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Діаметр оболонки зорового нерва, середня швидкість потоку крові, індекс пульсації та прееклампсія

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Вступ. Ультразвук уможливив неінвазивний нейромоніторинг для спостереження та прийняття рішень щодо аспектів, які впливають на центральну нервову систему.

Мета. Визначити зв'язок між середнім артеріальним тиском і двостороннім діаметром оболонки зорового нерва, індексом пульсації та середньою швидкістю потоку крові в середній мозковій артерії у випадку прееклампсії/еклампсії.

Матеріали та методи. Було проведено проспективне групове дослідження, зокрема за участі вагітних жінок, у яких встановлено діагноз прееклампсія/еклампсія та які отримували медичну допомогу у відділенні інтенсивної терапії. Зафіксовані ультрасонографічні показники (діаметр оболонки зорового нерва, індекс пульсації і середня швидкість потоку крові) було зіставлено із середнім артеріальним тиском під час поступлення та після 24 і 72 годин. Зафіксовані дані було внесено в таблицю Excel, і далі використовували веб-сторінку Соціальної статистики.

Результати. Кореляційний аналіз показав, що під час поступлення середній артеріальний тиск мав суттєву негативну кореляцію із середньою швидкістю потоку крові (справа: R2 = -0,52547, p = 0,04426 і зліва: R2 = -0,63628, p = 0,01077). Що стосується діаметра оболонки зорового нерва, єдиною й важливою позитивною кореляцією було співвідношення артеріального тиску через 24 годин після поступлення (R2 = 0,56980, p = 0,2659).

Висновок. Показники середньої швидкості потоку крові дають послідовнішу й кориснішу інформацію, ніж діаметр оболонки зорового нерва під час оцінки гемодинаміки в жінок із прееклампсією протягом перших 24 годин.

Ключові слова: середній артеріальний тиск; середня швидкість потоку крові; діаметр оболонки зорового нерва; індекс пульсації.

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Optic nerve sheath diameter, mean flow rate, pulsatility index and preeclampsia

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Background. Ultrasound has led to non-invasive neuromonitoring for surveillance and decision-making of aspects affecting the central nervous system. The aim was to determine the correlation between mean blood pressure and bilateral optic nerve sheath diameter, pulsatility index and mean flow rate of the middle cerebral artery in cases of preeclampsia/eclampsia.

Methods. It was a prospective cohort study, including pregnant women diagnosed with preeclampsia/eclampsia who received medical attention in an Intensive Care Unit. The registered ultrasonographic measurements (optic nerve sheath diameter, pulsatility index and mean flow rate) were correlated against mean blood pressure at admission and after 24 and 72 hours. The recorded data were entered in an Excel sheet with subsequent use of the Social Science Statistics online web page.

Results. The correlation analysis indicated that at admission, mean blood pressure had a significant negative correlation with mean flow rate (right: R2 = -0.52547, p = 0.04426 and left: R2 = -0.63628, p = 0.01077). In relation to optic nerve sheath diameter, the only positive and significant correlation was the one observed with mean blood pressure after 24 hours following admission (R2 = 0.56980, p = 02659).

Conclusion. Mean flow rate measurements give more consistent and useful information than optic nerve sheath diameter in the hemodynamic evaluation of the preeclamptic women in the first 24 hours.

Keywords: mean blood pressure; mean flow rate; optic nerve sheath diameter; preeclampsia; pulsatility index.

Introduction

Hypertensive pregnancy disorders are a group of high blood pressure derangements that are prevalent among pregnant women. According to the report of the American College of Obstetricians and Gynecologists' Task Force, these medical spectrum alterations include preeclampsia and eclampsia, chronic hypertension, chronic hypertension with superimposed preeclampsia, and gestational hypertension, all of which are commonly diagnosed after 20 weeks of gestation [1].

