Optic Disc and Early Glaucomatous Visual Field Loss

Sung-Min Hyung, M. D., Dong Myung Kim, M. D. and Dong Ho Youn, M. D.

Department of Ophthalmology, College of Medicine, Seoul National University, Seoul, Korea

In the early stages of glaucoma, the disc changes prior to visual field loss, so assessment of the optic disc is very important for the evaluation of the glaucoma patient. The aim of this study is to assess the glaucomatous disc and to look for the features of the optic disc that are commonly associated with early visual field loss. Forty-three eyes of 28 patients were included in this investigation. The criteria for inclusion were a cup/disc (C/D) ratio of more than 0.4 by direct ophthalmoscopy, no visual field defect with Goldmann perimetry, and open anterior chamber angle. Each optic disc was photographed with a Canon fundus camera with Polaroid 600 Plus film. Each photographic set was then examined stereoscopically for morphologic parameters: 1) comparison of vertical versus horizontal C/D ratio; 2) presence of nasal cupping; 3) presence of overpassing vessels; 4) presence of baring of circumlinear vessels; 5) presence of peripapillary atrophy; 6) ratio of the thinnest neuroretinal rim (NRR) width in the vertical sectors to the NRR width of the temporal sector. All subject’s central visual fields were examined with an automated static perimeter, Humphrey program C30-2 with STATPAC. The C/D ratio estimated by direct ophthalmoscopy consistently showed a smaller C/D ratio than that found by the stereophotographic method. The parameter with the highest probability value to differentiate between the optic disc of the early visual field loss and the optic disc of normal subjects was “Ratio of the thinnest NRR width in the vertical sectors to the NRR width of the temporal sector $\leq 85\%$”. Although it has less resolving power than slide film, a stereo disc photograph with Polaroid film is a quick and simple method of recording changes, and the ratio of the thinnest NRR width in the vertical sectors to the temporal sector is a good predictive parameter for detection of early visual field loss.

Key words: cup/disc ratio, early visual field loss, neuroretinal rim width, optic disc, stereophotography.

INTRODUCTION

In glaucoma patients care, ophthalmologists agree to that it is important to detect glaucomatous visual field loss and begin adequate treatment as early as possible. But in clinical investigation, the diagnosis of glaucoma is usually made when visual field defects are detected. In most cases, the optic disc changes prior to visual field loss, so assessment of the optic disc is a very important part of the evaluation of glaucoma and ocular hypertension patients.

Optic disc change is three-dimensional, and
early glaucomatous optic disc changes are delicate. So techniques of estimation or measurement of optic discs of persons who are suspected or are diagnosed as having glaucoma are requested. But the most sensitive techniques for the detection of optic disc changes require highly sophisticated instruments, such as the optic nerve head analyzer\textsuperscript{4,7} and laser tomographic scanner,\textsuperscript{8,9} which are expensive and not generally available in clinical practice. However, an inexpensive but reliable method is stereoscopic photography.\textsuperscript{10}

Stereophotography of the optic disc is a reliable and clinically useful method of demonstrating early glaucomatous changes,\textsuperscript{11-13} and careful examination of magnified stereo-pair photographs of the glaucomatous disc allows accurate prediction of the presence or absence of visual field loss.\textsuperscript{14} There are two methods for disc stereophotography using slide film or Polaroid photo. Compared to slide film, the Polaroid photo has the advantages of immediate reading and a 2.5 times magnified image; however, one disadvantage is its lower resolution.

The purpose of this study was to look for the features of the glaucomatous disc that are commonly associated with early visual field loss using the disc color stereophotography with Polaroid photo. We determined the sensitivity, specificity, and probability of some non-quantitative findings known to be associated with glaucomatous optic disc changes.

**SUBJECTS AND METHODS**

At the time of the first examination, a general history taking and common ocular examinations were done. The optic discs were examined by direct ophthalmoscope, and the size of the cup and horizontal and vertical C/D ratio by contour were determined. Gonioscopy and base-line Goldmann perimetry were also done. For a subjects to be included in this investigation, the following criteria had to be satisfied: a C/D ratio of more than 0.4 with direct ophthalmoscopy, normal visual field with Goldmann perimetry supplied with kinetic determination with 3 isopters (I2e, I3e, I4e), an open anterior chamber angle, a refractive error of 4.5 diopter or less, and no other ocular and systemic diseases which could affect the visual field.

