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CLINICAL ARTICLE

Obstetrics

Differences in cerebral blood flow patterns assessed by transcranial doppler in patients with severe pre-eclampsia and eclampsia

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Abstract

Objective: To investigate cerebral perfusion variables derived from transcranial Doppler (TCD) in patients with severe hypertensive disorders of pregnancy and determine their association with the development of eclampsia.

Methods: A cross-sectional study was conducted in an intensive care unit in Argentina. The study included 31 patients with severe pre-eclampsia (sPE), 35 with eclampsia (E), and 20 healthy pregnancies (HP). Doppler indices from the middle cerebral artery (MCA), anterior cerebral artery (ACA), posterior cerebral artery (PCA), and basilar artery (BA) were compared among the groups.

Results: Compared to HP, patients with sPE and E exhibited higher values of cerebral flow index (CFI) (48 [42–57] and 51 [41–68] vs 34 [28–44], $P=0.001$), higher cerebral perfusion pressure (CPP) (69 mmHg [56–77] and 68 mmHg [54–92] vs 49 mmHg [42–73], $P=0.044$), and increased cerebral blood flow velocities (CBFV) with lower resistance in most examined territories. Patients with E demonstrated significantly higher CBFV values in MCA, PCA, and BA compared to those with sPE, along with a significant decrease in resistance index (RI) of the BA ($P<0.05$). In multivariate analysis, the RI of the BA was the only Doppler variable independently associated with E.

Conclusion: Increased cerebral flow velocities and lower resistance are characteristic findings in patients with sPE and E. While these changes are evident across all cerebral vascular territories, significant alterations in the Doppler indices of the basilar artery may provide insights into the mechanisms underlying the development of eclampsia.

KEYWORDS
basilar artery, eclampsia, resistance index, transcranial doppler

1 | INTRODUCTION

Hypertensive disorders affect between 5% and 10% of pregnancies worldwide,[1] and are a major cause of maternal morbidity and mortality, with 16% of maternal deaths worldwide being a direct consequence of complications related to pre-eclampsia (PE) and eclampsia (E).[2]

The underlying pathophysiology of cerebral complications in severe PE and E has not been fully elucidated. Previous studies have reported endothelial dysfunction, neuroinflammation, blood–brain

barrier dysfunction and alterations in cerebral blood flow as part of their pathophysiological mechanism.[3–5] Studies evaluating cerebral circulation with transcranial Doppler (TCD) in patients with sPE and E have shown an increase in cerebral perfusion pressure (CPP), cerebral autoregulation disorders and an increase in cerebral blood flow velocity (CBFV). However, large variations among the groups were observed.[6–8]

Belfort et al. reported an increase in CPP in patients with sPE compared with patients with mild PE due to cerebral hyperperfusion.[9]

A recent study including 48 PE patients, with and without neurologic symptoms, showed greater alterations in TCD parameters in women with symptomatic PE. The authors reported increased cerebral flow index (CFI) and CPP in all vessels studied. However, changes were more prominent in the posterior cerebral artery (PCA) area, suggesting that alterations in posterior territories might contribute to the development of symptoms.[10] In line with these findings, it has been argued that alterations in cerebral autoregulation in these territories are the result of the practical absence of sympathetic innervation, which would result in cerebral hyperperfusion in the face of rapid increases in blood pressure.

In most TCD studies performed in PE and E cerebral hemodynamics were assessed in the middle cerebral artery (MCA), anterior cerebral artery (ACA), and posterior cerebral artery (PCA). In contrast, there is little information on cerebral blood flow alterations in the basilar artery territory. Consequently, including basilar artery (BA) in the study of cerebral hemodynamics in patients with sPE and E could provide new relevant information and a better understanding of their pathophysiologies.

This study aimed to evaluate differences in TCD-derived variables including basilar artery assessment in patients with sPE, E and healthy pregnant women and to investigate those variables associated with the development of E.

