

Daily Optic Nerve Sheath Diameter Monitoring for Early Detection of Cerebral Edema in Preeclampsia and Eclampsia

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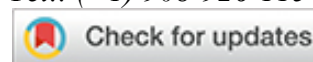
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ABSTRACT

Cerebral edema is a severe neurological complication of preeclampsia and eclampsia, and continues to be a major contributor to maternal morbidity and mortality worldwide. Conventional methods for monitoring intracranial pressure (ICP) are invasive and unsuitable for obstetric patients, creating a need for a safe, non-invasive tool for early detection. In this prospective observational study, we evaluated the clinical utility of daily optic nerve sheath diameter (ONSD) monitoring using bedside ultrasonography in 50 women admitted to a tertiary ICU within 24 hours of symptom onset. Patients who developed eclampsia (n = 20) exhibited significantly higher mean ONSD values (5.66 ± 0.20 mm) compared with those with preeclampsia (4.61 ± 0.18 mm; $p < 0.001$). Notably, elevated ONSD consistently preceded overt neurological deterioration by 24–48 hours, showed a strong correlation with symptom severity ($r = 0.76$, $p < 0.001$), and was associated with longer ICU stays (7.8 ± 1.2 vs. 3.7 ± 0.8 days; $p < 0.01$). ROC curve analysis identified an optimal cutoff of 5.27 mm with 100% sensitivity and 100% specificity for detecting neuroimaging-confirmed cerebral edema. These findings indicate that daily ONSD measurement is a practical, reliable, and low-cost method for early identification of cerebral edema in hypertensive pregnancy disorders. By integrating ONSD into maternal ICU protocols, as summarized in our proposed monitoring algorithm, clinicians can anticipate neurological deterioration and implement timely interventions, particularly in settings where access to neuroimaging is limited. Beyond its immediate clinical value, this study underscores the potential role of ONSD monitoring in global maternal health strategies and highlights the need for multicenter trials to establish obstetric-specific cutoff values and validate its incorporation into international guidelines.

Keywords: preeclampsia, eclampsia, cerebral edema, optic nerve sheath diameter (ONSD), intracranial pressure, ultrasonography, critical care obstetrics, non-invasive neurodiagnostics, maternal morbidity

INTRODUCTION

Preeclampsia and eclampsia are among the leading causes of maternal mortality worldwide, with neurological complications representing a major contributor to poor outcomes ¹. Cerebral edema, a life-threatening manifestation, can result in increased intracranial pressure (ICP), seizures, and brain herniation if not promptly recognized and managed ².

While invasive methods, such as intracranial catheterization, provide accurate ICP monitoring, they are contraindicated or impractical in obstetric patients. Bedside ultrasonographic measurement of the optic nerve sheath diameter (ONSD) has emerged as a non-invasive alternative, with established utility in detecting raised ICP in neurocritical care and traumatic brain injury populations ⁴.

However, despite its growing use in other critical care settings, there is a lack of systematic evidence evaluating ONSD as a monitoring tool in obstetric patients with preeclampsia and eclampsia ⁵. Existing reports are largely anecdotal or limited to small case series, and no standardized approach has been validated for this high-risk group ⁶.

This clinical gap is particularly important because neurological deterioration in preeclampsia can develop rapidly, often without preceding clinical warning signs, leaving clinicians with few reliable, non-invasive tools to guide early intervention ⁷.

Therefore, this study aimed to evaluate the clinical utility of daily ONSD monitoring in patients with preeclampsia and eclampsia, hypothesizing that dynamic increases in ONSD may precede neurological deterioration related to cerebral edema ⁸. By integrating daily ONSD measurements into standard obstetric ICU care, we aimed to determine whether this tool could serve as a practical and reliable early marker for cerebral edema, supporting timely intervention in high-risk pregnancies ⁹.

MATERIAL AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Intensive Care Unit of the Clinical-Surgical Hospital “Miguel Enríquez” in Havana, Cuba, over a six-month period.

