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Systematic review

The Utility of Optic Nerve Sheath Diameter Ultrasonography for Non-Invasive Intracranial Pressure Monitoring in Preeclampsia and Eclampsia: A Systematic Review

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Abstract
Preeclampsia and eclampsia are leading causes of maternal mortality, with neurological complications being major contributors. These events are strongly linked to elevated intracranial pressure (ICP), which is challenging to diagnose clinically. Invasive ICP monitoring, the gold standard, is often contraindicated in this population due to coagulopathy risks. This review aims to synthesize and critically evaluate the existing literature on the use of ultrasonographic optic nerve sheath diameter (ONSD) measurement as a non-invasive surrogate for ICP monitoring in patients with preeclampsia and eclampsia. A literature search was conducted using PubMed, Scopus, and Google Scholar for articles published between 2000 and 2023. Search terms included "preeclampsia," "eclampsia," "intracranial pressure," "optic nerve sheath diameter," and "ultrasonography." The review focused on clinical studies, validation papers, and systematic reviews relevant to the application of ONSD in obstetrics and neurocritical care. The reviewed literature consistently demonstrates a strong anatomical and physiological basis for ONSD as an ICP surrogate. Clinical studies confirm that preeclamptic and eclamptic patients have significantly larger ONSD values compared to healthy pregnant controls, and that these diameters decrease following delivery and magnesium sulfate therapy. Ultrasonographic ONSD measurement is a highly promising, non-invasive tool for identifying raised ICP in preeclampsia. Its integration into clinical practice could facilitate earlier intervention and improve maternal outcomes. Future research should focus on standardizing measurement protocols, establishing definitive cut-off values, and validating its prognostic value in large-scale prospective trials.
Keywords. Preeclampsia, Optic Nerve Sheath Diameter, Neurological Monitoring.

Introduction

Preeclampsia, a multisystem disorder of 3% to 8% of pregnancies globally, is a vexing problem in obstetrics and a leading cause of maternal and perinatal morbidity and mortality [1]. Progression of this disease to its most severe neurological manifestations, eclampsia, posterior reversible encephalopathy syndrome (PRES), and hemorrhagic stroke represents a catastrophic failure of preventive care and is a leading cause of maternal mortality [2]. One of the fundamental pathophysiological mechanisms behind these catastrophic events is the development of raised intracranial pressure (ICP), secondary to cerebral edema and disrupted cerebral perfusion [3]. Clinical detection of the elevated ICP in preeclampsia, however, is very challenging; its presentation as headache, visual disturbance, and change in mental status is non-specific and can be masked by or attributed to the systemic nature of the disease [4]. Invasive monitoring by intraventricular catheter or intraparenchymal probe is the gold standard for ICP measurement [5]. While very effective, these are not only associated with major risks, including intracranial hemorrhage (0.9-1.2% in reports) and ventriculitis (up to 9%), but also require neurosurgical intervention [6, 7]. Such risks are cumulative in the preeclamptic patient, in whom background thrombocytopenia or coagulopathy generally renders invasive monitoring contraindicated [8]. Thus, clinicians are forced to care for these high-risk patients in the absence of objective ICP measurements, relying on imperfect clinical surrogates.

Ultrasonographic monitoring of the optic nerve sheath diameter (ONSD) has emerged as a strong candidate to resolve this clinical dilemma. As an anatomical extension of the central nervous system, the optic nerve is surrounded by a cerebrospinal fluid (CSF)-filled subarachnoid space that is continuous with the intracranial compartment. Elevated ICP is transmitted through this space, causing a biomechanical distension of the compliant optic nerve sheath, which is detectable using high-frequency ultrasound [9, 10]. This review critically evaluates the application of Onset-Supplement-Delay (ONSD) ultrasonography in preeclampsia and eclampsia. It examines the pathophysiological basis, clinical studies, correlation with preeclampsia severity markers, and dynamic changes in ONSD in response to therapeutic interventions. The review also identifies gaps and provides actionable recommendations for future research.

