Original Article

Optic nerve sheath diameter as a surrogate for intracranial pressure: a noninvasive follow-up strategy using ocular ultrasonography

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ABSTRACT

Background: Idiopathic intracranial hypertension (IIH), characterized by increased intracranial pressure (ICP) without a clear cause, typically affects obese women of reproductive age. Although lumbar puncture (LP) is diagnostic, its invasiveness limits its repeated use. Consequently, a non-invasive alternative is essential. Therefore, we assessed whether optic nerve sheath diameter (ONSD) measurement via orbital ultrasonography could serve as an alternative method for monitoring changes in ICP in patients with IIH.

Methods: In this prospective observational study, patients with IIH, diagnosed using the modified Dandy criteria, underwent ONSD assessment using B-scan ultrasonography. Bilateral measurements were performed 3 mm posterior to the optic disc with the probe and sterile gel placed on the closed upper eyelid. ONSD was recorded before LP and one month after initiation of medical treatment. Comprehensive ophthalmologic examinations were also conducted. Patients with ocular pathology, neuroimaging abnormalities, or contraindications to LP were excluded.

Results: Twenty-four eyes from 12 female patients with IIH were evaluated. The mean (standard deviation [SD]) age was 27.3 (6.9) years, and the mean ICP was 34.8 (10.3) cm H_2O. Although the ONSD decreased one month after LP, changes in mean ONSD of the right eye, left eye, and their average were not statistically significant (all $P > 0.05$). No significant correlations were observed between baseline ICP and ONSD values (all $P > 0.05$).

Conclusions: Although ONSD measurement via ultrasonography provides a noninvasive method for assessing ICP in IIH, our findings revealed no significant change one month after treatment initiation. ONSD may gradually decrease following LP; however, a return to baseline values appears to require a prolonged period, even after ICP normalization. This should be considered during patient follow-up. Our findings underscore the limitations of using ONSD as a standalone marker for monitoring therapeutic response. Further research is warranted to explore the factors influencing ONSD dynamics and to establish standardized, patient-centered measurement protocols.

KEYWORDS

idiopathic intracranial hypertension, papilledema associated with increased intracranial pressure, optic nerves, ultrasonographic imaging, lumbar puncture

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INTRODUCTION

Idiopathic intracranial hypertension (IIH) is characterized by elevated intracranial pressure (ICP) without an identifiable underlying cause. It most commonly affects obese women of reproductive age [1-3]. Although lumbar puncture (LP) is a key diagnostic and therapeutic intervention in IIH, it is invasive, often technically challenging, and unsuitable for frequent monitoring [4, 5].

In contrast, measuring the optic nerve sheath diameter (ONSD) using orbital ultrasonography (US) offers a noninvasive, rapid, and accessible method to indirectly evaluate ICP [6, 7]. Anatomically, the optic nerve is enveloped by a continuation of the intracranial subarachnoid space, allowing cerebrospinal fluid pressure to be transmitted along the sheath. Consequently, an increased ICP—as in cases of IIH—can distend the optic nerve sheath. This distension can be detected using US [8-11].

However, the correlation between ICP and ONSD is not strictly linear. Significant elevations in ICP do not always accompany proportional increases in the ONSD, and vice versa [12]. Factors such as the magnitude and duration of ICP elevation, intracranial compliance, and patient individuality may influence ONSD variability [12, 13]. In cases of chronic ICP elevation, as detected in IIH, prolonged pressure may also lead to reduced sheath compliance over time, thereby limiting its reactivity to pressure changes [14].

Given that IIH often requires long-term monitoring, and that repeated LPs are neither practical nor desirable, a reliable, noninvasive alternative is needed [4, 15]. This study evaluated the utility of ONSD measurement using US as a noninvasive tool for monitoring treatment response in adults with IIH. Specifically, we investigated whether the ONSD significantly changes following LP and treatment initiation, evaluating its potential as a surrogate marker for ICP reduction.

METHODS

This prospective, observational study consecutively enrolled patients with IIH referred to the Department of Ophthalmology, Faculty of Medicine, Port Said University, Egypt, from July 2022 to March 2024. The study protocol was approved by the relevant institutional authority and adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their inclusion.

