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Original Research Article

A Prospective Observational Study on Doppler Indices for Predicting Adverse Perinatal Outcomes in Preeclampsia in Assam Medical College

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Abstract

Background: Preeclampsia remains a leading cause of perinatal morbidity and mortality worldwide. Doppler ultrasonography of fetoplacental and fetal cerebral vessels offers a non-invasive means of detecting hemodynamic compromise and guiding delivery timing.

Objective: To evaluate umbilical artery (UA) resistive index (RI), UA pulsatility index (PI), middle cerebral artery (MCA) PI, and cerebroplacental ratio (CPR) as predictors of adverse perinatal outcomes in pregnancies complicated by preeclampsia.

Methods: A hospital-based prospective cross-sectional study enrolled 70 antenatal women aged 18–35 years with preeclampsia at ≥28 weeks of gestation at Assam Medical College and Hospital, Dibrugarh. Doppler ultrasonography was performed for UA and MCA; CPR was derived as MCA PI/UA PI. Adverse perinatal outcomes included intrauterine growth restriction (IUGR), intrauterine demise (IUD), Apgar score <7 at 5 minutes, neonatal respiratory morbidity, NICU admission, and perinatal death. Diagnostic performance was assessed by receiver operating characteristic (ROC) curve analysis and multivariate binary logistic regression.

Results: Mean maternal age was 27.4 ± 4.1 years; mean gestational age at Doppler assessment was 33.2 ± 2.3 weeks. Early-onset preeclampsia (<34 weeks) occurred in 40% and severe disease in 41.4%. Overall, 32 of 70 pregnancies (45.7%) experienced at least one adverse outcome. Women with adverse outcomes had significantly higher UA RI (0.78 ± 0.07 vs 0.69 ± 0.08) and UA PI (1.49 ± 0.27 vs 1.19 ± 0.22), with lower MCA PI (1.08 ± 0.19 vs 1.32 ± 0.21) and CPR (0.77 ± 0.16 vs 1.08 ± 0.18; all p<0.001). ROC analysis showed CPR had the highest discriminatory performance (AUC 0.88, 95% CI 0.79–0.96; sensitivity 81.3%, specificity 84.2% at cutoff <1.0), followed by UA RI (AUC 0.83), UA PI (AUC 0.81), and MCA PI (AUC 0.78). On multivariate logistic regression, CPR <1.0 was the strongest independent predictor of adverse outcome (adjusted OR 5.8, 95% CI 2.1–16.3; p=0.001), followed by UA RI >0.72 (adjusted OR 3.4, 95% CI 1.3–9.0; p=0.012). Each additional gestational week was protective (adjusted OR 0.72; p=0.004).

Conclusions: Combined Doppler assessment—particularly CPR and UA RI—reliably identifies preeclamptic pregnancies at high risk of adverse foetal outcomes. CPR <1.0 is the most powerful independent predictor. Routine integration of UA and MCA Doppler with CPR calculation into high-risk obstetric practice can refine fetal surveillance and optimise delivery timing.

Keywords: Preeclampsia; Doppler Velocimetry; Umbilical Artery; Middle Cerebral Artery; Cerebroplacental Ratio; Adverse Perinatal Outcome.

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Introduction

Preeclampsia, a pregnancy-specific hypertensive disorder arising after 20 weeks of gestation, affects 2–8% of pregnancies worldwide and accounts for up to 15% of maternal mortality in low- and middle-income countries (LMICs). [1] Its pathophysiology involves defective trophoblastic invasion of uterine spiral arteries, resulting in a high-resistance uteroplacental circulation, placental

ischaemia, oxidative stress, and maternal endothelial dysfunction. These changes compromise nutrient and oxygen delivery to the fetus, predisposing to intrauterine growth restriction (IUGR), preterm birth, fetal distress, and perinatal death. [2]

Timely identification of fetuses at risk of haemodynamic compromise is critical for optimising both the intensity of surveillance and the timing of delivery. Doppler ultrasonography of fetoplacental and fetal cerebral vessels provides quantitative, non-invasive assessment of vascular impedance. The umbilical artery (UA) reflects downstream placental resistance, while the middle cerebral artery (MCA) captures the fetal cerebral vasodilatory response to chronic hypoxia—the so-called 'brain-sparing effect.' The cerebroplacental ratio (CPR), calculated as MCA pulsatility index (PI) divided by UA PI, integrates both signals into a single parameter that reflects the balance between placental insufficiency and fetal cerebral redistribution. [3]

