International Journal of Reproduction, Contraception, Obstetrics and Gynecology
Srivastava R et al. Int J Reprod Contracept Obstet Gynecol. 2026 Oct;15(10):4046-4050
www.ijrcog.org
pISSN 2320-1770 | eISSN 2320-1789

DOI: https://dx.doi.org/10.18203/2320-1770.ijrcog20263444

Original Research Article

Association of third trimester cerebroplacental ratio with obstetric and neonatal outcomes in uncomplicated singleton pregnancies: a prospective observational study

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Received: 18 August 2026
Accepted: 17 September 2026

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ABSTRACT

Background: The cerebroplacental ratio (CPR) integrates information from the middle cerebral and umbilical artery circulations and may reflect fetal haemodynamic adaptation. This study evaluated the association between third-trimester CPR and obstetric and neonatal outcomes in uncomplicated singleton pregnancies.
Methods: This prospective observational study included 90 uncomplicated singleton pregnancies in the third trimester. Middle cerebral artery pulsatility index and umbilical artery pulsatility index were assessed by colour Doppler, and CPR was calculated as MCA PI/UA PI. The last CPR measurement before delivery was used for analysis. CPR values were compared between pregnancies with and without selected obstetric and neonatal outcomes. A secondary analysis used the study-derived CPR cut-off of ≤0.85.
Results: Mean CPR was significantly lower with non-reactive NST than reactive NST (0.72±0.19 vs 1.05±0.20; p=0.001). Lower CPR was also associated with Apgar score <7 at 5 minutes, NICU admission, meconium-stained liquor, respiratory distress syndrome, neonatal death, sepsis, assisted and extensive respiratory support, and birth weight <10th centile (p≤0.002). CPR was lower among cesarean than vaginal deliveries (0.81±0.22 vs 1.03±0.20; p=0.002). Overall, 72 (80.0%) had an adverse perinatal outcome; 52/54 (96.3%) with CPR ≤0.85 had an adverse outcome versus 20/36 (55.6%) with CPR >0.85 (p<0.001).
Conclusions: Lower third-trimester CPR was associated with several adverse obstetric and neonatal outcomes. The study-derived cut-off of ≤0.85 was also associated with adverse perinatal outcome. CPR may provide adjunctive information for perinatal risk assessment, while the study-derived threshold requires external validation.

Keywords: Cerebroplacental ratio, Fetal doppler, Middle cerebral artery, Umbilical artery, Obstetric outcome, Neonatal outcome

INTRODUCTION

Fetal compromise contributes substantially to perinatal morbidity and mortality, and antenatal assessment aims to identify pregnancies at increased risk before clinical deterioration occurs. Doppler velocimetry provides information regarding fetal and placental circulation and may demonstrate haemodynamic changes associated with fetal adaptation. The umbilical artery pulsatility index (UA PI) reflects placental vascular resistance, whereas the middle cerebral artery pulsatility index (MCA PI) provides information regarding fetal cerebral circulation. A reduction in MCA PI may occur as part of fetal circulatory redistribution in response to reduced oxygen availability. The cerebroplacental ratio (CPR), calculated as MCA PI divided by UA PI, combines information from these two vascular beds.[1]

Several studies have reported associations between reduced CPR and fetal heart-rate abnormalities, operative delivery, low Apgar score, neonatal-unit admission and other adverse neonatal outcomes.[2-6] Reported thresholds have varied across studies according to gestational age, population characteristics, Doppler methodology and outcome definitions.[3,4,6]

The prognostic value of CPR in uncomplicated singleton pregnancies remains clinically relevant because conventional fetal assessment may not fully reflect subtle changes in fetal-placental haemodynamics. At the same time, evidence regarding the additional predictive value of CPR beyond conventional Doppler parameters is not uniform.[7-12]

METHODS

Study design and setting

This was a prospective, hospital-based observational study conducted in the Department of Obstetrics and Gynaecology, Panna Dhaya Rajkiya Mahila Chikitsalaya, R.N.T. Medical College, Udaipur, Rajasthan, India. The study was conducted after institutional ethical approval and written informed consent from participants.

