Comparison of the Pattern of Macular Ganglion Cell-Inner Plexiform Layer Defect Between Ischemic Optic Neuropathy and Open–Angle Glaucoma

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PURPOSE. To compare the pattern of macular ganglion cell plus inner plexiform layer (GCIPL) and peripapillary retinal nerve fiber layer (RNFL) thickness changes in moderate to severe primary open–angle glaucoma (POAG) with nonarteritic anterior ischemic optic neuropathy (NAION) using optical coherence tomography (OCT) auto-segmentation.

METHODS. A total of 138 eyes (42 eyes with chronic unilateral NAION and their 42 unaffected fellow eyes, 32 eyes of 32 moderate to severe glaucoma patients, and 22 eyes of 22 healthy normal subjects) underwent neuro-ophthalmologic examinations and spectral-domain OCT in a cross-sectional study at a single academic institution. GCIPL and total retinal thicknesses were obtained from 20° by 20° cube scans of the macula centered around the fovea. The scanned region was divided into two concentric regions (inner and outer, with diameters of 3 and 6 mm, respectively) and eight sectors (four sectors in each of the inner and outer regions). Peripapillary RNFL thickness was also measured.

RESULTS. Peripapillary RNFL, total macula, and GCIPL were significantly thinner in NAION and POAG eyes compared to unaffected fellow eyes of NAION and to age-matched healthy control eyes in all eight sectors (\(P < 0.001\)). There was no significant difference in peripapillary RNFL, total macula, and outer region GCIPL thicknesses between the affected eyes of the patients with NAION and glaucoma patients. However, the inner region GCIPL was significantly thinner in NAION eyes compared to POAG eyes after adjusting for age, sex, and mean deviation of the visual field (\(P = 0.001\)). Also, the GCIPL sector thicknesses were more strongly correlated with visual acuity than were the macular sectors in all patients (most sectors \(P < 0.001\)).

CONCLUSIONS. Patients with NAION show differences in the tissue damage with greater loss of parafoveal GCIPL tissue thickness compared to patients with POAG.

Keywords: ischemic optic neuropathy, glaucoma, ganglion cells

Primary open–angle glaucoma (POAG) and nonarteritic anterior ischemic optic neuropathy (NAION) are two diseases that cause irreversible damage to the optic nerve. Unlike POAG, which is a chronic progressive optic neuropathy, NAION is characterized by acute injury to the optic nerve. Each optic neuropathy produces specific effects on the optic nerve head structure.1,2 In contrast to NAION, POAG results in the enlargement of the optic disc cup and thinning of the neuroretinal rim.2 The neuroretinal rim is pale in NAION but often pink in POAG.3,4 Histologically, the nerve damage involves loss of retinal ganglion cells in a characteristic pattern in these two diseases. In POAG, the axons of superior and inferior poles of the optic nerve are commonly involved. In NAION, the most peripheral portion of the nerve is spared.5,6 In addition, the form of neuronal loss caused by optic nerve damage can vary in both conditions.7 Therefore, selective regional differences in ganglion cells involvement might distinguish a glaucomatous optic neuropathy from the ischemic optic neuropathy.

Recent advances in the optical coherence tomography (OCT) technology allow segmentation of discrete retinal layers and measurement of the thickness of the macular ganglion cell plus inner plexiform layer (GCIPL), which includes the ganglion cell layer (GCL) and the inner plexiform layer (IPL). In fact, GCIPL measurement has proven useful for the early detection of glaucoma.8–13 Several OCT studies have revealed that the GCL thickness decreases in the chronic phase of NAION eyes.14–17 Although both glaucoma and NAION cause thinning of GCIPL,8–17 the pattern and extent of damage to retinal ganglion cell axons might be different in these two diseases and warrants further study. Using the Spectralis-OCT segmentation software, we evaluated GCIPL thickness in NAION and POAG to further characterize and distinguish the patterns of loss in these two conditions.

