Diagnostic Value of Orbital Ultrasound and Orbital Magnetic Resonance Imaging in Idiopathic Intracranial Hypertension

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Abstract

Background: The optic nerve sheath is anatomically continuous with the dura mater and has a trabeculated arachnoid space through which cerebrospinal fluid (CSF) slowly percolates. Optic nerve sheath diameter (ONSD) measurements may help to estimate the degree of intracranial hypertension in patients with papilledema.

Objectives: To evaluate the usefulness of orbital ultrasonography (OUS) and orbital MRI in the assessment of cerebrospinal fluid pressure elevation in patients with idiopathic intracranial hypertension.

Methods: Twenty female subjects with IIH and 20 normal controls age and sex matched were included. Measurements of ONSD were done using OUS. The operator was blinded to the clinical background or data. Two readings were recorded in each eye and an average was calculated. MRI brain and orbit was also performed and optic sheath/optic nerve (OS-ON) ratio was calculated.

Results: The ONSD was higher in patients than controls when measured by OUS on both right and left sides (p=0.007 and <0.001 respectively). No correlation existed between the ONSD measured by OUS and CSF pressure. The most significant abnormalities on orbital MRI were increased OS-ON ratio >2.5 and empty sella in 80%, followed by small cortical veins and slit like ventricles in 70%.

Conclusion: ONSD measurements via OUS and OS-ON ratio via orbital MRI can reflect elevation of ICP in IIH patients, but cannot replace LP. No significant relation between the abnormalities detected by MRI Brain and orbit and the ONSD by OUS, opening pressure, or the field of vision.

Key Words: Idiopathic intracranial hypertension – Optic nerve sheath diameter – Orbital ultrasound – Orbital MRI.

Introduction

IDIOPATHIC intracranial hypertension (IIH) is a neurological disorder characterized by increased pressure around the brain; intracranial pressure (ICP), in the absence of a tumor or other diseases, and is associated with swelling of the optic discs [1].

The free communication between the intracranial subarachnoid space and the subarachnoid space surrounding the optic nerve allows the transmission of cerebrospinal fluid (CSF) pressure between those two compartments, thus elevated CSF pressure is conveyed to the optic nerve sheath resulting in its distension [2].

The measurement of CSF pressure is based on invasive techniques; however, several maneuvers have been utilized to indirectly assess its elevation, including measurements of the optic disc head elevation with optical coherence tomography (OCT) [3]; optic nerve sheath diameter (ONSD) via orbital ultrasonography [2] and optic sheath-optic nerve (OS-ON) diameter ratio using orbital MRI [4,5].

This work evaluates the efficacy of orbital ultrasonography and orbital MRI in the detection of CSF pressure elevation in patients with IIH.

Subjects and Methods

This was a case control study including 20 female patients with IIH according to the established diagnostic criteria [6] and 20 control, age-matched female volunteers as a control group. The mean age of the patients and the control subjects did not differ (29±4.9 years and 28.7±7.1 years respectively; p>0.05), whereas the mean body mass index (BMI) was higher in the patients group (35.6±4.6) compared with the control subjects (23.1±3.1) (p<0.001). Patients were recruited from Neurology Outpatient Clinic, Cairo University.
Hospitals, during the period from April 2012 to April 2013. Ethical approval was obtained from Medical Research Ethical Committee, Cairo University and informed patient consents were received for this study.

Lumbar puncture (LP) was done for all patients and the opening CSF pressure was measured after patients’ assessment by Orbital ultrasonography (OUS) and Orbital MRI. Any patient whose CSF pressure was less than 25cm was to be excluded from the study, but all our patients had an opening CSF pressure of \( \geq 25 \)cm.

The field of vision for patients was assessed using automated perimetry. The field changes were graded from 0 to IV according to Wall and George [7] (Table 1).

Table (1): Field of vision grading using automated perimetry [7].

