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To cite this article: Asmaa M. Ebraheim, Husam S. Mourad, Nirmeen A. Kishk, Nashwa Badr Eldin & Abdullah A. Saad (2018): Sonographic assessment of optic nerve and ophthalmic vessels in patients with idiopathic intracranial hypertension, Neurological Research, DOI: 10.1080/01616412.2018.1473097

To link to this article: https://doi.org/10.1080/01616412.2018.1473097
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ARTICLE

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ABSTRACT

Background: Early diagnosis and proper monitoring of intracranial pressure (ICP) in idiopathic intracranial hypertension (IIH) could reduce morbidity.

Objectives: The objective was to explore and monitor reflection of raised ICP in IIH on optic nerve sheath diameter (ONSD), papillary height and ophthalmic vessels hemodynamics, using transorbital sonography (TOS).

Methods: The study included 24 IIH patients and 30 controls. Patients were compared to controls (phase I) then reassessed twice; 1 week and 4 weeks later (phase II). Both groups underwent clinical evaluation and TOS to measure ONSD, papillary elevation, and color Doppler indices of the ophthalmic vessels. Patients underwent lumbar puncture (LP) to measure cerebrospinal fluid (CSF) pressure.

Results: ONSD was significantly higher in patients compared to controls (p < 0.001). The cutoff value was 6.2 mm. Papillary elevation (p = 0.006) and ONSD (p = 0.006) were significantly reduced 4 weeks following LP. Baseline color Doppler indices of the ophthalmic vessels were comparable between both groups and the changes observed during the follow-up visits in the patients were insignificant.

Conclusion: Reflected ICP changes on ONSD and papilla, measured by TOS, could be a valuable noninvasive additional tool to diagnose and monitor IIH patients. IIH insignificantly influences ophthalmic vessels hemodynamics.

Abbreviation


Introduction

The term idiopathic intracranial hypertension (IIH) or pseudotumor cerebri syndrome describes a neurological disorder characterized by ICP pressure elevation of unidentified etiology [1]. However, epidemiologic studies have revealed an association between IIH, female sex, and obesity [2]. Individuals with consistently elevated ICP typically report a wide variety of symptoms including headaches, blurring of vision, and pulsatile tinnitus [1]. Untreated cases may suffer severe sequelae such as permanent visual loss [3,4]. The progressive nature of IIH emphasizes the importance of developing diagnostic techniques that allow for early detection and monitoring of this treatable disorder. However, monitoring IIH is often challenging. Relying on the optic disc swelling is not ideal since its development or regression is often delayed [5]. Several recent investigations have presented evidence to advocate the use of sonographic assessment of the optic nerve sheath diameter (ONSD) to, reliably and noninvasively, detect early-stage elevations in ICP [6,7]. Additionally, other reports have also explored the utility of color Doppler indices of the ophthalmic vessels to monitor changes in hemodynamics secondary to intracranial hypertension (IH) [8,9].

The primary objective of the present study was to assess the value of ONSD and papillary elevation, measured by transorbital sonography (TOS), in diagnosing and monitoring raised intracranial pressure in IIH patients. The secondary objective was to monitor the reflection of intracranial hypertension on ophthalmic vessels hemodynamics.
Materials and methods

Subjects, setting, and ethical considerations

This prospective, single-center, case-control study was performed at Kasr Al-Ainy Neurology Department. Twenty definite and four probable IIH patients (48 papilledemic eyes), according to the revised diagnostic criteria for the pseudotumor cerebri syndrome [10], and 30 healthy controls were recruited from March 2016 to August 2016. All included subjects were postpubertal females (≥ 18 years of age). Patients under 18 years of age and those with other neurological disorders that may result in elevated ICP (e.g. venous sinus thrombosis) or comorbidities which may potentially affect the visual pathway—either structurally or functionally—were excluded.