2 | MATERIALS AND METHODS

2.1 | Design and participants

This cross-sectional observational study was conducted in the intensive care unit (ICU) of Ramón Carrillo Regional Hospital, a high-complexity maternal-fetal medicine center located in the province of Santiago del Estero, Argentina. The Argentine Ministry of Health has classified it as a Level III hospital in obstetric care, meaning it is able to cope with patients with the highest level of perinatal risk. Patients with a diagnosis of sPE and E admitted to the ICU consecutively between December 2021 and January 2024 were included. The inclusion criteria were age greater than or equal to 16 years and a TCD performed during the first 24 h after the diagnosis.

Patients with previous neurologic injury (stroke, subarachnoid hemorrhage, brain tumor, meningitis, hypoxic encephalopathy, hepatic encephalopathy, neurosurgery, etc), poor insonation windows, poor quality or incomplete ultrasound records were excluded from the study.

A group of healthy pregnant women ($n = 20$) who attended the obstetric follow-up clinic in the third trimester of pregnancy and who had no history of pre-eclampsia in previous pregnancies, chronic arterial hypertension, stroke, subarachnoid hemorrhage, brain tumor, meningitis, hypoxic encephalopathy, hepatic encephalopathy, neurosurgery or previous smoking, were included in the study and made up the control group (Figure 1).

Severe PE was defined according to the American College of Obstetricians and Gynecologists Consensus criteria,[11] based on the presence of one or more of the following findings: systolic blood pressure of 160 mmHg or higher, or a diastolic blood pressure of 110 mmHg or higher on two occasions at least 4 h apart, thrombocytopenia (platelet count $<100000\,10^9$/L), impaired liver function, renal failure, pulmonary edema, new-onset headache unresponsive to medication, and visual disorders.

E was defined as new-onset tonic–clonic, focal, or multifocal seizures in the absence of other causative conditions such as epilepsy, cerebral arterial ischemia or infarction, intracranial hemorrhage or drug use.

2.2 | Data collection

Upon admission to the ICU (first 24 h), the following clinical-epidemiologic and biochemical data were garnered from the patients' medical history: body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), gestational age (documented by date of the last confirmed menstrual period and/or ultrasound of the first trimester), Charlson comorbidity scale,

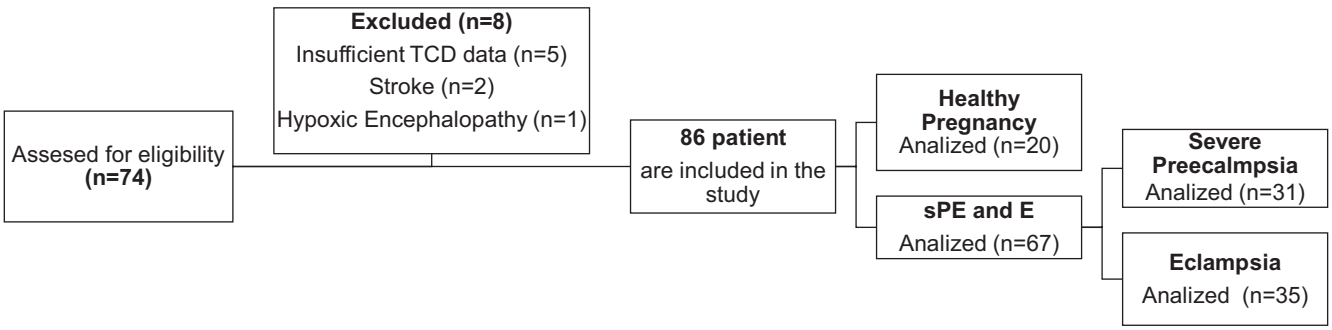

FIGURE 1 Flow chart showing the study population, analysis between healthy pregnancies and severe hipertensive disorder of pregnancy and comparative analysis according to the presence of severe pre-eclampsia (sPE) and eclampsia (E).

disease severity using the acute physiology and chronic health assessment (APACHE) II score, sepsis-related organ failure assessment (SOFA), the need for invasive mechanical ventilation, vasopressors requirement and blood and urine laboratory variables (uric acid, LDH, albumin, arterial gases and 24-h urine protein dosage).