In this cross-sectional study, we measured total macular thickness, peripapillary retinal nerve fiber layer (RNFL) thickness, and macular GCIPL thickness in patients with chronic unilateral NAION, in patients with moderate to severe
Macular GCIPL Defect Between ION and OAG

glaucoma, and healthy normal subjects and compared the results among these three groups.

METHODS

Subjects

Patients with chronic unilateral NAION and moderate to severe POAG who visited the outpatient clinic of Farabi Eye Hospital between July 2014 and March 2015 were enrolled in this cross-sectional study. Age- and refractive error–matched healthy subjects were enrolled as controls. The study was approved by the local ethics committee of the Tehran University of Medical Science and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients. All the subjects underwent a thorough ophthalmic evaluation including slit-lamp biomicroscopy, best-corrected visual acuity (BCVA) using a logMAR chart, refractive error examination with an autorefractometer, intraocular pressure (IOP) by Goldmann application tonometry (GAT), fully dilated fundus examination, gonioscopy, and axial length measurement with Ocular Biometry (IOLMaster, Carl Zeiss Meditec, Dublin, CA, USA). Perimetry was performed with standard Swedish Interactive Thresholding Algorithm (SITA) with the 24-2 pattern on the Humphrey Field Analyzer (Carl Zeiss Meditec). Only reliable visual field results were included (fixation loss < 20%, false-positive error < 15%, and false-negative error < 15%).

Unilateral NAION

NAION was diagnosed using the following criteria: a history of sudden-onset, painless visual loss in one eye together with optic disc swelling and/or superficial hemorrhage on the disc border or adjacent retina that occurred at least 3 months ago (confirming by objective signs or by asking the referring ophthalmologist), and an ophthalmologically healthy fellow eye. At the time of the study, optic disc swelling must have subsided, and disc borders must be sharp and discrete.

The exclusion criteria for NAION patients were having an ocular or neurologic disease other than NAION, especially those with possible evidence of glaucoma, bilateral NAION, acute NAION, evidence of arteritic AION (systemic manifestations of giant cell arteritis, an erythrocyte sedimentation rate > 50 mm/h, and a positive C-reactive protein), or inflammatory optic neuritis.

Moderate to Severe POAG

We used Hodapp-Parrish-Anderson criteria for diagnosis of glaucomatous visual field and its staging.18 Patients with moderate to severe POAG who had an eye with an open iridocorneal angle on gonioscopy, a typical glaucomatous optic disc appearance (enlargement of the vertical cup-to-disc ratio, apparent difference in the vertical cup-to-disc ratio between both eyes, diffuse or focal thinning of the neuroretinal rim, splinter hemorrhage, or visible nerve fiber layer defect), and glaucomatous visual field results with a mean deviation (MD) of less than −6.00 dB.18 To make glaucoma and NAION groups more similar in terms of severity, only patients with MD scores less than −6.00 dB (i.e., moderate to severe defects) were recruited in this study.2

Exclusion criteria were the following: age below 18 years, history of ocular surgery other than uncomplicated cataract surgery; history of ocular or neurologic disease other than glaucoma; history of secondary glaucoma, angle closure glaucoma, or early glaucoma.

Controls

Age- and refractive error–matched subjects with BCVA of ≥ 20/30, IOP of ≤ 21 mm Hg, an open angle, normal optic disc appearance on fundus examination, and no visual field or RNFL defects were enrolled as controls.

OCT Measurements

After pupillary dilation, patients underwent spectral-domain OCT imaging (Spectralis, HEYEX software 6.0; Heidelberg Engineering, Heidelberg, Jena, Germany). Images were analyzed using the new Heidelberg Eye Explorer software (version 6.0; Heidelberg Engineering). Two sets of scans were obtained for each eye: (1) macular scan to measure total macular thickness and GCIPL thickness; and (2) optic disc scan to measure peripapillary RNFL.

Optic disc scans were performed using the standard 360°, 3.4-mm peripapillary circle centered around the optic disc, and the thickness values were recorded in seven sectors: global (G), supero-nasal (NS), nasal (N), infero-nasal (ND), infero-temporal (IT), temporal (T), and supero-temporal (TS).