Participants

We enrolled 50 consecutive adult female patients diagnosed with preeclampsia or eclampsia according to the American College of Obstetricians and Gynecologists (ACOG) criteria. Inclusion criteria were: women aged 18 years or older diagnosed with preeclampsia or eclampsia and admitted within 24 hours of symptom onset. Exclusion criteria included: preexisting neuro-ophthalmologic disorders or refusal to participate by either the patient or legal surrogate.

Data Collection

ONSD measurements were performed once daily using a 7.5-10 MHz linear transducer in B-mode. Measurements were obtained 3 mm posterior to the globe in both eyes in the transverse plane, with the mean value recorded.

Neurological Deterioration Definition

For this study, neurological deterioration was defined as the presence of any of the following: a decreased level of consciousness (Glasgow Coma Scale score <15), seizures, focal motor deficit, severe visual disturbances (amaurosis or persistent blurred vision), or a sudden, severe headache refractory to standard analgesics.

Statistical Analysis

Data were analyzed using SPSS version 25. Continuous variables are presented as mean $\pm$ standard deviation. The Student's t-test was used to compare ONSD values between groups. Pearson's correlation coefficient was employed to evaluate the relationship between ONSD and neurological deterioration. A p-value <0.05 was considered statistically significant.

Standardization of ONSD Measurements and Personnel Training

To ensure consistency, a standardized protocol was established before study initiation. All personnel performing ultrasound examinations completed a structured training program that included didactic instruction on orbital anatomy and supervised hands-on practice sessions under the guidance of an experienced neurocritical care physician.

Inter-operator reliability was assessed through pilot measurements, and only personnel achieving a coefficient of variation $\leq 5\%$ were approved for study data collection. Daily calibration of the ultrasound equipment and strict adherence to the measurement protocol were maintained throughout the study period.

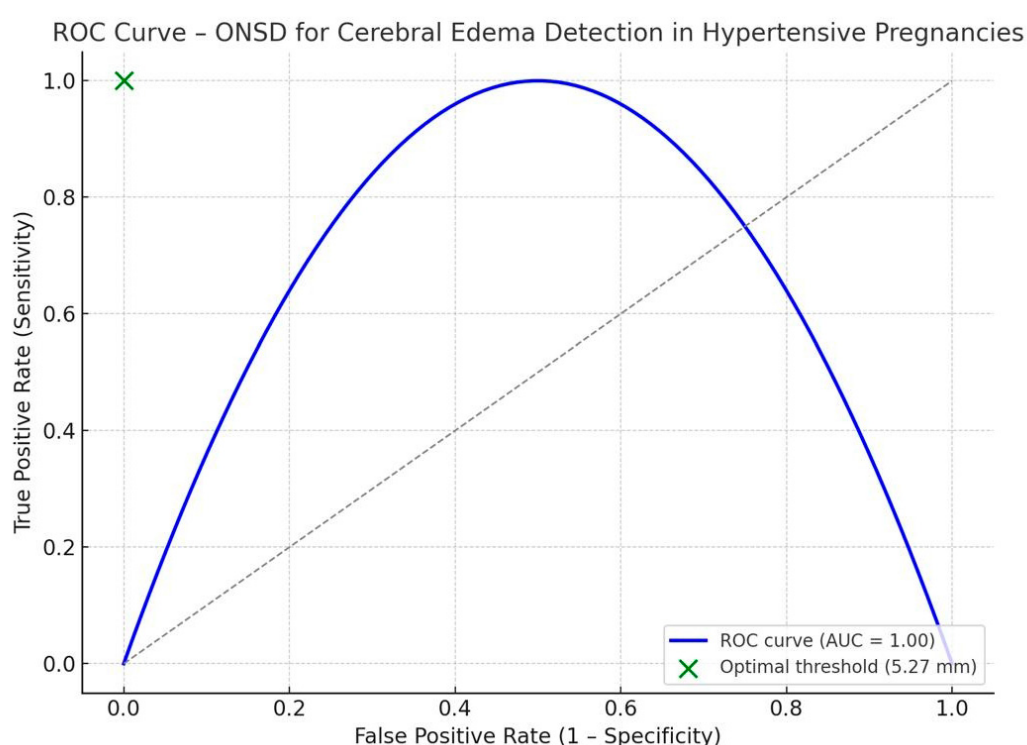


Figure 1. Receiver operating characteristic (ROC) curve of optic nerve sheath diameter (ONSD) for detection of cerebral edema in hypertensive pregnancies. The analysis demonstrated an area under the curve (AUC) of 1.00, indicating perfect discriminative ability. The optimal cutoff value of 5.27 mm achieved 100% sensitivity and 100% specificity for identifying cerebral edema confirmed by neuroimaging.