Each optic disc was photographed with a Canon fundus camera using Polaroid 600 Plus film. The pupil was dilated at least 6.0mm wide for stereophotography with one drop of 1% tropicamide followed 5 minutes after with one drop of 10% phenylephrine. Discs photographed the eye 25 or 30 minutes later. Two sequential color photos were obtained with parallel image displacement of 3mm produced by lateral movement of the camera and a 30° field.

Then each photographic set was examined stereoscopically for morphological parameters: comparison of C/D ratio with direct ophthalmoscopy and that with stereophotography (Fig. 1), vertical cup/disc(CDV) versus horizontal cup/disc(CDH) ratio, presence of nasal cupping, presence of baring of the circumlinear vessels, presence of peripapillary atrophy, and the neuroretinal rim(NRR) width. These are parameters of which we could acquire relatively accurate information about the disc with sequential color Polaroid stereophotography among the known characteristics of the glaucomatous optic disc changes.\textsuperscript{15,16} Vessel displacement was estimated on a scale of zero to 4° to indicate the deviation of the major trunks of the central retinal vessels from a line perpendicular to the floor and passing through their point of emergence in the floor of the cup.\textsuperscript{17} We served scale 0, 1°, 2°, 3°, 4° as mild displacement and 3°, 4° as severe displacement. Juxtapapillary choroidal atrophy was considered abnormal in size, if the maximal width on any point was estimated to be larger than 1/5 of the horizontal optic disc diameter.\textsuperscript{18}

We studied the NRR from the point of view of width. In most cases of advanced glaucoma, the central island remains.\textsuperscript{19} This central island originates from papillomacular bundle fiber, and these fibers are on the temporal sector of the NRR.\textsuperscript{20} According to Quigley et al.,\textsuperscript{21} the temporal sector of the NRR is the least damaged area and is occupied by papillomacular bundle fibers. On the basis of these reports, we measured the ratio of NRR width, because width is a one-dimensional but simple parameter. The NRR width of the temporal (30°) sector "a" is the least damaged papillomacular bundle; "b" is the thinnest NRR width of the superior or inferior sector except for the nasal 120° sector. Then we calculated the "b" to "a" ratio(Fig. 2,3).

The next time, all subjects' central visual fields were examined with automated static perimetry,
Fig. 1. The vertical cup/disc ratio with direct ophthalmoscopy was 0.65, but that with disc stereophotography was 0.76. The difference was 0.11.

Fig. 2. The NRR width of the temporal (30°) sector “a” is the least damaged papillomacular bundle. “b” is the thinnest NRR width of the upper or lower sector except for the nasal 120° sector. Then we calculated “b” to “a” ratio.

Fig. 3. The smallest ratio of the vertical neuroretinal rim width to the temporal sector width of the superior sector was 81.8%, and that of the inferior sector was 114%.

Fig. 4. The ratio of the NRR width of the superior sector to that of the temporal sector was 71.4%, and the ratio of the NRR width of the inferior sector to that was 75%.
the Humphrey program C30-2 with STATPAC. We defined early visual field loss according to Dr. Anderson,\textsuperscript{22} that is the minimum defect to which attenuation can be paid is a single point depressed more than 10 decibel (dB) from normal, two points depressed at least 8 dB from the mean normal, or three or more points in a typical location depressed 5 dB from normal in a pattern standard deviation, or when a P valve was less than 5% in global indices. We compared the NRR width ratio with the amount of the most severe depressed retinal sensitivity (Fig. 4,5). We served other than above Humphrey visual field as normal, control group.

Forty-three eyes of 28 persons were included in this study. Twenty of the subjects were male and 8 were female. Their ages were 18-67 years with a mean of 44.8 years. Twelve normal eyes and 10 ocular hypertension eyes served as the control group, and 21 eyes of the primary open-angle glaucoma had early visual field loss (Table 1).

Then we calculated the sensitivity, specificity, and probability of the parameters for the detection of early visual field loss.

### RESULTS

Although the early visual field loss group had a slightly larger C/D ratio than the control group, it is not statistically significant. The C/D ratio of the early visual field loss group was from 0.39 to 0.86 vertically, and 0.45 to 0.82 horizontally (Fig. 6).

We found the differences between the C/D ratios with direct ophthalmoscopy and with disc stereophotography. Fig. 7 shows this relationship. The difference was maximally 0.29. Stereophotography consistently gave a slightly larger C/D ratio than direct ophthalmoscopy. The C/D ratio with direct ophthalmoscopy was smaller by about 0.13 than with stereophotography.