For macular scans, 25 horizontal optical coherent tomographic sections were obtained in a 20° × 20° rectangle centered around the fovea. In each B-scan, the boundaries between the individual retinal layers were automatically segmented or manually adjusted if necessary. Recently, excellent repeatability and reproducibility of each of eight individual retinal layer thickness measurements using this Spectralis software has been demonstrated in a young, healthy cohort.19 The GCL and IPL layer thicknesses over the macula were determined separately by the instrument software. However, the reflectivity of the GCL and IPL layers is very similar. Therefore, we defined GCIPL as the summation of GCL and IPL in each sector (Figure). The total macular thickness was defined as the distance between the inner border of the RNFL to the inner border of the retinal pigment epithelium. For both total macular and GCIPL thicknesses, three circular lines representing 1-, 3-, and 6-mm scan diameters (Early Treatment Diabetic Retinopathy Study; ETDRS macula) were obtained. The data of the innermost circle that defined the fovea were not used. The outer region total macular and GCIPL thicknesses (outer nasal, outer temporal, outer superior, and outer inferior sectors) are delineated by the two outer circles, whereas the inner region total macular and GCIPL thicknesses are delineated by the area between the inner circle and the fovea (inner nasal, inner temporal, inner superior, inner inferior sectors). Because the total points and the area measured by the inner and outer regions were different (inner and outer macular sectors contain 38 and 74 data points, respectively), we averaged the inner sectors independently of the outer sectors as follows: the mean of the inner superior, inner inferior, inner nasal, and inner temporal sectors and the mean of outer superior, outer inferior, outer nasal, and outer temporal sectors, respectively.

Images with poor centration, segmentation errors, or poor quality (< 15 dB) were excluded from analysis.

Statistical Methods

Continuous variables are presented as mean and standard deviation. We used Generalized Estimating Equation (GEE) to evaluate the differences between groups when the possible correlation of the outcomes of the two eyes was considered. Another GEE was used to adjust for the effects of age, sex, and MD of the visual field in addition the possible above-mentioned correlation. In both GEE analyses, whenever two groups where the possible correlation of the outcomes of the two eyes was considered.

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multiple comparisons. The correlations between the baseline visual acuity (logMAR) and the inner and outer total macular and GCIPL thicknesses were analyzed. To evaluate the differences between the correlations of the logMAR with different covariates, we used a method introduced by Meng through the package `cocor` in R (R Core Team [2014]; http://www.R-project.org/; provided in the public domain by the R Foundation for Statistical Computing, Vienna, Austria). Differences were considered significant if the $P$ value was less than 0.05.

**RESULTS**

**Subject Characteristics**

One hundred two patients were initially enrolled in this study. Six patients with poor retinal layer segmentation were excluded. Therefore, 84 eyes of 42 patients with chronic unilateral NAION, 32 eyes of 32 moderate to severe glaucoma patients, and 22 eyes of 22 healthy normal subjects (a total of 96 patients) were included in this study. When both eyes were eligible in patients with glaucoma or in normal subjects, one eye was chosen at random.

The basic characteristics of the study participants are listed in Table 1.

Peripapillary RNFL, total macula, and macular GCIPL sector thickness parameters are shown in Table 2.

**Comparison Between the Affected and Unaffected Fellow Eye of the Patients With NAION**

Peripapillary RNFL, total macula, and macular GCIPL were significantly thinner in the affected eye in all sectors (all $P < 0.001$) (Table 2).

**Comparison Between Patients With Glaucoma and Normal Subjects**

We observed a significant difference in all sectors of the peripapillary RNFL and macular GCIPL thickness between the two groups ($P < 0.001$). Differences were observed in all sectors of the total macular thickness between glaucoma and normal subjects, except for the nasal inner ($P = 0.08$) and temporal outer ($P = 0.05$) sectors.

