Sonographic Evaluation of Optic Nerve Diameter in Children With Raised Intracranial Pressure

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Objective. The optic nerve is part of the central nervous system, and a rise in intracranial pressure (ICP) can directly affect the perioptic nerve space, leading to an increase in nerve diameter. Transorbital sonography is a safe and easy-to-perform method to measure optic nerve diameter for rapid diagnosis of increased ICP.

Methods. The optic nerve diameter was measured in 3 individual occasions by transorbital sonography in the transverse view, 3 mm posterior to the papilla in both eyes, and the mean was calculated. Two groups were examined: a control group of children with normal ICP and normal ophthalmologic and optic nerve examination results and a case group with increased ICP as determined by an alternative method.

Results. The sample consisted of 156 children, of which 78 (50%) were in the case group and 78 (50%) were in the control group. Eighty-four subjects (53.7%) were male, and 72 (46.1%) were female. The mean ± SD ages were 6.9 ± 5.6 years in the case group and 6.8 ± 5.5 years in the control group. The mean optic nerve diameters were 5.6 ± 0.6 mm (range, 4.55 ± 0.7 to 7.6 ± 0.6 mm) in the case group and 3.3 ± 0.6 mm (range, 2 ± 0.6 to 4.35 ± 0.6 mm) in the control group. The difference in the means was significant at \(P < .001\).

Conclusions. Optic nerve diameter, measured by transorbital sonography, was significantly greater in pediatric patients with increased ICP compared with a control group. Transorbital sonography can be used to identify pediatric patients with raised ICP. Key words: intracranial pressure; optic nerve diameter; transorbital sonography.

Raised intracranial pressure (RICP) is a neurologic emergency with several etiologies such as brain tumors, obstructive hydrocephaly, posttraumatic intracranial hemorrhage, meningoencephalitis, and toxic encephalitis.\(^1,2\) Although evaluation in critically ill patients may require complicated procedures, there is a need for rapid diagnosis and treatment of these patients along with frequent reevaluation of RICP.\(^3-5\) The most reliable method for measurement of intraventricular, brain parenchymal, subdural, and epidural pressure is via a transducer or intraventricular catheter that is introduced directly through a craniotomy. This method is invasive and has the risk of intracranial infection. The other (noninvasive) modality is computed tomography (CT), in which RICP is shown by narrowing of ventricles and cisterns and fading of the brain sulci. Computed
tomography is also able to show underlying abnormalities, such as mass lesions and hemorrhage. This method, however, is difficult to perform in critically ill patients in intensive care units. It is also expensive and has the risk of exposure to radiation. Other noninvasive methods, such as fontanometry, Doppler sonography of the brain, and evoked potential studies, need specialized equipment and experienced examiners. Moreover, they can only show RICP in late stages; therefore, they may increase the risk of severe side effects and poor prognosis in these patients.3,6

Anatomically, the optic nerve is a part of the central nervous system, which is surrounded by the dura mater, the subarachnoidal space, and cerebrospinal fluid; therefore, any change in ICP affects the peri optic nerve sheath, changing its diameter. After closure of the fontanelles, the optic nerve diameter and its sheath can be easily assessed by transorbital sonography.3,7

Clinical studies on the optic nerve in cadavers and patients with RICP show changes in the optic nerve diameter, especially in the anterior segment (the posterior 3 mm of the papilla);6 transorbital sonography is a noninvasive, safe, and easy-to-perform modality to assess optic nerve anatomic characteristics in these patients. It should also be noted that, with RICP, the optic nerve diameter increases initially and then leads to papilledema, so transorbital sonography is able to show the increased ICP earlier than ophthalmoscopy.1,3,5,7,9,10

Materials and Methods

Seventy-eight children (<18 years) with normal ICP were recruited as the control group. Another group of 78 children (<18 years) with RICP, admitted to the neurology and neurosurgery departments and the intensive care unit of Tehran Children Medical Center, were recruited. The procedure was described to each participant and their relatives, and written consent to the procedure was obtained.