Subject recruitment commenced only following a review and approval/favorable opinion—based on all applicable local laws and regulations and the principles established by the 18th World Medical Assembly (Helsinki, 1964)—of the study protocol by the local ethics committee/institutional review board. Informed consent was obtained from all participants involved in the study prior to the conduct of any study-related activities.

Diagnostic procedures and interventions

Controls were subjected to a single clinical and neuro-ophthalmological assessment as well as TOS (Figure 1). IIH patients were administered to the following procedures: (1) an initial clinical assessment, (2) an ophthalmic evaluation, (3) TOS, (4) brain imaging, and (5) lumbar puncture (LP) at the diagnosis.

Recorded measurements

(1) Medical histories were recorded for all our patients using Kasr Al-Ainy Neurology Department IIH form. The body mass indices (BMIs) were determined on the basis of height and weight measurements that were collected during the initial assessment. The ophthalmological evaluation included visual acuity assessment, by means of the Snellen chart (following correction) and fundus examination. Modified Frisén staging scale [11] was used for papilledema grading. TOS was conducted once for control subjects, and three times for IIH patients; once during the diagnostic phase and twice following the LP procedure (1 and 4 weeks later; Figure 1). Monitoring the response to management at short intervals allows the change of treatment strategy—if needed—as early as possible. The following four parameters were measured during TOS evaluations: (1) optic nerve diameter (OND), (2) ONSD, (3) papillary elevation, and (4) color-coded Doppler indices of the ophthalmic vessels. Brain imaging—namely, magnetic resonance imaging (MRI) and magnetic resonance venography (MRV)—was used during the diagnostic phase to exclude other causes of elevated ICP like venous sinus thrombosis.

Transorbital sonography

TOS was carried out for all subjects (prior to the LP for patients) by a certified neurosonographer (N.K.) at Cairo University Neuro-sonography Unit (CUNU), Cairo University. We used a PHILIPS IU22 xMATRIX ultrasound system, California, USA, and a linear probe frequency of 7–13 MHz. Subjects were examined in the supine position and the back-rest was elevated by 20–30° to avoid or reduce any strain on the eye and avoid pain. The transducer was placed on the temporal portion of patients’ closed eyelids—following application
of a thick layer of ultrasound gel—to detect the anterior optic nerve. The mechanical index was reduced to 0.2 as a precautionary safety measure. The settings for TOS were as the following: for B-mode, transmit frequency = 14 MHz, mechanical index (MI) = 0.1, single focal zone at 2.5 cm, and bandwidth 74 dB; for C-mode, transmit frequency = 10 MHz and MI = 0.2.

OND and ONSD were measured 3 mm behind the posterior edge of the globe in a horizontal plane. Two separate readings were recorded in each eye and an average for each side was subsequently calculated. The mean of both left and right sonographic measurements was then subsequently calculated. Orbital color coded Doppler sonography was used to measure the peak systolic velocity (PSV) and end diastolic velocity (EDV) of the ophthalmic arteries and veins [12]. On the basis of these measurements, the pulsatility indices (PIs) were calculated.

**Lumbar puncture**

Diagnostic LP was performed without sedation in all IIH patients following TOS. Patients were placed in the lateral recumbent position during this procedure; the hips, knees, and chin were flexed toward the chest. Patients’ heads were supported with a pillow. In instances where the LP in this position was challenging (e.g. in obese patients) a seated position was adopted as a suitable alternative. Sitting patients were then shifted to the lateral recumbent position once the spinal needle was inserted. During the measurement of opening CSF pressures, patients were instructed to straighten their legs to avoid false pressure readings. Approximately 10–15 cc of CSF were withdrawn. No abnormality in cell count or chemistry was detected.

**Statistical considerations**

Data were coded and entered using the statistical package SPSS version 23. Data were summarized using mean, standard deviation, median, minimum, and maximum. Comparisons for quantitative variables were performed using the nonparametric Mann–Whitney test. For comparisons of serial measurements within each patient, the nonparametric Wilcoxon signed rank test was employed [13]. Potential correlations between quantitative variables were identified using Spearman correlation coefficient [14]. A receiver operating characteristic (ROC) curve was constructed, and area under curve analysis was performed to detect the ideal cutoff value of ONSD for detection of IIH. The p values less than 0.05 were considered as statistically significant. The p values less than 0.01 were considered as highly significant.

