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Cerebroplacental Ratio as A Non-invasive Predictor of Fetal Compromise in Hypertensive Pregnancies: Comparative Evaluation with Conventional Doppler Parameters

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Abstract

Hypertensive disorders of pregnancy are major contributors to maternal and perinatal morbidity and mortality worldwide. Doppler velocimetry has emerged as a valuable non-invasive tool for fetal surveillance, with the cerebroplacental (CP) ratio integrating the effects of placental resistance and fetal compensatory mechanisms. This study aimed to evaluate the predictive value of the CP ratio for adverse perinatal outcomes and compare it with the individual Doppler indices of the umbilical artery (UA) and middle cerebral artery (MCA). This prospective observational study included 114 pregnant women with hypertensive disorders attending a tertiary care center. Detailed history, clinical examination, and ultrasound Doppler assessments were performed, measuring UA pulsatility index (PI), MCA PI, S/D ratios, and the CP ratio. A CP ratio <1.08 was considered abnormal. Perinatal outcomes including cesarean section for fetal distress, small-for-gestational-age neonates, APGAR scores, NICU admissions, and perinatal mortality were recorded. Statistical analysis included calculation of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and chi-square testing. An abnormal CP ratio was observed in 32.5% of participants. Significant associations were noted between abnormal CP ratio and adverse perinatal outcomes, including cesarean section for fetal distress (81.1%), small-for-gestational-age neonates (70.3%), NICU admissions (70.3%), and low APGAR scores at 1 and 5 minutes. The CP ratio demonstrated superior predictive accuracy compared to S/D ratios of UA and MCA, with a sensitivity of 60.34%, specificity of 100%, and diagnostic accuracy of 77.19% for predicting composite adverse perinatal outcomes. The cerebroplacental ratio is a superior non-invasive marker for predicting adverse perinatal outcomes in pregnancies complicated by hypertensive disorders. Routine assessment of the CP ratio in antenatal Doppler surveillance protocols could enhance early identification of fetuses at risk and facilitate timely clinical intervention.

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Key Words

Cerebroplacental ratio, Hypertensive disorders of pregnancy, Doppler ultrasound, Perinatal outcome, Umbilical artery

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INTRODUCTION

Hypertensive disorders of pregnancy (HDP) are significant contributors to maternal and perinatal morbidity and mortality worldwide, affecting approximately 3-10% of all pregnancies[1]. Complications arising from HDP, such as pre-eclampsia and eclampsia, account for nearly 30,000 maternal deaths and 500,000 perinatal deaths annually[2,3]. Early identification of fetuses at risk of adverse outcomes is therefore crucial to guide timely intervention and improve perinatal outcomes.

Doppler velocimetry has emerged as a key non-invasive tool in antenatal surveillance, offering valuable insights into fetal circulation and placental function[4]. Among the various Doppler parameters, the cerebroplacental (CP) ratio, calculated as the ratio of the pulsatility index (PI) of the middle cerebral artery (MCA) to that of the umbilical artery (UA), has gained prominence[5]. The CP ratio serves as a composite marker, integrating information about both placental insufficiency (elevated UA resistance) and fetal compensatory mechanisms (brain-sparing effect seen as reduced MCA resistance)[6].

Studies have shown that an abnormal CP ratio is associated with increased rates of cesarean section for fetal distress, small-for-gestational-age neonates, low APGAR scores, neonatal intensive care unit (NICU) admissions, and perinatal mortality[7,8]. The CP ratio is believed to have superior predictive value for adverse perinatal outcomes compared to isolated Doppler indices of either the UA or MCA[9]. Furthermore, it reflects the complex hemodynamic adaptation of the fetus to intrauterine stress, making it a comprehensive marker for fetal well-being[10].

Given the rising burden of HDP and the need for reliable prognostic markers, the present study was undertaken to assess the role of the CP ratio in predicting adverse perinatal outcomes among pregnant women with hypertensive disorders. Additionally, the predictive performance of the CP ratio was compared against its constituent Doppler parameters (S/D ratios of the UA and MCA) to evaluate its clinical utility in fetal surveillance.

MATERIALS AND METHODS

This prospective observational study was conducted over a period of two years at a tertiary care center. Ethical clearance was obtained from the Institutional Ethics Committee prior to the commencement of the study, and informed written consent was obtained from all participants in their vernacular language. A total of 114 pregnant women diagnosed with hypertensive disorders of pregnancy, including gestational hypertension, pre-eclampsia, severe pre-eclampsia, and eclampsia, were enrolled based on the following inclusion criteria: singleton pregnancy, live fetus in cephalic presentation, intact membranes, and gestational age between 32 and 37 weeks confirmed by first-trimester ultrasound or reliable last menstrual period.

