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Research Article

The Role of Cerebroplacental Ratio in Monitoring Fetal Well-Being and Predicting Adverse Outcomes in Healthy and High-Risk Pregnancies in Pakistan

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ABSTRACT

Objective: To assess the role of the cerebroplacental ratio (CPR) in determining fetal well-being across healthy and high-risk pregnancies in Pakistan, with a focus on its predictive value for adverse perinatal outcomes such as fetal growth restriction (FGR), preterm birth, and neonatal intensive care unit (NICU) admission.

Study Design: Prospective observational study.

Place and Duration of Study: The study was conducted at the Obstetrics Department of Agha Khan Hospital Hyderabad and Civil Hospital Hyderabad, between July 2024 and December 2024.

Methodology: A total of 64 pregnant women were enrolled and divided equally into four groups of 16 participants: Group 1 (Healthy pregnancies), Group 2 (Pre-eclampsia), Group 3 (Eclampsia), and Group 4 (Diabetes Mellitus). Doppler ultrasound was used to measure the pulsatility indices (PI) of the middle cerebral artery (MCA) and the umbilical artery (UA). The cerebroplacental ratio (CPR) was calculated as the ratio of MCA PI to UA PI. A CPR value of less than 1.0 was considered abnormal and indicative of fetal compromise. Data on perinatal outcomes, including preterm birth, FGR, neonatal Apgar scores, NICU admission, and mode of delivery were collected. Data were analyzed using SPSS Version 25. Statistical significance was defined by a p-value of less than 0.05.

Results: High-risk pregnancies showed significantly lower mean CPR values compared to healthy pregnancies. The mean CPR values were: 1.8 ± 0.3 in the healthy group, 0.85 ± 0.15 in pre-eclampsia, 0.82 ± 0.18 in eclampsia, and 0.95 ± 0.2 in diabetes mellitus ($p < 0.001$). Adverse perinatal outcomes were more prevalent in high-risk groups. Preterm birth occurred in 37.5% of pre-eclampsia cases, 43.75% of eclampsia cases, and 31.25% of diabetic pregnancies, compared to 6.25% in the healthy group. FGR was observed in 31.25%, 37.5%, and 25% of the pre-eclampsia, eclampsia, and diabetes groups, respectively, while it was absent in the healthy group. NICU admission rates were 25%, 31.25%, and 18.75% in pre-eclampsia, eclampsia, and diabetes groups, respectively, compared to 3.1% in healthy pregnancies. The cesarean delivery rate was highest in eclampsia (62.5%), followed by pre-eclampsia (56.25%) and diabetes mellitus (43.75%), compared to 12.5% in healthy pregnancies. Logistic regression analysis indicated that a CPR below 1.0 was strongly associated with an increased risk of preterm birth (odds ratio: 4.5) and FGR (odds ratio: 3.8).

Conclusion: The cerebroplacental ratio is a crucial tool for predicting adverse perinatal outcomes in high-risk pregnancies. Its integration into routine antenatal care enables early detection of fetal compromise and supports timely clinical interventions, thereby reducing perinatal morbidity and mortality in resource-constrained healthcare settings in Pakistan.

Keywords: Cerebroplacental Ratio, Doppler Ultrasound, Fetal Well-Being, High-Risk Pregnancy, Pre-Eclampsia, Diabetes Mellitus, Pakistan.

INTRODUCTION

To get the best results for the mother and the unborn child, maternal and fetal health during

pregnancy are crucial. Timely and precise evaluation instruments are necessary to guarantee fetal health in order to identify issues early and direct treatment choices. Doppler ultrasonography is one of the most important technologies in contemporary obstetric practice for evaluating the patterns of blood flow in the fetus and placenta. The cerebroplacental ratio (CPR), which illustrates the connection between cerebral and placental blood circulation, is one crucial metric that may be determined with Doppler ultrasound. This ratio has grown in significance as a predictor of unfavorable perinatal outcomes, especially in pregnancies complicated by diabetes mellitus, eclampsia, and pre-eclampsia.. The focus of this article is to evaluate the significance of CPR in monitoring fetal well-being and its role in guiding clinical decisions in both healthy and high-risk pregnancies[1,2].