Inclusion criteria for the study were (1) the presence of clinical symptoms and signs of RICP, including nausea, vomiting, mental status impairment (after ruling out of metabolic, medication, and seizure etiologies), and symptoms of brain herniation such as secondary midbrain syndrome and papilledema on ophthalmoscopy; and (2) the presence of indicative signs of increased ICP on CT or sonography of the brain (in <1-year-old infants), including narrowing of ventricles and cisterns, fading of the brain sulci, and the presence of the main etiologic abnormalities of RICP accompanied by shifting and herniation of the brain through the falx or tentorium. Exclusion criteria for the study were optic nerve diseases such as optic neuritis, meningioma, and gliomas.

Transorbital sonography with a 7.5-MHz linear probe and an Aloka SSD 1700 sonography system (Aloka Co, Ltd, Tokyo, Japan) was performed on all selected cases. The probe was placed on the eyelids, and, if cooperative, the patients were asked to keep their eyes in the midline position. This provided an axial view of the orbit and optic nerve on transorbital sonography. It should be noted that we avoided any distortion of ultrasound waves by the eye lens and, therefore, inaccurate measurements by placing the probe on the superior aspect of closed eyelids. The optic nerve diameter was measured 3 mm posterior to the papillae. Three individual measurements of the optic nerve diameter were made on each eye, and the mean of these values was used as the optic nerve diameter for the statistical analysis.11

The optic nerve appeared as a hypoechoic and tubular structure in the echogenic retrobulbar fat perpendicular posterior to the retina, choroids, and sclera of the globe (Figure 1).5,8

**Figure 1.** Transorbital sonography in an 8-year-old girl with normal ICP. The optic nerve appears as a hypoechoic structure (arrow) in the echogenic retrobulbar fat. We measured the optic nerve diameter 3 mm posterior to the papilla, as shown by the arrow. In this case, the measured diameter is 2.3 mm.
Results

This case-control study was performed on 156 children (72 female and 84 male) younger than 18 years, equally divided into case and control groups. The case group consisted of 46 boys (59%) and 32 girls (41%), and the control group consisted of 38 boys (48.7%) and 40 girls (51.2%). The mean ± SD age in the case group was 6.9 ± 5.6 years (range, 2 weeks to 17 years), and that in the control group was 6.8 ± 5.5 years (range, 5 weeks to 16.5 years); age was not significantly different between the 2 groups (t = 0.166; P = .868). The etiologic factors for RICP were head trauma and intracranial hemorrhage in 30 cases (38%), brain tumors in 25 (32%), intracranial infections in 10 (12.8%), hydrocephalus in 9 (11.5%), encephalopathy in 2 (2.6%), and simultaneous brain tumors and hydrocephalus in 2 cases (2.6%).

Fifty-one patients (65%) underwent CT scanning as the single modality to diagnose the etiology of RICP. Ophthalmoscopy was performed in 5 patients (6.4%); CT and ophthalmoscopy were performed in 17 (21.8%); CT and brain sonography were performed in 3 (3.8%); and simultaneous CT, brain sonography, and ophthalmoscopy were performed in 2 (2.6%).

The difference between the 2 optic nerve diameters in the fellow eyes was maximally 0.2 mm in both the case and control groups, seen in 35 (40%) individuals in the case group and 28 (35.8%) in the control group. The difference was not significant.

The maximal measured optic nerve diameter ± SD in the case group was 7.6 ± 0.7 mm; the minimal diameter was 4.55 ± 0.7 mm; and the mean was 5.6 ± 0.6 mm. In the control group, the maximal diameter of the optic nerve was 4.35 ± 0.6 mm; the minimal diameter was 2 ± 0.6 mm; and the mean was 3.3 ± 0.6 mm. The difference between the optic nerve diameters in these 2 groups was statistically significant (t = 20.2; P < .001; Table 1).

