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Reports

Dynamic Change in Optic Nerve After Intracranial Pressure Reduction in Children

Advances in optical coherence tomography (OCT) have enabled researchers to obtain in vivo information regarding the lamina cribrosa (LC) in a noninvasive manner. We used swept-source OCT (SS-OCT) to investigate the dynamic changes in deep anterior optic nerve head (ONH) structures after surgical decompression for increased intracranial pressure (IICP) in pediatric patients.

After obtaining investigational review board approval, we enrolled consecutive patients with IICP who visited the Division of Pediatric Neurosurgery at Seoul National University Children's Hospital. The protocols of the Division of Pediatric Neurosurgery were followed for all patients. If the patients exhibited overt hydrocephalus, endoscopic fenestration of the third ventricle or entrapped ventricles was performed. For patients with an intraventricular brain tumor accompanied by hydrocephalus, extraventricular drainage was performed just before tumor resection in the operating theater. The preoperative intracranial pressure (ICP) was measured at the time of endoscope or drainage catheter insertion into the lateral ventricle by skilled neurosurgeons. The postoperative ICP was measured 3 to 7 days after the neurosurgical procedures using the external ventricular drain catheter (if it was maintained after surgery) or lumbar puncture (if it was clearly indicated for the evaluation of postoperative fever, chemical meningitis, or metastatic spread of tumor cells). All patients underwent complete ophthalmologic examinations, including visual acuity testing, slit-lamp examinations, intraocular pressure measurements using Goldmann applanation tonometry, color disc photography, red-free retinal nerve fiber layer photography and SS-OCT, before and after surgical decompression.

The SS-OCT (DRI-OCT-1 Atlantis, Topcon, Tokyo, Japan) scans were acquired for each patient using 6-mm five-line raster scans of ONH with 0.25-mm spacing between the cross lines. Visibility of the LC configuration on all scan images was restored by adaptive enhancement.

We marked a reference line that connected the 2 Bruch's membrane openings; this distance represented the transverse neural canal diameter. We defined the papillary vertical height as the distance from Bruch's membrane opening to the highest point on the internal limiting membrane and anterior LC depth as the distance from the reference line to the deepest point on the visible anterior LC surface. Measurements obtained from both vertical and horizontal scans were averaged, and the acquired value was considered as the parameter for each eye.

All 10 study patients were children with a mean age of 12.7±2.7 years. The mean preoperative and postoperative ICP values were 24.0±5.0 and 13.2±6.3 mmHg, respectively. Figure 1 demonstrates representative SS-OCT images obtained before and after surgery for a patient with IICP. Table S1 (available at www.aaojournal.org) shows the clinical characteristics for the 10 enrolled patients. Because of severe swelling in 4 eyes of 2 patients, LC could not be visualized despite imaging enhancement. Figure S2 (available at www.aaojournal.org) shows SS-OCT parameters obtained before and after neurosurgical decompression. The mean neural canal diameter decreased from 1858.03±232.04 μm before surgery to 1768.479±154.94 μm after surgery; this change was statistically significant ($P = 0.027$). Similarly, the mean papillary vertical height showed a significant decrease from 818.60±262.21 μm before surgery to 488.50±196.45 μm after surgery ($P < 0.001$). However, the mean anterior LC depth showed a significant increase from 276.07±111.51 μm before surgery to 428.57±133.15 μm after surgery ($P = 0.001$).

Previous studies reported structural changes in ONH according to changes in ICP. Using an experimental animal model, Morgan et al[1] showed that IICP anteriorly displaces ONH structures and LC. Furthermore, several studies using noninvasive imaging modalities such as OCT have evaluated ONH according to changes in ICP.[2,3] Kupersmith et al[2] reported that papilledema with IICP results in anterior bowing of the retinal pigment epithelium/Bruch's membrane layer at the neural canal opening. More recently, 1 group evaluated the correlation between quantitative measurements of the peripapillary retinal structures obtained using spectral-domain OCT and ICP measured using invasive methods.[3] The findings of anterior bowing of the retinal pigment epithelium/Bruch's membrane layer and increased papillary height in patients with IICP are comparable with our findings; however, some differences can be pointed out. First, compared with previous imaging studies, our study evaluated deep structures, including the position of LC. We used SS-OCT, which can visualize deep structures because of higher speed and higher penetration with a longer wavelength compared with spectral-domain OCT. Second, we confirmed a decrease in ICP after surgical decompression by direct measurement of ICP and compared papilledema before and after decompression rather than performing cross-sectional imaging.

Not only intraocular pressure, but also low cerebrospinal fluid (CSF) pressure plays an important role in the pathogenesis of glaucoma.[4] Although the forces exerted on the ONH in patients with IICP differ from those in patients with glaucoma, our findings provide insights on the association between ICP changes and dynamic changes in deep ONH structures.

As anticipated, decreasing ICP resulted in relative posterior movement of LC accompanied by trans-LC pressure difference normalization. The posterior displacement of LC may be explained by trans-LC pressure difference normalization after a decrease in ICP achieved by neurosurgical decompression. In addition, the tissue swelling resolves after the pressure is decreased.