Women with multiple gestations, anomalous fetuses, intrauterine fetal demise, antepartum hemorrhage, diabetes mellitus, severe anemia, Rh-negative pregnancies, or pre-existing chronic hypertension were excluded. All patients underwent detailed history taking and clinical examination, and relevant laboratory investigations were performed. Ultrasound examination with Doppler assessment was performed using a high-resolution machine equipped with a 3.5 MHz transabdominal probe. The following parameters were measured: fetal biometry, amniotic fluid index, umbilical artery (UA) pulsatility index (PI), middle cerebral artery (MCA) PI, systolic/diastolic (S/D) ratios of UA and MCA, and cerebroplacental (CP) ratio. Doppler studies were performed following the guidelines of the Pre-Conception and Pre-Natal Diagnostic Techniques (PCPNDT) Act. For UA Doppler, waveforms were obtained from a free-floating loop of the umbilical cord during fetal quiescence, and the mean of three similar consecutive waveforms was used for analysis. For MCA Doppler, the proximal third of the MCA was sampled near its origin from the circle of Willis, ensuring a minimal angle of insonation. The CP ratio was calculated as the ratio of mean MCA PI to mean UA PI. A CP ratio less than 1.08 was considered abnormal. Similarly, UA S/D ratio >3 and MCA S/D ratio <3 were taken as abnormal based on established normative data.

Participants with normal Doppler findings were followed up every two weeks, while those with abnormal Doppler findings were followed weekly. The final Doppler study prior to delivery was considered for analysis. The decision for timing and mode of delivery was made according to institutional protocols. Perinatal outcomes were recorded, including cesarean section for fetal distress, instrumental delivery for fetal distress, small-for-gestational-age neonates, meconium-stained liquor, APGAR scores less than 7 at 1 and 5 minutes, NICU admissions, and perinatal mortality. A composite adverse perinatal outcome was defined as the occurrence of any of these adverse events.

Statistical analysis was performed using appropriate software. Categorical variables were presented as frequencies and percentages, while continuous variables were presented as mean ± standard deviation. The chi-square test or Fisher's exact test was used for comparing qualitative variables. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for the CP ratio and the S/D ratios of UA and MCA in predicting adverse outcomes. McNemar's test was

employed for comparison of diagnostic performance. A p-value <0.05 was considered statistically significant.

RESULTS AND DISCUSSIONS

Table 1 shows the distribution of maternal characteristics and Doppler findings among 114 study subjects. The majority of women (43.9%) were in the 20-25 years age group, and 57% were primigravida. Nulliparity was observed in 63.2% of cases, reflecting the known association between hypertensive disorders and first pregnancies. Most deliveries occurred before 37 weeks of gestation (68.4%), and pre-eclampsia was the most common hypertensive disorder (43.9%). An abnormal cerebroplacental ratio (CPR <1.08) was observed in 32.5% of the population, highlighting a considerable burden of impaired fetal circulation in hypertensive pregnancies.

Table 2 demonstrates the association between adverse perinatal outcomes and the cerebroplacental ratio. A significantly higher incidence of cesarean sections for fetal distress (81.1%), small-for-gestational-age neonates (70.3%), low APGAR scores at 1 minute (64.9%) and 5 minutes (37.8%), NICU admissions (70.3%), and stillbirth/perinatal death (13.5%) was seen among cases with an abnormal CP ratio. The p-values for most outcomes were highly significant (<0.001), underlining the CP ratio's robust predictive value for adverse outcomes in hypertensive pregnancies

Table 3 compares the predictive performance of the cerebroplacental ratio against the systolic/diastolic (S/D) ratios of the umbilical artery (UA) and middle cerebral artery (MCA). The CP ratio demonstrated superior sensitivity (60.34%), specificity (100%), positive predictive value (100%), and diagnostic accuracy (77.19%) compared to the S/D ratios of UA and MCA. This finding reinforces the cerebroplacental ratio's role as a more reliable indicator of adverse perinatal outcomes than isolated Doppler indices

Table 4 summarizes the overall perinatal outcomes among the 114 study participants. Cesarean section for fetal distress was the most frequent adverse outcome, seen in 42.1% of cases, followed by meconium-stained liquor (31.6%), NICU admission (31.6%), and small-for-gestational-age neonates (28.1%). Stillbirth and perinatal death, although less common (5.3%), were still notable events. These outcomes highlight the significant perinatal risks associated with hypertensive disorders of pregnancy.

Hypertensive disorders of pregnancy continue to pose major challenges to maternal and fetal health globally, accounting for significant rates of morbidity and mortality[1,2]. Early detection of fetuses at risk of adverse outcomes is crucial for appropriate perinatal management. In the present study involving 114 pregnant women with hypertensive disorders, we assessed the predictive value of the cerebroplacental (CP) ratio compared to the traditional Doppler indices of the umbilical artery (UA) and middle cerebral artery (MCA).

Our study found that an abnormal CP ratio (<1.08) was significantly associated with increased rates of cesarean section for fetal distress (81.1%), small-for-gestational-age neonates (70.3%), low APGAR scores at 1 and 5 minutes, NICU admissions, and perinatal mortality. These findings are consistent with previous studies where abnormal CP ratios were linked with poor perinatal outcomes[7,8]. Alanwar et al. demonstrated that CP ratio had a high prognostic accuracy for adverse neonatal outcomes among pregnancies complicated by severe pre-eclampsia[7], similar to the observations in our cohort.