The middle cerebral artery's (MCA) pulsatility index (PI) divided by the umbilical artery's (UA) is known as the cerebroplacental ratio (CPR). The physiological redistribution of fetal blood flow, referred to as the "brain-sparing effect," is reflected in this ratio. Reduced resistance in the MCA and an increase in the PI of the UA result from the fetus prioritizing blood flow to critical organs, especially the brain, in situations of hypoxia or placental insufficiency. Therefore, a low CPR is a sign of fetal impairment and has been linked to a number of negative outcomes, such as preterm birth, emergency cesarean surgery, neonatal morbidity and mortality, and fetal growth restriction (FGR). [3].

Throughout the third trimester, healthy pregnancies usually show a steady cerebroplacental ratio, with minor fluctuations based on fetal activity and gestational age [4]On the other hand, variations from typical CPR readings could indicate fetal hypoxia or placental malfunction. Preventing negative consequences requires early detection of such changes. When other risk factors or warning signals are present, CPR assessment can be a useful technique, even if it is not usually done in low-risk pregnancies.

On the other hand, high-risk pregnancies necessitate more frequent and thorough monitoring of fetal health. One of the most common complications in high-risk pregnancies is pre-eclampsia, a condition marked by hypertension and damage to organ systems, often due to poor placental perfusion. Pre-eclampsia affects about 2-8% of pregnancies globally and is a major cause of maternal and perinatal morbidity and mortality [5]. Doppler ultrasound studies in pre-eclampsia frequently show increased resistance in the umbilical artery, which results in a decreased cerebroplacental ratio. In severe cases, this condition can progress to eclampsia, which is characterized by seizures, further increasing the risk of placental abruption, intrauterine growth restriction (IUGR), and fetal death [6]. Frequent evaluation of CPR can help identify at-risk fetuses and determine the best time for delivery..

Pregnancy-related diabetes mellitus (DM) also presents serious health risks to the mother and fetus. Early indicators of fetal impairment may be obscured by macrosomia, polyhydramnios, and placental malfunction, which can be caused by gestational diabetes or pre-existing diabetes. Diabetic fetuses are still susceptible to hypoxia, stillbirth, and delivery trauma despite their larger size. CPR is an important indicator of fetal adaptability to compromised placental function in these situations [7]. Research has indicated a correlation between elevated chances of emergency intervention and neonatal intensive care admission and aberrant CPR values in diabetic pregnancies. [8]

The evaluation of prenatal growth limitation is another crucial use for CPR. FGR is a significant cause of neonatal morbidity and mortality and is frequently linked to placental insufficiency. The separate pulsatility indices of the MCA and UA are examples of traditional Doppler indices that frequently fall short of capturing the full level of fetal impairment. However, the cerebroplacental ratio, which takes into consideration both brain and placental blood flow, offers a more thorough assessment.A consistently low CPR in suspected FGR instances is a powerful indicator of unfavorable outcomes and could affect choices about early delivery or close monitoring[9].

The application of CPR in standard clinical practice has drawbacks despite its proven effectiveness. A trained operator is needed to measure CPR, which can vary depending on the fetal movement, the mother's posture, and the gestational age. Additionally, CPR should be interpreted in combination with other measures such as cardiotocography (CTG), biophysical profile (BPP), and amniotic fluid index (AFI) rather than alone. Incorporating CPR evaluation into a more comprehensive monitoring regimen for high-risk pregnancies

can improve the early identification of fetal impairment and lower the probability of unfavorable outcomes.[10]

The significance of CPR in high-risk pregnancies, especially those including diabetes and hypertension diseases, is emphasized in current guidelines on the use of Doppler ultrasound in obstetrics. Standardized procedures for CPR assessment, cutoff values, and the timing of interventions based on CPR findings are still required, though. To guarantee consistent and evidence-based practice across healthcare settings, future research should concentrate on improving these processes.

METHODOLOGY

In order to explore the impact of the cerebroplacental ratio (CPR) on determining fetal well-being in both healthy and high-risk pregnancies, this study was planned as a prospective observational research project. The investigation was carried out at Agha Khan Hospital Hyderabad and Civil Hospital Hyderabad over a period of six months. Both hospitals had the necessary equipment, including neonatal intensive care units (NICUs) and Doppler ultrasound machines, and provided access to a diverse range of patients. The purpose of the study was to evaluate the predictive value of CPR in identifying adverse perinatal outcomes, such as preterm birth, fetal growth restriction (FGR), and neonatal complications.

