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SHORT COMMENTARY

Assessment of Transcranial Doppler (TCD)-based Cerebral Hemodynamics in Preeclamptic Women

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Abstract

Introduction Preeclampsia (PE) is a hypertensive disorder of pregnancy associated with endothelial dysfunction and neurological complications such as posterior reversible encephalopathy syndrome (PRES). Conventional laboratory tests do not adequately capture cerebral involvement. Transcranial Doppler (TCD) offers a non-invasive method to assess cerebral hemodynamics. This study aimed to characterize cerebral flow dynamics in Indian women with PE.

Methods A cross-sectional observational study was conducted including 44 pregnant women (25 with PE, 19 normotensives). PE wasdiagnosed using ISSHP criteria. TCD insonation of middle, anterior, and posterior cerebral arteries was performed with a 2 MHzprobe via transtemporal windows. Parameters measured were peak systolic velocity (PSV), end-diastolic velocity (EDV), cerebralperfusion pressure (CPP), and resistance-area product (RAP). Data were analyzed using SPSS v20.0 with Student's t-test andKruskal-Wallis tests.

Results PE participants demonstrated significantly higher systolic, diastolic, and mean arterial pressures (p 0.001). TCD revealed increased PSV in bilateral MCA, reduced EDV, and elevated CPP across MCA, ACA, and PCA compared to controls. RAP was markedly raised in the PCA, suggesting impaired autoregulation and posterior circulation vulnerability to hyperperfusion.

Discussion The study revealed significantly elevated peak systolic velocities (PSV), raised cerebral perfusion pressures (CPP) in the middle and posterior cerebral arteries (MCA and PCA) of preeclamptics, with concurrent reductions in end-diastolic velocity (EDV). Resistance Area Product (RAP) was increased in the PCA, suggesting impaired autoregulation and increased susceptibility to hyperperfusionrelated injury. These hemodynamic disturbances, particularly in the posterior circulation, may serve as early indicators of PRES risk. TCD provides a feasible bedside tool for antenatal neurovascular risk stratification. Larger, multicenter studies are warranted to establish predictive thresholds for clinical use.

Keywords Preeclampsia · Hypertensive Disease of Pregnancy · Transcranial Doppler · Cerebral Haemodynamics · Cerebral Autoregulation

Preeclampsia (PE), a multisystem hypertensive disorder of pregnancy, is associated with endothelial dysfunction and elevated cerebrovascular risk. Indian research shows significant prevalence of PE and its contribution to maternal morbidity and mortality [1], particularly through neurological complications such as seizures and posterior reversible encephalopathy syndrome (PRES) [2]. TCD helps identify and real-time monitor vasospasm and hemodynamic progression [3]. Conventional laboratory tests inadequately

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assess neurovascular involvement, necessitating specific diagnostic tools [4]. This commentary summarizes a pilot observational study conducted at ESIC Medical College and Hospital, Faridabad, aimed at characterizing cerebral hemodynamic alterations in PE using transcranial Doppler (TCD).

The study enrolled 65 pregnant women, with 13 exclusions due to non-consent and 08 exclusions where vessels could not be insonated through TCD with 2 MHz probe. Data from a total of 44 pregnant women—25 with PE and 19 normotensive controls—were recorded and analyzed. According to ISSHP guidelines, PE patients were classified with BP ≥140/90 mmHg after 20 weeks' gestation with proteinuria (≥300 mg/24 h or 1+ dipstick) or if no proteinuria, then maternal organ/uteroplacental dysfunction 5.

TCD insonation was performed using a power M-mode DIGI-Lite™ system with a 2 MHz pulsed probe via bilateral transtemporal windows, with patients resting at 45° after 5 min. A single experienced operator insonated MCA (40–65 mm), ACA (65–80 mm), and PCA (55–70 mm), recording peak systolic velocity (PSV), end-diastolic velocity (EDV), mean cerebral velocity (MCV), cerebral perfusion pressure (CPP) using optimized presets for reproducibility. Data were analyzed using SPSS v20.0. Normality was tested with the Shapiro-Wilk test. Normally distributed variables were expressed as mean ± SD and compared with Student's t-test, while non-normally distributed data were expressed as median (IQR) and analyzed using the Kruskal-Wallis test. Systolic, diastolic, and mean blood pressures with TCD velocity parameters were compared between PE and normotensive participants for various intracranial arteries. The results are illustrated in Table 1.