2.3 | Transcranial Doppler measurements

During the first 24 h of admission, two trained operators, members of the research team (RG, IG), performed a complete TCD study in the supine position with headrest at 30°. The CBFV of the middle, anterior, and posterior cerebral arteries of both sides were recorded through the temporal window, and the basilar artery through the suboccipital window. To evaluate static cerebral autoregulation,[12] the transient hyperemic response test was performed, using the technique described by Giller, and validated by Smielebski.[13] Procedure and technique are included in the supplementary material S1.

We used Rimed Digi-Lite Equipment with a 2 MHz Doppler transducer. The measurements were carried out in hemodynamically stabilized patients (MAP >65 mmHg), and in case invasive mechanical ventilation was needed, it was appropriately adapted to avoid situations that could transiently alter the measurement values, such as cough or Valsalva maneuver. At the time of the TCD study, vital signs (axillary temperature, brachial blood pressure, and heart rate) and pCO_2 (mmHg) obtained from arterial gasses in patients with sPE and E were recorded simultaneously. All measurements were taken post-load and during maintenance infusion of magnesium sulfate. For the analysis of the flow velocities of the MCA, ACA and PCA arteries, the average values between both sides were used. The velocity waveform was obtained at a depth at which the most stable hemodynamic waveform of each artery was reached (ACA, 65–80 mm; MCA, 40–65 mm; PCA, 55–70 mm, and BA, 70–90 mm).

Healthy pregnant women who attended the hospital obstetrics clinic for routine prenatal care in their third trimester were recruited for the study after signing an informed consent. During the consultation, all women underwent clinical and laboratory measurements, and a TCD ultrasound was performed. This information was collected to provide a comprehensive comparison with the data obtained from patients with sPE and E.

Variables derived from TCD were calculated using the following formulae:

- Pulsatility index (PI): Systolic velocity (SV)-diastolic velocity (DV)/mean velocity (MV).
- Resistance index (RI): SV – DV/SV.
- Cerebral perfusion pressure (CPP) calculated with the formula described by Belfort et al.[14] CPP = (MV/DV) × (MAP – diastolic blood pressure [DBP]).
- Resistance area product (RAP): MAP/MV.[15]
- Cerebral blood flow index (CFI): CPP/RAP.[16]

2.4 | Statistical analysis

Continuous variables are shown as median and interquartile range [IQR], categorical variables as absolute and relative frequencies. The *t*-test or the Wilcoxon rank sum test was used to compare continuous variables and the Fisher exact test or the χ^2 test for categorical variables. Analysis of variance (ANOVA) with Bonferroni post hoc test was performed to evaluate differences among two or more groups. A logistic regression model was used to determine the association of the parameters derived from the TCD and the presence of E adjusted for confounders. The variables associated with E in the bivariate analysis with a P value <0.20 were evaluated in a multivariable model. For the final selection of the model, at least 10 events were considered for each predictor variable included, as well as their clinical and statistical relevance. The model was calibrated using the Hosmer-Lemeshow goodness-of-fit test to evaluate the discrepancy between the observed and expected values. All statistical tests were two-tailed with a statistical significance level of P <0.05. The statistical package Stata (version 14.0) was used for the analysis.

2.5 | Ethics statement

The Ethics Committee of the "Secretaría de Innovación, Desarrollo y Extensión Universitaria de la Facultad de Medicina de la Universidad Nacional de Tucumán de la República Argentina" (no. 81376-2023) approved the study on October 13, 2023. All procedures were performed after the informed consent of each patient.

3 | RESULTS

From January 12, 2021 to February 12, 2024, 86 patients were incorporated, 35 with diagnosis of E, 31 with sPE and 20 healthy pregnant women (Figure 1). Eclamptic women were younger (24 years [IQR: 18–28] vs 31 years [IQR: 23–33] vs 30 years [IQR: 24–37], P = 0.004) and had a lower BMI (28 [IQR: 25–35] vs 34 [IQR: 29–35] vs 32 [IQR: 30–34], P = 0.040, respectively). There were no differences among groups in gestational age (P = 0.205) (Table 1).

As to laboratory variables, patients with sPE and E showed higher levels of LDH and uric acid and lower levels of albumin compared with healthy women (P = <0.001) (Table 1).