**Results**

**Description of cohorts**

Enrolled participants included 24 IIH patients (20 definite and 4 probable). Their mean age and BMI were 31.40 ± 7.65 years (range: 19–47 years) and 31.9 ± 8.6 kg/m², respectively. Thirty subjects were included in the control cohort and presented with a mean age of 31.66 ± 8.86 years (range: 18–52 years). The patient and control cohorts were well matched; all enrolled participants were females and no significant difference in the mean age between both groups was observed (p = 0.944).

Eight (33.3%) of IIH patients reported irregular menstrual patterns during the baseline assessment, and five (20.8%) practiced contraception (injectable forms of progesterone). Neurological evaluation of both groups was normal. Visual acuity in our IIH cohort—as assessed during the ophthalmic evaluation—ranged from 6/6 to 6/18. Furthermore, the extent of optic disc abnormalities varied; papilledema grades I–IV were identified throughout our patient population. Following the initial baseline evaluation, enrolled IIH patients underwent a LP procedure (N = 24). Twenty patients had CSF pressure ≥ 250 mm H₂O (definite IIH) and 4 patients had CSF pressure ≥ 220 but less than 250 mm H₂O (probable IIH). All were prescribed acetazolamide (range: 1.5–4 g daily). None of the patients underwent surgical procedure. The disease characteristics and the commonly reported symptoms by patients are presented in Table 1.

During the follow up period, 16/24 (66.6%) enrolled IIH patients attended the initial follow-up visit at week 1 and 19/24 (79.2%) attended the subsequent follow up visit at week 4.

**Baseline sonographic assessment**

IIH patients presented with significantly increased mean binocular ONSD measurements compared to controls at baseline (IIH: 6.7 ± 0.5 vs. control:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>IIH patients</th>
<th>Control patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical data</td>
<td>(N = 24)</td>
<td></td>
</tr>
<tr>
<td>Age at disease onset (SD), years</td>
<td>29.6 (8.13)</td>
<td></td>
</tr>
<tr>
<td>Duration of disease (SD), months</td>
<td>20.04 (12.4)</td>
<td></td>
</tr>
<tr>
<td>CSF opening pressure (SD), mm H₂O</td>
<td>314 (88.77)</td>
<td></td>
</tr>
<tr>
<td>Menstrual irregularities, No. (%)</td>
<td>8 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Hormonal contraception usage, No. (%)</td>
<td>5 (20.8)</td>
<td></td>
</tr>
<tr>
<td>Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptoms experienced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headaches, No. (%)</td>
<td>24 (100)</td>
<td></td>
</tr>
<tr>
<td>Visual blurring, No. (%)</td>
<td>24 (100)</td>
<td></td>
</tr>
<tr>
<td>Tinnitus, No. (%)</td>
<td>13 (54.2)</td>
<td></td>
</tr>
<tr>
<td>Nausea w/o vomiting, No. (%)</td>
<td>10 (41.7)</td>
<td></td>
</tr>
<tr>
<td>Sixth nerve palsy, No. (%)</td>
<td>2 (8.3)</td>
<td></td>
</tr>
</tbody>
</table>

