Optic Nerve Head Morphologic Characteristics in High-Tension and Normal-Tension Glaucoma

Michele Iester, MD; Frederick S. Mikelberg, MD

Objectives: To determine the morphometric parameters in high-tension glaucoma (HTG) and normal-tension glaucoma (NTG) with a confocal scanning laser ophthalmoscope, and to determine the relationship to disc size.

Methods: One hundred eighty-six patients with glaucoma were recruited for this study. For each patient, only one eye was randomly chosen. Patients with NTG and HTG were classified using untreated intraocular pressure (IOP) as the variable; the NTG group had IOP less than 22 mm Hg during a diurnal tension curve, while patients with HTG had IOP greater than 21 mm Hg in at least 3 measurements. All the patients were examined with Humphrey perimeter program 30-2 and a Heidelberg Retina Tomograph. Findings were assessed by t test. Patients were then divided by disc area size into 3 subgroups: small discs with an area less than 2 mm², mid-sized discs with an area of 2 to 3 mm², and large discs with an area greater than 3 mm².

Results: One hundred thirty-two HTG eyes and 50 NTG eyes were assessed. Four eyes were excluded because they were classified as having secondary glaucoma. No significant differences were found between HTG and NTG eyes for any Heidelberg Retina Tomograph morphometric parameters, even when patients were divided into subgroups.

Conclusion: No differences were apparent between HTG and NTG in morphometric parameters as measured by scanning laser ophthalmoscopy.


Normal-tension glaucoma (NTG) has long been recognized as a clinical entity characterized by typical glaucomatous optic nerve head (ONH) damage and visual field defects.1 Greve and Geijser2 found that NTG was characterized by larger optic discs, a thinner inferotemporal rim area, more pallor than cupping, and a pale, sloping, moth-eaten disc appearance. Others have also noted optic disc and visual field differences between patients with high-tension glaucoma (HTG) and NTG.1,3 Some authors believe that the appearance of the optic disc and visual field in patients with NTG is similar to that found in HTG.10-14 It is important to determine if there are differences in optic disc topography between these 2 entities since this may provide clues as to the possible different factors responsible for the damage to these patients’ eyes. We evaluated the optic disc topography using a Heidelberg Retina Tomograph (HRT) (Heidelberg Engineering, Heidelberg, Germany) in patients with NTG and HTG to address this question.

Results

Four eyes were excluded because they were classified as having secondary glaucoma.

The 182 eyes were classified in 2 different groups: 132 subjects had HTG and 50 had NTG. The distribution of the data was normal, so the t test was used to compare data between groups.

The mean ± SD age of patients with HTG was 63.89 ± 12.06 years; patients with NTG, 63.74 ± 11.4 years. This difference was not statistically significant.

No significant difference was found between HTG and NTG for refraction (mean ± SD, −0.76 ± 2.84 D and −1.04 ± 3.18 D, respectively) or for visual field indices (Table 1).

The t test revealed no significant differences between HTG and NTG for the following HRT parameters: disc area, cup area, cup-disc area ratio, rim area, cup volume, rim volume, mean cup depth, maximum cup depth, cup shape measure, high-variation contour, mean RNFL thickness, and RNFL cross-section area (Table 2).

No significant difference between HTG and NTG was found for the HRT parameters, even when the cohort was divided on the basis of optic disc size.

A power calculation on cup shape measure revealed that there was less than a 5% chance that we were incorrect in accepting that there was no difference between the HTG and NTG groups for this parameter. We calculated the power assuming an effect size of .05.
PATIENTS AND METHODS

One hundred eighty-six subjects were enrolled consecutively into this study between July 1995 and March 1996. Patients were recruited from the practices of 2 university-based glaucoma specialists. All consecutive patients had at least 1 eye with glaucoma. One eye from each subject was selected on a random basis.

Patients were not excluded on the basis of visual acuity, media opacity, sex, age, race, or refractive error. In the present study, no patient had a refractive error greater than 7 diopters (D) (spherical equivalent). Patients were excluded if they had an ocular or systemic disease potentially associated with optic neuropathy, such as anterior ischemic optic neuropathy or congenital optic nerve anomaly.

All consecutive patients with reliable visual fields and adequate HRT imaging, defined as images with appropriate focus and scan depth, were used.

Patients were defined as having primary open-angle glaucoma if they had an abnormal visual field (as described below) and/or an abnormal ONH or retinal nerve fiber layer (RNFL) using a Volk 90 lens, an open angle at gonioscopy, and no clinically apparent secondary cause for their glaucoma. The abnormal ONH and RNFL classifications were based on the presence of an optic rim notch or diffuse/generalized loss of optic rim tissue, vertical cup-disc diameter ratio asymmetry unexplained by side differences in optic disc size, disc hemorrhage, or subjectively ascertained localized defect within the RNFL. Among the 132 eyes with HTG, 95 had abnormal visual fields and 37 had normal visual fields with abnormality of the ONH. Among the 50 eyes with NTG, 35 had abnormal visual fields and 15 had normal visual fields with abnormality of the ONH.