Compared with healthy pregnant women, patients with sPE and E had: higher mean arterial pressure values at the time of assessment (98 mmHg [IQR: 89–108], 97 mmHg [IQR: 88–109] and 78 mmHg [73–85], respectively, P = <0.001), higher values of the CFI (48 cm/s [42–57], 51 cm/s [41–68] and 34 cm/s [28–44], respectively, P = 0.001) and higher CPP (69 mmHg [56–77], 68 mmHg [54–92] and 49 mmHg [42–73], respectively, P = 0.044). No differences were found in the RAP.

Differences in the TCD variables between healthy pregnant women with sPE and E are shown in Table 1. In general terms, it can be seen that in the majority of the vascular areas studied, CBFV were higher in patients with sPE and E compared to healthy ones, while

TABLE 1 Clinical characteristics, biochemical variables and TCD indices in HP women, sPE and E.

	Healthy pregnancy	Severe pre-eclampsia	Eclampsia	*P* value
n	20	31	35	-
Age (years)	30 [24–37]	31 [23–33]	24 [18–28][a,b]	0.004
BMI (kg/m[b])	32 [30–34]	34 [29–35]	28 [25–35][b]	0.040
Gestational age (week)	31 [26–37]	33 [27–37]	36 [30–37]	0.205
Biochemical variable				
LDH (IU/mL)	351 [248–386]	600 [449–908][a]	615 [497–770][a]	<0.001
Uric acid (mg/dL)	3.1 [2.6–3.5]	5.1 [4.1–6.2][a]	5.3 [4.6–7.7][a]	<0.001
Urine protein (g/24 h)	-	250 [117–455]	266 [125–551]	0.850
pCO2 (mmHg)	-	35 [31–43]	39 [32–44]	0.129
Albumin serum (g/dL)	3.4 [3.3–3.5]	3.1 [2.8–3.2][a]	2.9 [2.8–3][a]	<0.001
Scores and severity				
Apache II	-	8 [4–8]	8 [5–11]	0.212
SOFA	-	2 [1–4]	3 [2–5]	0.018
Charlson	-	0 [0–1]	0 [0–0]	<0.001
Shock (%)	-	6 (19)	5 (14)	0.583
MVA (%)	-	8 (26)	17 (49)	0.060
Variables of cerebral hemodynamics				
MAP (mmHg)	75 [73–85]	98 [89–108][a]	97 [88–109][a]	<0.001
CPP (mmHg)	49 [42–73]	69 [56–77][a]	68 [54–92][a]	0.044
Resistance area product (mmHg/cm/s)	1.55 [1.3–2.1]	1.90 [1.4–2.2]	1.47 [1.1–2.1]	0.103
Preserved cerebrovascular autoregulation *n* (%)	-	17 (55)	13 (37)	0.149
CFI	34 [28–44]	48 [42–57][a]	51 [41–68][a]	0.001
Middle cerebral artery (MCA)				
SV (cm/s)	85 [72–94]	85 [74–102]	95 [76–108]	0.140
DV (cm/s)	37 [33–46]	41 [38–49]	48 [35–65][a,b]	0.019
MV (cm/s)	53 [47–64]	56 [51–67]	65 [48–79][a]	0.040
RI	0.50 [0.47–0.61]	0.50 [0.43–0.56]	0.45 [0.37–0.51][a]	0.016
PI	0.74 [0.67–0.9]	0.83 [0.64–1.0]	0.67 [0.5–0.86][b]	0.027
Anterior cerebral artery (ACA)				
SV (cm/s)	61 [51–65]	62 [57–72]	68 [57–79]	0.170
DV (cm/s)	28 [24–33]	32 [29–39]	38 [29–46][a]	0.018
MV (cm/s)	39 [36–44]	43 [37–49]	46 [38–58][a]	0.045
RI	0.50 [0.47–0.6]	0.48 [0.40–0.55]	0.46 [0.4–0.5][a]	0.01
PI	0.72 [0.6–1.1]	0.82 [0.7–0.9]	0.65 [0.5–0.8][a,b]	0.380
Posterior cerebral artery (PCA)				
SV (cm/s)	55 [48–68]	69 (59–81]	69 [59–78]	0.124
DV (cm/s)	27 [26–34]	33 (27–39]	35 [28–46][a]	0.046
MV (cm/s)	37 [32–48]	46 (39–53]	47 [39–58]	0.081
RI	0.49 [0.47–0.55]	0.49 (0.45–0.56]	0.45 [0.41–0.5]	0.122
PI	0.75 [0.6–1.0]	0.79 [0.60–0.9]	0.70 [0.6–0.9]	0.777
Basilar artery (BA)				
SV (cm/s)	50 [40–56]	56 [45–69]	59 [47–71)[a]	0.021
DV (cm/s)	23 [20–30]	26 [22–31]	31 [26–37][a,b]	0.001