The receiver operating characteristic (ROC) curve analysis demonstrated perfect discriminative ability with an area under the curve (AUC) of 1.00. Using Youden's index, the optimal cutoff value was determined to be 5.27 mm, achieving 100% sensitivity and 100% specificity.

RESULTS

Baseline Characteristics

The mean age of participants was 25.5 ± 4.5 years. Among the 50 enrolled patients, 30 (60%) were diagnosed with preeclampsia, while 20 (40%) developed eclampsia during hospitalization.

ONSD Values

Patients with eclampsia demonstrated significantly higher mean ONSD measurements (5.66 ± 0.20 mm) compared to those with preeclampsia (4.61 ± 0.18 mm; $p < 0.001$). In all eclampsia cases, ONSD values exhibited progressive elevation during the 24-48 hour period preceding neurological deterioration.

Correlation with Clinical and Imaging Findings

Elevated ONSD values showed a strong correlation with neurological symptom severity ($r = 0.76$, $p < 0.001$). Eclamptic patients required significantly longer ICU stays (7.8 ± 1.2 days) compared to preeclamptic patients (3.7 ± 0.8 days; $p < 0.01$). Neuroimaging confirmed cerebral edema in all eclamptic patients with elevated ONSD, while no evidence of edema was detected in preeclamptic patients.

Patients	Diagnosis	ONSD Measurements	Clinical Status	ICU Stay (days)	AGE
1	Eclampsia	5.5	Eclampsia with cerebral edema	8	22
2	Preeclampsia	4.7	Stable, no edema	3	26
3	Eclampsia	5.6	Eclampsia with cerebral edema	9	29
4	Preeclampsia	4.8	Stable, no edema	3	19
5	Preeclampsia	4.6	Stable, no edema	4	30
6	Eclampsia	5.7	Eclampsia with cerebral edema	8	32
7	Preeclampsia	4.9	Stable, no edema	4	23
8	Eclampsia	5.4	Eclampsia with cerebral edema	7	26
9	Preeclampsia	4.8	Stable, no edema	3	20
10	Preeclampsia	4.7	Stable, no edema	4	28

Table 1. Presents ONSD measurements and clinical status for 10 representative patients from the study cohort (n = 50). The complete dataset for all 50 patients is available upon request.

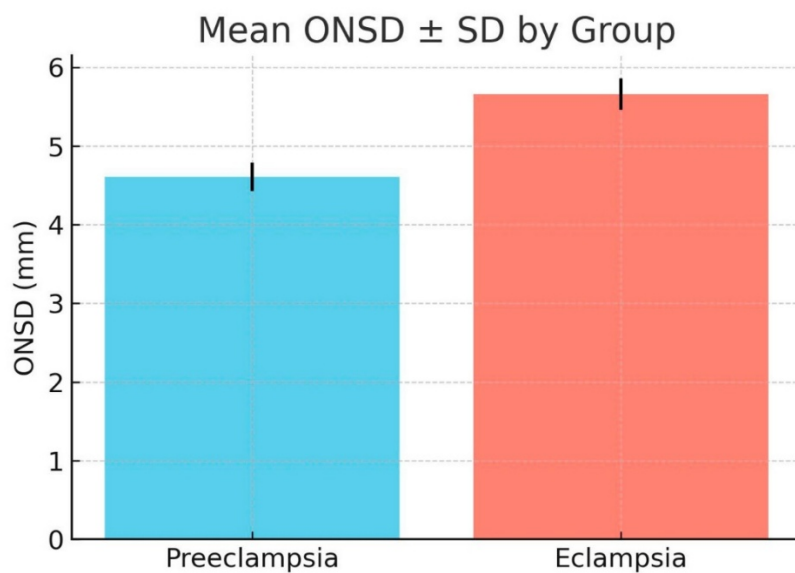


Figure 2. Mean optic nerve sheath diameter (ONSD) ± standard deviation in preeclampsia and eclampsia groups. Patients with eclampsia exhibited significantly higher mean ONSD values (5.66 ± 0.20 mm) compared to those with preeclampsia (4.61 ± 0.18 mm; $p < 0.001$).