Eligible participants were adults aged 18 to 60 years who presented with papilledema, confirmed by fundus examination, along with symptoms of increased ICP, including headache, nausea, and vomiting [16]. In all patients, IIH was diagnosed according to the modified Dandy criteria [17], and all were scheduled for diagnostic LP. The exclusion criteria comprised a history of glaucoma; prior orbital or ocular surgery; neuroimaging findings suggestive of space-occupying lesions, hydrocephalus, meningeal pathology, venous sinus thrombosis, or Chiari malformation; and any contraindication to LP, such as coagulopathy or bleeding disorders. Patients with optic neuropathy, primary optic atrophy, or papillitis and those who declined participation were also excluded.

All participants underwent a comprehensive ophthalmological evaluation, including a detailed visual assessment, as well as anterior and posterior segment examinations using a NIDEK slit lamp (SL-1800; Gamagori, Japan) and a 90 D lens (Volk Optical, USA), performed by an experienced ophthalmologist. Aside from mild refractive errors and papilledema, participants had no significant ocular, systemic, or drug-related conditions affecting the visual system.

The diagnosis of IIH was confirmed by a qualified neurosurgeon based on the modified Dandy criteria [17]. ONSD measurements were performed using B-scan US with a NIDEK Echoscan US 4000–500 device (Gamagori, Japan), equipped with a 10 MHz probe. Sterile gel was applied to the closed upper eyelid, and transverse scans were obtained by positioning the probe gently on the upper lateral quadrant of the globe, while avoiding direct pressure. Three measurements were taken for each eye 3 mm posterior to the optic disc, which is considered the reference standard location for ONSD evaluation, as this region most reliably correlates with ICP changes [18-21]. All US examinations were performed by a trained operator. LP was performed within 24 h of the baseline US assessment.

Following LP, all patients received standard medical treatment and were advised on weight reduction. One month later, participants returned for a follow-up assessment. Repeat ONSD measurements were performed using the same ultrasonographic protocol, and the results were compared with baseline values obtained prior to LP.

Data were analyzed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was used to assess the normality of data distribution. Quantitative variables are presented as means (standard deviations [SDs], and qualitative variables as frequencies (percentages). Paired *t*-tests were used to compare pre- and post-treatment ONSD values, and Pearson's correlation coefficient was employed to assess potential correlations. *P*-values less than 0.05 were considered statistically significant.

RESULTS

Twenty-four eyes of 12 female patients with IIH were assessed in this study. The mean (SD) age of the participants was 27.3 (6.9) years (range: 18–38 years). The mean (SD) ICP at diagnosis was 34.8 (10.3) cm H_2O.

Table 1 summarizes the ONSD measurements before and 1-month after LP. Although the mean ONSD reduced for both eyes, the changes in the mean ONSD values for the right eye, left eye, and overall average were not significant (all $P > 0.05$).

Additionally, no significant correlation was detected between baseline ICP and ONSD measurements of the right eye, left eye, or their average (all $P > 0.05$), as shown in Table 2.

Representative images from one patient are shown in Figures 1 and 2. At presentation, this 35-year-old woman with chronic headache and nausea exhibited bilateral chronic papilledema on fundus examination, with the corresponding B-scan US revealing markedly elevated ONSD values of 6.61 mm in the right eye and 6.8 mm in the left eye (Figure 1). One month following LP, the follow-up US demonstrated a mild reduction in peripapillary fluid and ONSDs (6.3 mm in the right eye and 6.5 mm in the left eye). However, persistent optic nerve sheath distension was noted, indicating continued elevation in ICP despite partial improvement (Figure 2).

Table 1. Optic nerve sheath diameter (ONSD) before and one month after lumbar puncture

Variable	Time point (n = 12)		*P*-value
	Baseline	1-month post-LP	
ONSD of right eye (mm), Mean ± SD	6.4 ± 0.8	6.2 ± 0.5	0.369
ONSD of left eye (mm), Mean ± SD	6.7 ± 0.9	6.2 ± 0.6	0.206
Average ONSD (mm), Mean ± SD	6.5 ± 0.8	6.2 ± 0.5	0.266

Abbreviations: n, number of participants; ONSD, optic nerve sheath diameter; mm, millimetres; SD, standard deviation; LP, lumbar puncture.