TABLE 1 (Continued)

	Healthy pregnancy	Severe pre-eclampsia	Eclampsia	*P* value
MV (cm/s)	33 [27–38]	37 [30–43]	40 [33–48][a]	0.002
RI	0.49 [0.45–0.5]	0.50 [0.45–0.55]	0.46 [0.4–0.5][a,b]	0.013
PI	0.72 [0.6–0.8]	0.80 [0.6–0.9]	0.71 [0.5–0.9]	0.162
Maternal-fetal and neonatal outcomes				
Maternal mortality (%)	-	0	1 (2.9)	0.537
Fetal mortality (%)	-	5 (16.2)	5 (14.3)	0.835
Neonatal mortality (%)	-	1 (3.2)	3 (8.7)	0.363

Note: Values are presented as median [interquartile range], *n* (%). BMI, calculated as weight in kilograms divided by the square of height in meters.

Abbrevations: ACA, anterior cerebral artery; APACHE II, acute physiology and chronic health assessment; BMI, body mass index; CFI, cerebral flow index; CPP, cerebral perfusion pressure; DV, diastolic velocity; E, eclampsia; HP, healthy pregnancies; IMV, invasive mechanical ventilation; LDH, lactic acid dehydrogenase enzyme; MAP, mean arterial pressure; MCA, middle cerebral artery; MV, mean velocity; MVA, mecahnical ventilatory assistance; PCA, posterior cerebral artery; PE, pre-eclampsia; PI, pulsatility index; RAP, resistance area product; RI, resistance index; SOFA, sepsis-related organ failure assessment; SV, systolic velocity; TD, transcranial Doppler.

Differences among the groups.

[a]$P \leq 0.05$ versus healthy pregnancy.

[b]$P \leq 0.05$ versus severe pre-eclampsia.

resistance indices were lower (Figure 2a–e). Cerebrovascular autoregulation was preserved in 100% of the healthy pregnant women, in 55% of pre-eclamptic and in 37% of the eclamptic women (Table 1).

3.1 | Comparison between E and sPE

The eclamptic patients were younger (24 years [IQR: 18–28] vs 31 years [IQR: 23–33], $P=0.004$) and had a lower BMI (28 [IQR: 25–35] vs 34 [IQR: 29–35], $P=0.040$). Although there were no differences in APACHE II score or presence of shock, requirement for mechanical ventilation on admission, SOFA scores were higher in group E ($P=0.018$).

However, Charlson scores were higher in severe pre-eclamptic women ($P=<0.001$). No differences were found in laboratory parameters (LDH, albumin, proteinuria, uric acid, pCO2), in MAP, CPP and RAP values, nor in static cerebral autoregulation.

Concerning the ultrasound variables, patients with E had higher CBFV values in the middle, posterior and basilar cerebral arteries and a significant decrease in the RI of the BA ($P=0.013$) (Table 2).

In the multivariate analysis, the RI of the BA was the only Doppler variable independently associated with the presence of E (OR: 0.01 (95% CI: 0.0002–0.68), $P=0.032$) (Table 3). The model had good calibration (Hosmer and Lemeshow $P=0.97$) and discrimination (receiver operating characteristic [ROC] curve: 0.79) (Figure 3).

4 | DISCUSSION

4.1 | Main findings

The present study key findings, comparing transcranial Doppler variables in pre-eclampsia, eclampsia and normal pregnancy, revealed increased cerebral blood flow velocities, cerebral perfusion pressure, and static cerebral autoregulation disorders in pre-eclamptic and eclamptic patients compared to normal pregnant women. Notably, the basilar artery resistance index was the sole Doppler-derived variable linked to eclampsia development. This result is noteworthy, given the lack of existing research on hemodynamic changes in the basilar territory in this patient population.