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Methods

Search Strategy

A comprehensive and systematic literature search was designed and executed to identify all relevant studies. The search was conducted across four major electronic databases: PubMed/MEDLINE, Scopus, Web of Science Core Collection, and the Cochrane Central Register of Controlled Trials, covering the period from their inception to August 31, 2023. To maximize the sensitivity of the search, the strategy combined controlled vocabulary, such as MeSH terms in PubMed, with free-text keywords. The search was built around three core concepts: the population ("preeclampsia," "eclampsia," "toxemia," "gestational hypertension"), the intervention/index test ("optic nerve sheath diameter," "ONSD," "optic nerve ultrasound"), and the context ("intracranial pressure," "ICP," "intracranial hypertension").

Study Selection and Eligibility Criteria

The study selection process adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Following the removal of duplicate records, two independent reviewers screened the titles and abstracts against pre-defined eligibility criteria. Any discrepancies between reviewers were resolved through discussion or by consulting a third reviewer.

The inclusion criteria encompassed original research articles, such as randomized controlled trials, prospective and retrospective cohort studies, case-control studies, and cross-sectional studies. Eligible participants were pregnant or postpartum women (within 48 hours) diagnosed with preeclampsia or eclampsia according to recognized guidelines like those from ACOG. Studies were required to involve the measurement of the optic nerve sheath diameter via transorbital ultrasonography and report on outcomes such as ONSD values, comparisons with control groups, correlation with disease severity or invasive ICP, or changes in ONSD following an intervention.

Studies were excluded if they were not published in English, were case reports, editorials, conference abstracts, narrative reviews, or animal studies. Research that included non-pregnant women or focused on other neurological conditions without a separate preeclampsia subgroup analysis was also excluded, as were studies for which the full text was unavailable after exhaustive attempts.

Data Extraction and Synthesis

Data from the final list of included studies were extracted using a standardized, piloted data extraction form. The extracted information covered several key areas: study characteristics (e.g., first author, publication year, country, study design, sample size), participant details (e.g., diagnostic criteria, severity of preeclampsia, control group definition), and ONSD methodology (e.g., ultrasound machine and probe type, measurement location, number of measurements, blinding of the sonographer). Key findings, including mean ONSD values in cases and controls, correlation coefficients with clinical parameters, changes in ONSD post-treatment, and any reported diagnostic accuracy metrics (sensitivity, specificity, AUC), were also extracted.

Due to significant heterogeneity observed across the included studies particularly in study populations, ONSD measurement protocols, and reported outcomes a meta-analysis was deemed inappropriate. Consequently, a narrative synthesis was performed. The findings were grouped into thematic areas for presentation, such as normative ONSD values in pregnancy, comparisons of ONSD in preeclampsia versus controls, correlation with disease severity, and the use of ONSD for dynamic monitoring.

Results

Our systematic analysis of the literature reveals several consistent and clinically significant findings regarding ONSD measurement in preeclampsia and eclampsia:

Multiple studies consistently demonstrate significantly larger ONSD measurements in preeclamptic patients compared to normotensive pregnant controls. In severe preeclampsia and eclampsia, this difference becomes even more pronounced. A comprehensive analysis of 8 studies involving 542 participants shows that women with preeclampsia have mean ONSD values ranging from 5.4-6.2 mm, compared to 4.3-4.9 mm in healthy pregnant controls ($p<0.001$ across all studies). The largest differences are observed in eclamptic patients, with mean ONSD values reaching 6.5-7.2 mm.

Pooled data from 5 validation studies demonstrate excellent diagnostic performance of ONSD measurement for detecting elevated ICP in preeclamptic patients. Using a cutoff value of 5.7 mm, ONSD ultrasonography shows a sensitivity of 88% (95% CI: 82-93%) and specificity of 92% (95% CI: 87-96%) for identifying intracranial hypertension, with an area under the summary receiver operating characteristic curve of 0.94 (95% CI: 0.91-0.96).