Table 2. Correlation between baseline optic nerve sheath diameter and intracranial pressure

Variable	ICP
ONSD of right eye	r = + 0.27, *P*-value = 0.389
ONSD of left eye	r = + 0.08, *P*-value = 0.807
Average ONSD	r = + 0.07, *P*-value = 0.835

Abbreviations: ONSD, optic nerve sheath diameter; ICP, intracranial pressure; r, correlation coefficient.

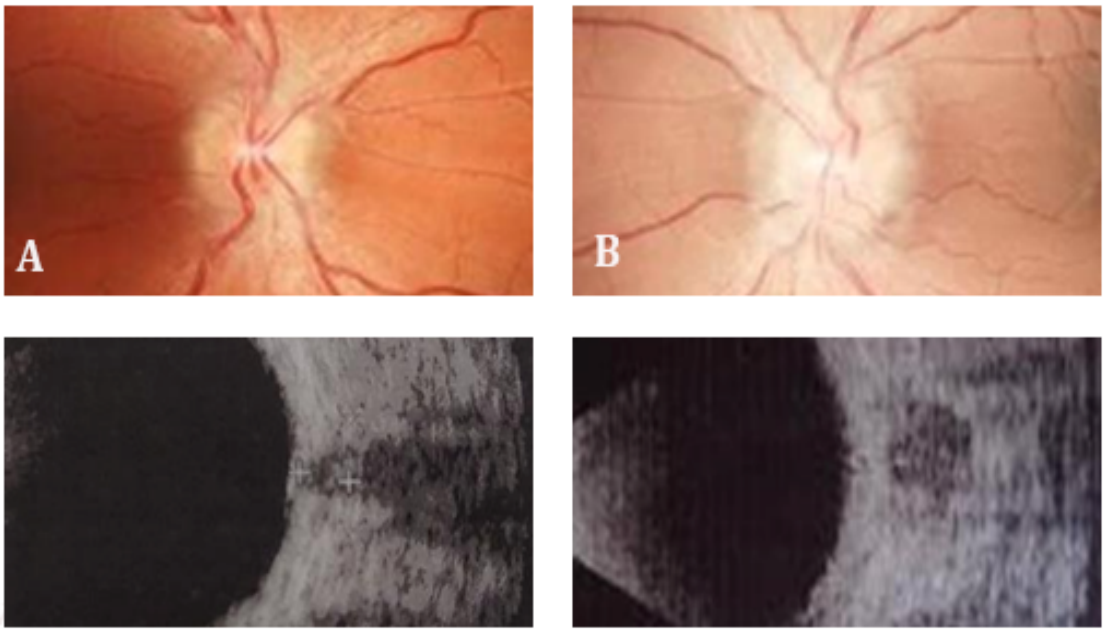

Figure 1. Chronic bilateral papilledema in a 35-year-old woman presenting with persistent headache and nausea. (A, B) Color fundus photographs of the right and left eyes, respectively, demonstrating optic disc swelling consistent with chronic papilledema. Corresponding B-scan ultrasonography images are shown below each photograph, taken with a NIDEK Echoscan US 4000–500 device (Gamagori, Japan) equipped with a 10 MHz probe. Optic nerve sheath diameters (ONSDs) of 6.61 mm in the right eye and 6.77 mm in the left eye indicate elevated intracranial pressure.