IIH: idiopathic intracranial hypertension; SD: standard deviation
Table 2. Baseline sonographic parameters.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>IIH Patients</th>
<th>Controls</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONSD (SD), mm</td>
<td>6.7 (0.5)</td>
<td>5.5 (0.3)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>ONSD (SD), mm</td>
<td>3.1 (0.3)</td>
<td>3.0 (0.3)</td>
<td>0.069</td>
</tr>
<tr>
<td>OA PSV (SD), m/s</td>
<td>38.01 (9.50)</td>
<td>38.48 (7.77)</td>
<td>0.542</td>
</tr>
<tr>
<td>OA EDV (SD), m/s</td>
<td>7.80 (3.61)</td>
<td>8.71 (2.61)</td>
<td>0.261</td>
</tr>
<tr>
<td>OA PI (SD)</td>
<td>1.83 (0.55)</td>
<td>1.97 (1.98)</td>
<td>0.254</td>
</tr>
<tr>
<td>OV PSV (SD), m/s</td>
<td>21.35 (4.48)</td>
<td>21.13 (3.65)</td>
<td>0.903</td>
</tr>
<tr>
<td>OV EDV (SD), m/s</td>
<td>9.23 (4.26)</td>
<td>9.76 (2.77)</td>
<td>0.497</td>
</tr>
<tr>
<td>OV PI (SD)</td>
<td>1.07 (0.68)</td>
<td>1.06 (0.75)</td>
<td>0.741</td>
</tr>
</tbody>
</table>

ONS: optic nerve sheath diameter; ONSD: optic nerve sheath diameter; OND: optic nerve diameter; OA: ophthalmic artery; OV: ophthalmic vein; PSV: peak systolic velocity; EDV: end diastolic velocity; PI: pulsatility index; SD: standard deviation; p < 0.01 is highly significant.

Table 3. Visit 2/week 1 sonographic parameters of IIH patients compared to baseline.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline</th>
<th>1 week</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONSD (SD), mm</td>
<td>6.7 (0.6)</td>
<td>6.6 (0.5)</td>
</tr>
<tr>
<td>ONSD (SD), mm</td>
<td>3.1 (0.3)</td>
<td>3.1 (0.3)</td>
</tr>
<tr>
<td>Papillary elevation (SD), mm</td>
<td>1.1 (0.3)</td>
<td>1.0 (0.3)</td>
</tr>
<tr>
<td>OA PSV (SD), m/s</td>
<td>40.0 (8.83)</td>
<td>36.14 (7.64)</td>
</tr>
<tr>
<td>OA EDV (SD), m/s</td>
<td>7.91 (3.29)</td>
<td>6.29 (4.01)</td>
</tr>
<tr>
<td>OA PI (SD)</td>
<td>1.85 (0.58)</td>
<td>1.98 (0.59)</td>
</tr>
<tr>
<td>OV PSV (SD), m/s</td>
<td>21.30 (4.75)</td>
<td>18.73 (2.99)</td>
</tr>
<tr>
<td>OV EDV (SD), m/s</td>
<td>8.47 (4.30)</td>
<td>8.15 (3.44)</td>
</tr>
<tr>
<td>OV PI (SD)</td>
<td>1.15 (0.76)</td>
<td>1.40 (1.47)</td>
</tr>
</tbody>
</table>

ONS: optic nerve sheath diameter; ONSD: optic nerve sheath diameter; OND: optic nerve diameter; OA: ophthalmic artery; OV: ophthalmic vein; PSV: peak systolic velocity; EDV: end diastolic velocity; PI: pulsatility index; SD: standard deviation.

Table 4. Visit 3/week 4 sonographic parameters of IIH patients compared to baseline.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline</th>
<th>4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONSD (SD), mm</td>
<td>6.8 (0.5)</td>
<td>6.4 (0.6)</td>
</tr>
<tr>
<td>ONSD (SD), mm</td>
<td>3.1 (0.3)</td>
<td>3.1 (0.3)</td>
</tr>
<tr>
<td>Papillary elevation (SD), mm</td>
<td>1.1 (0.3)</td>
<td>0.9 (0.9)</td>
</tr>
<tr>
<td>OA PSV (SD), m/s</td>
<td>40.12 (9.39)</td>
<td>38.19 (9.80)</td>
</tr>
<tr>
<td>OA EDV (SD), m/s</td>
<td>8.33 (3.55)</td>
<td>9.73 (2.80)</td>
</tr>
<tr>
<td>OA PI (SD)</td>
<td>1.81 (0.54)</td>
<td>1.60 (0.33)</td>
</tr>
<tr>
<td>OV PSV (SD), m/s</td>
<td>21.22 (4.57)</td>
<td>20.85 (5.86)</td>
</tr>
<tr>
<td>OV EDV (SD), m/s</td>
<td>8.19 (4.03)</td>
<td>8.41 (2.98)</td>
</tr>
<tr>
<td>OV PI (SD)</td>
<td>1.19 (0.71)</td>
<td>1.07 (0.46)</td>
</tr>
</tbody>
</table>