To compare the effect of age on the sonographic measurements of nerve diameters in the case and control groups, we divided them into 2 groups: younger and older than 4 years. In the symptomatic group, the mean ± SD optic nerve diameters were 5.5 ± 0.6 mm in patients younger than 4 years (34 patients) and 5.6 ± 0.7 mm in those older than 4 years (44 patients); this difference was not statistically significant (t = 0.66; P = .829). In the control group, the mean diameters of the optic nerve were 3 ± 0.6 mm (range, 2–4 mm) in subjects younger than 4 years (32 subjects) and 3.6 ± 0.4 mm (range, 2.8–4.35 mm) in those older than 4 years (46 patients); this difference was significant (t = 5.30; P < .001; Table 2).

Discussion

In this study, transorbital sonographic measurement of the optic nerve diameter was shown to correlate with RICP; there was a statistically significant difference between the optic nerve diameters in children with RICP and those in the control group. There was no overlap between the minimal value of the symptomatic group’s optic nerve diameter (4.55 mm) and the maximal value of the control group’s optic nerve diameter (4.35 mm). The optic nerve diameter has a certain size range in the healthy pediatric population. Because of the relationship between the nerve sheath and the cerebrospinal fluid, the diameter of this nerve changes with alteration of the ICP. This change in size can be detected by transorbital sonography, as shown in this study (Figures 2 and 3).

Because development of the optic nerve and increases in its diameter continue until 4 years of age, we also examined the relationship between age and optic nerve diameter. We found no significant difference between the optic nerve diameter in children younger and

Table 1. Comparison Between Mean Optic Nerve Diameters in Case and Control Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Diameter, mm</th>
<th>SD, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>78</td>
<td>5.63</td>
<td>0.69</td>
</tr>
<tr>
<td>Control</td>
<td>78</td>
<td>3.34</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Table 2. Comparison Between Optic Nerve Diameters in Different Age Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Age, y</th>
<th>n</th>
<th>Diameter, mm</th>
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</thead>
<tbody>
<tr>
<td>Case</td>
<td>&lt;4</td>
<td>34</td>
<td>5.55</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>44</td>
<td>5.68</td>
<td>0.71</td>
</tr>
<tr>
<td>Control</td>
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<td>32</td>
<td>3.00</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>46</td>
<td>3.60</td>
<td>0.42</td>
</tr>
</tbody>
</table>

older than 4 years in the symptomatic group, whereas the difference was statistically significant in the control group. This is probably due to the expansile structure of the optic nerve sheath and its anatomic characteristics.7,13,14

Transorbital sonography in conjunction with transcranial sonography could be the first-line modality in diagnosis of RICP for patients younger than 1.5 years because of the ability to show the intracranial structures so that any suspected abnormalities inside the cranial cavity also could be investigated (Figure 2). Therefore, transorbital sonography may be used as a reliable alternative to or in conjunction with other diagnostic modalities for RICP. Transorbital sonography also could be a good choice in patients who are in an active seizure state, patients with multiple trauma, and uncooperative patients, in whom the RICP is a concern and the use of modalities such as CT and magnetic resonance imaging is both time-consuming and difficult to perform.15-18

Figure 2. A, Transcranial sonography in a 3-month-old infant with choroid plexus papilloma (arrow) in the midline. B, Transcranial sonography shows severe hydrocephaly and increased right ventricle (RV) and left ventricle (LV) volume. C, Transorbital sonography in the same infant with a brain tumor and consequent RICP. Note the increase in optic nerve diameter (right optic nerve [R.O.N.] measured 4.5 mm).

Figure 3. Transorbital sonography in an 8-year-old boy with RICP due to septic meningitis. Note the marked increase in the optic nerve diameter (left optic nerve [L.O.N.] diameter measured 4.8 mm).
References