Study population

Women with singleton pregnancies in the third trimester were eligible for inclusion. Women with recognized chronic maternal disease, including hypertension, diabetes mellitus, chronic kidney disease or heart disease, pregnancies complicated by fetal chromosomal or structural abnormalities, and women who did not provide consent were excluded. Participants were selected using non-probability convenience sampling.

Sample size

The calculated sample size was 82 based on an anticipated CPR sensitivity of 82.8% with 10% relative precision. After allowing for a 10% dropout rate, 90 participants were enrolled.

Ethical considerations

The study was approved by the Institutional Ethics Committee of R.N.T. Medical College & Controller & Attached Hospitals, Udaipur (Approval No. RNT/Acad./Ethical/2025/915). Written informed consent was obtained from all participants.

Doppler assessment

All enrolled participants underwent Doppler ultrasonography. MCA PI and UA PI were recorded, and CPR was calculated as: CPR = MCA PI / UA PI. When repeat Doppler examinations were performed, the last CPR measurement before delivery was used for analysis.

Outcome assessment

The study evaluated obstetric and neonatal outcomes recorded during the antenatal, intrapartum and neonatal periods. Obstetric outcomes included non-reactive NST and mode of delivery. Neonatal outcomes included birth weight below the 10th centile, Apgar score <7 at 5 minutes, NICU admission, meconium-stained liquor, respiratory distress syndrome, sepsis, neonatal death, assisted respiratory support and extensive respiratory support.

For the present analysis, an adverse perinatal outcome was considered present when any one or more of the predefined adverse neonatal outcomes occurred. Thus, the composite outcome included one or more of the following: birth weight <10th centile, Apgar score <7 at 5 minutes, NICU admission, meconium-stained liquor, respiratory distress syndrome, sepsis, neonatal death, assisted respiratory support or extensive respiratory support.

CPR cut-off

A secondary categorical analysis was performed using CPR ≤0.85 as the study-derived CPR cut-off. This threshold was derived within the study cohort and is not presented as a universally established or externally validated clinical threshold.

Statistical analysis

Data were entered and analysed using SPSS version 26.0 and Microsoft Excel. Continuous variables were expressed as mean±standard deviation, while categorical variables were presented as frequencies and percentages. Continuous variables were compared using the independent-samples t-test, and categorical variables were compared using the chi-square test, as appropriate. A p value <0.05 was considered statistically significant. The association between the study-derived CPR cut-off of ≤0.85 and adverse perinatal outcome was assessed using categorical analysis.

RESULTS

Study population

A total of 90 women with singleton pregnancies were included. Most participants were aged 21–30 years (75.6%), primigravida (55.6%), had normal BMI (75.8%), and were at ≥37 weeks of gestation (55.6%). CPR ≤0.85 was observed in 60.0% of participants.

Table 1: Distribution of obstetric and neonatal outcomes.

Outcomes	N (%)
Non-reactive NST	20 (22.2)
Cesarean delivery	41 (45.6)
Birth weight <10th centile	50 (55.6)
Apgar score <7 at 5 minutes	19 (21.1)
NICU admission	19 (21.1)
Meconium-stained liquor	27 (30.0)
Respiratory distress syndrome	28 (31.1)
Sepsis	11 (12.2)
Assisted respiratory support	39 (43.3)
Extensive respiratory support	19 (21.1)
Neonatal death	4 (4.4)

NST: non-stress test; NICU: neonatal intensive care unit.

Association of CPR with obstetric and neonatal outcomes

Lower CPR was significantly associated with all individual outcomes evaluated. The mean CPR among pregnancies with a non-reactive NST was 0.72±0.19 compared with 1.05±0.20 among pregnancies with a reactive NST (p=0.001).

Among neonatal outcomes, mean CPR was significantly lower in neonates with Apgar score <7 at 5 minutes, NICU admission, meconium-stained liquor and respiratory distress syndrome. Lower CPR was also significantly associated with neonatal death, sepsis, need for assisted respiratory support, extensive respiratory support and birth weight below the 10th centile.

Table 2: Association of mean cerebroplacental ratio with obstetric and neonatal outcomes.