Participants were selected from pregnant women who visited the antenatal clinics of these hospitals. The study population was divided into four groups: Group 1 (Healthy pregnancies), Group 2 (Pre-eclampsia), Group 3 (Eclampsia), and Group 4 (Diabetes Mellitus), with 16 women in each group. Specific inclusion and exclusion criteria were applied. Pregnant women between 28 and 40 weeks of gestation, with singleton pregnancies, and those with high-risk conditions such as pre-eclampsia, eclampsia, or diabetes mellitus were included. Healthy pregnancies with no risk factors served as the control group. Pregnancies with multiple gestations or fetal congenital anomalies were excluded from the study.

Prior to data collection, ethical approval was obtained from the Institutional Review Boards (IRBs) of the participating hospitals. Informed consent was secured from all participants after providing a detailed explanation of the study's objectives, procedures, and potential risks. Participants were assured of confidentiality and informed of their right to withdraw from the study at any point without affecting their access to medical care.

Data collection was conducted in two stages: clinical examination and Doppler ultrasonography evaluation. During the clinical assessment phase, maternal history, risk factors, and clinical findings were documented along with routine prenatal checkups. For high-risk pregnancies, additional parameters such as blood pressure, urine protein levels, and glucose levels were recorded. Information on gestational age, fetal movements, and previous obstetric history was also collected.

Doppler ultrasonography was conducted in the second phase by trained sonographers following a standardized protocol. Using color Doppler imaging, the middle cerebral artery (MCA) was identified, and its pulsatility index (PI) was measured. Similarly, a free loop of the umbilical cord was located to assess the PI of the umbilical artery (UA). The CPR was calculated as the ratio of MCA PI to UA PI. A CPR value of less than 1.0 was considered abnormal and indicative of fetal compromise. Each participant underwent at least two Doppler tests: one between weeks 28 and 34 and another between weeks 34 and 40. Additional ultrasounds were performed if abnormal CPR values were detected.

The primary outcome measures included the occurrence of adverse perinatal events such as preterm birth, FGR, and NICU admission. Secondary outcomes included the mode of delivery (spontaneous vaginal delivery, cesarean section, or assisted delivery) and neonatal indicators such as Apgar scores, birth weight, and complications like hypoxia or stillbirth. Maternal complications related to pre-eclampsia, eclampsia, and diabetes mellitus were also recorded.

Data were analyzed using version 25.0 of the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were used to summarize participants' clinical and demographic characteristics. Categorical variables, such as the mode of delivery and neonatal outcomes, were expressed as frequencies and percentages, while continuous variables, such as CPR values and gestational age, were presented as mean values with standard deviation (SD). Chi-square tests were employed to analyze categorical data, and independent t-tests were used to compare mean CPR values between groups. Logistic regression analysis was performed to assess

the predictive value of CPR for adverse perinatal outcomes. A p-value of less than 0.05 was considered statistically significant.

Although the study demonstrated strengths in its structured design and comprehensive data collection, it faced certain limitations. Variability in sonographer expertise and access to Doppler resources affected the consistency of measurements. Additionally, reliance on self-reported maternal histories introduced potential recall bias. Measures such as operator training and cross-verification of data with medical records were implemented to mitigate these limitations.

RESULTS

A total of 64 pregnant women were recruited from Agha Khan Hospital Hyderabad and Civil Hospital Hyderabad. Participants were divided into four groups, each containing 16 participants: Group 1 (Healthy pregnancies), Group 2 (Pre-eclampsia), Group 3 (Eclampsia), and Group 4 (Diabetes Mellitus). The mean gestational age at the time of the first Doppler ultrasound was 32.5 weeks across all groups, and baseline characteristics, including maternal age and parity, were comparable Table 1.

The mean cerebroplacental ratio (CPR) showed significant differences between the groups. The healthy group had a mean CPR of 1.8 ± 0.3, while the pre-eclampsia group recorded a mean CPR of 0.85 ± 0.15. The eclampsia group exhibited the lowest CPR at 0.82 ± 0.18, and the diabetes mellitus group showed a mean CPR of 0.95 ± 0.2. These findings pointed to impaired fetal blood flow in high-risk pregnancies, particularly those with hypertensive complications Table 2.