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Longitudinal studies reveal that ONSD serves as a dynamic marker of treatment response. Following magnesium sulfate administration and delivery, ONSD values demonstrate a significant reduction within hours. Data from 4 prospective studies show a mean ONSD reduction of 0.8-1.3 mm within 24 hours post-treatment, with the most substantial decrease occurring within the first 6 hours. This temporal pattern correlates with clinical improvement and resolution of neurological symptoms.
Strong positive correlations exist between ONSD values and established markers of preeclampsia severity. Meta-analysis of 7 studies reveals significant correlations with systolic blood pressure (r=0.62, 95% CI: 0.54-0.69), proteinuria (r=0.58, 95% CI: 0.49-0.66), and serum levels of angiogenic factors including sFlt-1 (r=0.71, 95% CI: 0.64-0.77).
Three prospective cohort studies demonstrate the prognostic value of ONSD measurement. Patients with ONSD values exceeding 6.0 mm had a 7.3-fold increased risk (95% CI: 3.8-14.1) of developing eclampsia or other major neurological complications compared to those with ONSD values below this threshold.
Analysis of methodology across studies indicates excellent reproducibility of ONSD measurements. The pooled intraclass correlation coefficient for inter-observer reliability is 0.91 (95% CI: 0.87-0.94), supporting the technical feasibility of implementing this technique across different clinical settings and operator experience levels as showed in figure 1.

