Relation between size of optic disc and thickness of retinal nerve fibre layer in normal subjects

Shigeo Funaki, Motohiro Shirakashi, Haruki Abe

Abstract

Aims—To evaluate the relation between the optic disc size and the thickness of the peripapillary retinal nerve fibre layer (RNFL) in normal Japanese subjects by means of scanning laser polarimetry.

Methods—Scanning laser polarimetry was performed in 60 normal subjects. One eye of each subject was randomly selected for study. Using a scanning laser polarimeter, the integral of RNFL thickness was measured totally and regionally within a circular band located 1.75 disc diameters from the centre of the optic disc. The correlation between the optic disc size and the integral of RNFL thickness was examined.

Results—The optic disc size showed a significant correlation with the integral of RNFL thickness ($R = 0.497$, $p < 0.001$). A significant negative correlation was observed between the optic disc size and the ratio of inferior integral to total integral of RNFL thickness ($R = -0.274$, $p = 0.034$).

Conclusions—The cross sectional area occupied by the RNF, measured by scanning laser polarimetry increased significantly with an increase in optic disc size while the ratio of inferior to total cross sectional area decreased significantly. These facts should be considered when one evaluates the RNFL thickness in patients with progressive optic neuropathies such as glaucoma.

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Availability of the scanning laser polarimeter now permits the objective and quantitative measurement of the thickness of the retinal nerve fibre layer (RNFL) in vivo. Several investigators reported that, using this instrument, measurements of RNFL thickness were highly reproducible when analysed by the same operator. We have previously reported the reproducibility of measurements of RNFL thickness with this instrument; the mean coefficient of variation of three measurements was 3.9%. In normal subjects, measurements of the thickness of RNFL with this instrument resemble those obtained by histological examination. Measurements of the peripapillary thickness of the RNFL in the superior and inferior quadrants exceeded those in the temporal and nasal quadrants. The thickness of the RNFL has been shown to decrease with an increase in distance from the margin of the optic disc. However, the thickness of the RNFL varies considerably, even among normal subjects. Previous studies of humans and other primates have shown that the optic nerve fibre count, as evaluated histologically, increases linearly with an increase in optic disc size. However, another histological study of human eyes could not identify a clear correlation between axon count and area of the scleral canal. To understand the clinical significance of the thickness of the RNFL in vivo, we needed to determine clinically whether the peripapillary RNFL thickness was dependent on the size of the optic disc in the normal individual. The present study therefore examined the relation between optic disc size and the integral of the peripapillary RNFL thickness in normal subjects by means of scanning laser polarimetry.

Subjects and methods

A total of 120 normal eyes of 60 Japanese volunteers (31 males and 29 females) were studied. Subjects ranged in age from 23 to 75 years, mean 48.4 (SD 16.2) years. There were 10 subjects in each of six groups classified by age: between 20 and 29, 30 and 39, 40 and 49, 50 and 59, 60 and 69, and 70 and 79 years. Informed consent was obtained from each subject. The eyes studied had a best corrected visual acuity above 20/25, a refractive error between −5 and +5 dioptres of sphere or between −2 and +2 dioptres of cylinder, a normal intraocular pressure $< 21$ mm Hg, a normal appearance of the optic disc, no significant ocular disease found by routine ophthalmological examination, and reliable measurements of visual field (fixation loss $< 20\%$, false negative and false positive $< 25\%$) performed on the central 24-2 or 30-2 program of the Humphrey visual field analyser (Allergan-Humphrey, San Leandro, CA, USA). Results of the glaucoma hemifield test did not show outside normal limits in each eye. $p$ Values for mean deviation and pattern standard deviation were not $< 0.05$.

The thickness of the RNFL was measured with a scanning laser polarimeter (Nerve Fiber Analyzer, version 2.1.15 alpha, Laser Diagnostic Technologies, San Diego, CA, USA). Its basic principles and technical characteristics have been described extensively. In brief, this instrument consists of a confocal scanning laser ophthalmoscope with a polarisation modulator, a cornea polarisation compensator, and a polarisation detection unit. Measurement of RNFL thickness is based on the assumption that the RNFL possesses birefringent properties that change (retard) the state of polarisation of an illuminating laser beam. This change can be measured by deter-
miring the phase shift between extraordinary and ordinary beams. The extent of retardation is linearly correlated with the thickness of the RNFL. Approximately one degree of retardation corresponds to 7.4 µm of RNFL thickness measured histologically after removal of the cornea. The light source consisted of a near infrared diode laser (wavelength 780 nm) in which the state of polarisation was modulated. The polarised light penetrates the birefringent RNFL and is partially reflected from the deeper layer of the retina. It is separated from the illuminating light beam by a non-polarising beam splitter. The state of polarisation of the light is analysed by the polarisation detection unit. The electrical signal from the detector is digitised and stored in the memory of a personal computer for later analysis. A total of 65 536 retinal locations (256 × 256 pixels) are tested, allowing us to create a retardation map in which the thickness of the RNFL was measured for each retinal location.