The main manifestations of preeclampsia are caused by vasospasm (volume and blood pressure control disturbances), coagulation cascade activation, humoral and autacoid system alteration, oxidative stress, and inflammatory response [2]. These conditions can lead to systemic ischemia, thereby impairing lungs and kidneys and causing other body dysfunctions

[2, 3]. If left untreated, many of its non-hypertensive complications can be fatal even if the pressure elevations are mild [2, 3]. Clinicians are aware that preeclampsia is characterized by the onset of hypertensive symptoms. For example, cases of mild hypertension (mean blood pressure [MBP] = 105-126 mmHg) or minimal proteinuria can progress rapidly to eclampsia or other complications [4]. These maternal disorders, however, are mainly diagnosed with regular surveillance of weight, urine tests, and blood pressure [5].

In the last few years, ultrasound (US) has led to non-invasive neuromonitoring for surveillance and decision-making of those entities affecting the central nervous system (CNS), thus making it a useful tool in operating rooms, intensive care units, and emergency areas [5, 6]. More specifically, the correlation of ultrasonographic measurements of the optic nerve sheath diameter (ONSD) with the intracranial pressure (ICP) has been previously confirmed [7, 8].

Evidence shows the important diagnostic utility for non-invasive neuromonitoring and acute setting of transcranial Doppler (TCD) and transcranial color-coded duplex (TCCD) [9]. Other measurements obtained with the US include pulsatility index (PI), peak, end-diastolic, and mean flow rate (MFR) velocities of the middle cerebral artery [10]. This study aims to determine the correlation between MBP and bilateral ONSD, as well as the PI and MFR of the right and the left middle cerebral artery in cases of preeclampsia and eclampsia.

Methods

Setting

A prospective, cohort study was carried out in the obstetric intensive care unit (O-ICU) of the «Mónica Pretelini Sáenz» Maternal Perinatal Hospital (HMPMPS), Health Institute of the State of Mexico (ISEM) from April 2017 to October 2017.

Patients

Pregnant women with 20 weeks of gestation or more, postpartum women with preeclampsia, and those with seizures without an attributable cause were included in this research. However, pregnant women with hypertensive disorders not related to pregnancy were excluded from this study. Women with inadequate US data were not included in the final analysis either. The sample was constructed with consecutive cases of pregnant or puerperal women fulfilling the inclusion criteria.

General data

The study variables included age, place of residence, secondary maternal complications, natural deliveries, cesarean sections, abortions, days of hospital stay in the O-ICU, and MBP as registered using an electronic sphygmomanometer (Infinity Delta XL, Draeger).

US measurements

The following US equipment was used:

- A USG General Electric Model Vivid 7 Dimension (available in the O-ICU) with M4S and 7S transducers (7-10 MHz). This device was used for MFR and PI measurements.
- A USG General Electric Model Logiq 7 (available in the Radiology Service) with a linear transducer. This tool was used for ONSD measurements.

The ONSD measurement was taken using the equipment configured to visualize structures with a depth of up to 5-6 cm. It was placed on the closed eyelid after applying a conductive gel and eye protection with Tegaderm. The optic nerve was identified as the hypoechoic structure with a regular path after the eyeball.

To carry out the transcranial Doppler, a 1-5 MHz micro convex or convex transducer was used, along with a color Doppler function software. Through the transtemporal window, the middle cerebral artery was found. The transducer was then placed in the temporal bone over the zygomatic arch and the anterior to the external ear canal or the earlobe.

All the ultrasound steps are described in the Radiology Key [11]. The most important anatomical feature that needs to be identified is the midbrain, which is at a depth of about 5-8 cm with the «Mickey Mouse ears» of the crus cerebri seen towards its side. After the middle brain was identified in the grayscale image, the color box was placed on the expected anatomical location of the site of interest with «red» usually representing the flow. The window allows an ideal visualization of the circle of Willis to measure the MFR and PI.

Statistical analysis

Data were obtained and imported into an Excel sheet. Quantitative variables were represented using measures of central tendency and qualitative variables were formatted in percentages. Among all variables, the Spearman correlation was chosen due to the non-Gaussian distribution of variables. It was used on the Social Science Statistics online web page [12]. In all cases, $p \leq 0.05$ was considered statistically significant.