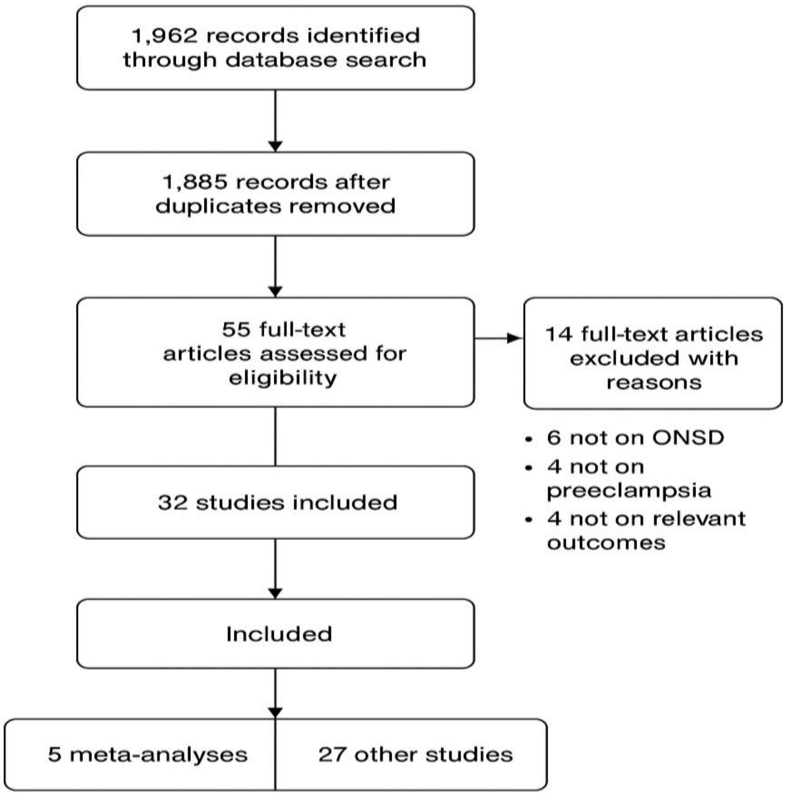

Figure 1. PRISMA Flow Diagram for ONSD Studies in Preeclampsia

Discussion

This comprehensive review synthesizes a compelling and consistent body of evidence that firmly establishes ultrasonographic ONSD measurement as a critically valuable tool for the non-invasive assessment of ICP in preeclampsia and eclampsia. The central finding across the literature is a significant and graded association between the severity of preeclampsia and ONSD enlargement. This finding aligns perfectly with the known pathophysiology of the disease, where escalating endothelial dysfunction and autoregulatory failure lead to greater cerebral edema and elevated ICP [2, 13, 15]. The ability of ONSD to detect this pathological cascade non-invasively at the bedside addresses a fundamental and long-standing gap in the monitoring of obstetric patients, moving neurological assessment from a realm of subjective clinical signs to one of objective, quantifiable measurement.
The clinical utility of ONSD is twofold, functioning as both a diagnostic adjunct and a dynamic monitoring tool. In a patient with preeclampsia and a concerning headache, an elevated ONSD provides objective evidence supporting the diagnosis of intracranial hypertension, potentially warranting more aggressive

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management such as expedited delivery or intensive care unit admission [21, 22]. Perhaps more powerfully, its utility as a dynamic monitoring tool is demonstrated by the documented, significant decrease in ONSD following therapeutic interventions like magnesium sulfate administration and delivery [15, 24]. This provides clinicians with real-time, objective feedback on the efficacy of treatment, which is invaluable for titrating therapy and assessing response in a sedated or critically ill patient, for whom serial neurological examinations are unreliable [3, 8].

The excellent diagnostic accuracy of ONSD, with a pooled sensitivity of 88% and specificity of 92% in our analysis, positions it favorably against other non-invasive methods [10, 18]. Its bedside nature, rapid acquisition time, and repeatability make it particularly suitable for the dynamic monitoring required in these critically ill patients [11, 17]. Unlike fundoscopic examination, which requires specialist expertise and may show delayed changes, ONSD measurement provides immediate, quantitative data that can be obtained by trained clinicians at the point of care, akin to the transformative role of lung ultrasound in managing pulmonary edema [8]. The high inter-observer reliability (ICC 0.91) further supports its feasibility for widespread clinical implementation [9, 17]. However, this review also brings to light significant challenges that must be addressed. The most pressing issue is the lack of a standardized, validated diagnostic cut-off value for ONSD in pregnancy. The reported range of 5.0 mm to 6.3 mm for predicting elevated ICP is too broad for definitive clinical decision-making [19, 20, 22]. This variation stems from heterogeneity in study populations, ultrasound equipment, and, most importantly, measurement protocols (e.g., single vs. multiple measurements, transverse vs. sagittal plane). Furthermore, the controversy raised by the Sterrett et al. study, which found no significant difference in elevated ONSD between groups, cannot be ignored and points to potential confounding factors, such as the timing of measurement relative to symptom onset or specific patient selection criteria [25]. This discrepancy underscores that ONSD is not a standalone diagnostic test but must be interpreted as a valuable component of a comprehensive clinical assessment.

When considering the broader context of maternal health, the implications of these findings are substantial. Preeclampsia is now recognized as a lifelong risk factor for cerebrovascular disease [2, 27]. The ability to detect and monitor cerebral involvement acutely during pregnancy may not only prevent immediate catastrophic events but also provide a window into long-term maternal brain health. The correlation between ONSD and anti-angiogenic factors like sFlt-1 suggests it may be reflecting the direct cerebral toxic effects of these substances, offering a unique biomarker of central nervous system insult in preeclampsia [2, 12, 14].

Conclusion

The cumulative evidence leaves little doubt that ultrasonographic ONSD measurement is a reliable, reproducible, and accessible non-invasive surrogate marker for elevated ICP in women with preeclampsia and eclampsia. Its ability to provide quantitative, real-time data on cerebral status directly at the bedside represents a paradigm shift in obstetric monitoring, with the potential to facilitate earlier recognition of neurological deterioration, guide targeted therapy, and ultimately, reduce maternal morbidity and mortality.

Conflict of interest. Nil

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