Effect of intracranial pressure on the diameter of the optic nerve sheath

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Object. The subarachnoid space around the optic nerve in the orbit can be visualized using T2-weighted MR imaging with the fat-saturation pulse sequence. The optic nerve sheath (ONS) diameter can be estimated by measuring the outer diameter of the subarachnoid space. Dilated ONS is associated with idiopathic intracranial hypertension and hydrocephalus, and is believed to reflect increased intracranial pressure (ICP). The relationship between dilated ONS and ICP is unclear because of the difficulty in obtaining noninvasive measurements of ICP. The authors investigated the relationship between subdural pressure measured at the time of surgery and ONS diameter measured on MR images in patients with chronic subdural fluid collection.

Methods. Twelve patients underwent bur-hole craniostomy with continuous drainage for chronic subdural hematoma or hygroma in 2006. Orbital thin-slice fat-saturated MR images were obtained before and after surgery, and the ONS diameters were measured just behind the optic globe. Subdural pressure was measured using a manometer before opening of the dura mater.

Results. A significant correlation was found between the ONS diameter and the subdural pressure (correlation coefficient 0.879, p = 0.0036). The ONS diameter before surgery (6.1 ± 0.7 mm) was significantly reduced after surgery (4.8 ± 0.9 mm, p = 0.003; measurements are expressed as the mean ± standard deviation).

Conclusions. Increased ONS diameter measured on coronal orbital thin-slice fat-saturated T2-weighted MR images is a strong indicator of increased ICP, and helps to differentiate between passive subdural fluid collection due to brain atrophy and subdural hygroma with increased ICP. (DOI: 10.3171/JNS/2008/109/8/0255)

Key Words • chronic subdural hematoma • intracranial pressure • optic nerve sheath • subarachnoid space • subdural pressure

Increased ICP is an important indicator for surgical intervention to treat lesions that are causing mass effect. Lumbar puncture is a simple way to measure the ICP, but carries the risk of inducing brain herniation in patients with raised pressure. Several devices to measure ICP have been invented, but their use requires invasive procedures. Superior ophthalmic vein enlargement associated with diffuse cerebral swelling noted on high-resolution CT scans may be an indirect result of increased ICP. Dilation of the superior ophthalmic vein (especially by > 2.5 mm) detected on MR imaging and CSF flow and blood flows measured at the craniocervical junction by using MR imaging are also possible methods to detect increased ICP. However, ICP remains difficult to evaluate using only neuroimaging methods.

Dilation of the ONS may be associated with idiopathic intracranial hypertension or hydrocephalus, indicating increased ICP. The subarachnoid space around the ON in the orbit can be detected using T2-weighted MR imaging with the fat-saturation pulse sequence. This technique can differentiate CSF in the subarachnoid space around the ON from the surrounding fat tissue as high-intensity circles on the coronal images. The ONS diameter can be evaluated by measuring the outer diameter of the subarachnoid space.

In the present study we investigated the potential use of ONS diameter as a possible marker of ICP by using fat-saturated orbital MR imaging to measure the correlation between ICP and ONS diameter in patients with CSDH or hygroma.
Methods

Patient Population

This study included 12 patients, 9 men and 3 women between 21 and 90 years of age (mean age 73 years), who underwent bur-hole surgery with continuous drainage for CSDH or subdural hygroma in 2006. Patients in whom fine orbital MR images were not obtained because of motion artifacts, or with inaccurate measurement of subdural pressure because of glutinous fluid or leakage of fluid through the puncture site before measurement, were excluded. The MR imaging was performed in 12 patients within 24 hours before surgery and follow-up studies were obtained in 8 patients between 1 week and 4 months after surgery.

Evaluation With MR Imaging

Fat-saturated T2-weighted fast spin echo MR images of the orbit were obtained using a 1.5-T MR unit (GE Medical Systems) with TR 3500 msec, TE 100 msec, flip angle 90°, slice thickness 3.5 mm, slice gap 0.3 mm, matrix 320 × 224, field of view 16 × 16 cm, echo train length 12, and bandwidth 31.2 kHz. The ONS diameter was measured just behind the optic globe.

Subdural Pressure Measurement

Patients were positioned to locate the bur hole position at the highest point with 15° of head elevation. To prevent subdural fluid leakage through the puncture site, the dura mater was punctured using a 23-gauge needle and then the subdural pressure was measured. In patients with bilateral lesions, the thicker side was treated first, and the subdural pressure was measured in this side. After measurement of the subdural pressure, the dura mater was opened and the drainage tube was placed in the subdural space.

Statistical Analysis

The Spearman rank correlation was calculated to assess the correlation between ONS diameter and subdural pressure. The Student t-test was performed to compare the ONS diameter before and after surgery, and differences in the two-tailed t-test at probability values of less than 0.05 were considered to be significant. Measurements are expressed as the mean ± standard deviation.

Results

Table 1 summarizes the measurements of ONS diameter and subdural pressure. The mean ONS diameter in the 12 patients before surgery (6.1 ± 0.7 mm) was significantly decreased after surgery in 7 patients (4.8 ± 0.9 mm, p = 0.003). The ONS diameter could not be measured 1 week postsurgery because of collapse of the subarachnoid space in 1 patient. The association between the ONS diameter and the subdural pressure is shown in Fig. 1. The approximate curve is expressed as

\[ y = 0.00079x^3 - 0.03929x^2 + 0.64216x + 2.3062, \quad r^2 = 0.834 \]

There was a significant correlation between these variables (correlation coefficient 0.879, p = 0.0036).