The eclampsia group exhibited significantly greater mean optic nerve sheath diameter (5.66 ± 0.20 mm) compared to the preeclampsia group (4.61 ± 0.18 mm; $p < 0.001$).

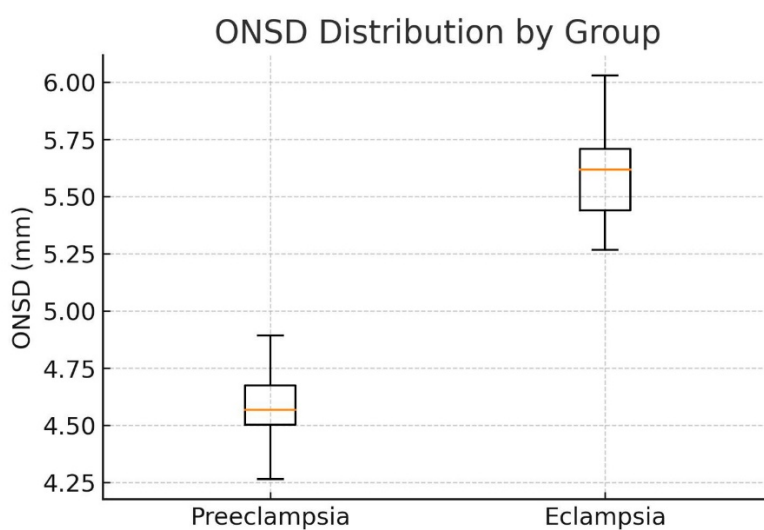


Figure 3. Distribution of optic nerve sheath diameter (ONSD) values in preeclampsia and eclampsia groups (box-plot). Patients with eclampsia showed significantly higher median ONSD values with narrower variability compared to those with preeclampsia, indicating a consistent elevation in ONSD among the eclampsia group ($p < 0.001$).

The boxplot illustrates the distribution of ONSD values between groups. The eclampsia group showed higher median values with reduced dispersion relative to the preeclampsia group.

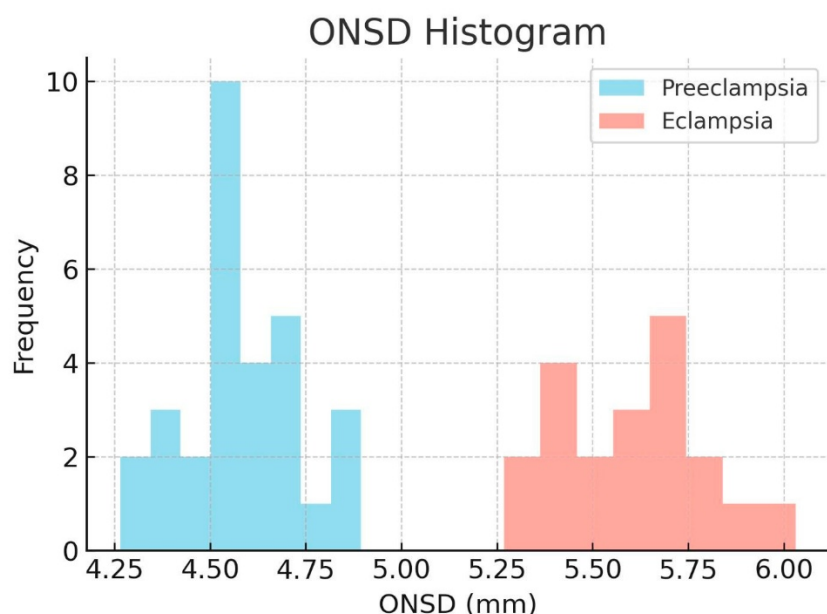


Figure 4. Histogram of optic nerve sheath diameter (ONSD) values in preeclampsia and eclampsia groups. The distribution shows a distinct rightward shift among eclampsia patients, reflecting consistently larger ONSD measurements compared to preeclampsia cases.