Results

In 7 months, 15 patients were involved with a mean age of 23.6 years ± 6.8 years (range: 16–37 years). Of them, 13 (86.6%) were residents of the State of Mexico (the most populated State of the Mexican Republic that surrounds Mexico City). The mean duration of hospitalization in the O-ICU was of 2.26 + 0.96 days (range 1–4 days). Table 1 shows general patient data.

According to the diagnosis at admission, eight patients (53.3%) were admitted with post-natal severe preeclampsia and five (33.3%) with post-natal eclampsia. Only two pregnant patients (13.3%) were admitted with severe preeclampsia, which was interrupted in less than 48 hours. Among detected complications, HELLP syndrome (46.6%) and acute renal insufficiency (40%) were the most frequent.

At admission, MBP was 106.82 ± 15.69 mmHg (range 77–130.33 mmHg), which dropped to 94.55 ± 12.14 mmHg (range 70.66–117.66 mmHg) after 24 hours, 89.80 ± 9.56 mmHg (range 82–105.33 mmHg) after 48 hours, and 97.20 ± 13.50 mmHg (range 82.66–118.33 mmHg) after 72 hours. The ONSD on admission was above normal ranges; despite a slight drop after 24, 48, and 72 hours of admission, it never reached a normal value (Table 2).

Out of 15 patients at admission, 13 (86.66%) had increased ONSD, between 4.9 and 5.8 mm. Of these, five (33.33%) corresponded to the eclampsia group in puerperium with values between 5.1 and 5.8 mm. Moreover, two patients (13.33%) with eclampsia developed cerebral edema with ONSD between 5.1 and 5.5 mm. During the 24-hour control, the values of 12 patients (80%) remained within the range of 5 to 5.6 mm. In five cases of eclampsia, the ONSD was between 5.1 and 5.6 mm. Of these, two (13.33%) with eclampsia and cerebral edema maintained ONSD between 5.1 and 5.2 mm.

Out of 13 women from the State of Mexico, two did not develop alterations in the ONSD, while the remaining ones maintained a range of 4.9 to 5.8 mm. After 24 hours, only 10 maintained increased ranges between 5.1 and 5.6 mm.

The bilateral MFR continued an inverse pattern compared to MBP; first, within normal ranges at admission and then, with increments at 24 and 48 hours but without exceeding the upper limit; in fact, women who left the hospital after 72 hours, remained in ranges close to admission values (Table 2).

Upon admission, the MFR of 12 patients (80%) was classified as within the normal range. One patient (6.66%) had decreased values on both sides, and two patients (13.33%) showed an increment tendency for the right eye values. In this case, one had a normal MFR on the left.

Table 1

General patient characteristics

Variable	Minimum	Maximum	Mean	SD
Age (years)	16	37	23.66	6.84
Pregnancies (number)	1	2	1.26	0.45
Vaginal deliveries (number)	0	1	0.2	0.41
Abortions (number)	0	1	0.13	0.35
Cesareans (number)	0	2	0.8	0.67
SBP (mmHg)	107	175	140.06	20.96
DBP (mmHg)	62	109	90.2	13.69

DBP: Diastolic Blood Pressure, SBP: Systolic Blood Pressure, SD: Standard Deviation.