ONS: optic nerve sheath diameter; ONSD: optic nerve sheath diameter; OND: optic nerve diameter; OA: ophthalmic artery; OV: ophthalmic vein; PSV: peak systolic velocity; EDV: end diastolic velocity; PI: pulsatility index; SD: standard deviation; p < 0.01 is highly significant.

5.5 ± 0.3; p < 0.001). No significant differences in sonographic measurements between the two groups were observed—regarding ONSD; ophthalmic artery (OA) PSV, EDV, and PI; ophthalmic vein (OV) PSV, EDV, and PI (Table 2).

Changes in follow-up sonographic parameters in IIH patients

IIH patients were assessed 1 (N = 16/24) and 4 weeks (N = 19/24) following the initial baseline assessment and LP procedure (Figure 1). The sonographic measurements that were collected during the follow-up period are detailed in Tables 3 (1 week) and 4 (4 weeks). At week 1, no statistically significant changes in ultrasound parameters were observed—including ONSD, OND, and papillary elevation. Conversely, IIH patients exhibited significant reductions in both ONSD (6.8 ± 0.5 vs. 6.4 ± 0.6 mm; p = 0.006) and papillary elevations (1.1 ± 0.3 vs. 0.9 ± 0.9 mm; p = 0.006) 4 weeks following the initial LP procedure. On the other hand, no statistically significant changes in color-coded Doppler indices of the ophthalmic vessels were observed, during the follow-up visits, compared to the baseline measurements.

Accuracy of ONSD in detecting elevated ICP

ROC curve and sensitivity/specificity analyses were conducted to identify whether ONSD measurements can be utilized to diagnostically distinguish whether a patient has IIH or not. On the basis of our analyses, the ideal cut-off value that best differentiated IIH patients from controls was 6.2 mm with an area under the curve of 0.975 (95% confidence interval [CI] 0.940 to 1.010, p < 0.001, 87.5% sensitivity and 100% specificity), Figure 2.

Correlates of CSF opening pressure

Potential correlations between opening CSF pressures and other variables during the baseline LP—including BMI, papillary elevation, ONSD, and disease duration—were examined. Statistically significant positive correlations between opening CSF pressures and papillary elevation (r = 0.572; p = 0.004) and BMI (r = 0.695; p < 0.001) were identified (Figure 3). On the other hand, no statistically significant correlations with ONSD (r = 0.126; p = 0.557), or disease duration (r = −0.98; p = 0.648) were identified. Although papillary elevation was significantly correlated with CSF opening pressure, its correlations with ONSD initially and at follow up visits were insignificant (supplemental online material).