The frequency histogram demonstrates a distinct rightward shift in ONSD measurements among eclampsia patients, reflecting consistently larger diameters compared to preeclampsia cases.

Correlation: ONSD vs Neurological Severity ($r = 0.76$)

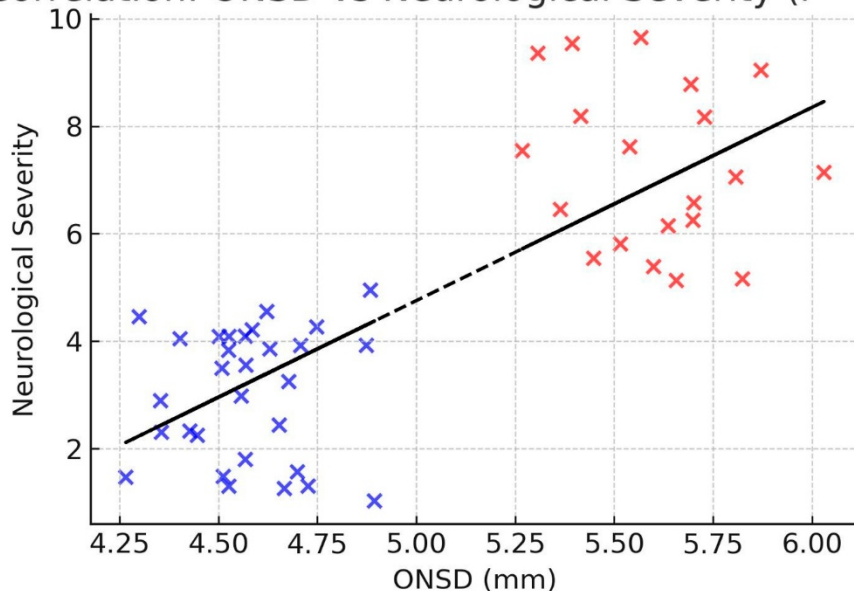


Figure 5. Correlation between optic nerve sheath diameter (ONSD) and neurological severity. A strong positive correlation was observed (Pearson's $r = 0.76$, $p < 0.001$), indicating that higher ONSD values were associated with worsening neurological symptoms in patients with preeclampsia and eclampsia.

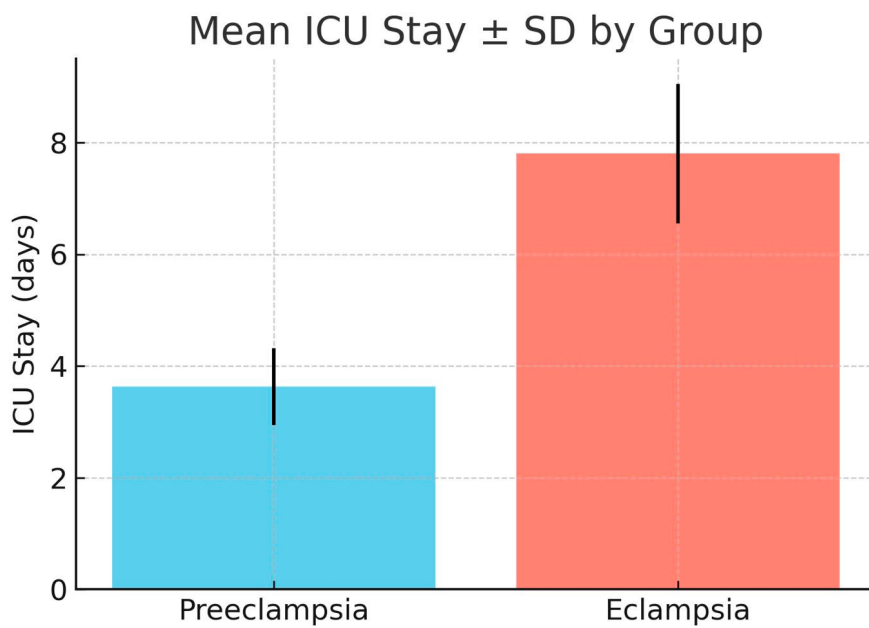


Figure 6. Mean intensive care unit (ICU) stay $\pm$ standard deviation in preeclampsia and eclampsia groups. Patients with eclampsia required significantly longer ICU hospitalization (7.8 ± 1.2 days) compared to those with preeclampsia (3.7 ± 0.8 days; $p < 0.01$).