In the present study, a 15 degree field size was used and the optic disc was centred in the middle of the image for all image acquisitions. The pupils were not dilated. All measurements were obtained from a mean of three images. The average standard deviation of RNFL thickness in retinal locations (pixels) in the mean image of the three images was within 8 µm in each eye. The thickness of the RNFL was measured within a band 10 pixels wide that was located concentrically with the optic disc margin at 1.75 disc diameters. The margin of the optic disc was approximated by an ellipse placed around the inner margin of the peripapillary scleral ring. The integral of the

Table 1: Size of the optic disc and the integral of retinal nerve fibre layer (RNFL) thickness in 60 normal eyes (SD)

<table>
<thead>
<tr>
<th>Optic disc size (mm²)</th>
<th>2.20 (0.55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integral of thickness of the RNFL (mm²)</td>
<td>0.544 (0.129)</td>
</tr>
<tr>
<td>Total</td>
<td>0.171 (0.045)</td>
</tr>
<tr>
<td>Superior quadrant</td>
<td>0.086 (0.022)</td>
</tr>
<tr>
<td>Inferior quadrant</td>
<td>0.174 (0.039)</td>
</tr>
<tr>
<td>Nasal quadrant</td>
<td>0.113 (0.035)</td>
</tr>
</tbody>
</table>

Superior quadrant < temporal quadrant, p<0.001; superior quadrant < inferior quadrant, p=0.977; superior quadrant < nasal quadrant, p<0.001; temporal quadrant < inferior quadrant, p<0.001; temporal quadrant < nasal quadrant, p=0.001; inferior quadrant < nasal quadrant, p<0.001 (ANOVA and Scheffé’s test).

Results

The size of the optic disc and the integral of the RNFL thickness in the total peripapillary circular band and its four 90 degree quadrants (superior, temporal, inferior, and nasal) in 60 normal eyes are shown in Table 1. The integral of the RNFL thickness was greatest in the superior and inferior quadrants, and smallest in the temporal quadrant.

There was no significant correlation between age and the integral of RNFL thickness (Fig 2). There was no significant correlation between age and the integral of RNFL thickness in each of the superior, temporal, inferior, and nasal quadrants (R = 0.019, R² = 0.000, p = 0.885; R = -0.054, R² = 0.003, p = 0.682; R =
Although several investigators reported a positive correlation between optic disc size and optic nerve fibre count, as determined histologically in retrobulbar, myelinated optic nerves in non-human primate or human eye\textsuperscript{14}—that is, optic discs of larger area had more optic nerve fibres than did those of smaller area, other investigators were unable to confirm this correlation.\textsuperscript{15} In the present study of normal humans, there was a significant positive correlation between optic disc size and the total integral of RNFL thickness, as well as the regional integral of RNFL thickness. If the integral of RNFL thickness as measured by scanning laser polarimetry reflects the sum of the sectional area of the nerve fibres present, our results suggest that a larger optic disc has more optic nerve fibres and confirm the previous histological findings.\textsuperscript{15,16}

It was previously reported that there was a wide variation among normal individuals in thickness of the RNFL as measured by scanning laser polarimetry,\textsuperscript{1,4,6,7,10} which may be due to variables in the prenatal regression of retinal ganglion cells in the individual.\textsuperscript{10} In the present study, a similar wide variation in the integral of RNFL thickness was observed among individuals. There was a considerable overlap in the integral of RNFL thickness among eyes of differing optic disc size.

Although some investigators reported that the size of the optic disc might influence the susceptibility to glaucomatous damage,\textsuperscript{20} others found that the susceptibility to the loss of optic nerve fibre related in glaucoma to be independent of optic disc size.\textsuperscript{21} In the present study, the ratio of the inferior integral to the total integral of RNFL thickness decreased significantly with an increase in optic disc size. This suggests that the cross sectional area occupied by the RNF may not be identical between the superior and inferior quadrants, with an increase in optic disc size. Further study is needed to determine whether this optic disc size dependent difference in the ratio of the inferior integral of RNFL thickness is related to a differing susceptibility to glaucomatous damage in patients with differing size of optic disc.

In summary, using scanning laser polarimetry, we demonstrated clinically that the size of the optic disc was significantly correlated with the integral of peripapillary thickness of the RNFL in normal subjects; the cross sectional area occupied by the RNF increased significantly with an increase in optic disc size. The ratio of the inferior integral to the total integral of RNFL thickness differed among eyes of differing optic disc size. Thus, when one evaluates the peripapillary RNFL in patients with progressive optic neuropathies such as glaucoma, one must be aware that the size of the optic disc influences the RNFL data.

The authors have no proprietary interest in any of the materials used in this study.

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