Patients with primary open-angle glaucoma were divided into 2 subgroups on the basis of untreated intraocular pressure (IOP). Patients with IOP greater than 21 mm Hg were defined as having HTG and those with IOP less than 22 mm Hg after a diurnal tension curve from 8 AM to 8 PM as measured by Goldmann applanation tonometry at 2-hour intervals were defined as having NTG. In the NTG group, there was no history of high IOP.

OPTIC DISC ANALYSIS

The optic disc of each eye studied was analyzed by an HRT running software version 1.11S. Using this confocal diode laser (670 nm), we obtained a series of 32 confocal images at consecutive focal planes, each 256 × 256 pixels, which the computer then converted to a single topographic image. The depth of each topographic image series ranged from 0.3 to 4.0 mm in 0.3-mm increments, depending on individual differences in optic disc morphologic characteristics. The field of each image was 10° × 10°. Three images were obtained for each eye, and the mean of the 3 topographic image height measurements for each pixel location was calculated. Magnification error was corrected using keratometry values for each individual. The optic disc margin outline, at the inner edge of the scleral ring (Elschnig ring), was drawn under visual guidance by a trained observer using a computer mouse system. The outline was verified by one of the authors and used to determine the disc area. Then the Stereometric Measurements (Heidelberg Engineering, Heidelberg, Germany) program calculated a number of predefined shape parameters. To determine some of these HRT parameters, such as rim area and volume, cup area and volume, cup-disc area ratio, mean RNFL thickness, and RNFL cross-sectional area, it is necessary to define a reference plane that is placed at 50 µm below the retinal surface within the papillomacular bundle (the temporal 350°-356° sector). In addition, 4 other parameters independent of the reference plane (mean and maximum cup depth, height variation contour, and cup shape measure) were determined. The HRT topographical parameters measured have been described in detail elsewhere. Both this method and the reproducibility/reliability of several of the shape measures have been described in detail elsewhere.16,17

To evaluate whether disc area size had influenced our results, patients were divided on the basis of disc area size; small discs were defined as having an area less than 2 mm², mid-sized discs an area of 2 to 3 mm², and large discs an area greater than 3 mm².

VISUAL FIELD ANALYSIS

The visual field of all the subjects was analyzed by Humphrey Perimeter program 30-2 (Humphrey Instruments, San Leandro, Calif). Subjects were classified as having glaucoma if they had (1) at least 3 adjacent points reduced in sensitivity by 5 dB, with 1 of the points being reduced by at least 10 dB; (2) at least 2 adjacent points reduced in sensitivity by 10 dB; or (3) a difference of at least 10 dB across the nasal horizontal meridian at 2 adjacent points. None of the points could be edge points except immediately above or below the nasal horizontal meridian. Only reliable fields were used, as determined by the reliability parameters (false-positive responses <10%, false-negative responses <10%, and fixation loss <3%). The last reliable visual field within 3 months of the nearest HRT measurements was chosen. All patients were experienced visual field subjects, and the first visual field was never used for the study purposes. Mean deviation, pattern SD, short-term fluctuation, and corrected pattern SD were used to describe the cohort of considered subjects.

STATISTICAL ANALYSIS

Data for both HRT parameters and visual field indices of the 2 glaucomatous subgroups were analyzed by descriptive analysis. The t test was used to compare morphological and perimetric results between the HTG and NTG groups when the distribution of the data was normal, and the Mann-Whitney test was used when the distributions of the HTG and NTG data were not normal. P<.05 was considered statistically significant.

There remains considerable disagreement within the glaucoma community as to the possible differences in optic disc appearance and visual field damage present in patients with HTG and NTG. Some authors believe that the optic disc is significantly different in these 2 patient groups and that the visual fields of patients with NTG exhibit visual field defects that are deeper and closer to fixation than in patients with HTG. Others believe that the disc
and visual field appearances are similar in the 2 groups.10-14 These different findings may relate to selection bias, since NTG is usually detected only when significant disc damage has already occurred.

Our study looked at optic disc morphometry as recorded by the HRT to determine if there are apparent differences in the disc damage found in these 2 patient groups. We were unable to find any significant differences in any of the measured parameters of optic disc structure. Perhaps most interesting is the finding that even the parameter cup shape measure was not different between the 2 groups. This parameter has already been shown to be very precise in differentiating the normal disc from the disc from patients with glaucomatous visual field loss.24,25 Since this parameter is sensitive to small variations in the topography of the optic disc, the lack of significant difference in this parameter between the 2 groups suggest that the disc changes are similar in appearance.