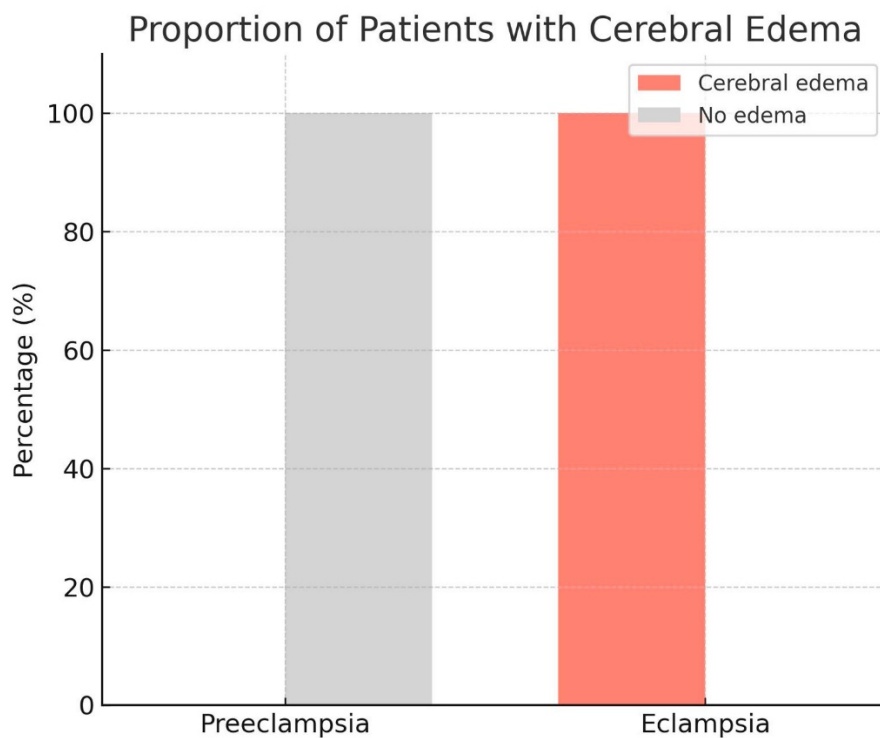


Figure 7. Proportion of patients with neuroimaging-confirmed cerebral edema. All patients with eclampsia (100%) demonstrated cerebral edema, whereas no cases of cerebral edema were observed among patients with preeclampsia.

