Short-term Change of Optic Nerve Head Topography after Trabeculectomy in Adult Glaucoma Patients as Measured by Heidelberg Retina Tomograph

Ki Ho Park, M.D., Dong Myung Kim, M.D., and Dong Ho Youn, M.D.*

Department of Ophthalmology, Seoul National University College of Medicine,
*Department of Ophthalmology, Eulji Hospital, Seoul, Korea

Using the Heidelberg Retina Tomograph (HRT, Heidelberg Engineering, Heidelberg, Germany) we investigated whether reversal of glaucomatous optic disc cupping occurs in adult glaucoma patients following intraocular pressure (IOP) reduction by trabeculectomy, and whether topographic change in the optic disc differs according to region. Thirteen eyes of 13 glaucoma patients in whom IOP reduction was 25% or more at postoperative follow-up of 2 months were enrolled in the study. Cup/disc area ratio had decreased significantly, while rim area and rim volume showed significant increases (p < 0.05, Wilcoxon signed rank test). Among the optic disc sectors, rim area in the superior and inferior quadrants, especially in the superotemporal and inferotemporal octant, had increased significantly. The decrease in maximum cup depth correlated significantly with the percent IOP reduction (r = 0.698, p = 0.016). Reversal of glaucomatous optic disc cupping after IOP reduction following trabeculectomy in adult patients was confirmed by HRT. Furthermore, the regions of selective reversal in the superior and inferior quadrants coincided with those parts of the optic nerve head in which early functional and structural glaucomatous damage has been known to occur.

Key words: adult glaucoma, cupping reversal, intraocular pressure, trabeculectomy

INTRODUCTION

It is well known that optic disc cupping is reversed after intraocular pressure (IOP) reduction following glaucoma surgery in congenital or juvenile glaucoma.1–5 Cupping reversal, on the other hand, is rarely observed in adult glaucoma,6–11 since the change in optic disc cupping is so minimal that detection by a conventional method is difficult. The degree of IOP reduction10,11 and of optic nerve head damage7,12 at the time of treatment may also affect morphologic change in the optic nerve head after treatment. Conventional methods of optic nerve head analysis include photography, stereophotography, and computer assisted videoanalysis.8–10

The recently developed Heidelberg Retina Tomograph (HRT, Heidelberg Engineering, Heidelberg, Germany), which uses a confocal scanning laser tomography technique, has proved superior to conventional techniques in terms of reproducibility and accuracy.13–17 Using HRT, the authors investigated quantitative change in optic nerve head topography after IOP reduction following trabeculectomy in adult glaucoma patients and also analyzed the segmental predilection of the optic nerve head for morphologic change.
MATERIALS AND METHODS

We prospectively enrolled 13 eyes of 13 patients who had undergone trabeculectomy and met the following inclusion criteria: 1) glaucomatous visual field defect as seen on the Humphrey Field Analyzer, program C30-2 (Zeiss-Humphrey Inc, San Leandro, California, U.S.A.); 2) preoperative IOP equal to or above 22 mmHg; 3) IOP reduction after trabeculectomy greater than 25%; 4) mean standard deviations of triple measurement by HRT at preoperative and postoperative 2 months of less than 30 μm; 5) postoperative IOP measured at two to three-weeks intervals consecutively greater than 5 mmHg. Where trabeculectomy was performed in both eyes, one eye was randomly selected.

The patients mean age was 59.3 ± 9.1 years old and the male to female ratio was 9:4. Four patients were suffering from primary open angle glaucoma, eight of chronic angle closure glaucoma, and one from pseudophakic glaucoma. The average mean deviation, as determined by Humphrey Field Analyzer, was −14.77 ± 9.34 dB.

Triple measurements of the optic nerve head were performed at preoperative and postoperative 2 months with a Heidelberg Retina Tomograph version 1.11, using a 15-degree field. To correct for magnification error, K-readings and refractive errors were measured at preoperative and postoperative 2 months. During each session, mean topographic images were obtained. The contour line of disc margin was automatically exported from preoperative mean topography to that of postoperative 2 months by HRT software.

The parameters compared between the two sessions were cup/disc area ratio, rim area, rim volume, cup volume, maximum cup depth, and mean retinal nerve fiber layer thickness. We investigated whether these parameters changed significantly after IOP reduction following trabeculectomy and whether there was any correlation between the IOP change and the change in parameters. After dividing the optic nerve head into 6 segments - temporal and nasal quadrant, superotemporal, inferotemporal, superonasal, and inferonasal octant, we determined whether there was any difference in change of parameters among these segments.

Trabeculectomy was performed by one operator. A limbus based conjunctival flap, and then a triangular scleral flap with a 4 mm base was made. 0.01-0.04% mitomycin C was applied to the subconjunctiva for 5 minutes and a 1 × 3 mm sized trabeculectomy was performed.

Wilcoxon signed rank tests were used to compare the parameters at preoperative and postoperative 2 months, and Spearman correlation analyses were performed to investigate any possible correlation between percent change in IOP and percent change in parameters. A P-value less than 0.05 was considered significant.