Our study has some limitations. First, the sample size was relatively small; therefore, we could not determine a significant correlation between morphologic changes in ONH and ICP and/or trans-LC pressure difference changes. Further investigations with a large sample will facilitate a better understanding of this issue. Second, although we used SS-OCT, the overlying swelling limited penetration of the light source. Therefore, in-depth imaging may not be accurate in some patients because the Bruch's membrane opening borders are obscured. Third, we were unaware of the orbital CSF pressure. Recently, Hou et al[5] investigated the relationship between intracranial and orbital pressure using a dog

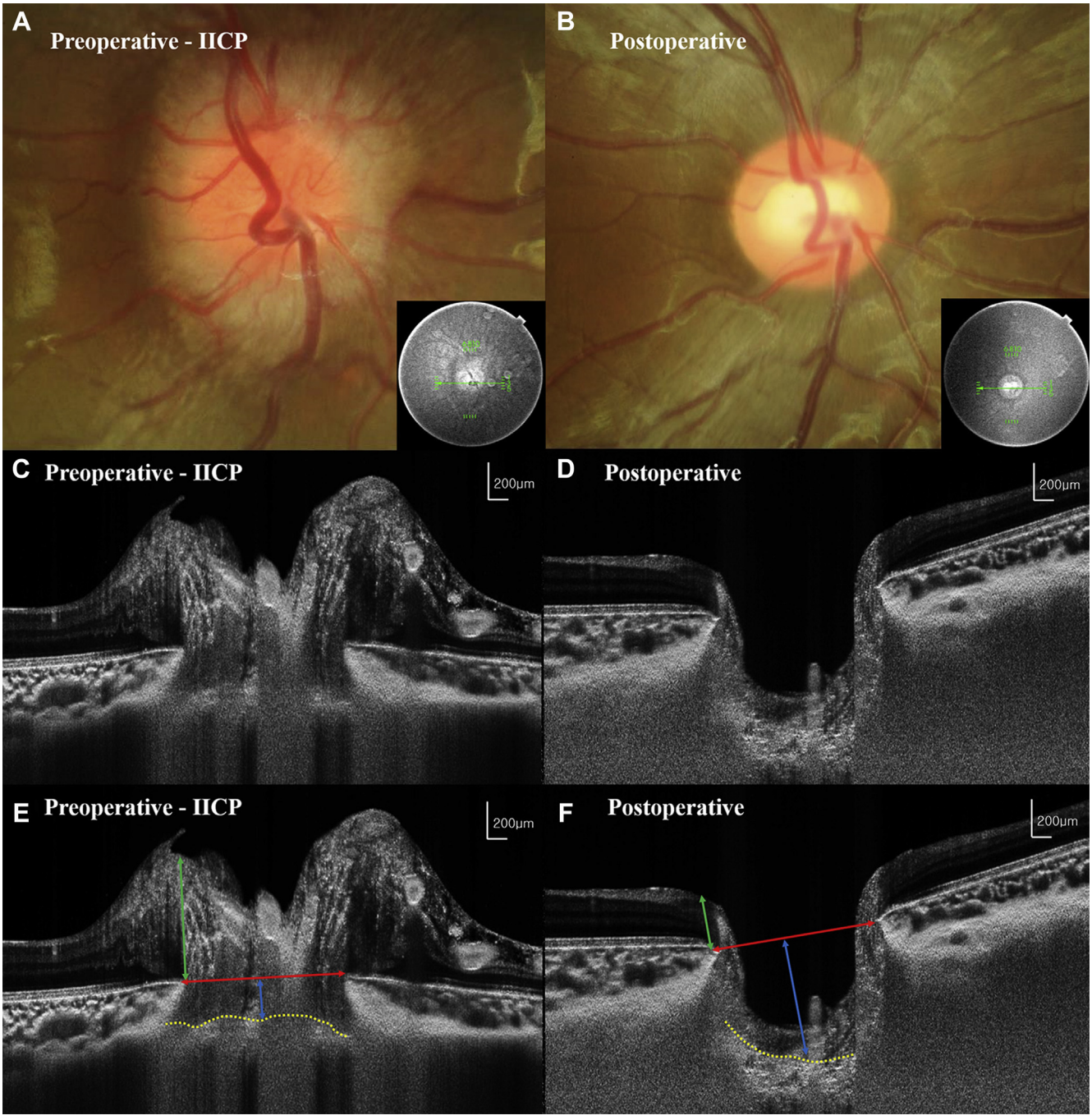

Figure 1. Swept-source optical coherence tomography (SS-OCT) images (horizontal scan) of optic nerve head structures in the right eye of an 8-year-old boy with pilocytic astrocytoma (case 3). Disc photographs showing preoperative papilledema (**A**) and postoperative resolution of the same (**B**) are presented with the indicating OCT section (*small squares*). A row SS-OCT image of preoperative (**C**) and postoperative (**D**) states can be observed. Measurements are obtained using the preoperative (**E**) and postoperative (**F**) images. After surgical decompression, the neural canal diameter (*red line*) and papillary vertical height (*green line*) have decreased and the lamina cribrosa (LC) shows posterior displacement (*yellow dotted line*; anterior surface of the LC contour). IICP = increased intracranial pressure.

model. A further understanding of the pressure transmissibility between these 2 compartments is necessary.

In conclusion, we investigated the dynamic changes in deep anterior ONH structures using SS-OCT after surgical decompression for IICP in this in vivo study involving pediatric patients. This finding will provide an insight into the potential role of translaminar pressure dynamics in determining the positional characteristics of deep ONH structures.

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