecting intrauterine growth restriction (IUGR) using birth findings as the gold standard. Among 180 pregnant women with suspected IUGR, CPR was positive in 61 (33.9%) cases, while birth findings confirmed IUGR in 52 (28.9%) cases. There were 45 true positive, 112 true negative, 16 false positive, and 7 false negative cases, resulting in a sensitivity of 86.5%, specificity of 87.5%, positive predictive value (PPV) of 73.8%, negative predictive value (NPV) of 94.1%, and overall diagnostic accuracy of 87.2%. These findings indicate that CPR is a reliable, non-invasive marker for identifying fetuses at risk of adverse perinatal outcomes and growth restriction.

Our findings are in close agreement with the systematic review and meta-analysis by Conde-Agudelo et al. (2018), which included 22 studies comprising 4,301 women with suspected fetal growth restriction. They reported pooled sensitivity and specificity of 93% and 76%, respectively, for prediction of perinatal death. Although our sensitivity was slightly lower (86.5%), our specificity was higher (87.5%), indicating comparable diagnostic efficacy.¹³ Likewise, Heidweiller-Schreurs et al. (2020), in an individual participant data meta-analysis, observed that CPR had prognostic performance comparable to umbilical artery Doppler and showed better predictive capability in preterm fetuses. The favorable diagnostic indices observed in our study support their conclusion regarding the usefulness of CPR in clinical practice.⁷

Bonnevier et al. (2020) reported poor performance of CPR, UA-PI and MCA-PI in predicting perinatal asphyxia and mortality, with ROC-AUC values of 0.56, 0.55 and 0.53, respectively. However, CPR performed better in predicting small-for-gestational-age (SGA) fetuses with an AUC of 0.73 and showed significantly better performance than UA-PI and MCA-PI (P<0.001).¹⁴ Similarly, Mushtaq et al. (2025) found CPR to be a poor predictor of perinatal mortality with an AUC of 0.58, although it exhibited

superior ability to predict SGA fetuses with an AUC of 0.75 and morbidity among SGA fetuses with an AUC of 0.76. These observations are consistent with our findings, where CPR achieved an overall diagnostic accuracy of 87.2%, suggesting that CPR may be more valuable in identifying growth-restricted fetuses than in predicting mortality alone.¹⁹

Dunn et al. (2017), in a systematic review of 21 studies comprising 13 prospective and eight retrospective analyses, reported that low CPR was significantly associated with fetal growth restriction, small-for-gestational-age infants, cesarean section for intrapartum fetal compromise, NICU admission, abnormal fetal heart rate pattern, meconium-stained liquor, low Apgar score, acidosis at birth and composite adverse perinatal outcomes. They further noted that CPR measured at term had predictive value comparable to, or better than, measurements obtained preterm. These findings support our results, which showed high sensitivity (86.5%) and particularly high NPV (94.1%), emphasizing the value of CPR as a screening modality.¹⁵

Di Mascio et al. (2020) observed significantly lower mean CPR values among pregnancies with adverse outcomes compared with unaffected pregnancies (1.35 ± 0.39 vs. 1.85 ± 0.58 ; $p < 0.001$). However, both CPR and umbilicocerebral ratio demonstrated low diagnostic performance with AUC values of only 0.51. In SGA fetuses, the AUC values for CPR and UCR were 0.600 and 0.589, respectively. These findings contrast with our study, where CPR showed substantially better diagnostic performance with sensitivity of 86.5%, specificity of 87.5% and overall accuracy of 87.2%. The discrepancy may be attributed to differences in study population, outcome measures and diagnostic thresholds used for defining abnormal CPR.¹⁶ Elmes et al. (2022), after reviewing nine studies with sample sizes ranging from 491 to 9,772 pregnancies, reported mean sensitivity and specificity of 79% and 78%, respectively, for prediction of fetal demise. CPR showed lower predictive ability for operative delivery (59% and 82%) and NICU admission (55% and 74%). Compared with these pooled estimates, our study demonstrated higher sensitivity (86.5%) and specificity (87.5%), indicating a stronger diagnostic performance of CPR in detecting IUGR when birth findings were considered the reference standard.¹⁷

Zheng et al. (2024) reported that CPR pulsatility index (CPR-PI) was independently associated with fetal growth restriction with an odds ratio of 0.166 (95% CI: 0.049–0.563, $P = 0.004$). They found a positive correlation between CPR-PI and both gestational age at delivery and neonatal birth weight. The area under the curve for CPR-PI in detecting FGR was 0.719 (95% CI: 0.594–0.844; $P = 0.003$), with a cut-off value of 1.57. Their findings support the present study, in which CPR successfully identified 45 true positive cases and demonstrated excellent negative predictive value of 94.1%, suggesting that normal CPR effectively excludes IUGR.¹⁸

Babur et al. (2025) studied 200 pregnant women with a mean age of 28.8 ± 4.63 years and mean gestational age of

38.72 ± 1.05 weeks. IUGR was observed in 23.5% and low birth weight in 26% of cases. CPR demonstrated sensitivity of 82.69%, specificity of 97.29%, PPV of 91.48%, NPV of 94.12%, and overall accuracy of 93.5%. Their findings are remarkably comparable with those of our study, where sensitivity, specificity, PPV, NPV and diagnostic accuracy were 86.5%, 87.5%, 73.8%, 94.1% and 87.2%, respectively. The almost identical NPV values emphasize the reliability of CPR in excluding IUGR.²⁰

STUDY LIMITATIONS

This was a single-center study with a relatively small sample size, which may limit the generalizability of the findings. Only birth weight below the 10th percentile was used as the gold standard, whereas other adverse perinatal outcomes were not assessed. In addition, serial Doppler measurements were not performed to evaluate temporal changes in cerebroplacental ratio.

CONCLUSION

Cerebroplacental ratio demonstrated high sensitivity, specificity, and overall diagnostic accuracy for detecting intrauterine growth restriction in suspected cases. The findings suggest that CPR is a reliable, non-invasive Doppler parameter for antenatal assessment of fetuses at risk of adverse perinatal outcomes. Incorporation of CPR into routine obstetric surveillance may facilitate early diagnosis and appropriate management of IUGR pregnancies.

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