4.2 | Interpretation

Our findings are consistent with previous studies reporting increased cerebral arterial blood flow velocities in patients with severe pre-eclampsia/eclampsia,[17–19] in addition they provide novel insights by highlighting the importance of flow assessment in the basilar artery, which has not been previously reported in patients with E.

Cerebral hyperperfusion, resulting from altered cerebral autoregulation and increased mean arterial pressure, is a critical factor in the pathophysiological mechanism of neurologic complications in pregnant patients with hypertensive disorders. We observed alterations in autoregulation in 45% of patients with sPE and 63% with E, consistent with previous findings.[20]

Notably, CBFV and basilar artery resistance index (RI) were significantly different in patients with E. These results suggest that ultrasound evaluation of the basilar artery may better reflect cerebral hyperperfusion injury than other cerebral arteries. This is particularly relevant, as brain lesions in patients with pre-eclampsia are primarily located in the white matter of the posterior region of the brain, which is more susceptible to rapid blood pressure increases and cerebral hyperperfusion due to reduced sympathetic innervation.[21,22]

Posterior reversible encephalopathy syndrome (PRES)[23] is another neurologic entity associated with hypertensive disorders of pregnancy, characterized by vasogenic edema and cerebral hypoxia secondary to uncontrolled acute arterial hypertension, which is usually diagnosed by magnetic resonance imaging (MRI). An et al. investigated the risk factors for this syndrome in 78 pregnant women with PE and E