Table 2

Mean Blood Pressure and US measurements at several time-points

	Admission (n = 15)	**After 24 hours (n = 15)**	**After 48 hours (n = 10)**	**After 72 hours (n = 5)**
	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
MBP (mm Hg)	106.82 ± 15.69 (77 – 130.33)	94.55 ± 12.14 (70.66 – 117.66)	89.80 ± 9.56 (82 – 105.33)	97.20 ± 13.50 (82.66 – 118.33)
Right ONSD (mm)	5.22 ± 0.44 (4.1 – 5.8)	5.08 ± 0.29 (4.4 – 5.5)	4.95 ± 0.29 (4.3 – 5.1)	5.26 ± 0.18 (5.1 – 5.5)
Left ONSD (mm)	5.16 ± 0.40 (4.3 – 5.6)	5.09 ± 0.34 (4.3 – 5.6)	5.01 ± 0.41 (4.1 – 5.3)	5.24 ± 0.23 (5 – 5.6)
Right MFR (mm)	60.81 ± 17.54 (27.36 – 85.04)	79.29 ± 21.09 (42.7 – 114.63)	81.01 ± 26.97 (32.38 – 111.28)	66.14 ± 17.02 (43.93 – 91.73)
Left MFR (mm)	60.10 ± 18.00 (35.54 – 99.64)	79.30 ± 21.21 (37.89 – 111.26)	80.96 ± 25.78 (37.76 – 113.79)	73.19 ± 11.22 (64.08 – 92.29)
Right PI (mm)	0.97 ± 0.17 (0.68 – 1.25)	0.90 0.14 (0.65 – 1.21)	0.84 ± 0.08 (0.75 – 0.98)	0.96 ± 0.18 (0.69 – 1.18)
Left PI (mm)	0.94 ± 0.17 (0.65 – 1.20)	0.88 ± 0.14 (0.67 – 1.13)	0.84 ± 0.08 (0.75 – 0.95)	0.98 ± 0.20 (0.7 – 1.2)

MBP: Mean Blood Pressure, MFR: Mean Flow Rate, ONSD: optic nerve sheath diameter, PI: Pulsatility Index, SD: Standard Deviation.

Out of five patients with eclampsia, one (20%) had low MFR, whereas the remaining four (80%) maintained normal ranges. Concerning ten patients with preeclampsia, only two (20%) developed high MFR, while other patients (80%) maintained normal ranges.

After 24 hours, the number of patients with normal MFR decreased to eight (53.33%). None showed decreased ranges, and the number of patients with high MFR increased to seven (46.66%). Of five patients with eclampsia, two (40%) maintained normal MFR, and the remaining three (60%) had an increase in MFR. In contrast, in the case with preeclampsia (n = 10), only six (60%) patients maintained normal MFR, while the remaining four (40%) progressed to high values (Table 2). The PI did not show any variation at the time when measurements were taken. Only patients discharged after 48 hours indicated a slight decrease, but their measurements were still within normal reference ranges. Patients who left the O-ICU after 72 hours had values similar to those registered at admission, but they did not exceed the maximum limit (Table 2).

Five patients with eclampsia (33.33% of the entire sample n = 15) were between 16 and 23 years. Upon admission, two (40%) were normotensive, while the remaining three (60%) developed mild hypertension. After 24 hours, only four (80%) maintained normotension, while one had mild hypertension. Of five cases of eclampsia discharged after 48 hours, only one (20%) maintained mild hypertension; the same thing happened after 72 hours (20% of five cases of eclampsia). In those cases, with eclampsia, a simple skull tomography was performed, and two patients (13.33%) were found with mild cerebral edema. Between these patients, one was normotensive, while the other had mild hypertension. There was no cerebral vascular event or death as a result of preeclampsia or its complications.

When comparing ultrasonographic values of puerperal women with severe preeclampsia and those with eclampsia, there were no statistical differences (Table 3). In this comparison, values obtained from pregnant women with severe preeclampsia were not included as this group consisted only of two patients.

The correlation analysis indicated that at admission, MBP had a significant negative correlation with MFR (right: R^2 = -0.52547, p = 0.04426 and left: R^2 = -0.63628 and p = 0.01077). Concerning ONSD, the only positive and significant correlation was the one observed with MBP at 24 hours after admission (R^2 = 0.56980, p

Table 3

Mann-Whitney U Test between cases of severe preeclampsia and eclampsia on puerperium