Although UA Doppler is well established in guidelines for surveillance of high-risk pregnancies, the relative predictive value of individual indices—UA resistive index (RI), UA PI, MCA PI, and CPR—remains a subject of active investigation, particularly in LMICs where gestational-age-specific reference ranges derived from local populations are lacking. [4,5] Northeast India, served by tertiary centres such as Assam Medical College and Hospital (AMCH), Dibrugarh, has a high burden of preeclampsia but limited systematic evidence on the diagnostic performance of these indices in its patient population.

The present study was therefore undertaken to evaluate and compare UA RI, UA PI, MCA PI, and CPR as predictors of adverse perinatal outcomes in preeclamptic pregnancies at ≥28 weeks of gestation at AMCH, and to identify the optimal Doppler thresholds for clinical use in this setting.

Materials and Method

Study Design and Setting: A prospective hospital-based cross-sectional study was conducted in the Department of Obstetrics and Gynaecology, Assam Medical College and Hospital, Dibrugarh, Assam, India, over one year (27 September 2024 to 26 September 2025). Ethical approval was granted by the Institutional Human Ethics Committee (H), AMCH (No. AMC/EC/2026/43, dated 6 March 2026). Written informed consent was obtained from all participants.

Participants: Antenatal women aged 18–35 years with a singleton pregnancy at ≥28 weeks of gestation and a diagnosis of preeclampsia were enrolled consecutively. Preeclampsia was defined as systolic blood pressure (BP) ≥140 mmHg and/or diastolic BP ≥90 mmHg on two occasions ≥4 hours apart after 20 weeks, with proteinuria (≥300 mg/24 h or ≥1+ on dipstick) or at least one of the following: thrombocytopenia (<100,000/μL), renal insufficiency (creatinine >1.1 mg/dL), abnormal liver function tests (AST/ALT ≥2× upper limit of normal), or pulmonary oedema. Severe preeclampsia was defined by BP ≥160/110 mmHg or any end-organ involvement.

Exclusion criteria were: multiple gestation, major fetal structural anomaly, chronic hypertension superimposed on preeclampsia, pre-existing diabetes mellitus, or significant pre-existing renal, hepatic, cardiac, or vascular disease.

Sample Size: Sample size was calculated based on a reported sensitivity of 85.71% for UA RI in predicting adverse perinatal outcomes, using 95% confidence and 10% relative precision, yielding a minimum of 70 participants.

Clinical Assessment and Laboratory Investigations: Baseline data included maternal age, gestational age (confirmed by first-trimester ultrasound or LMP), BMI, BP recordings, and systemic examination. Laboratory investigations comprised complete blood count, serum creatinine, liver function tests (AST, ALT), and urine albumin.

Doppler Ultrasonography: All Doppler examinations were performed by a single trained operator using a Samsung RS80A Prestige ultrasound system equipped with a 5-MHz convex transducer, with women in the semi-recumbent position and with an empty bladder. Foetal biometry, estimated foetal weight, and amniotic fluid index (AFI) were recorded prior to Doppler assessment.

Umbilical artery Doppler was obtained from a free-floating loop of cord, away from both the placental and fetal insertions, to minimise artefactual variation. A minimum of three uniform waveforms were recorded and RI, PI, and systolic-to-diastolic (S/D) ratio were averaged. Absent end-diastolic flow (AEDF) and reversed end-diastolic flow (REDF) were noted separately.

MCA Doppler was obtained at the level of the circle of Willis, with the pulsed-wave gate placed in the proximal third of the vessel at the transthalamic plane. PI and RI were recorded. An insonation angle of <30° was maintained throughout.

CPR was calculated as MCA PI divided by UA PI. Abnormal UA Doppler was defined as UA RI/PI above the 95th centile for gestational age or the presence of AEDF/REDF. Low MCA PI was defined as below the 5th centile for gestational age. Reduced CPR was defined as <1.0 regardless of gestational age, consistent with published evidence.

Outcome Definitions: Perinatal outcomes were recorded prospectively until hospital discharge. The composite adverse perinatal outcome included: IUGR (estimated foetal weight or birth weight below the 10th centile), IUD, Apgar score <7 at 5 minutes, transient tachypnoea of the newborn (TTN), respiratory distress syndrome (RDS), NICU admission, and perinatal death (including IUD and early neonatal death within 7 days).