RESULTS

Mean preoperative IOP, IOP at postoperative 2 months, amount of IOP reduction, and percent reduction of IOP were 26.2 ± 10.4 mmHg, 11.5 ± 4.0 mmHg, 14.8 ± 9.3 mmHg, and 53.2%, respectively.

The following changes were noted: cup/disc area ratio decreased significantly (p = 0.013) from 0.615 ± 0.173 preoperatively to 0.537 ± 0.172 postoperatively; rim area increased significantly (p = 0.015) from 0.924 ± 0.469 mm² preoperatively to 1.106 ± 0.425 mm² postoperatively; rim volume increased significantly (p = 0.046) from 0.185 ± 0.131 mm³ preoperatively to 0.234 ± 0.135 mm³ postoperatively; and cup volume decreased, with marginal significance (p = 0.059), from 0.455 ± 0.339 mm³ preoperatively to 0.375 ± 0.331 mm³ postoperatively. Maximum cup depth decreased from 0.636 ± 0.183 mm to 0.592 ± 0.212 mm and mean retinal nerve fiber layer thickness increased from 0.135 ± 0.129 mm to 0.162 ± 0.091 mm, but, without statistical significance (p = 0.279, p = 0.485, respectively) (Table 1).

Individual changes in parameters are shown in Table 2. Six of 13 eyes (46.2%) showed improvement in all five parameters (cases 2,6,7,9,11, and 12) while two eyes (cases 1 and 4) showed deterioration in more than half the parameters. Four eyes (cases 2,6,9, and 11) with IOP reduction equal to or greater than 65% showed improvement of all parameters.

There was a significant correlation between
REVERSAL OF OPTIC DISC CUPPING AFTER TRABECULECTOMY

Table 1. Postoperative changes in parameters of optic nerve head topography

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Preop</th>
<th>Postop (2mo)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDAR</td>
<td>0.615 ± 0.173</td>
<td>0.537 ± 0.172</td>
<td>0.013</td>
</tr>
<tr>
<td>RA(mm²)</td>
<td>0.924 ± 0.469</td>
<td>1.106 ± 0.425</td>
<td>0.015</td>
</tr>
<tr>
<td>RV(mm³)</td>
<td>0.185 ± 0.131</td>
<td>0.234 ± 0.135</td>
<td>0.046</td>
</tr>
<tr>
<td>CV(mm³)</td>
<td>0.455 ± 0.339</td>
<td>0.375 ± 0.331</td>
<td>0.059</td>
</tr>
<tr>
<td>MCD(mm)</td>
<td>0.636 ± 0.183</td>
<td>0.592 ± 0.212</td>
<td>0.279</td>
</tr>
<tr>
<td>mRNFLT(mm)</td>
<td>0.135 ± 0.129</td>
<td>0.162 ± 0.091</td>
<td>0.485</td>
</tr>
</tbody>
</table>

*: Wilcoxon signed rank test (n = 13)
CDAR: cup/disc area ratio, RA: rim area, RV: rim volume, CV: cup volume, MCD: maximum cup depth, mRNFLT: mean retinal nerve fiber layer thickness

Table 2. Individual changes in parameters of optic nerve head topography

<table>
<thead>
<tr>
<th>patient</th>
<th>Age</th>
<th>Sex</th>
<th>Dx</th>
<th>%IOPR</th>
<th>CDAR</th>
<th>RA</th>
<th>RV</th>
<th>CV</th>
<th>MCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54</td>
<td>M</td>
<td>POAG</td>
<td>56</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>*2</td>
<td>74</td>
<td>M</td>
<td>CACG</td>
<td>65</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>47</td>
<td>M</td>
<td>POAG</td>
<td>46</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>M</td>
<td>PSPG</td>
<td>50</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>63</td>
<td>M</td>
<td>POAG</td>
<td>33</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>*6</td>
<td>57</td>
<td>F</td>
<td>CACG</td>
<td>65</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*7</td>
<td>65</td>
<td>F</td>
<td>CACG</td>
<td>38</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>62</td>
<td>F</td>
<td>CACG</td>
<td>25</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>*9</td>
<td>65</td>
<td>M</td>
<td>CACG</td>
<td>78</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>65</td>
<td>M</td>
<td>POAG</td>
<td>50</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>*11</td>
<td>60</td>
<td>F</td>
<td>CACG</td>
<td>85</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*12</td>
<td>63</td>
<td>M</td>
<td>CACG</td>
<td>48</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>58</td>
<td>M</td>
<td>CACG</td>
<td>54</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

*: reversal in all parameters, +: increase, -: decrease,

percent IOP reduction and percent decrease in maximum cup depth (r = 0.697, p = 0.016, Spearman correlation analysis) (Fig. 1).

Segmental analysis of changes in rim area showed that the most significant increases had occurred in the superotemporal and inferotemporal octants (p = 0.002). The next most significant segments were the superonasal and inferonasal octants (p = 0.011, p = 0.023, respectively). The rim area of the temporal and nasal quadrants did not show any significant change (p > 0.05) (Table 3), and on segmental analysis nor did the other parameters.