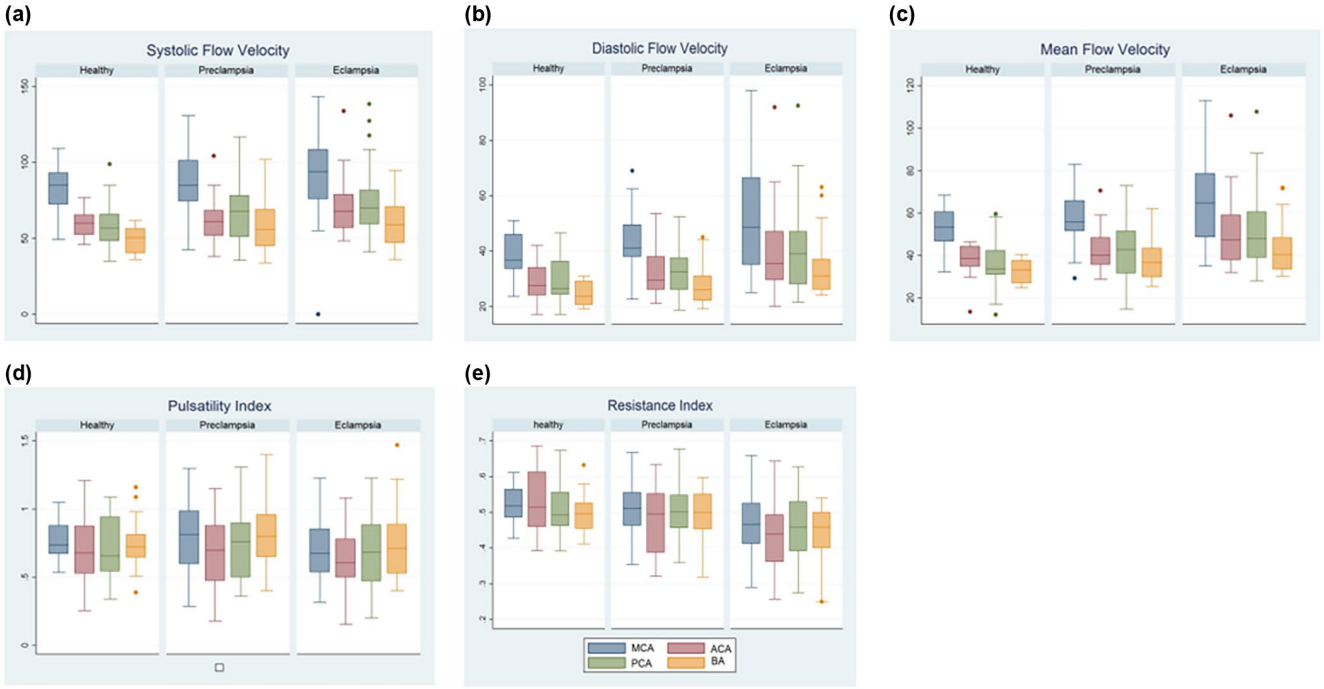

FIGURE 2 Box plots of flow velocities, pulsatility indices and resistance indices of the middle cerebral artery (MCA), anterior cerebral artery (ACA), posterior cerebral artery (PCA) and basilar artery (BA) in the different groups. (a) Box plots of systolic fow velocities of the middle, anterior, posterior and basilar arteries. (b) Box plots of diastolic flow velocies of the middle, anterior, posterior and basilar arteries. (c) Box plots of mean flow velocities of the mean, anterior, posterior and basilar arteries. (d) Box plots of pusatility indices of the medium, anterior, posterior and basilar arteries. (e) Box plots of resistance indices of the medium, anterior, posterior and basilar arteries.

TABLE 2 Univariate and multivariate analyses in patients with severe hypertensive disorders.

	Univariate analysis			Multivariate analysis		
	Crude OR	95% CI	*P* value	Adjusted OR	95% CI	*P* value
Age (year)	0.88	0.81–0.95	0.003			
Gestational age (week)	1.08	0.98–1.21	0.133			
BMI (kg/m^2)	0.91	0.85–0.99	0.031			
SV MCA (cm/s)	1.01	0.99–1.02	0.190			
DV MCA (cm/s)	1.03	1.01–1.06	0.013	1.03	0.98–1.06	0.456
MV MCA (cm/s)	1.03	1.00–1.04	0.045	1.01	0.99–1.03	0.231
RI MCA (cm/s)	0.05	0.00–0.25	0.094			
PI MCA (cm/s)	0.29	0.05–1.14	0.074			
SV PCA (cm/s)	1.01	0.99–1.03	0.185			
DV PCA (cm/s)	1.02	0.99–1.06	0.070			
MV PCA (cm/s)	1.02	0.99–1.05	0.083			
RI PCA (cm/s)	0.03	0.00–1.34	0.071			
PI PCA (cm/s)	0.73	0.21–2.62	0.637			
SV BA (cm/s)	1.02	0.99–1.06	0.231			
DV BA (cm/s)	1.08	1.01–1.16	0.023	1.05	0.98–1.14	0.119
MV BA (cm/s)	1.04	0.99–1.11	0.065			
RI BA (cm/s)	0.05	0.00–0.14	0.014	0.02	0.01–0.25	0.029
PI BA (cm/s)	0.21	0.02–1.90	0.166			

Note: Values are presented as crude OR, adjusted OR and 95% CI. BMI, calculated as weight in kilograms divided by the square of height in meters. Eclampsia as a dependent variable.

Abbreviations: BA, basilar artery; BMI, body mass index, CI, confidence interval; DV, diastolic velocity; MCA, middle cerebral artery; MV, mean velocity; OR, odds ratio; PCA, posterior cerebral artery; PI, pulsatility index; RI, resistance index; SV, systolic velocity.

TABLE 3 Multivariate logistic regression model.

	OR	SE	95% CI	*P* value
Age (year)	0.85	0.04	0.77–0.94	0.003
Basilar artery RI	0.00001	0.007	0.00–0.52	0.032
Cons	15397.68	48317.79	32.83–7219	0.002

Note: Eclampsia as a dependent variable.

Abbreviations: CI, confidence interval; OR, odds ratio, RI, resistance index; SE, standard error; Cons, Constant.