Statistical Analysis: Data were entered into Microsoft Excel and analysed using SPSS version 27.0. Continuous variables are expressed as mean ± SD or median (IQR); categorical variables as frequencies and percentages. Differences between adverse and non-adverse outcome groups were assessed using the independent-samples t-test or Mann–Whitney U test for continuous variables, and Chi-square or Fisher's exact test for categorical variables. Pearson's or Spearman's correlation was used as appropriate. Receiver operating characteristic (ROC) curves were constructed for each Doppler index; area under the curve (AUC) ≥0.70 was considered evidence of acceptable discrimination. Optimal cut-offs were determined by maximising the Youden index. Multivariate binary logistic regression, with backward selection, was used to identify independent predictors of composite adverse outcome, adjusting for gestational age at delivery, preeclampsia severity, UA RI, and CPR. Odds ratios (OR) with 95% confidence intervals (CI) are reported. Model fit was assessed by the Hosmer–Lemeshow goodness-of-fit test and Nagelkerke R^2. Statistical significance was set at $p<0.05$.

Results

Baseline Characteristics: Seventy women with preeclampsia were enrolled. Mean maternal age was 27.4 ± 4.1 years and mean gestational age at Doppler assessment was 33.2 ± 2.3 weeks. Early-onset preeclampsia (<34 weeks) accounted for 40% of cases and severe disease for 41.4%. Systemic involvement in the form of thrombocytopenia, elevated liver enzymes, and raised creatinine was present in 17.1%, 14.3%, and 11.4% of women, respectively (Table 1).

Table 1: Baseline Characteristics of the Study Population (n=70)

Parameter	Value
Mean maternal age (years)	27.4 ± 4.1
Mean gestational age at Doppler (weeks)	33.2 ± 2.3
Early-onset preeclampsia (<34 weeks), n (%)	28 (40.0%)
Late-onset preeclampsia (≥34 weeks), n (%)	42 (60.0%)
Severe preeclampsia, n (%)	29 (41.4%)
Mean systolic BP (mmHg)	153.6 ± 9.8
Mean diastolic BP (mmHg)	98.4 ± 6.7
Thrombocytopenia (<100,000/μL), n (%)	12 (17.1%)
Elevated liver enzymes, n (%)	10 (14.3%)
Raised serum creatinine (>1.1 mg/dL), n (%)	8 (11.4%)

BP: blood pressure; SD: standard deviation.

Doppler Findings: Abnormal UA Doppler was documented in 37.1% of participants. AEDF and REDF were observed in 6 (8.6%) and 3 (4.3%) pregnancies, respectively. Reduced CPR (<1.0) was the most prevalent Doppler abnormality (42.9%; Table 2).

Table 2: Doppler Ultrasound Findings (n=70)

Doppler Parameter	Mean ± SD	Range	Abnormal, n (%)
UA Resistive Index (RI)	0.73 ± 0.09	0.54–0.92	26 (37.1%)
UA Pulsatility Index (PI)	1.32 ± 0.29	0.90–1.95	26 (37.1%)
MCA Pulsatility Index (PI)	1.21 ± 0.24	0.75–1.65	24 (34.3%)†
Cerebroplacental Ratio (CPR)	0.94 ± 0.23	0.50–1.45	30 (42.9%)‡

Low MCA PI: below 5th centile for gestational age. Reduced CPR: <1.0. UA: umbilical artery; MCA: middle cerebral artery; CPR: cerebroplacental ratio; SD: standard deviation.

Adverse Perinatal Outcomes: Of the 70 pregnancies, 32 (45.7%) experienced at least one adverse perinatal outcome. The most frequent were IUGR (31.4%), NICU admission (28.6%), neonatal respiratory morbidity (20.0%), low Apgar score at 5 minutes (17.1%), perinatal death (7.1%), and IUD (4.3%). Preterm delivery occurred in 38 women (54.3%), of whom 71.1% belonged to the adverse-outcome group. Mean birth weight was significantly lower in the adverse-outcome group (1.86 ± 0.41 kg vs 2.33 ± 0.44 kg; $p<0.001$).