Variable	Time	
	Admission (n = 15)	**After 24 hours (n = 15)**
	P-value (Z score)	P (Z score)
MBP (mm Hg)	.50926 (-0.65873)	.9442 (-0.07319)
Right ONSD (mm)	.41794 (-0.80512)	.61006 (-0.51235)
Left ONSD (mm)	.82588 (-0.21958)	.18684 (-1.31747)
Right MFR (mm)	.61006 (0.51235)	.41794 (-0.80512)
Left MFR (mm)	.82588 (0.21958)	.71138 (-0.36596)
Right PI (mm)	.9442 (0.07319)	.88076 (-0.14639)
Left PI (mm)	.88076 (-0.14639)	1 (0)

MBP: Mean Blood Pressure, MFR: Mean Flow Rate, ONSD: optic nerve sheath diameter, PI: Pulsatility Index, SD: Standard Deviation.

= 0.2659) (Table 4). None of the ultrasonographic measurements showed a significant correlation with the days of stay in the O-ICU compared to the MBP (R^2 = 0.52279, p = 0.04555).

Discussion and conclusion

Bellner et al. found a correlation between ICP, perfusion pressure and PI (p <0.0001), especially if the PI approached 3 [13]. In this study, all patients had a PI greater than 0.6. On the other hand, previous research indicated that severe preeclampsia was associated with a significantly higher ONSD and that it increased optic disc height (ODH), which could be ultrasonographic evidence of papilledema [14]. Moreover, pilot studies that apply point-of-care ultrasound (POCUS) may serve as a useful adjunct to clinical examination for obstetric anesthesiologists that are managing these complex patients [15].

Also, it is important that ONSD > 4.53 mm is completely accurate in detecting elevated ICP.[16] For example, Dubost et al. examined preeclampsia patients with increased ICP through ONSD. They found that women with preeclampsia had higher values than those without this disorder (5.4 mm [95% CI: 5.2, 5.7] vs. 4.5 mm [95% CI: 4.3, 4.8], p <0.0001) [5]. In this study, the cutoff point of ONSD had to be 4.8 mm to be considered high; as a result, 13 patients exceeded this limit.

Interestingly, a lack of significance was observed between MBP and ONSD on admission, but it was present after 24 hours

Table 4

Spearman correlation between mean blood pressure and ultrasonographic measures

Time	Variables	R^2	P-value
Admission	MBP and right ONSD	0.23078	0.40793
	MBP and left ONSD	-0.05616	0.84241
	MBP and right MFR	-0.52547	0.04426
	MBP and left MFR	-0.63628	0.01077
	MBP and right PI	0.23903	0.3909
	MBP and left PI	0.09042	0.74861
24 hours	MBP and right ONSD	0.5698	0.02659
	MBP and left ONSD	0.26599	0.33795
	MBP and right MFR	0.225	0.4201
	MBP and left MFR	0.19643	0.4829
	MBP and right PI	-0.27167	0.32734
	MBP and left PI	-0.25581	0.35744

MBP: Mean Blood Pressure, MFR: Mean Flow Rate, ONSD: optic nerve sheath diameter, PI: Pulsatility Index.

following admission. This observation showed the complexity of hemodynamic response and aforementioned measurements.

As found by Dubost et al., cerebral edema correlated with an increased ONSD due to ICP, especially if the former exceeded 5.8 mm (95% probability). The obtained ONSD value continued increasing until after 72 hours of staying in the O-ICU. In case of two patients with the tomographic report of cerebral edema, values were not as high as expected compared to patients who did not develop eclampsia or cerebral edema.

It can be concluded that MFR behavior is more important than that of ONSD in the hemodynamic evaluation of preeclamptic women in the first 24 hours. This is confirmed by the finding that at admission, there were only two women with high right MFR and seven after 24 hours, while for the left MFR, there were one and seven cases in the same periods respectively. Another crucial consideration is that preeclampsia and its complications may be determined by CNS alterations, which would distort the principles of ultrasonography used in explaining correlations observed in this study. Hence, further studies are required to establish US reference ranges for this vulnerable group.

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Conflict of interest statement
All of the authors declare that there are no competing interests regarding the publication of this paper.

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