Outcomes	CPR with outcome, mean±SD	CPR without outcome, mean±SD	P value
Non-reactive NST	0.72±0.19	1.05±0.20	0.001
Cesarean delivery	0.81±0.22	1.03±0.20	0.002
Birth weight <10th centile	0.73±0.19	1.04±0.20	0.001
Apgar score <7 at 5 minutes	0.72±0.20	1.02±0.21	0.001
NICU admission	0.70±0.18	1.05±0.20	0.001
Meconium-stained liquor	0.74±0.19	1.03±0.21	0.002
Respiratory distress syndrome	0.69±0.17	1.04±0.21	0.001
Sepsis	0.68±0.16	1.03±0.21	0.001
Assisted respiratory support	0.71±0.18	1.04±0.20	0.001
Extensive respiratory support	0.66±0.17	1.05±0.20	0.001
Neonatal death	0.65±0.15	1.02±0.22	0.001

CPR: cerebroplacental ratio; NST: non-stress test; NICU: neonatal intensive care unit. Values are mean±SD.

CPR cut-off and adverse perinatal outcome

A CPR value of ≤0.85 was used as the study-derived cut-off for categorical analysis. In the study cohort, 54 of 90 participants (60.0%) had CPR ≤0.85. Adverse perinatal outcome was recorded in 72 of 90 participants (80.0%). Among participants with CPR ≤0.85, 52 of 54 (96.3%) had an adverse perinatal outcome compared with 20 of 36 (55.6%) among those with CPR >0.85. The association was statistically significant (p<0.001).

Table 3. Association of the study-derived CPR cut-off with adverse perinatal outcome.

CPR category	Adverse perinatal outcome, N (%)	Uneventful outcome, N (%)	Total, N (%)
≤0.85	52 (96.3)	2 (3.7)	54 (60.0)
>0.85	20 (55.6)	16 (44.4)	36 (40.0)
Total	72 (80.0)	18 (20.0)	90 (100)

p<0.001, CPR ≤0.85 represents the study-derived cut-off used for categorical analysis and is not presented as a universally established clinical threshold. CPR: cerebroplacental ratio.

DISCUSSION

The present prospective observational study demonstrated a consistent association between lower third-trimester CPR and a range of clinically relevant obstetric and neonatal outcomes in uncomplicated singleton pregnancies. Lower CPR values were observed in pregnancies with abnormal fetal surveillance, caesarean delivery, lower birth weight, low 5-minute Apgar score, NICU admission and several neonatal morbidities. The study also demonstrated a significant association between the study-derived CPR cut-off of ≤0.85 and adverse perinatal outcome.

CPR combines the pulsatility indices of the MCA and UA and therefore reflects changes in both fetal cerebral circulation and placental vascular resistance. A reduction in CPR may occur with increased placental resistance and/or cerebral vasodilatation associated with fetal circulatory adaptation[1].The consistent direction of the findings in the present study is therefore biologically plausible.

A significant association was observed between CPR and NST findings. Mean CPR was substantially lower in pregnancies with a non-reactive NST than in those with a reactive NST (0.72±0.19 vs 1.05±0.20; p=0.001). Ropacka-Lesiak et al reported an association between cerebroplacental Doppler abnormalities and fetal heart-rate disturbances in uncomplicated pregnancies at 40 weeks and beyond.[2] Khalil et al similarly reported an association between CPR and intrapartum fetal compromise and neonatal-unit admission.[3]

Mean CPR was significantly lower among women undergoing cesarean delivery than among those delivering vaginally (0.81±0.22 vs 1.03±0.20; p=0.002). The finding is consistent with previous reports linking lower CPR with operative delivery and suspected fetal compromise.[4,6] However, mode of delivery is determined by several clinical and obstetric factors. Consequently, the present result demonstrates an association and should not be interpreted as evidence that CPR alone determines the mode of delivery.