<table>
<thead>
<tr>
<th>Normal (grade 0)</th>
<th>Normal visual field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild damage (grade I)</td>
<td>Enlargement of the blind spot</td>
</tr>
<tr>
<td>Moderate damage (grade II)</td>
<td>Mild generalized depression of retinal sensitivity</td>
</tr>
<tr>
<td>Severe damage (grade III)</td>
<td>Nasal or infero nasal field defect</td>
</tr>
<tr>
<td>Advanced damage (grade IV)</td>
<td>Moderate generalized depression of retinal sensitivity</td>
</tr>
</tbody>
</table>

Orbital ultrasonography:

All study subjects (40 subjects with 80 eyes) had their optic nerve sheath diameters (ONSD) measured using B-mode-transmit frequency 10 MHz, mechanical index (MI) = 0.23, single focal zone at 2.5cm, band width 74dB; using “Phillips HDI 5000” ultrasound equipment. The examination was carried out in the Neurosonology Unit, Neurology Department, Cairo University. The operator (certified from European Society of Neurosonology and Cerebral Haemodynamic) was blinded to the subjects, whether patients or controls.

The patient was put in the supine position with the eyes closed. The transducer was placed temporally on the upper eyelid, with the examiner’s hand resting on the orbital margin to minimize pressure on the globe. The optic nerve was visualized as a hypoechogenic structure beyond the globe surrounded by hyperechogenic subarachnoid space and hypoechogenic dura mater in the horizontal scanning plane. The measurements of optic nerve sheath diameter (OSND) were taken in a position of 3mm behind the posterior edge of the globe in a horizontal plane (Fig. 1-A,B). Two readings were recorded for each eye and an average measure was calculated.

Fig. (1-A,B): Female patient, 45 years with with measurement of optic nerve sheath diameter using ultrasound: The optic nerve sheath is demonstrated as a thin bilateral hyperechogenic line (arrows) surrounding the hypoechogetic optic nerve. The diameter is calculated by the distance of the two cursors (X) measured 3mm posterior to the posterior border of the globe.
MRI brain and orbit:

All examinations were performed in Radiology Department, Faculty of Medicine, Cairo University with a 1.5 T MR system (Gyroscan Philips) with an 8-channel head coil using array spatial sensitivity encoding technique parallel acquisition. Our standard brain MRI protocol included whole-brain sagittal T1, axial T2, FLAIR, and spin-echo T1 sequences. High-resolution orbit sequences included fast spin-echo axial T2, axial T1, axial T1-fat suppression and coronal T2 sequences. The parameters were as follows: 256x192 matrix, 16-cm field of view, 3mm slice thickness, and 0.5mm interslice gap. The MRI scans of the brain were assessed for the presence or absence of parenchymal abnormalities, masses, and dural sinus thrombosis. The ventricles, sulci, and basal cisterns were visually assessed for signs of effacement or enlargement. The presence of partial or complete empty sella was recorded as well as the assessment of the cortical veins [8].

MRI scans of the orbits were assessed for abnormalities of the globe, optic nerve, extraocular muscles, and intracanal abnormalities. The OS-ON ratio was measured using the outer diameter of the subarachnoid space and the nerve at the point of maximum OS distension, as depicted from the fat-saturated T2-weighted images (normal OS-ON ratio was <2.5) [9].

Statistical methods:

SPSS version 15 statistical package was used. Data was summarized using range, mean and standard deviation for quantitative variables, and number, and percentage for qualitative variables. Comparisons between two groups were done using Chi Square test for quantitative variables, and Mann Whitney for qualitative variables. Pearson correlations were done to test for linear relations between quantitative variables. Significant level was considered at \( p \)-value \( \leq 0.05 \). A cut off value for OSND, for the prediction of high ICP, was calculated, and the sensitivity and specificity tests were done using cross tabulation, based on the presence or absence of papilledema together with enlargement of the blind spot on automated perimetry.

Results

Demographic, Clinical and Automated Perimetry Data of Study Subjects:

In our patients, the mean CSF opening pressure was 389\( \pm 54 \)mm H\(_2\)O ranging from 320 to 490mm H\(_2\)O. Papilledma grades and degree of automated perimetry affection in IHH patients are illustrated in Table (2).