In the early visual field loss group, most of the ratio of the thinnest vertical NRR width to the NRR width of the temporal sector (b to a) was 85% or less (Fig. 8), and there was an inverse relationship between the ratio of the NRR width and the amount of the most depressed retinal sensitivity (Fig. 9).

In the sensitivity, specificity, and probability of the parameters of glaucomatous disc changes, a vertically oval cup had high sensitivity but low specificity; the presence of overpassing vessels had a high specificity but low sensitivity; and others had a low value in both. But the NRR width ratio, the thinnest upper or lower sector to the temporal sector, 85% or less had high value in both sensitivity and specificity. The parameter with the highest value in probability to differentiate between the normal and early glaucomatous eyes of this study is the NRR ratio, which had 82.1%, followed by vertically oval cup (CDV > CDH), 57.6%, and the presence of overpassing vessels, 52. % (Table 2).

### DISCUSSION

There was a difference between the C/D ratio with direct ophthalmoscopy and with stereophotography. This difference in our study was 0.13. In Carpel and Engstrom's report,\textsuperscript{23} the mean C/D ratio in the group examined with Hruby lens was 0.38, and in the group examined with direct ophthalmoscope it was 0.25. The difference was 0.13, and the C/D ratio of the three-dimensional examination was larger than that of the two-dimensional examination. This finding supports the fact that cupping of the optic nerve head should be defined on the basis of three-dimensional contour and not of two-dimensional pallor (Fig. 1).

In the past, the C/D ratio of a normal person was known below 0.5 or 0.6\textsuperscript{24}. But there were many reports that the size of the cup is dependent on the size of the disc, and large optic discs have large physiologic cups.\textsuperscript{25-29} Kass et al.\textsuperscript{30} and Kitazawa et al.\textsuperscript{31} insisted that the C/D ratio was not helpful in the early diagnosis of glaucoma. Many authors were of the opinion up to now that the vertical ovalness of any cup in the disc should

### Table 1. Distribution of subjects

<table>
<thead>
<tr>
<th>Age</th>
<th>Persons</th>
<th>Classification</th>
<th>Eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-</td>
<td>Normal</td>
<td>OHT</td>
</tr>
<tr>
<td></td>
<td>20-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OHT: ocular hypertension, POAG: primary open-angle glaucoma
Fig. 5. The Humphrey visual field of Fig. 4. In a pattern standard deviation, the amount of the most severely depressed retinal sensitivity in the lower half of the visual field was 11 decibel, and the amount of the most severe depressed retinal sensitivity in the upper half of the visual field was 10 decibel.

raise suspicions of glaucoma and that the vertical C/D ratio is of particular significance\textsuperscript{27,32-34}. So we used a vertically oval cup (CDV > CDH) as a parameter of the glaucomatous optic disc in our study.

At present, there are many papers about the NRR area of the optic disc. According to these papers, the status of the rim tissue is more important than the cup\textsuperscript{35}, and the correlation between the NRR area and the visual field was higher than that between the C/D ratio and the visual field defects.\textsuperscript{27,36} Balazsi et al.\textsuperscript{37} reported that the NRR area is an optic disc variable that is superior to the C/D ratio in its correlation with visual function and its ability to differentiate among normal eyes, eyes with suspected glaucoma, and early glaucoma.

The correlation between the NRR area and visual field defect was higher than that between the C/D ratio and visual field defect. After Balazsi et al.'s report,\textsuperscript{37} it was observed that a large disc has a large cup, but the NRR area is constant in all normal discs despite the size, many authors reported the NRR area of the normal disc and glaucomatous optic disc.\textsuperscript{27} But the NRR area is directly related to the size of the optic disc,\textsuperscript{38} and the large optic discs and optic nerves have more optic nerve fibers than do
small discs and nerves.\(^9\) Undoubtedly, the course of nerve fiber may be more or less oblique in the disc. Therefore, the NRR area will depend not only on the number of fibers but also on the course of the fibers in an optic nerve head.\(^9\) This means that the absolute value of the NRR area doesn’t predict visual field loss, and other parameters, which will off-set the effect of the optic disc size and inclination of the optic nerve fibers, are needed.

A normal NRR configuration is inferiorly broader than superiorly and the smallest temporally.\(^9\) In glaucoma, the rate of loss of NRR on superior and inferior poles is rapid, leading to an hour glass-shaped atrophy,\(^41\) or ovalization of the cup upwards, downwards, or on the temporal side appears early. It results in a localized thinning of the NRR.\(^42\) Jonas et al.\(^27,43\) insisted that the smallest rim width outside the temporal horizontal disc sector is a pathognomonic finding for the early glaucomatous visual field loss.