Fig. 1. Scatter plot showing the percent decrease in maximum cup depth correlated significantly with the percent IOP reduction.
Table 3. Changes in rim area (mm²) of six predefined segments

<table>
<thead>
<tr>
<th>Segments</th>
<th>Preop</th>
<th>Postop (2mo)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal</td>
<td>0.134 ± 0.079</td>
<td>0.164 ± 0.066</td>
<td>0.064</td>
</tr>
<tr>
<td>Superotemporal</td>
<td>0.104 ± 0.064</td>
<td>0.134 ± 0.063</td>
<td>0.002</td>
</tr>
<tr>
<td>Inferotemporal</td>
<td>0.090 ± 0.069</td>
<td>0.115 ± 0.072</td>
<td>0.002</td>
</tr>
<tr>
<td>Nasal</td>
<td>0.321 ± 0.148</td>
<td>0.357 ± 0.173</td>
<td>0.101</td>
</tr>
<tr>
<td>Superonasal</td>
<td>0.135 ± 0.076</td>
<td>0.164 ± 0.079</td>
<td>0.011</td>
</tr>
<tr>
<td>Inferonasal</td>
<td>0.164 ± 0.081</td>
<td>0.193 ± 0.079</td>
<td>0.023</td>
</tr>
<tr>
<td>Total</td>
<td>0.924 ± 0.469</td>
<td>1.106 ± 0.425</td>
<td>0.015</td>
</tr>
</tbody>
</table>

*: Wilcoxon signed rank test (n = 13)

DISCUSSION

This study confirmed the short-term reversal of optic disc cupping in adult glaucoma patients after IOP reduction following trabeculectomy. If we reconstruct three-dimensionally our findings of morphologic change in the optic nerve head (Fig. 2), cup/disc area ratio decreases and rim area and rim volume increase significantly while mean retinal nerve fiber layer thickness tends to increase and maximum cup depth decrease. Increased rim area and rim volume in the anterior and centripetal direction is the main change. These increases in rim area were in the superior and inferior quadrants, predominantly in the superotemporal and inferotemporal octants (Fig. 2). These segments coincide with the portion of optic disc where early damage to the neuroretinal rim has been known to occur.

Katz reported that the improved optic disc cupping was seen in nearly one third of glaucomatous eyes (16 of 51 eyes) in which IOP decreased by at least 30%. Shin and associates reported that reversal of optic disc cupping is directly proportional to the percent IOP reduction. In our study, six of 13 eyes (46.2%) in which IOP reduction was at least 25% showed improvement in all measured parameters. In all four eyes in which IOP reduction was at least 65%, improvement was seen in all measured parameters. In addition the significant correlation between the percent IOP reduction and percent decrease in maximum cup depth, suggests a close relationship between the percent IOP reduction and the extent to which disc cupping is reversed.

The detailed mechanism of cupping reversal after IOP reduction has not been clearly explained. Levy et al. and Yan et al. observed posterior movement of the lamina cribrosa after IOP elevation in enucleated human eyes. It can be speculated that when IOP was reduced after trabeculectomy, anterior repositioning of posteriorly displaced lamina cribrosa and simultaneous reformation of neuroretinal tissue occurred. On the basis of our results showing that maximum cup depth decreased after IOP reduction, it may support the fact that anterior movement of the lamina cribrosa occurred. This alone, however, cannot fully explain optic
nerve head changes in vivo.

Optic nerve head blood flow\textsuperscript{20-24} and axoplasmic flow\textsuperscript{25-29} can in fact be affected by changes in IOP. After IOP reduction, optic nerve head reversal may therefore be due to improved blood flow in that area and the restoration of axoplasmic flow. The possibility of restoration of depressed neuronal tissue itself should also be considered. Sogano et al.,\textsuperscript{30} using an optic nerve head analyzer, reported that increased relative nerve fiber layer height was pressure dependent and speculated that this reversal may reflect the recovery of the compressed nerve fiber layer.

Although disc edema that may develop after acute IOP reduction can affect the results, it has been reported that two months postoperatively, the occurrence of this condition is minimal.\textsuperscript{31} On ophthalmoscopy, it was not seen in our patients.

In this study, visual field change was not evaluated. Katz et al.\textsuperscript{9} reported that in 41\% of eyes in which IOP decreased by at least 30\%, visual field improved. Spaeth\textsuperscript{31} and Sogano et al.\textsuperscript{30} reported a positive correlation between the degree of visual field improvement and amount of IOP reduction.

In summary, anterior repositioning of the laminar cribrosa and morphological recovery of compressed neuronal tissue may contribute to cupping reversal. This suggestion is supported by the fact that the segment in which major recovery is seen in the superior and inferior portion of the neuroretinal rim, where there is more neuronal tissue and more nerve fiber. For a more exact explanation of the mechanism involved in the reversal of optic nerve head, further study with a larger number of patients and longer follow-up combined with functional evaluation may be required.

REFERENCES

17. Rohrschneider, K., Burk, R.O.W., Kruse, F.E., and