All of the patients in this study were part of a university-based practice. This may be a source of potential bias. Another potential source of bias could be a mismatch in the amount of visual field damage present in the 2 patient groups. We do not believe that this is a problem in our study, since the mean values of the visual field indices were almost identical in the HTG and NTG groups. If a mismatch was present, this would have biased the study toward detecting a selection-induced difference in optic disc morphologic characteristics between the 2 groups. Since no significant difference in optic disc morphologic characteristics was detected, this potential bias is not relevant.

These results suggest that the separation of HTG and NTG on the basis of an arbitrary pressure difference threshold is probably not useful. Pressure remains an important controllable factor in the pathogenesis of both of these disease entities.23,27 Other factors remain to be determined that will probably be important at both ends of the spectrum in this disease. The fact that the optic disc topographical appearance is the same at both the HTG and NTG ends of the spectrum suggests that the final damage to the optic nerve is similar in both cases.

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Corresponding author: Frederick S. Mikelberg, MD, FRCS, Department of Ophthalmology, University of British Columbia, 2550 Willow St, Vancouver, British Columbia, Canada V5Z 3N9 (e-mail: fsm@interchange.ubc.ca).

REFERENCES


Table 1. Demographic Analysis of Patients With Glaucoma*

<table>
<thead>
<tr>
<th>Glaucoma</th>
<th>High Tension (n = 132)</th>
<th>Normal Tension (n = 50)</th>
<th>P†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>63.89 (12.06)</td>
<td>63.74 (11.4)</td>
<td>.94</td>
</tr>
<tr>
<td>Refraction, D</td>
<td>-0.76 (2.83)</td>
<td>-1.04 (3.18)</td>
<td>.56</td>
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<tr>
<td>Mean deviation, dB</td>
<td>-6.33 (6.31)</td>
<td>-6.41 (5.75)</td>
<td>.94</td>
</tr>
<tr>
<td>Pattern SD, dB</td>
<td>5.8 (3.77)</td>
<td>6.82 (4.3)</td>
<td>.12</td>
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<tr>
<td>Short-term fluctuation, dB</td>
<td>2.01 (1.1)</td>
<td>1.93 (0.94)</td>
<td>.67</td>
</tr>
<tr>
<td>Corrected pattern SD, dB</td>
<td>5:13 (3.85)</td>
<td>6:26 (4.48)</td>
<td>.10</td>
</tr>
</tbody>
</table>

*Values are mean (SD). †By t test.

Table 2. Heidelberg Retina Tomograph Parameters in Patients With Glaucoma*

<table>
<thead>
<tr>
<th>Glaucoma</th>
<th>High Tension (n = 132)</th>
<th>Normal Tension (n = 50)</th>
<th>P†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc area, mm²</td>
<td>2.33 (0.62)</td>
<td>2.33 (0.89)</td>
<td>.99</td>
</tr>
<tr>
<td>Cup area, mm²</td>
<td>1.07 (0.58)</td>
<td>1.12 (0.74)</td>
<td>.67</td>
</tr>
<tr>
<td>Cup-disc ratio</td>
<td>0.48 (0.41)</td>
<td>0.46 (0.16)</td>
<td>.77</td>
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<tr>
<td>Rim area, mm²</td>
<td>1.26 (0.44)</td>
<td>1.22 (0.42)</td>
<td>.54</td>
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<tr>
<td>Cup volume, mm³</td>
<td>0.36 (0.41)</td>
<td>0.28 (0.20)</td>
<td>.18</td>
</tr>
<tr>
<td>Rim volume, mm²</td>
<td>0.27 (0.17)</td>
<td>0.26 (0.14)</td>
<td>.61</td>
</tr>
<tr>
<td>Mean cup depth, mm</td>
<td>0.31 (0.15)</td>
<td>0.28 (0.08)</td>
<td>.15</td>
</tr>
<tr>
<td>Maximum cup depth, mm</td>
<td>0.72 (0.27)</td>
<td>0.66 (0.19)</td>
<td>.22</td>
</tr>
<tr>
<td>Cup shape measure</td>
<td>-0.11 (0.09)</td>
<td>-0.13 (0.13)</td>
<td>.41</td>
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<tr>
<td>High-variation contour, mm</td>
<td>0.39 (0.24)</td>
<td>0.36 (0.14)</td>
<td>.43</td>
</tr>
<tr>
<td>Mean RNFL thickness, mm²</td>
<td>0.21 (0.20)</td>
<td>0.18 (0.09)</td>
<td>.35</td>
</tr>
<tr>
<td>RNFL cross-section area, mm²</td>
<td>0.95 (0.52)</td>
<td>0.89 (0.45)</td>
<td>.47</td>
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<tr>
<td>Reference plane, mm</td>
<td>0.29 (0.11)</td>
<td>0.29 (0.11)</td>
<td>.82</td>
</tr>
</tbody>
</table>

*Values are mean (SD). RNFL indicates retina nerve fiber layer. †By t test.