Table (2): Frequency of grades of papilledema and degree of automated perimetry impairment in patients.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Visual Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 0</td>
<td>Normal visual field</td>
</tr>
<tr>
<td>Grade I</td>
<td>Enlargement of the blind spot</td>
</tr>
<tr>
<td>Grade II</td>
<td>Mild generalized depression of retinal sensitivity</td>
</tr>
<tr>
<td>Grade III</td>
<td>Nasal or infero nasal field defect</td>
</tr>
<tr>
<td>Grade IV</td>
<td>Moderate generalized depression of retinal sensitivity</td>
</tr>
<tr>
<td></td>
<td>Central field defect or large paracentral defect</td>
</tr>
<tr>
<td></td>
<td>Marked generalized depression of retinal sensitivity</td>
</tr>
<tr>
<td></td>
<td>Tubular field.</td>
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</table>

Orbital ultrasonography findings:

The ONSD in IHH patients ranged from 5-8mm on the right side and 5.8-8.5mm on the left side, and in control subjects the right ONSD was 4.3-6.8mm and the left was 4.1-6.3mm. Compared with controls, the mean ONSD was significantly higher among patients with IHH on either side; where the right side was 6.2\( \pm 0.7 \)mm vs. 5.3\( \pm 0.6 \)mm (\( p=0.007 \)), and the left side was 6.7\( \pm 0.7 \)mm vs. 5.4\( \pm 0.5 \)mm (\( p<0.001 \)) (Fig. 2-A,B). However, no correlation existed between the right or left ONSD measured by OUS and the CSF opening pressure (\( r=0.574, p=0.083; r=0.08, p=0.80 \) respectively).

Orbital ultrasound sensitivity and specificity:

An ONSD cut off value of 5.8mm, above which ICP \( \geq 250 \)cm is expected, was yielded based on the sensitivity and specificity tests which showed a sensitivity of 75% for this value and a specificity of 90%.

MRI brain and orbit:

Sixteen patients showed an OS-ON ratio of >2.5. Findings are illustrated in Table (3) and Fig. (3-A,B).
Fig. (2): (A) Right & (B) Left ONSD in IIH patients compared with controls using orbital ultrasound.

Table (3): MRI Brain and Orbit findings in IIH patients.

<table>
<thead>
<tr>
<th>MRI finding brain and orbit</th>
<th>Patients (No. = 20)</th>
<th>Controls (No. = 20)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased OS-ON ratio &gt;2.5</td>
<td>16 (80)</td>
<td>2 (10)</td>
<td>0.005 *</td>
</tr>
<tr>
<td>Empty sella</td>
<td>16 (80)</td>
<td>2 (10)</td>
<td>0.006 *</td>
</tr>
<tr>
<td>Small cortical vein and slit like ventricle</td>
<td>14 (70)</td>
<td>0 (0)</td>
<td>0.003 *</td>
</tr>
<tr>
<td>Optic nerve tortuosity</td>
<td>8 (40)</td>
<td>1 (5)</td>
<td>0.167</td>
</tr>
<tr>
<td>Flattening of posterior sclera</td>
<td>6 (30)</td>
<td>0 (0)</td>
<td>0.039 *</td>
</tr>
</tbody>
</table>

Fig. (3): (A) Female, 51 years old showing flattening of posterior sclera (straight white arrow), optic nerve tortuosity (Tortuous arrow). (B): Optic nerve tortuosity (Tortuous arrow). (C): Increased OS-ON ratio (straight black arrow), empty sella (open arrow). (D): Increased OS-ON ratio (straight black arrow).
There was no significant relation between the presence of abnormal findings in MRI brain and orbit and between the CSF opening pressure, the ONSD in 40 eyes, or the field of vision grades ($p>0.05$).

**Discussion**

The continuity of the dura mater around the brain, spinal cord and orbital nerve allows free communication and the transmission of CSF pressure in the subarachnoid space evenly. Thus, in cases of elevation of ICP, the subarachnoid space around the optic nerve gets distended and can reflect the extent of increased pressure.

Accurate estimation of CSF pressure is applied via invasive methods. Considering this anatomical fact can help us to assess the CSF pressure elevation via indirect non invasive techniques which can measure the degree of expansion of the dura around the optic nerve or in other words the ONSD. An emerging but established technique is orbital ultrasonography.