Discussion

Detection of elevated ICP has traditionally been performed using LP and intraventricular catheters connected to external pressure transducers [15]. In addition to being invasive and inconvenient, these techniques also expose patients to a risk of infection, hemorrhage, undesirable nervous, respiratory, and cardiac events, and subsequent mortality [16]. Recently, there has been much interest in identifying and developing reliable, non-invasive and bedside methods of detecting elevated ICP. Over the last few years, ocular ultrasonography has been heavily posited as an alternative means of assessing ICP. In addition to being relatively simple, inexpensive, and noninvasive, ultrasonography is a predominant accessible tool that is widely available in many healthcare facilities and emergency units [17].
This prospective case-control study assessed the ability of ocular ultrasonography to diagnose IIH and monitor treatment efficacy. Potential differences in optic nerve, disc and ophthalmic vessels sonographic parameters for IIH patients in comparison to controls as well as the changes to these parameters prior to and following the LP procedure were evaluated. The major observations from our study included the following: (1) IIH patients presented with significantly increased ONSD at baseline ($p < 0.001$); (2) the ideal cut-off ONSD value for IIH detection was 6.2 mm with a sensitivity and specificity of 87.5% and 100%, respectively; (3) statistically significant reductions in ONSD ($p = 0.006$) and papillary elevation ($p = 0.006$) were observed in IIH patients 4 weeks following the initial LP, but no significant changes were observed one week following LP; (4) no notable changes in ophthalmic vessel hemodynamics were observed up to 4 weeks following LP; (5) at baseline, significant positive correlations between opening CSF pressure and both mean papillary elevation ($p = 0.004$) and BMI ($p < 0.001$) were detected.

While IIH can be asymptomatic, the majority of patients afflicted by this disorder present with typical and/or atypical signs and symptoms that may include headaches, pulsatile tinnitus, papilledema, sixth cranial nerve paresis, transient visual obscuration, and visual loss [4]. In the current study, all enrolled IIH patients suffered a frontal, diffuse throbbing headache that was particularly severe during the morning hours and worsened when leaning forward or straining. Initially, the headache was paroxysmal then became continuous. Some of our patients also experienced associating nausea, photophobia, and phonophobia; all of which coincide with reports from previously conducted studies [18–20]. Also consistent with previous reports was the fact that all of our IIH patients had visual complaints (either foggy vision or diplopia) and papilledema (grades I–IV) that was secondary to elevated ICP [1,21].

Orbital sonographic assessments in enrolled participants revealed a significant difference in ONSD for IIH patient and controls, with the IIH cohort exhibiting notable ONSD increase. This observation was anticipated considering that the optic nerve sheath is sensitive to pressure fluctuations within the intracranial cavity; on account of its connection to the dura matter surrounding the brain [22]. Our
observations were concordant with previous investigations in neurocritical care patients [6,23] as well as reports from studies conducting ocular ultrasonography in IIH patients [5,24,25]. Based on our observations and previously reported findings, ultrasound-based assessment of the eye could be a valuable non-invasive method of detecting elevated ICP [23].

To date, a unified cut-off ONSD value for detecting elevated ICP has not been established. Earlier studies reported cut-off values ranging from less than 5 mm and up to 5.8 mm, with varying sensitivities and specificities [6,22,24,26–28]. According to our analyses, the identified cut-off was 6.2 mm with 87.5% sensitivity and 100% specificity. While del Saz-Saucedo et al. [25] reported a very similar cut-off in their diagnostic phases I and II validity study (6.3 mm); these values are notably higher than previous reports. The variability in reported cut-offs is likely an outcome of the divergent designs for the different studies. These include differences in subject selection, methods of assessing ICP, imaging modalities employed to measure ONSD, and the lower limit employed to diagnose ICP. The possibility of ethnic variations should also be considered as a potential cause of variability; different cut-offs were reported from studies conducted in Germany [29], Pakistan [30], Malawi [31], Iran [28], and China [32]. Given the variability in the scientific literature regarding the cut-off ONSD value for detecting ICP, additional investigations—including meta-analyses—are required to establish a unified definition for normal and abnormal ONSD.

In contrast to ONSD, no significant difference in OND was observed in IIH patients. This observation indicates a lack of association between fluctuations in ICP and the measure of the OND; an observation that is consistent with previous reports [5,6,24,25]. This is a likely consequence of the anatomy of the optic nerve and sheath; the optic nerve is surrounded by meninges and CSF, and ONSD enlargement in patients with elevated ICP is expected due to an increase in CSF pressure as opposed to an increase in OND [24].