**Comparison Between the Affected Eye of the Patients With NAION and Glaucoma Patients**

There was no significant difference in peripapillary RNFL and total macular thicknesses in any of the sectors between the affected eye of the patients with NAION and glaucoma patients. The GCIPL inner region thickness (average of four sectors: superior inner, inferior inner, nasal inner, and temporal inner) was $51.71 \pm 12.19 \mu m$ in the affected NAION eyes and $61.61 \pm 17.75 \mu m$ in the glaucoma patients, which showed a significant difference between the two groups (unadjusted $P = 0.03$, after adjusting for age, sex, and MD $P = 0.001$). No
significant difference was observed when comparing the outer GCIP1 region thickness between NAION and POAG eyes ($P = 1.00$).

Of the four inner GCIP1 sectors, the inner nasal and inner superior sectors were significantly thinner in NAION eyes compared to POAG eyes ($P = 0.006$ and $P = 0.01$, respectively).

After adjusting for age, sex, and visual field MD, the inner temporal sector was also thinner in NAION eyes ($P = 0.007$).

Visual acuity (logMAR) was significantly correlated with GCIP1 and macular thickness in all sectors. However, visual acuity had a stronger correlation with GCIP1 thickness when compared to the total macular sectors (Table 3).

### DISCUSSION

Our study showed the greater decrease in the inner GCIP1 region thickness in the NAION group than the POAG group, although the degree of visual field defects and the thickness of outer GCIP1 region and peripapillary RNFL were similar between the groups. This GCIP1 thinning was more prominent in superior, nasal, and temporal sectors of the inner macula in the NAION group. In other words, greater loss of parafoveal GCIP1 tissue thickness was observed in NAION compared to POAG.

### TABLE 1. Demographic and Baseline Characteristics of Patients With Unilateral Nonarteritic Anterior Ischemic Optic Neuropathy, POAG, and Normal Subjects

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>NAION</th>
<th>Fellow Eye</th>
<th>POAG</th>
<th>Normal Subjects</th>
<th>NAION vs. Fellow</th>
<th>POAG vs. Normal</th>
<th>NAION vs. POAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>58.02 ± 8.83</td>
<td>58.02 ± 8.83</td>
<td>64.59 ± 9.79</td>
<td>64.82 ± 8.37</td>
<td>—</td>
<td>1.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Sex, female/male</td>
<td>22/20</td>
<td>22/20</td>
<td>10/232</td>
<td>13/9</td>
<td>—</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>LogMAR</td>
<td>0.92 ± 0.91</td>
<td>0.05 ± 0.10</td>
<td>0.30 ± 0.36</td>
<td>0.07 ± 0.07</td>
<td>&lt;0.001</td>
<td>0.77</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MD, dB</td>
<td>−16.47 ± 9.05</td>
<td>−1.02 ± 2.8</td>
<td>−16.28 ± 9.98</td>
<td>−1.0 ± 2.09</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>1.00</td>
</tr>
<tr>
<td>PSD, dB</td>
<td>8.78 ± 4.2</td>
<td>3.17 ± 2.7</td>
<td>6.91 ± 2.95</td>
<td>1.07 ± 0.52</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.07</td>
</tr>
<tr>
<td>Axial length, mm</td>
<td>22.7 ± 0.8</td>
<td>22.8 ± 0.8</td>
<td>23.2 ± 0.8</td>
<td>23.2 ± 0.6</td>
<td>1.00</td>
<td>1.00</td>
<td>0.22</td>
</tr>
</tbody>
</table>

PSD, pattern standard deviation.