The CP ratio integrates both aspects of fetal hemodynamic adaptation: increased placental resistance indicated by UA Doppler and compensatory brain-sparing shown by MCA Doppler[5,6]. This dual mechanism likely explains why the CP ratio exhibited superior sensitivity (60.34%), specificity (100%), and positive predictive value (100%) compared to isolated UA or MCA Doppler indices in our study. Similar results were noted by Regan et al., who found that the CP ratio was more predictive of adverse outcomes than abnormal UA Doppler alone in suspected fetal growth restriction[9].

Furthermore, small-for-gestational-age (SGA) rates were markedly higher among those with an abnormal CP ratio. This aligns with the findings of Baschat and Gembruch, who emphasized that CP ratio reduction precedes the onset of fetal growth restriction and hypoxia?5?. Recent meta-analyses have also reinforced that CP ratio is a better screening tool than isolated Doppler parameters for predicting SGA and stillbirth in high-risk pregnancies[11].

NICU admission rates were significantly higher among fetuses with abnormal CP ratios in our study, in line with prior reports by Nayak et al. and Zarean *et al*.[8,12]. Given that NICU admissions correlate with both immediate and long-term neonatal morbidity, the CP ratio could serve as an early warning tool to prioritize intensive monitoring and timely intervention.

It is important to note that while the CP ratio had excellent specificity and PPV in predicting adverse outcomes, the sensitivity remained moderate (60.34%). This suggests that although an abnormal CP ratio reliably identifies fetuses at risk, a normal CP ratio does not completely rule out the possibility of adverse events. Hence, CP ratio assessment should complement, rather than replace, comprehensive clinical and ultrasonographic evaluation[13].

A strength of our study is the prospective design and standardized Doppler evaluation protocol, minimizing bias. However, being a single-center study,

Table 1: Maternal Characteristics and Doppler Findings of Study Subjects (n=114)

Parameter (%)	Category	Frequency (n)	Percentage
Age (years)	20-25	50	43.9%
	26-30	40	35.1%
	31-35	24	21.0%
Gravidity	Primi	65	57.0%
	Multi	49	43.0%
Parity	Nulliparous	72	63.2%
	Multiparous	42	36.8%
Gestational Age at Delivery	<37 weeks	78	68.4%
	=37 weeks	36	31.6%
Type of Hypertensive Disorder	Gestational Hypertension	34	29.8%
	Pre-eclampsia	50	43.9%
	Severe Pre-eclampsia	20	17.5%
	Eclampsia	10	8.8%
Cerebroplacental Ratio	Normal (=1.08)	77	67.5%
	Abnormal (<1.08)	37	32.5%

Table 2: Association of Adverse Perinatal Outcomes with Cerebroplacental Ratio

Outcome	Normal CP Ratio (n=77)	Abnormal CP Ratio (n=37)	Total	p-value
Cesarean section for fetal distress	18 (23.4%)	30 (81.1%)	48	<0.001
Small for Gestational Age (SGA)	6 (7.8%)	26 (70.3%)	32	<0.001
APGAR <7 at 1 minute	8 (10.4%)	24 (64.9%)	32	<0.001
APGAR <7 at 5 minutes	5 (6.5%)	14 (37.8%)	19	<0.001
Meconium-stained liquor (MSL)	20 (26.0%)	16 (43.2%)	36	0.046
NICU admission	10 (13.0%)	26 (70.3%)	36	<0.001
Stillbirth/Perinatal death	1 (1.3%)	5 (13.5%)	6	0.005

Table 3: Comparison of Doppler Indices for Prediction of Adverse Perinatal Outcome

Parameter (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy
Cerebroplacental Ratio	60.34%	100%	100%	66.67%	77.19%
S/D Ratio (UA)	30.0%	100%	100%	57.5%	62.28%
S/D Ratio (MCA)	18.97%	85.71%	61.5%	51.85%	53.51%

Table 4: Perinatal Outcome Summary Among the Study Population (n=114)

Perinatal Outcome (%)	Frequency (n)	Percentage
Cesarean Section for Fetal Distress	48	42.1%
Instrumental Vaginal Delivery	4	3.5%
Small for Gestational Age (SGA)	32	28.1%

generalizability might be limited. Additionally, factors such as operator variability in Doppler assessment, unmeasured confounders like maternal comorbidities, and variability in neonatal care could have influenced the outcomes.

CONCLUSION

Hypertensive disorders of pregnancy remain a significant cause of adverse perinatal outcomes. In this study, the cerebroplacental (CP) ratio emerged as a reliable and superior predictor of fetal compromise compared to isolated Doppler indices of the umbilical artery and middle cerebral artery. An abnormal CP ratio was significantly associated with higher rates of cesarean delivery for fetal distress, small-for-gestational-age neonates, low APGAR scores, NICU admissions, and perinatal mortality. The CP ratio demonstrated excellent specificity and positive predictive value, making it a valuable tool for risk stratification in high-risk pregnancies. Incorporating routine CP ratio assessment into antenatal Doppler surveillance for hypertensive pregnancies could facilitate earlier detection of fetal compromise and improve perinatal outcomes through timely intervention. Future larger multicentric studies are recommended to validate these findings and standardize CP ratio use across diverse clinical settings.

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