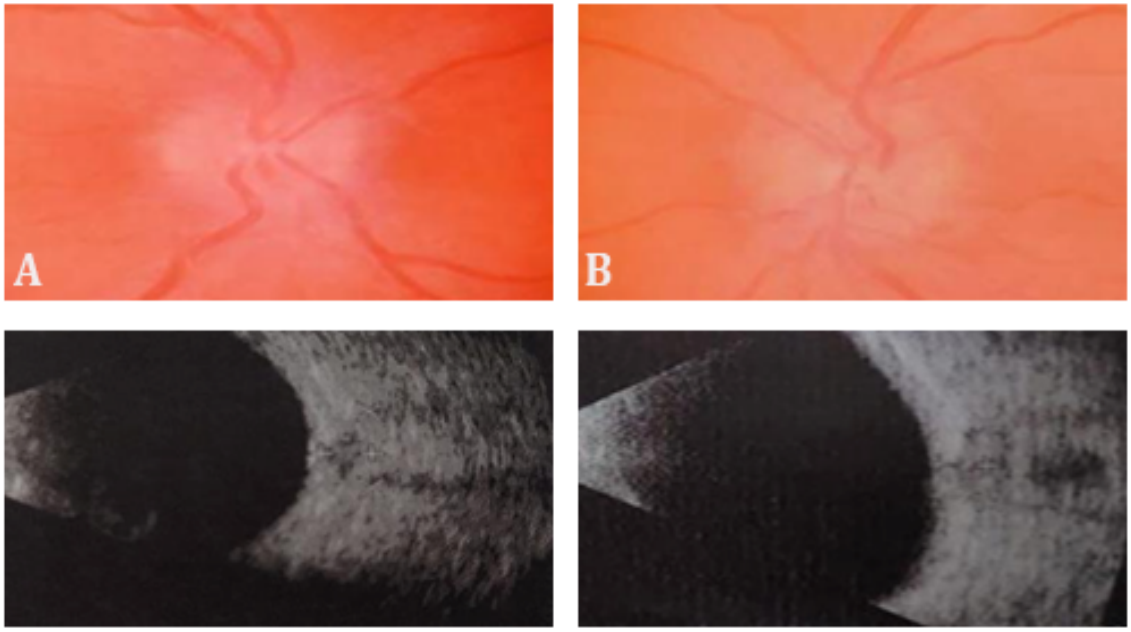

Figure 2. Follow-up imaging one month after lumbar puncture and treatment initiation in the same patient. (A) Color fundus photograph of the right eye with corresponding B-scan ultrasonography image taken with a NIDEK Echoscan US 4000–500 device (Gamagori, Japan) equipped with a 10 MHz probe, showing reduced peripapillary fluid and an optic nerve sheath diameter (ONSD) of 6.25 mm. (B) Color fundus photograph of the left eye with corresponding B-scan image below, demonstrating similar findings with an ONSD of 6.51 mm. Mild reduction in ONSD is observed bilaterally; however, optic nerve sheath distension persists, indicating ongoing elevated intracranial pressure despite partial improvement.

DISSCUSSION

In this study, the ONSD was measured before and one month after LP. A reduction in diameter was observed; however, the ONSD did not reach baseline or normal-range values. There were no significant differences between pre- and post-LP values in the right, left, and average ONSD.

The use of ONSD assessments for monitoring changes in ICP remains uncertain. Previous studies have reported varying relationships between changes in ICP and ONSD. Some studies have shown a significant reduction in ONSD following LP, correlating with decreased ICP [22-30]. In contrast, others have indicated that ONSD may not be a reliable indicator of ICP changes [31, 32]. Our findings align more closely with the latter, suggesting that ONSD may not always reflect changes in ICP following therapeutic interventions such as LP.

Butts et al. [33] found no statistically significant correlation between ICP changes and either the right or left ONSD [33]. Ultrasonographic ONSD measurements may not reliably reflect acute changes in ICP following LP [31]. As observed in a prospective cohort study involving ambulatory patients undergoing elective LP [31], we observed no significant change in ONSDs post-LP and found no correlation between ONSDs and measured ICP. This suggests that, although ONSD remains a promising noninvasive surrogate marker for elevated ICP, its sensitivity to short-term or moderate ICP fluctuations may be limited. This implies that ONSD responsiveness is likely influenced by factors such as chronicity or magnitude of pressure elevation, optic nerve sheath compliance, and inter-individual anatomical variability [12, 13]. Consequently, caution is warranted when interpreting ONSD changes as direct indicators of therapeutic response in IIH, particularly over short follow-up periods.