### TABLE 2. Peripapillary RNFL Thickness, Total Macular Sector Thickness, and Macular GCIP1 Sector Thickness Parameters Measured by Spectral-Domain OCT Before and After Adjustments by Age, Sex, and Visual Field MD

<table>
<thead>
<tr>
<th>Peroipapillary RNFL thickness parameters, μm</th>
<th>NAION</th>
<th>Fellow Eye</th>
<th>POAG</th>
<th>Normal Subjects</th>
<th>NAION vs. Fellow</th>
<th>POAG vs. Normal</th>
<th>NAION vs. POAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>59.8 ± 19.6</td>
<td>101.9 ± 10.7</td>
<td>57.5 ± 21.3</td>
<td>98.2 ± 12.7</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nasal superior</td>
<td>58.2 ± 31.5</td>
<td>120.6 ± 23.9</td>
<td>61.1 ± 24.9</td>
<td>116.0 ± 27.5</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nasal</td>
<td>48.6 ± 24.3</td>
<td>80.5 ± 15.2</td>
<td>44.8 ± 17.5</td>
<td>75.4 ± 12.8</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nasal inferior</td>
<td>78.0 ± 37.0</td>
<td>117.7 ± 23.2</td>
<td>65.5 ± 28.7</td>
<td>113.9 ± 24.9</td>
<td>&lt;0.001</td>
<td>0.52 (0.51)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporal inferior</td>
<td>85.8 ± 38.7</td>
<td>144.2 ± 26.3</td>
<td>80.3 ± 40.3</td>
<td>135.5 ± 18.8</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporal superior</td>
<td>44.9 ± 26.0</td>
<td>67.6 ± 11.6</td>
<td>45.3 ± 18.2</td>
<td>68.7 ± 12.4</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporal superior</td>
<td>67.4 ± 27.4</td>
<td>139.5 ± 23.5</td>
<td>71.9 ± 33.1</td>
<td>132.2 ± 20.0</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total macular thickness parameters, μm</td>
<td>306.6 ± 31.7</td>
<td>345.4 ± 21.6</td>
<td>311.9 ± 26.3</td>
<td>332.2 ± 22.3</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Superior inner</td>
<td>276.1 ± 27.0</td>
<td>297.9 ± 15.7</td>
<td>271.2 ± 24.1</td>
<td>291.8 ± 14.3</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inferior inner</td>
<td>309.6 ± 23.9</td>
<td>340.5 ± 21.7</td>
<td>312.2 ± 22.9</td>
<td>328.2 ± 20.6</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inferior outer</td>
<td>273.1 ± 21.0</td>
<td>287.6 ± 16.7</td>
<td>263.9 ± 21.9</td>
<td>280.4 ± 18.5</td>
<td>&lt;0.001</td>
<td>0.89 (0.14)</td>
<td>0.014</td>
</tr>
<tr>
<td>Nasal inferior</td>
<td>310.3 ± 26.1</td>
<td>345.4 ± 20.5</td>
<td>316.5 ± 25.2</td>
<td>331.5 ± 20.1</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>0.08</td>
</tr>
<tr>
<td>Nasal outer</td>
<td>287.7 ± 26.7</td>
<td>313.7 ± 16.1</td>
<td>287.7 ± 26.4</td>
<td>306.0 ± 18.3</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>0.013</td>
</tr>
<tr>
<td>Temporal inferior</td>
<td>297.9 ± 20.8</td>
<td>328.2 ± 20.6</td>
<td>302.7 ± 22.1</td>
<td>319.9 ± 20.2</td>
<td>&lt;0.001</td>
<td>1.00 (0.86)</td>
<td>0.016</td>
</tr>
<tr>
<td>Temporal outer</td>
<td>267.1 ± 16.5</td>
<td>283.4 ± 15.9</td>
<td>264.3 ± 24.2</td>
<td>278.1 ± 15.9</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Macular GCIP1 thickness parameters, μm</td>
<td>49.3 ± 15.2</td>
<td>94.5 ± 11.4</td>
<td>62.1 ± 18.0</td>
<td>88.0 ± 11.5</td>
<td>&lt;0.001</td>
<td>0.006 (&lt;0.001)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Superior inner</td>
<td>46.0 ± 7.5</td>
<td>63.4 ± 6.6</td>
<td>47.3 ± 8.8</td>
<td>61.6 ± 6.1</td>
<td>&lt;0.001</td>
<td>1.00 (0.52)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inferior inner</td>
<td>56.9 ± 16.2</td>
<td>93.2 ± 11.9</td>
<td>63.0 ± 18.2</td>
<td>85.9 ± 9.8</td>
<td>&lt;0.001</td>
<td>0.78 (0.19)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inferior outer</td>
<td>49.8 ± 8.5</td>
<td>60.9 ± 8.0</td>
<td>47.1 ± 7.1</td>
<td>59.4 ± 7.6</td>
<td>&lt;0.001</td>
<td>0.94 (0.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nasal inner</td>
<td>51.0 ± 15.9</td>
<td>93.6 ± 12.4</td>
<td>64.5 ± 20.2</td>
<td>85.5 ± 10.3</td>
<td>&lt;0.001</td>
<td>0.01 (&lt;0.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nasal outer</td>
<td>50.4 ± 9.7</td>
<td>67.4 ± 6.9</td>
<td>51.6 ± 9.8</td>
<td>66.1 ± 7.1</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporal inner</td>
<td>48.2 ± 12.7</td>
<td>87.7 ± 12.0</td>
<td>56.7 ± 18.4</td>
<td>82.5 ± 10.6</td>
<td>&lt;0.001</td>
<td>0.14 (0.007)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Temporal outer</td>
<td>45.2 ± 7.0</td>
<td>68.6 ± 8.6</td>
<td>48.7 ± 11.7</td>
<td>65.7 ± 8.0</td>
<td>&lt;0.001</td>
<td>0.75 (0.15)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Generalized estimating equation.
Similarly, another study showed diffuse GCIPL thinning in central field preservation. These patients had an extensive involvement of the nasal sector, which are associated with the temporal optic discquadrant.11 Furthermore, the inner superior GCIPL regions are more vulnerable to NAION. Aggarwal et al.14 and Gonul et al.15 measured ganglion cell complex using FD-OCT in chronic NAION eyes. They showed defects in hemispheric ganglion cell complex, which correlated with visual field. However, they did not measure sectoral ganglion cell thickness. Previously, we also measured posterior pole total retinal thickness. We showed that the widest area under the curve to discriminate NAION from unaffected eyes in the posterior pole belonged to superonasal and superotemporal regions.24 Superior GCIPL involvement in NAION corresponds to inferior nasal visual field loss, as it is the most common defect detected in NAION.25