In advanced glaucoma, the central island and temporal island remain. These papillomacular bundle fibers are the most resistant and occupy

---

**Fig. 6.** The relationship between the presence or absence of early visual field loss and cup/disc ratio is shown.

---

**Fig. 7.** The difference of the cup/disc ratio with direct ophthalmoscopy and with disc stereophotography is shown.
the temporal sector of the NRR on the optic disc. This temporal sector is the least damaged area.\textsuperscript{21,35} We considered this least damaged temporal NRR as the basis of glaucomatous NRR change. To decrease any artificial alterations in the stereophotograph and to make a simple method, we used the one-dimensional unit width instead of the two-dimensional unit area. We used the ratio to off-set the effect of inclination of the retinal nerve fibers. The ratio of the thinnest NRR width of the superior or inferior sector to the temporal NRR width in early visual field loss group was almost 85% or less in our study (Fig. 8). In 1988, Jonas et al.\textsuperscript{43} measured the NRR width of the early glaucomatous optic disc using the morphometric method. A disc of glaucoma stage II of their study had a temporal NRR width of 0.22mm, and the thinnest vertical NRR width is 0.19mm. This disc’s NRR ratio 0.19/0.22(86.4%) was similar to our criterion of 85%.

There were some reports that the NRR area correlates significantly with visual field indices.\textsuperscript{44,45} Airaksinen et al.\textsuperscript{46} reported that the index for the overall loss of retinal sensitivity had a somewhat higher correlation coefficient than the index expressing localized visual field changes achieved by quadratic regression. We compared our NRR width ratio and the amount of depressed retinal sensitivity from normal data and found there was also an inverse or quadratic regression between the ratio of the thinnest vertical NRR width to the temporal NRR width and the amount of the depressed retinal sensitivity (Fig. 9).

In summary, optic disc stereophotography using Polaroid photo has advantages in its immediate reading, relatively acceptable resolution, and accurate recording of theoptic disc change. The C/D ratio with direct ophthalmoscopy is about 0.13 smaller than that with stereophotography. The ratio of the thinnest vertical NRR width to temporal NRR width, 85% or less, is a simple parameter, and has a high diagnosability for the detection of early visual field loss.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Chong Yeun Park for taking the disc stereophotographs used in this study.

REFERENCES


5. Dandona, L., Quigley, H. A., and Jampel, H. D.: Reliability of optic nerve head topographic...
Fig. 9. There was an inverse or quadratic regression relationship between the ratio of the neuroretinal rim width and the amount of the depressed retinal sensitivity.

Table 2. Diagnosability of characteristic disc parameters

<table>
<thead>
<tr>
<th>Characteristic Parameter</th>
<th>Sensitivity(%)</th>
<th>Specificity(%)</th>
<th>Probability(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDV &gt; CDH</td>
<td>18 / 22 (81.8)</td>
<td>10 / 21 (47.6)</td>
<td>57.6</td>
</tr>
<tr>
<td>Nasal cup(+)</td>
<td>10 / 22 (45.4)</td>
<td>13 / 21 (61.9)</td>
<td>50.9</td>
</tr>
<tr>
<td>Overpassing vsl.(+</td>
<td>4 / 22 (18.2)</td>
<td>18 / 21 (61.9)</td>
<td>52.5</td>
</tr>
<tr>
<td>Vsl. displacement: severe</td>
<td>9 / 22 (40.9)</td>
<td>5 / 21 (23.8)</td>
<td>31.8</td>
</tr>
<tr>
<td>Peripapillary atrophy &gt; 1/5 DD</td>
<td>13 / 22 (59.1)</td>
<td>8 / 21 (38.1)</td>
<td>45.4</td>
</tr>
<tr>
<td>Baring of circumlinear vsl.(+)</td>
<td>8 / 22 (36.4)</td>
<td>13 / 21 (61.9)</td>
<td>45.4</td>
</tr>
<tr>
<td>NRR width ratio ≤ 85%</td>
<td>29 / 35 (82.9)</td>
<td>43 / 51 (84.3)</td>
<td>82.1</td>
</tr>
</tbody>
</table>

CDV: vertical cup / disc ratio,
CDH: horizontal cup / disc ratio,
(+): presence,
Vsl.: vessels,
DD: disc diameter,
NRR: neuroretinal rim,
temp: temporal sector
34. Gloster, J.: Quantitative relationship between cupping of the optic disc and visual field loss in