Representative Case

This 75-year-old man (Case 5) was referred to our institute after a diagnosis of left CSDH. He had a history of minor head injury that had occurred 1 month before admission. Neurological examination revealed right hemiparesis without papilledema. Brain CT and MR imaging studies showed left CSDH. Orbital imaging showed the dilated ONS. The ONS diameter just behind the optic globe was 6 mm on the right and 6.1 mm on the left (Fig. 2A). He underwent bur hole craniostomy for CSDH. Subdural pressure before opening the dura mater was 21 cm

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**TABLE 1**

Summary of measurements of the ONS diameter and subdural pressure*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Side &amp; Type of Lesion</th>
<th>Initial Findings</th>
<th>Follow-Up Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diameter of ONS (mm)</td>
<td>Subdural Pressure (cm H₂O)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lt</td>
<td>Rt</td>
</tr>
<tr>
<td>1</td>
<td>79, F</td>
<td>bilat hygroma</td>
<td>5.2</td>
<td>5.7</td>
</tr>
<tr>
<td>2</td>
<td>85, F</td>
<td>lt CSDH</td>
<td>5.6</td>
<td>5.5</td>
</tr>
<tr>
<td>3</td>
<td>89, F</td>
<td>lt CSDH</td>
<td>5.7</td>
<td>5.9</td>
</tr>
<tr>
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<td>rt CSDH</td>
<td>5.4</td>
<td>5.7</td>
</tr>
<tr>
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<td>75, M</td>
<td>lt CSDH</td>
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<td>6.0</td>
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<tr>
<td>6†</td>
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<td>bilat hygroma</td>
<td>6.1</td>
<td>6.2</td>
</tr>
<tr>
<td>7</td>
<td>80, M</td>
<td>lt CSDH</td>
<td>5.2</td>
<td>6.5</td>
</tr>
<tr>
<td>8</td>
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<td>6.6</td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
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<td>7.1</td>
<td>6.7</td>
</tr>
<tr>
<td>12</td>
<td>90, M</td>
<td>rt CSDH</td>
<td>5.6</td>
<td>5.5</td>
</tr>
</tbody>
</table>

* Avg = average; NA = not available.
† Diameter could not be measured at 1 week postsurgery because the subarachnoid space had collapsed.
H2O. The dura was then opened and a drainage tube was placed in the subdural space for 1 day. His right hemiparesis resolved. Brain MR imaging performed 3 months later showed disappearance of the CSDH, and orbital MR imaging demonstrated decreased ONS diameter of 4.9 mm on the right and 4.3 mm on the left (Fig. 2B).

Discussion

In this study we found a significant correlation between the ONS diameter and the ICP, confirming the observations of dilated ONS in patients with increased ICP.4,5,12 The normal ONS diameters just behind and 4 mm posterior to the globe are 5.52 ± 1.11 mm and 5.2 ± 0.9 mm, respectively;10,16 are consistent through all eyeball positions; and are relatively stable in individuals.10,15 In our study, the ONS diameter was measured as 5.4–8 mm (mean 6.1 ± 0.7 mm) and subdural pressure as 9–30 cm H2O (mean 19 ± 8.2 cm H2O) before surgery. The diameter of the ONS decreased to 3–5.7 mm (mean 4.8 ± 0.9 mm) after full recovery from symptoms. We propose a normal limit of diameter just behind the eyeball of 5.8 mm, because the upper normal limit of ICP has been considered to be ~ 20 cm H2O, and this numerical value was applied to the aforementioned approximate curve. Therefore, an ONS diameter of > 6 mm indicates an abnormally high ICP of > 20 cm H2O.

Follow-up MR imaging performed 1 week after surgery in 3 patients clearly showed that the ONS diameters were reduced. Such a rapid change in the ONS diameter indicates an immediate reflection of changes in ICP. The ONS is reported to have sufficient elasticity to allow detectable dilation in response to a change in the ICP, which was confirmed by measuring the ONS diameter with serial B-mode ultrasonography scans during the intrathecal infusion test.6

Subdural pressure is well correlated with lumbar
Subdural pressure measured by subdural screw monitor insertions is correlated with ventricular fluid pressure in patients with head injuries. However, no correlation is known between ventricular and subdural pressure in patients with CSDH. The subdural and ventricular pressures may differ because CSDH is encapsulated by a membrane. The compliance of the membrane may cause a pressure gradient. Therefore, one of the limitations of this study is the measurement of the subdural pressure rather than the ventricular pressure.

The subarachnoid space of the ON is anatomically classified into the bulbar segment, intraorbital segment, and canalicular portion. These divisions are not uniform, and the subarachnoid space is distinct at the bulbar segment and canalicular portion. These divisions are not uniform, and the subarachnoid space is distinct at the bulbar segment in healthy individuals. The ONS diameter varies at different points of measurement, so the measuring point should be consistent. In addition, variable depiction of the ON, CSF, and ONS depending on the MR sequence should be consistent. In addition, variable depiction of the ON, CSF, and ONS depending on the MR sequence is also important.

Conclusions
Measurement of the ONS diameter on coronal orbital thin-slice fat-saturated T2-weighted MR images has the potential to indicate abnormally high ICP in patients with subdural hygroma, which is sometimes difficult to distinguish from brain atrophy. Further study is needed to clarify the differences depending on an individual’s, age, sex, and race, and to establish this method as an accurate indicator of ICP.

References