In addition, we found a stronger correlation between central visual acuity (logMAR) and GCIPL sectors thickness compared to total macular thickness. GCIPL thinning in patients with resolved diabetic edema is also associated with visual impairment despite normal total macular thickness.26 In both NAION and POAG with predominant ganglion cell damage and relative sparing of photoreceptors, ganglion cell thickness has a stronger correlation with visual acuity than does total macular thickness. In addition, visual acuity depends on the foveal function. We believe that this also explains the strength of the correlation between the inner GCIPL and visual acuity since it is closer to the fovea than the outer GCIPL.27

Our study had several limitations. First, our sample size was small, but it was in line with prior studies. However, given the very significant difference in the thickness observed between the groups, the overall results of the study can be generalized. Second, our study was the second study using the new Spectralis software for retinal layer segmentation. There is still no normative database of the thickness of different retinal layers. However, recent study results showed that interobserver coefficient describing reproducibility of this software’s measurements was less than 4 μm for all individual layer thicknesses.19 Another study also reported comparable results of both Spectralis and Cirrus in NAION eyes.17 Third, using the 24-2 protocol (with a 6° grid) of the visual field might poorly sample the GCIPL and macular damage in our study. Future studies should include 10-2 pattern of visual field.12 Finally, the macular sectors in our study are divided based upon retinal damage (e.g., ETDRS sectors for diabetic damage); using the macular sectors related to the optic nerve damage would be more helpful.

In conclusion, we observed RNFL total macula, and GCIPL thinning in eyes with NAION and glaucoma compared to normal eyes. When comparing NAION eyes and glaucomatous
eyes with the same severity, inner GCIMP sectors were significantly thinner in NAION eyes.

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References