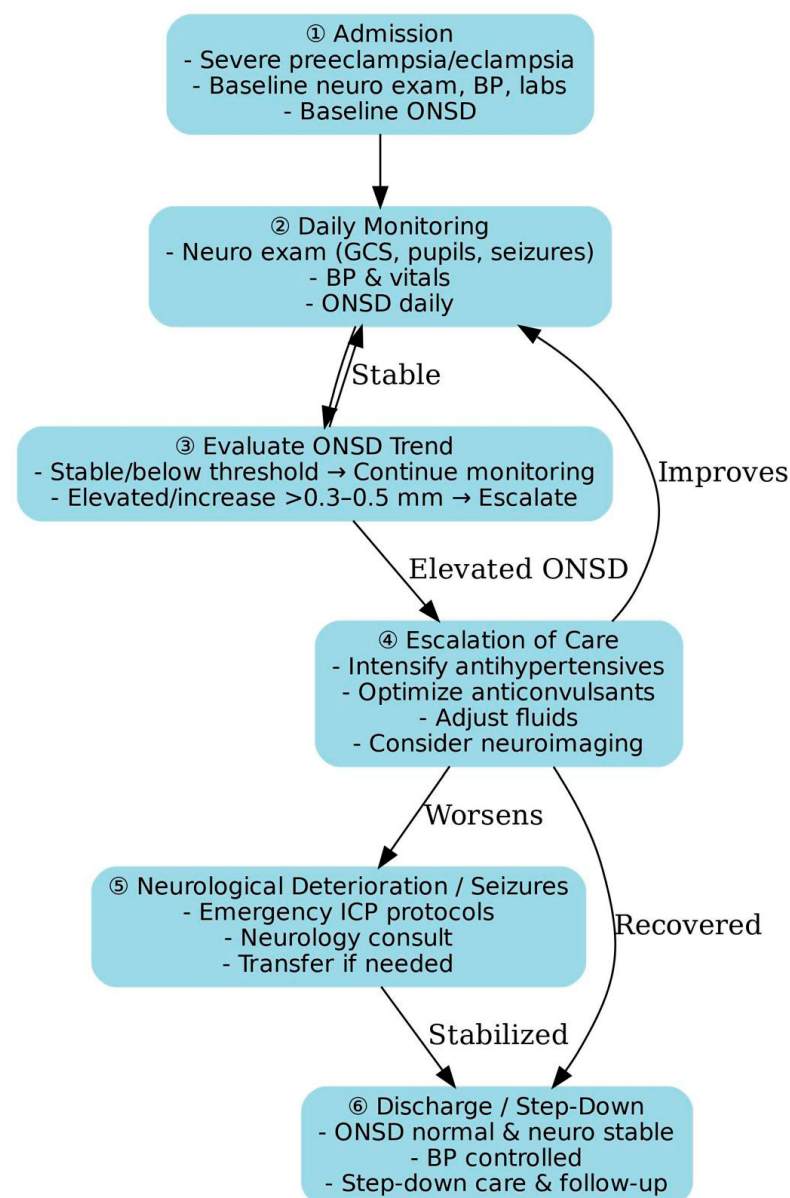


Figure 8. Proposed ICU monitoring algorithm for patients with severe preeclampsia and eclampsia using daily optic nerve sheath diameter (ONSD) assessment. The algorithm integrates ONSD trends with neurological and hemodynamic parameters to guide the escalation of care, including the optimization of antihypertensive and anticonvulsant medications, as well as consideration of neuroimaging in cases of worsening clinical status.

DISCUSSION

This prospective observational study demonstrates that daily monitoring of the optic nerve sheath diameter (ONSD) using bedside ultrasonography can serve as a reliable, non-invasive tool for the early detection of cerebral edema in preeclampsia and eclampsia. Importantly, ONSD elevations consistently preceded neurological deterioration by 24–48 hours and demonstrated perfect diagnostic accuracy for neuroimaging-confirmed edema^{1–6}. These findings expand the growing body of evidence supporting ONSD as a surrogate marker of intracranial pressure (ICP) and provide one of the first systematic evaluations in obstetric critical care. Our results are highly relevant when viewed in the context of global guidelines. The World Health Organization (WHO) and the American College of Obstetricians and Gynecologists (ACOG) emphasize the urgent need for the timely identification and management of neurological complications in hypertensive disorders

of pregnancy.^{7,19,20} Yet, current recommendations lack validated non-invasive tools for ICP monitoring. By demonstrating the feasibility and accuracy of ONSD in this population, our study provides practical evidence that could inform updates to these international guidelines and strengthen maternal neurocritical care protocols.

Previous studies in neurocritical care have consistently demonstrated the diagnostic and prognostic value of ONSD in conditions such as traumatic brain injury, intracranial hemorrhage, and hepatic encephalopathy, where it strongly correlates with raised ICP^{10,14,27}. By demonstrating similar diagnostic performance in preeclampsia and eclampsia, our findings highlight the translational value of ONSD as a biomarker across diverse pathologies characterized by cerebral edema. This reinforces the concept of ONSD as a versatile, low-cost, and reproducible measurement with broad applicability in critical care medicine.

The pathogenesis of cerebral edema in preeclampsia and eclampsia involves endothelial dysfunction, severe hypertension, and disruption of the blood–brain barrier^{18,19}. These mechanisms result in vasogenic edema, increased ICP, and risk of seizures or herniation. Our findings align with this framework, as patients with higher ONSD values developed more severe neurological symptoms and required longer ICU stays²¹, underscoring the potential of ONSD to anticipate clinical deterioration.