Lower CPR was significantly associated with birth weight below the 10th centile (0.73±0.19 vs 1.04±0.20; p=0.001). The association is consistent with the physiological relationship between placental function, fetal growth and fetal circulatory adaptation. Impaired placental function may result in increased placental vascular resistance and subsequent fetal haemodynamic adaptation. Gramellini et al reported that the cerebral-umbilical Doppler ratio was associated with adverse perinatal outcome and may provide information regarding fetal circulatory adaptation.[5]

The neonatal findings showed a consistent pattern. Lower CPR was significantly associated with low 5-minute Apgar score, NICU admission, meconium-stained liquor, respiratory distress syndrome, sepsis, neonatal death and the need for assisted or extensive respiratory support. Similar associations between reduced CPR and adverse neonatal outcomes have been reported in previous studies.[4,6]

The mean CPR among neonates with Apgar score <7 at 5 minutes was 0.72±0.20 compared with 1.02±0.21 among those without this outcome. Similarly, CPR was lower among neonates requiring NICU admission, those with meconium-stained liquor and those with respiratory morbidity. These findings support the association between lower CPR and clinically important neonatal morbidity.

The lowest mean CPR was observed among neonates requiring extensive respiratory support and among neonates who died. However, only four neonatal deaths occurred in the cohort. Therefore, the association with neonatal death should be interpreted cautiously because of the small number of events.

The categorical analysis demonstrated a strong association between CPR ≤0.85 and adverse perinatal outcome. Among participants with CPR ≤0.85, 52 of 54 (96.3%) had an adverse perinatal outcome, compared with 20 of 36 (55.6%) among those with CPR >0.85 (p<0.001). This categorical analysis complements the continuous CPR analysis by demonstrating a higher proportion of adverse outcomes below the study-derived threshold.

The value of 0.85 should nevertheless be interpreted as a study-derived cut-off. It should not be described as a universally accepted or independently validated clinical threshold. Published studies have used different absolute CPR thresholds and gestational-age-specific centiles, and these differences may reflect variation in study populations, gestational age, Doppler methodology and definitions of adverse outcome.

The present study therefore supports the association between lower CPR and adverse perinatal outcome within this cohort, while external validation would be necessary before the threshold could be applied more broadly.

The findings are broadly consistent with previous studies reporting associations between reduced CPR and adverse obstetric and neonatal outcomes. Previous studies have reported associations with fetal compromise, operative delivery, low Apgar score and NICU admission.[2-5,8,9]

The physiological explanation for these findings is also consistent with the concept of fetal circulatory redistribution. A reduction in MCA PI together with an increase in UA PI can result in a lower CPR, reflecting altered fetal-placental haemodynamics.[1]

However, the present findings should be interpreted as associations rather than proof of independent prediction or causation. A lower CPR may identify pregnancies in

which other adverse processes are occurring, rather than being an independent cause of the observed outcomes.

The present findings suggest that CPR may provide useful additional information when evaluating fetal well-being in uncomplicated singleton pregnancies. Clinical decision-making should incorporate gestational age, fetal growth, NST/CTG findings, conventional Doppler parameters and the overall clinical picture.

The study-derived threshold of ≤0.85 is useful for describing the categorical relationship observed in this cohort, but its clinical applicability requires validation in larger, independent populations.

Limitations

This was a single-centre observational study with a relatively small sample size of 90 participants. The use of non-probability sampling may limit generalizability. Several individual outcomes were examined, and some outcomes, particularly neonatal death, occurred infrequently. No multivariable adjustment was performed; consequently, the possibility of confounding by gestational age, fetal growth and other clinical factors cannot be excluded. Finally, the CPR value of ≤0.85 was a study-derived cut-off and was not externally validated.

CONCLUSION

Lower third-trimester CPR was significantly associated with several obstetric and neonatal outcomes in uncomplicated singleton pregnancies, including non-reactive NST, caesarean delivery, birth weight below the 10th centile, low 5-minute Apgar score, NICU admission and neonatal morbidity. The study-derived CPR cut-off of ≤0.85 was also significantly associated with adverse perinatal outcome. These findings support the potential role of CPR as an adjunctive marker of fetal-placental haemodynamic status and perinatal risk when interpreted alongside conventional fetal surveillance.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Srivastava R, Sen S, Ajmera Y, Laddha K. Association of third trimester cerebroplacental ratio with obstetric and neonatal outcomes in uncomplicated singleton pregnancies: a prospective observational study. Int J Reprod Contracept Obstet Gynecol 2026;15:4046-50.