Western studies highlights that cerebral hemodynamics in pregnant Mexican women significantly increased cerebral blood flow velocities and reduced resistance indices, suggesting adaptive vascular changes that may precede dysregulation seen in preeclampsia 6 Although TCD has been evaluated in uteroplacental circulation among Indian women, data on its use for intracranial vessel analysis especially the circle of Willis are limited [7]. An Indian study on healthy pregnancy shows altered autonomic regulation of cardiovascular and brain perfusion control [8]. The posterior cerebral circulation is recognized as more susceptible to dysautoregulation and hyperperfusion injuries, placing it at greater risk of complications like PRES [2]. This vulnerability may explain the observed RAP elevations in PCA, supporting the hypothesis that impaired resistance dynamics in posterior territories signal early neurovascular stress. While this study does not establish causality, the pattern of elevated CPP and RAP suggests evolving cerebral autoregulatory compromise in PE that may precede overt clinical symptoms.

These findings hold clinical significance, particularly for early detection and risk stratification. The feasibility of TCD as a bedside, noninvasive tool adds practical value in low-resource antenatal care settings. However, there are limitations. There are studies where uterine artery, umbilical artery and ophthalmic artery dopplers are widely studied for prediction in recent studies, only limited antenatal studies have explored cerebral doppler parameters as potential predictors of preeclampsia [9]. The relatively small sample size and single-center scope restrict generalizability. The absence of consistent findings in PI, RI, and CFI may indicate preserved compensatory mechanisms. Despite this, the RAP and CPP indices provided distinct patterns of cerebral dysregulation, warranting further large sample sized study.

The study contributes uniquely to Indian data on cerebral hemodynamics in preeclampsia—a domain largely

Table 1 Hemodynamic comparison between preeclamptic and normotensive women

Parameter	Preeclampsia (Mean ± SD)	Control (Mean ± SD)	*p* value	Interpretation
Systolic BP (mmHg)	146.0 ± 4.5	113.4 ± 13.9	< 0.001	Elevated BP in PE
Diastolic BP (mmHg)	98.0 ± 6.5	75.3 ± 7.4	< 0.001	Raised diastolic load
Mean arterial pressure (mmHg)	114.3 ± 5.2	88.0 ± 9.2	< 0.001	Increased MAP in PE
PSV-right MCA (cm/s)	76.02 ± 14.12	67.6 ± 13.43	0.05	Higher systolic velocity
PSV-left MCA (cm/s)	76.97 ± 12.89	67.52 ± 14.8	0.03	Bilateral PSV rise
EDV-right MCA (cm/s)	36.68 ± 8.10	30.88 ± 7.49	0.02	Reduced diastolic flow. ↑ resistance
CPP-left PCA (mmHg)	71.01 ± 26.85	52.13 ± 16.63	0.01	Raised CPP
CPP-right MCA (mmHg)	67.49 ± 21.53	54.98 ± 24.25	0.05	Significantly higher CPP
CPP-left MCA (mmHg)	61.15 ± 13.98	48.72 ± 14.93	0.01	Significantly higher CPP
CPP-left ACA (mmHg)	68.96 ± 21.53	54.98 ± 24.25	0.05	Significantly higher CPP
RAP-left ACA	− 3.12 ± 0.68 reduced	− 2.21 ± 0.67 higher in controls	< 0.001	Decreased resistance index
RAP-left PCA	4.27 ± 1.23 elevated	2.23 ± 0.64 lower in controls	< 0.001	Increased posterior resistance

Abbreviations: PSV = Peak systolic velocity; EDV = End-diastolic velocity; CPP = Cerebral perfusion pressure; RAP = Resistance-area product; MCA = Middle cerebral artery; ACA = Anterior cerebral artery; PCA = Posterior cerebral artery; PE = Preeclampsia; BP = Blood pressure; SD = Standard deviation

explored in Western literature [5]. Given regional differences in maternal profiles, environmental factors, and healthcare access, localized data are essential. It supports a growing body of research advocating for integration of neurovascular evaluation in hypertensive pregnancies.

Future research should involve multicenter, longitudinal studies tracking Doppler parameters across trimesters and postpartum. Correlating Doppler metrics with neurological symptoms, biochemical markers, and fetal outcomes would deepen understanding of PE-associated cerebral compromise. Moreover, establishing normative TCD values and thresholds for risk across diverse Indian populations could inform clinical protocols.

In conclusion, this study highlights significant cerebral hemodynamic disruptions in PE, especially within the posterior cerebral circulation. Elevated CPP and RAP in PCA reinforce the hypothesis of early dysautoregulation and potential vulnerability to PRES. Although preliminary, these findings point to the potential of TCD in antenatal surveillance strategies. Incorporating cerebral Doppler metrics into routine PE monitoring could enhance early detection, targeted management, and risk stratification, thereby improving maternal-neonatal outcomes in hypertensive pregnancies.

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Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical Approval The study protocol was reviewed and approved by the Institutional Ethics Committee (EC File No.: 134 X/11/13/2023-IEC/DHR/106). The study was conducted in compliance with the ethical standards of the institute and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all participants prior to inclusion.

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