Association between Doppler Indices and Adverse Outcomes: Women with adverse outcomes had significantly higher UA RI and UA PI, and significantly lower MCA PI and CPR (Table 3). Abnormal UA Doppler was present in 22 of 32 (68.8%) pregnancies with adverse outcomes

versus 4 of 38 (10.5%) without (OR 18.5, 95% CI 5.1–67.2; p<0.001).

Reduced CPR was present in 25 of 32 (78.1%) versus 5 of 38 (13.2%) in the non-adverse group (OR 22.5, 95% CI 6.3–80.2; p<0.001).

Table 3: Doppler Indices According to Perinatal Outcome Group

Parameter	Adverse (n=32) Mean ± SD	Non-adverse (n=38) Mean ± SD	p-value
UA RI	0.78 ± 0.07	0.69 ± 0.08	<0.001
UA PI	1.49 ± 0.27	1.19 ± 0.22	<0.001
MCA PI	1.08 ± 0.19	1.32 ± 0.21	<0.001
CPR	0.77 ± 0.16	1.08 ± 0.18	<0.001
Birth weight (kg)	1.86 ± 0.41	2.33 ± 0.44	<0.001

UA: umbilical artery; MCA: middle cerebral artery; CPR: cerebroplacental ratio; RI: resistive index; PI: pulsatility index.

Diagnostic Performance of Doppler Indices: ROC analysis demonstrated good discriminatory performance for all four Doppler indices (Table 4). CPR achieved the highest AUC (0.88, 95% CI 0.79–0.96) with a sensitivity of 81.3% and specificity of 84.2% at the optimal cutoff of <1.0. UA RI (AUC 0.83) and UA PI (AUC 0.81) also showed good performance.

MCA PI alone had the lowest AUC (0.78), consistent with its more dynamic behaviour. All AUC values were significantly above chance (p<0.001 for all).

Table 4. Diagnostic Performance of Doppler Indices for Composite Adverse Perinatal Outcome

Index	Cutoff	Sensitivity (%)	Specificity (%)	AUC (95% CI)
UA RI	>0.72	78.1	76.3	0.83 (0.73–0.93)
UA PI	>1.35	75.0	71.1	0.81 (0.70–0.92)
MCA PI	<1.15	71.9	68.4	0.78 (0.66–0.90)
CPR	**<1.0**	**81.3**	**84.2**	**0.88 (0.79–0.96)**

AUC: area under the receiver operating characteristic curve; CI: confidence interval; UA: umbilical artery; MCA: middle cerebral artery; CPR: cerebroplacental ratio; RI: resistive index; PI: pulsatility index. Bold denotes best-performing index.

Logistic Regression Analysis: On multivariate binary logistic regression (Nagelkerke R^2=0.68; Hosmer–Lemeshow p=0.72), CPR <1.0 was the strongest independent predictor of composite adverse outcome (adjusted OR 5.8, 95% CI 2.1–16.3; p=0.001), followed by UA RI >0.72 (adjusted OR 3.4, 95% CI 1.3–9.0; p=0.012). Gestational age at delivery was independently protective (adjusted OR 0.72 per additional week, 95% CI 0.58–0.90; p=0.004). Severe preeclampsia showed a trend towards significance (adjusted OR 2.1; p=0.08; Table 5).

Table 5: Univariate and Multivariate Logistic Regression for Composite Adverse Perinatal Outcome

Predictor	Univariate OR (95% CI), p	Adjusted OR (95% CI), p
CPR <1.0	22.5 (6.3–80.2), <0.001	5.8 (2.1–16.3), 0.001
UA RI >0.72	11.0 (3.4–35.6), <0.001	3.4 (1.3–9.0), 0.012
Severe preeclampsia	2.8 (1.2–6.5), 0.015	2.1 (0.9–4.8), 0.08
Early-onset preeclampsia	3.2 (1.4–7.1), 0.005	N/A*
Gestational age (per week)	0.68 (0.55–0.84), <0.001	0.72 (0.58–0.90), 0.004

OR: odds ratio; CI: confidence interval; UA: umbilical artery; CPR: cerebroplacental ratio. *Not retained in final multivariate model after backward selection.