IIH patients that participated in our investigation were sonographically reassessed 1 and 4 weeks following the LP. Statistically significant postpunctual changes were only identified at week 4; CSF pressure, ONSD, and papillary elevation were all significantly reduced. The lack of significant changes at week 1 indicates that 1 week may be too short a time interval to objectively assess treatment response using orbital sonography. Similar results were reported by Lochner et al. [33], where the authors concluded that improvements in ONSD and papillary elevation following LP were delayed. However, Bäuerle et al. [24] and del Saz-Saucedo et al. [25] were able to detect improvements in ONSD—but not papillary elevation—within 24 h of the LP. These contrasting reports may be a consequence of differences in disease management across different centers as well as variances in optic nerve sheath dynamics at different stages of the disease (acute vs. chronic). Furthermore, compartmentation of the subarachnoid space surrounding the optic nerve could potentially lead to reduced CSF circulation along the optic nerve in IIH patients, and this could in turn explain why patients can exhibit variable responses [34,35].

Potential changes to ophthalmic vessel color Doppler indices in IIH patients were investigated in the current study. It should be noted that the effect of elevated ICP on ophthalmic vessel parameters is currently unclear as a result of conflicting reports in the current literature. In our study, Baseline color Doppler indices (PSV, EDV, and PI) of the ophthalmic vessels were comparable between IIH patients and controls and the changes observed during the follow-up visits in the patients were insignificant. These results indicated that elevations in CSF pressure did not affect OA and OV hemodynamics and that ophthalmic vessels may accommodate gradual and progressive elevations in ICP, a conclusion that is supported by investigations from Zweifel et al. and Tarzamni et al. [8,9]. In contrast, Karami et al. [36] demonstrated significant elevations in transorbital Doppler parameters in IHP patients, and Gura et al. [37] identified a significant correlation between PI and invasive ICP measurements. The contradictory reports indicate a need for additional investigations to conclusively identify the effects of elevated ICP on ophthalmic vessel hemodynamics.

We were unable to identify a significant correlation between opening CSF pressure and ONSD for our IIH cohort. Our observation was consistent with previous investigations that specifically included IIH patients [5,24,38]. It should be noted that a correlation between these two parameters was identified in investigations involving patients with acute rise in ICP (neurocritical patients) [22,39,40]. We noted a significant correlation between opening CSF pressure and optic disc elevation which is consistent with previous TOS [25] and laser scanning tomography [41] studies on IIH patients. However, The CSF opening pressure was not always correlated with the mean degree of optic disc elevation even in the recently diagnosed patients in another report [42]. Furthermore, a significant positive correlation between CSF opening pressure and BMI was documented which is in accordance with earlier reports [24,33]. This correlation emphasizes the role of obesity in the pathogenesis of IIH and the crucial importance of weight reduction to treat IIH [43].

There are several limitations to the current study that should be addressed. Only a limited number of IIH patients were enrolled, and this was in part due to the rare nature of this disorder. Given the progressive nature of the disease, more frequent and longer-term assessment could provide additional information regarding changes to ophthalmic vessel Doppler indices in IIH patients. The variability of data for IIH patients
indicates a need for additional studies with larger patient pools, longer follow-up periods, and shorter intervals for reassessment. Moreover, assessment of ONSD with ultrasound is operator dependent; therefore the availability of trained personnel is mandatory.

Conclusion

Based on our observations, reflection of ICP changes on ONSD and papillary elevation made their measurement, using TOS, valuable non-invasive adjunct method to detect and monitor elevated ICP in IIH. Nevertheless, the disease insignificantly influenced ophthalmic vessels hemodynamics. We recommend the employment of this technique to follow-up ICP changes at least 1 month following treatment initiation. As the BMI was significantly correlated with CSF pressure, reduction of such modifiable risk factor in IIH patients might help in reduction of ICP.

Acknowledgments

The authors thank the members of the Cairo University Neurosonography Unit (CUNU) for their help in data collection.

Declaration of interest

None

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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