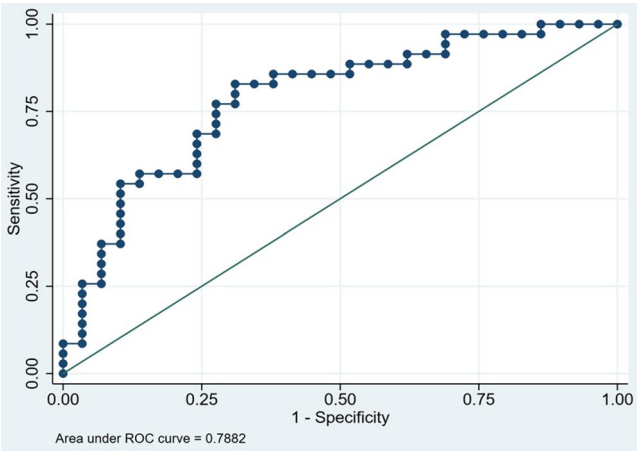

FIGURE 3 Receiver operating characteristic curve showing the performance of the multivariate model.

undergoing brain MRI and TCD testing. The authors found that basilar artery flow velocity and basilar artery resistance index were associated independently with PRES in the multivariate analysis.[24] Although we did not perform cerebral MRI, our findings in patients with E showed similar basilar artery flow velocities and resistances to those reported by An et al. These results underscore the importance of assessing cerebral autoregulation in the basilar territory, which appears to be more closely associated with clinical and radiologic manifestations.

Establishing a cutoff value for the basilar artery RI could help identify sPE in women at higher risk of developing brain complications and E. This information would enable physicians to save mothers' lives or boost their confidence when adopting a conservative approach to enhance fetal maturation before birth in specific situations. In our population, the basilar artery RI differed between sPE (0.50 [0.45–0.55]) and E (0.46 [0.4–0.5]), but we were unable to set a cutoff value with acceptable sensitivity and specificity to predict progression from sPE to E.

Most patients were on antihypertensive drugs, mainly labetalol and alpha-methyldopa, and blood pressure was controlled at the time of TCD. Although it has been suggested that these vasoactive drugs could affect cerebral vasoreactivity, previous studies have not shown alterations in cerebral autoregulation.[25] Other studies have even shown that cerebrovascular pulsatility and reactivity improve after administration of these drugs.[26] Therefore, these drugs may have intensified the autoregulatory attenuation effect on the PE and E group, rather than inhibiting it, which may lead our results towards a null hypothesis.

4.3 | Strengths and limitations

The strengths of this study are that it incorporates a considerable number of patients with E and unlike other studies; we evaluated all vascular territories, including the area of the basilar artery. To the best of our knowledge, this is one of the first studies to investigate TCD indices in the basilar artery in patients with hypertensive disorders of pregnancy admitted to the ICU.

However, our study had several limitations. First, the sample size was small, which may have affected the statistical power of the study to detect differences between the groups. Second, the studies were conducted during the infusion of magnesium sulfate, which could have affected CBFV and vascular resistance values, as previously reported.[27,28] Third, the cross-sectional design enabled us to investigate TCD variables associated with E, but not those variables that can predict its development. Fourth, all measurements were taken only upon ICU admission, and no follow-up was performed over time. Repeating the TCD in patients who progress from PE to E would have provided interesting information; however, given that E is a rare and unpredictable event, it is practically impossible to take measurements before and after a seizure onset. Although this may be considered a weakness of our study, it is a common flaw observed in all studies addressing this subject.

5 | CONCLUSION

Increases in cerebral flow velocities and decreased resistance are characteristic findings of patients with sPE and E. Although these changes can be observed in all cerebral vascular territories, significant alterations in the Doppler indices of the basilar artery were the only ones that were independently associated with the presence of eclampsia. These findings highlight the importance of monitoring hemodynamic parameters in the basilar artery as potential indicators of severe complications in this patient population.

AUTHOR CONTRIBUTIONS

Roberto Giannoni: Conceptualization, methodology, investigation, project administration, data curation, supervision, and writing. **Ezequiel Martinez:** Conceptualization, formal analysis, methodology, investigation, interpretation of data, and writing. **Ivana S. Gonzalez, Carlos R. Garnica, Franco F. Giannoni:** Investigation, data curation, and resources. **Maria Peral de Bruno**: Project administration. **Fabio D. Masevicius:** Conceptualization, formal analysis, investigation,

made substantial contributions to analysis, and editing and reviewing the manuscript.

FUNDING INFORMATION

None.

CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in [repository name e.g "figshare"] at http://doi.org/[doi], reference number [reference number].

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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