In our study we detected a higher cut off value for ONSD of 5.8mm for increased ICP $\geq 25$cm, with a sensitivity of 75% and specificity of 90%. This goes in accordance with Soldatos et al., [10] who found that the best cut-off value of ONSD for predicting elevated ICP was 5.7mm by using an intra-parenchymal catheter to directly measure ICP more than 20cm (sensitivity = 74.1% and specificity = 100%). The same cut off value was yielded by Geeraerts and colleagues [11] who reported an OSND of 5.8mm for an ICP $>20$cm with a sensitivity of 90% and a specificity of 92%. However, in a study by Bäuerle et al., [2] using a 9-3MHz linear array transducer, the mean ONSD of normal subjects was found to be 5.4±0.6mm with a range of 4.3-7.6mm. Studies on normal values found a relatively wide inter individual range of ONSD measurements [12]. Lower cut off values of 5mm and less were found in pediatric age group [12,13].

Our study confirms the findings of previous researchers that ONSD increases in patients with intracranial hypertension [14], however, there was no significant correlation between ONSD and CSF pressure measured by trans orbital ultrasonography. Although most study groups found a positive correlation between ONSD values and raised ICP [12,13,15,16], there are significant differences in the given standard and cut-off values for the ONSD [2]. In addition most of those studies investigated pediatric age group in the context of acute elevation of ICP e.g. following traumatic brain injury [16], or acute hydrocephalus [15]. There may be patho-logical or anatomical variations between conditions associated with acute ICP elevation and the steady chronic elevation of ICP in cases of IIH, which may impact the mechanics and biophysics of the region allowing for more adaptation of the dural orbital sheath in settings of chronic elevation of CSF compared to the acute distension of orbital sheath in acute settings. Also, in the chronic settings fibrosis of the dural sheath may contribute to a smaller diameter not corresponding to the actual CSF pressure. Another possible explanation of this contradictory data may lie in the utilization of relatively incongruent methods for ICP measurement. In our study we used the least invasive method via LP, whereas other studies used more invasive methods via direct intraparenchymal catheter [12], which was more feasible in the setting of intensive care units rather than performing the measurement as an outpatient procedure.

Bauerle et al., [2] reported that there was a great advantage in orbital ultrasonography compared to fundoscopy for re evaluation of optic disc to account for changes behind the level of optic disc can be visualized by orbital ultrasonography due to anatomical reasons that the anterior segment of ONSD responds quickly to changes of CSF pressure.

The advance of MR imaging paradigm in IIH converted it from simply a routine tool used to rule out other etiologies to detecting signs that may indicate IIH itself, including small cortical veins and slit like ventricles; empty sella; flattening in posterior sclera; tortuosity and elongation of optic nerve; and distention in periopctic subarachnoid space with an OS-ON ratio $>2.5$. All those findings were present in our IIH patients with varying degrees, which go in accordance with Brodsky and Vaphiades [17] who reported the same findings and were able to predict the presence of elevated intracranial pressure in 90% of cases with IIH. They also concluded that posterior globe flattening was the only sign that can strongly suggest the diagnosis of IIH. Another study was done by Watenabe et al., [18] who found that dilated optic sheath was associated with increased ICP in twelve patients with chronic subdural haematomas.

The most consistent abnormalities were empty sella and the increase of OS-ON ratio $>2.5$ in 8/10. The latter agrees with Lingawi et al., [19] who suggested that a ratio $>2.5$ is highly suggestive of the diagnosis of IIH.

In the current study, there was no relation between an OS-ON ratio $>2.5$ and the CSF opening
pressure, which agrees with Rohr et al., [20] who did not find significant correlation between CSF pressure and optic nerve sheath diameter in patient with secondary IIH.

This study could not detect a significant relation between ONSD by orbital ultrasonography and OS-ON ratio by orbital MRI, which disagrees with Sceinborn et al., [21] who found acceptable agreement between MRI orbit and orbital ultrasonography in the assessment of optic nerve sheath diameter, but they performed this study on normal adult volunteers. A suggestion to explain the mismatch between orbital ultrasonography and MRI findings in our study can be the inability to perform both investigations on the same day.

Conclusion:
ONSD measurements via OUS and OS-ON ratio via orbital MRI can reflect elevation of ICP in IIH patients, but cannot replace LP. However, they may be useful to monitor clinical evolution and treatment efficacy in patients with IIH. Orbital ultrasonography and MRI have their own advantages and disadvantages; however, cost effectiveness, availability, and being a bedside test render the ultrasonographic approach more appealing as a non invasive marker of ICP.

References