A recent study [32] evaluating serial ONSD measurements in patients undergoing invasive ICP monitoring demonstrated a strong baseline correlation between ONSD and ICP in the supine position. However, the correlation diminished significantly with positional changes [32]. Similarly, in our cohort, no significant correlation was found between ONSD and measured ICP, and no substantial change in ONSD was observed one month after LP. These findings suggest that ONSD may be limited as a dynamic monitoring tool in IIH, particularly for capturing short- to mid-term therapeutic effects. Caution is emphasized in interpreting longitudinal ONSD measurements during clinical follow-up.

Certain studies have reported little to no change in ONSDs among patients with IIH, with no correlation observed between ONSD reduction and the volume of cerebrospinal fluid removed. This was attributed to the compartmentalized subarachnoid space of the optic nerve [11, 34]. A case report by Lochner et al. [35] published the ONSD data acquired using optic nerve US for the diagnosis and treatment efficacy monitoring of an adult with IIH. The 45-year-old woman underwent serial ONSD measurements using US, both before and after acetazolamide and diet therapy. An early reduction in ONSD was noticed; however, normalization in ONSD required approximately one year. The authors recommended further studies to evaluate the accuracy and reliability of ONSD in follow-ups of IIH cases [35]. Kavi et al. [36] also indicated that ONSD

measurement was not reliable for ICP monitoring, as distension in the ONSD could persist after ICP is controlled [36]. As in prior investigations, our findings suggest that, although ONSD may reflect elevated ICP at a single time point, it lacks sufficient dynamicity to reliably track changes in ICP over time.

In a study of patients with IIH by Hoffmann et al. [37], therapeutic LP used to lower ICP did not cause a corresponding decrease in the optic nerve diameters and ONSDs over a brief 26-h period. However, some clinical characteristics of the illness (such as headache and related symptoms) and microstructural changes in the optic nerve identified on magnetic resonance imaging may improve in the hours after normalization of ICP [37]. Hansen et al. [38] sought a reasonable explanation, measuring ONSD to detect acutely elevated ICP and investigating optic nerve sheath distensibility and elastic properties. They observed that the ONSD began to decrease shortly after the optic nerve was decompressed in each preparation. However, ONSD failed to return to the baseline value [38]. This concept is crucial for the clinical use of noninvasive ONSD monitoring to detect increased ICP. Sheath diameter reversibility may be compromised following prolonged increases in ICP, and this must be considered before application of this technique in neurointensive care and emergency medicine [38]. Biomechanical changes in the optic nerve attributable to a chronic increase in ICP are supported by the ONSD distention observed in some cases, even after the resolution of papilledema [39-41].

This study offers meaningful insights into the use of ultrasonographic ONSD measurement as a noninvasive tool for monitoring ICP in IIH. A key strength lies in its prospective design and standardized ultrasonographic assessment by a single experienced operator, which minimized inter-observer variability. However, the relatively small sample size limits the statistical power and generalizability of the findings. Furthermore, the fixed one-month follow-up interval may not adequately reflect short-term fluctuations in ONSD following LP. Further studies should incorporate larger, more diverse cohorts and adopt a longitudinal design with multiple time-point measurements to better characterize the temporal dynamics of ONSD in relation to therapeutic interventions and ICP modulation in patients with IIH.

CONCLUSIONS

Although the US measurement of ONSD as a noninvasive method for assessing ICP in patients with IIH presents potential advantages, our study suggests that it may not be a definitive indicator of treatment efficacy or ICP changes. The variability in ONSD measurements following therapeutic interventions highlights the need for further research into the underlying mechanisms governing optic nerve sheath behavior in the context of IIH. Further investigations should focus on establishing standardized protocols for ONSD measurement, considering individual patient characteristics and the timing of assessments relative to treatment interventions.

ETHICAL DECLARATIONS

Ethical approval: The study protocol was approved by the relevant institutional authority and adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their inclusion.

Conflict of interests: None.

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