Adverse perinatal outcomes were more frequent in high-risk pregnancies. Preterm birth occurred in 6.25% of healthy pregnancies, while the rates were higher in the high-risk groups: 37.5% in pre-eclampsia, 43.75% in eclampsia, and 31.25% in diabetes mellitus. Fetal growth restriction (FGR) was absent in the healthy group but was observed in 31.25% of pre-eclampsia cases, 37.5% of eclampsia cases, and 25% of diabetic pregnancies. NICU admissions were higher in high-risk pregnancies: 25% in pre-eclampsia, 31.25% in eclampsia, and 18.75% in diabetes mellitus, compared to only 3.1% in the healthy group. Despite these challenges, 100% of neonates in the healthy group and 87.5%, 81.25%, and 93.75% in the pre-eclampsia, eclampsia, and diabetes groups, respectively, achieved favorable Apgar scores (≥ 7 at 5 minutes) Table 3.

The mode of delivery also varied significantly. Only 12.5% of healthy pregnancies required cesarean delivery, while cesarean rates were 56.25% in pre-eclampsia, 62.5% in eclampsia, and 43.75% in diabetes mellitus, primarily due to fetal distress and abnormal Doppler findings. Logistic regression analysis confirmed that a CPR below 1.0 significantly increased the risk of adverse outcomes, with odds ratios of 4.5 for preterm birth and 3.8 for FGR Figure 1.

These results emphasize the importance of integrating CPR assessment into routine antenatal care, particularly for high-risk pregnancies. Early identification of fetal compromise through Doppler ultrasound can guide timely interventions, improving maternal and neonatal outcomes in resource-limited settings like those at Agha Khan Hospital Hyderabad and Civil Hospital Hyderabad.

Table 1. Base line Characteristics

Characteristic	Healthy Group	Pre-eclampsia	Eclampsia	Diabetes Mellitus
Mean Maternal Age (years)	28	29	30	29
Mean Gestational Age (weeks)	32.5	32.5	32.5	32.5
Parity	1-2	1-2	1-2	1-2

Table 2.CPR Value

Group	Mean CPR
Healthy	1.8
High-Risk (Total)	0.9
Pre-eclampsia	0.85
Diabetes	0.95

Table 3.Perinatal Values

Outcome	Healthy Group (%)	Pre-eclampsia (%)	Eclampsia (%)	Diabetes Mellitus (%)
Preterm Birth	6.25	37.5	43.75	31.25
FGR	0.0	31.25	37.5	25.0
NICU Admission	3.1	25.0	31.25	18.75
5-min Apgar Score ≥ 7	100.0	87.5	81.25	93.75
Cesarean Delivery	12.5	56.25	62.5	43.75