Discussion

This prospective study of 70 preeclamptic pregnancies at ≥28 weeks of gestation demonstrates that combined Doppler assessment of UA RI, UA PI, MCA PI, and CPR provides reliable, non-invasive prediction of adverse perinatal outcomes. CPR emerged as the single most powerful predictor, and combined UA–MCA assessment was superior to any single-vessel index. The overall adverse-outcome rate of 45.7%—driven primarily by IUGR, NICU admission, and respiratory morbidity—is consistent with high-risk obstetric cohorts from tertiary Indian centres, where composite perinatal morbidity in moderate-to-severe preeclampsia typically ranges from 40–60%.[2] The high proportion of preterm delivery (54.3%) and the concentration of preterm births in the adverse-outcome group underscore the dual contribution of pathological and iatrogenic prematurity in this setting.

The pattern of elevated UA indices with reduced MCA PI and CPR in the adverse-outcome group reflects the well-characterised pathophysiology of preeclampsia-related placental insufficiency: impaired trophoblastic remodelling of spiral arteries increases downstream impedance in the

UA, while the resultant fetal hypoxia triggers cerebral vasodilation that lowers MCA PI—the brain-sparing response. [3]

CPR integrates both signals, making it sensitive to the transition from compensated to decompensated fetal haemodynamics before the individual indices become overtly abnormal.

The diagnostic performance of CPR (AUC 0.88) observed here is comparable to findings from other studies in hypertensive disorders of pregnancy. Shahinaj et al. reported that the MCA/UA Doppler ratio predicted adverse neonatal outcome with a sensitivity of 75.0% and specificity of 85.7% in hypertensive pregnancies. [3] Sharbaf et al. similarly found that combined MCA and UA Doppler was superior to either vessel alone for perinatal outcome prediction. [4] Our multivariate OR of 5.8 for CPR <1.0 is consistent with large cohort studies demonstrating 4–8-fold increased risk of adverse outcome with low CPR after adjustment for gestational age and disease severity.

The UA RI cut-off of >0.72 identified in this study aligns with gestational-age-adjusted thresholds for the 28–35-week period and yielded an AUC of 0.83, supporting its continued role as a first-line marker of placental insufficiency. UA PI performed similarly (AUC 0.81). MCA PI alone had the lowest AUC (0.78), consistent with literature showing that MCA vasodilation is a transient and sometimes late phenomenon, making it less reliable when used in isolation.

The protective effect of gestational age (adjusted OR 0.72 per additional week) highlights the importance of safely prolonging pregnancy when Doppler profiles remain reassuring, as each additional week of in-utero maturation significantly reduces the probability of adverse neonatal outcome. A practical Doppler-based risk stratification protocol for centres like AMCH could classify women with normal UA and CPR as low risk (routine surveillance), those with isolated UA or MCA changes as intermediate risk (twice-weekly Doppler), and those with CPR <1.0 and/or AEDF/REDF as high risk (daily surveillance and consideration of delivery after corticosteroid coverage according to gestational age). This would facilitate rational allocation of scarce NICU resources and enable personalised counselling of families.

This study has important strengths: a prospective design, well-defined preeclampsia and outcome criteria, a standardised Doppler protocol, robust statistical methods including ROC analysis and multivariate logistic regression, and the generation of locally relevant data from Northeast India where such evidence is limited. Limitations include the single-centre design with inherent referral bias, modest sample size precluding subgroup analysis by gestational age or severity, the absence of uterine artery Doppler and maternal biomarkers (e.g., placental growth factor), operator-dependency of Doppler measurement, and lack of long-term neurodevelopmental follow-up.

The dichotomised Doppler values used in the master chart reflect a pragmatic clinical protocol, and future work should capture the full continuous distribution of indices for regression analyses. Larger, multicentric studies incorporating uterine artery Doppler and angiogenic biomarkers are needed to validate locally derived cut-offs and build integrated prediction models.

Conclusion

Doppler velocimetry of the umbilical artery and middle cerebral artery, particularly the derived cerebroplacental ratio, is a powerful and readily applicable tool for predicting adverse perinatal outcomes in preeclamptic pregnancies. CPR <1.0 is the strongest independent predictor of composite adverse outcome, with UA RI providing complementary information on placental resistance.

Routine integration of combined UA–MCA Doppler assessment, with CPR calculation, into high-risk obstetric surveillance at tertiary centres can improve fetal risk stratification, guide corticosteroid administration and timing of delivery, and ultimately reduce perinatal morbidity and mortality in preeclampsia.

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