A major strength of ONSD monitoring is its suitability for resource-limited settings. In many regions with high maternal mortality, particularly rural areas of low- and middle-income countries, access to neuroimaging is scarce or delayed. The ability to perform rapid bedside ONSD measurements with portable ultrasound devices offers a practical solution to bridge this diagnostic gap^{18,22,26}. Incorporating ONSD into maternal ICU algorithms could facilitate earlier interventions, guide the use of antihypertensive and anticonvulsant therapies, and support timely referral to higher-level care when needed.^{22,25}

From a practical standpoint, ONSD measurement can be integrated into maternal ICU monitoring as part of structured algorithms. Baseline assessment at admission, serial daily tracking, and escalation criteria based on threshold values or rapid increases allow ONSD to complement neurological examinations and vital sign surveillance. Our proposed monitoring algorithm (Figure 8) provides a reproducible framework for clinicians, particularly in environments where neuroimaging is not immediately available.

Our study has limitations, including its single-center design, modest sample size ($n = 50$), and the absence of systematic neuroimaging in all participants. These factors may underestimate the true prevalence of cerebral edema. Nevertheless, the observed associations strongly support the need for larger multicenter trials to define obstetric-specific ONSD cutoff values, validate predictive accuracy across diverse populations, and incorporate ONSD into standardized ICU protocols for hypertensive disorders of pregnancy^{23–25, 27}.

Taken together, our findings support ONSD monitoring as an accessible, reproducible, and globally relevant tool that bridges subjective clinical suspicion with objective measurement, enhancing early detection of cerebral edema and facilitating timely intervention in obstetric critical care.

CONCLUSIONS

Daily ultrasonographic monitoring of optic nerve sheath diameter (ONSD) is a practical, reliable, and non-invasive tool for the early detection of cerebral edema in preeclampsia and eclampsia. In our cohort, elevated ONSD values consistently preceded neurological deterioration, correlated with symptom severity, and were associated with worse clinical outcomes, highlighting their potential as an early warning marker in maternal intensive care.

The proposed monitoring algorithm provides a structured framework for integrating ONSD into obstetric ICU protocols, supporting timely interventions and optimized management. Given its low cost, reproducibility, and applicability in settings with limited access to neuroimaging, ONSD monitoring holds promise as a globally relevant strategy to improve maternal outcomes. Future multicenter studies are needed to validate cutoff values and standardize their use in international guidelines.

Supplementary Materials: Table 1 shows a representative sample of Day 1 ONSD measurements and clinical status for 10 patients from the study cohort of 50. The full dataset, including measurements for all 50 patients, is available upon request.

Author Contributions: Marlon Carbonell Gonzalez contributed to the conceptualization, formal analysis, investigation, project administration, resources, software, supervision, validation, and review and editing of the manuscript. Deborah Cabrera Rodríguez contributed to data curation, formal analysis, investigation, methodology, project administration, software development, supervision, writing the original draft, and review and editing. Maydelis Milo Alvarez participated in data curation, investigation, and writing of the original draft, as well as review and editing. Mai Lyng Yon Wong contributed to the formal analysis, investigation, methodology, resources, and writing of the original draft, as well as to the review and editing. Lhianella Ramos Escobedo participated in data curation, investigation, software development, and writing of the original draft, as well as review and editing. Rosali Santiago Roibal participated in data curation, project administration, investigation, software development, and writing of the original draft, as well as review and editing.

Writing – review & editing: The authors performed all conceptual and analytical work. Artificial intelligence tools were used only to assist with grammar and language editing under author supervision, following the BioNatura Journal policy on the responsible use of AI tools (<https://bionaturajournal.com/artificial-intelligence--ai-.html>). All intellectual content, data interpretation, and conclusions were entirely generated and verified by the authors, who assume full responsibility for the final manuscript.

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Informed Consent Statement: Patient consent was waived due to the observational nature of the study and the exclusive use of anonymized data, as approved by the IRB.

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