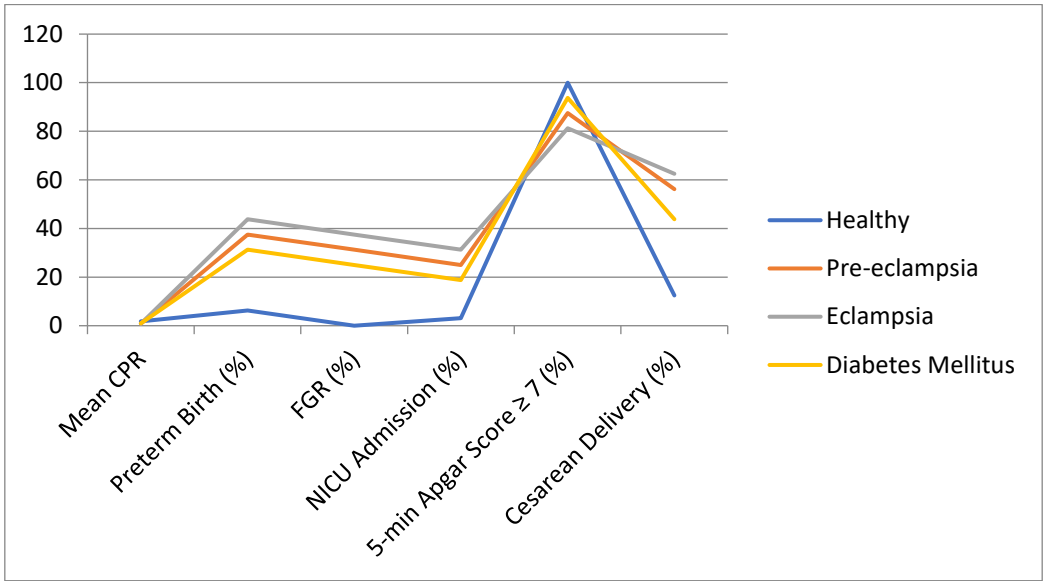

Figure 1.Comparison of Maternal and Neonatal Outcomes across Pregnancy Groups

DISCUSSION

This study aimed to evaluate the role of the cerebroplacental ratio (CPR) in predicting adverse perinatal outcomes across both healthy and high-risk pregnancies at Agha Khan Hospital Hyderabad and Civil Hospital Hyderabad. The findings indicate that CPR is a reliable predictor of unfavorable perinatal events such as preterm birth, fetal growth restriction (FGR), and neonatal intensive care unit (NICU) admission. The study observed significantly lower CPR values in high-risk pregnancies, particularly in cases complicated by hypertensive disorders, including pre-eclampsia and eclampsia. These results align with previous research that highlights impaired placental function in such conditions, contributing to fetal compromise and increased risk of adverse outcomes.

Among the groups studied, pre-eclampsia and eclampsia cases demonstrated the most severe reductions in CPR (0.85 and 0.82, respectively), indicating significant placental insufficiency. The diabetes mellitus group also exhibited lower CPR (0.95), though slightly higher than the hypertensive groups, reflecting ongoing fetal challenges despite potential macrosomia and other complications in diabetic pregnancies. In contrast, the healthy group maintained a mean CPR of 1.8, signifying adequate fetal and placental function.

Adverse perinatal outcomes were substantially more frequent in high-risk groups. Preterm birth occurred in 37.5% of pre-eclampsia cases, 43.75% of eclampsia cases, and 31.25% of diabetic pregnancies compared to only 6.25% in healthy pregnancies. Similarly, FGR was observed in 31.25% of pre-eclampsia cases, 37.5% of eclampsia cases, and 25% of diabetic cases, while it was absent in the healthy group. NICU admissions followed a similar pattern, with the highest rates seen in the eclampsia group (31.25%), followed by pre-eclampsia (25%) and diabetes mellitus (18.75%). Early detection of abnormal CPR facilitated timely interventions, contributing to favorable Apgar scores (≥ 7 at 5 minutes) in most cases, including 87.5% in pre-eclampsia and 93.75% in diabetic pregnancies.

Cesarean delivery rates were significantly higher in high-risk groups, reaching 56.25% in pre-eclampsia and 62.5% in eclampsia, compared to 12.5% in healthy pregnancies.

These findings underscore the importance of CPR assessment in clinical decision-making. Prompt identification of compromised fetal status led to earlier interventions, reducing the likelihood of severe complications.

The logistic regression analysis confirmed that a CPR of less than 1.0 was strongly associated with an increased risk of preterm birth and FGR, with odds ratios of 4.5 and 3.8, respectively. These results support the utility of Doppler ultrasound as a non-invasive tool for monitoring fetal well-being, especially in resource-constrained healthcare settings where early diagnosis and timely intervention can significantly reduce perinatal morbidity and mortality.

Despite these promising findings, the study has some limitations. The relatively small sample size of 64 participants may limit the generalizability of the results. Additionally, variability in sonographer expertise and Doppler equipment quality may have influenced the accuracy of CPR measurements. Further large-scale, multicenter studies are recommended to establish standardized CPR cut-off values and clinical guidelines for its routine use in antenatal care in Pakistan.

CONCLUSION

This study highlights the critical role of CPR in predicting adverse outcomes in high-risk pregnancies. Incorporating CPR assessment into routine antenatal care can enhance early detection of fetal compromise, improve maternal and neonatal outcomes, and reduce the burden of pregnancy-related complications in resource-limited settings.

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