Parapapillary Retinal Vessel Diameter in Normal and Glaucoma Eyes

II. Correlations

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The juxtapapillary diameters of the superior temporal and inferior temporal retinal artery and vein have been shown to be significantly smaller in glaucomatous eyes than in normal eyes. They had been measured in 473 eyes of 281 patients with chronic primary open-angle glaucoma and in 275 eyes of 173 normal subjects. In the current study the vessel diameters were correlated with intra- and parapapillary morphometric data and visual field indices. Only one eye per patient and subject was taken for statistical analysis. The retinal vessel calibers were significantly (P < 0.001) correlated with: (1) the area of the neuroretinal rim as a whole and in four different optic disc sectors; (2) the rim width determined every 30°; (3) the optic cup area and diameters; (4) the horizontal and vertical cup/disc ratios and (5) the quotient of them; (6) the retinal nerve fiber layer score; (7) the area of the parapapillary chorioretinal atrophy; and (8) the visual field indices. In the same eye the vessel caliber was smaller in that sector where the neuroretinal rim loss was highest and the retinal fiber layer score lowest. In intraindividual comparison the vessels were smaller in that eye with less neuroretinal rim tissue and lower nerve fiber layer score. No significant correlations were found with the form of the optic disc, the area of the peripapillary scleral ring, side, sex and refraction. The correlation coefficients were not significantly different when the control group was matched for age. The parapapillary retinal vessel diameter decreases with advancing glaucomatous optic nerve damage. It is correlated with morphometric intra- and parapapillary glaucomatous changes and perimetric defects. Invest Ophthalmol Vis Sci 30:1604-1611, 1989

In normal eyes the juxtapapillary retinal vessel diameter has recently been shown to be larger in the inferior temporal arcade compared to the superior temporal arcade. This corresponded with the width of the neuroretinal rim, which is broader at the inferior optic disc pole than at the superior disc pole, with the visibility of the retinal nerve fiber bundles, which are more detectable in the inferior temporal retinal area than in the superior temporal region, and with the location of the foveola 0.53 ± 0.34 mm inferior to the optic disc center. In eyes with chronic primary open-angle glaucoma the vessel diameter was significantly smaller than in the normal eyes. It has been suggested that vessel diameter reflects the need for vascular supply in the corresponding super-
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matched control group consisted of 131 eyes of 32 men and 51 women with a mean age of 62.5 ± 12.1 years and a mean refractive error of +0.70 ± 2.03 diopters. Highly myopic eyes with a myopic refraction of more than -8.00 diopters had generally been excluded because they have different morphometric optic disc characteristics. Computerized perimetry (Octopus program 32-34 or program G1) had been performed for 310 eyes of 172 glaucoma patients. The criteria for the diagnosis of chronic primary open-angle glaucoma and the glaucoma staging have been described previously.

If both eyes had been photographed and morphometrically analyzed, only one randomly chosen eye per patient and subject was taken for interindividual comparisons. For intraindividual studies the bilaterally evaluated eyes were taken.

Method

All optic nerve head photographs (15° color stereo diapositives) had been taken with a telecentric Zeiss fundus camera. They were magnified ×15 and projected. The outlines of the optic disc and cup, the peripapillary scleral ring of Elschnig, the parapapillary chorioretinal atrophy zones Alpha and Beta, and the inferior temporal and superior temporal retinal artery and vein at the disc border and 2 mm from the optic disc center were plotted on paper and morphometrically analyzed (Zeiss Morphomat 30). The photographic magnification was corrected according to Littmann. For the optic disc and optic cup we determined the area, the horizontal, vertical, minimal and maximal diameter, the ratio of minimal to maximal diameter, the angle between the maximal diameter and the horizontal, and a form factor. The latter ranged from 1.0 for an ideal circle to 0.0 for a structure quite unsimilar to a circle. The neuroretinal rim area resulted as the difference of disc area minus cup area, and as the sum of the rim areas in the four different disc sectors. The neuroretinal rim width was measured every 30°. In the juxtapapillary region the peripapillary scleral ring of Elschnig and zone Alpha and zone Beta of juxtapapillary chorioretinal atrophy were measured.

The intra- and parapapillary area was divided into four sectors (Fig. 1). The superior temporal and the inferior temporal sectors B and C were right-angled, and their middle lines were tilted 13° to the vertical optic disc axis. Sector A on the temporal side and sector D on the nasal side (116°) covered the remaining area. Theoptic disc was the area inside of the white peripapillary scleral ring of Elschnig. The optic cup was defined on the basis of contour and not of pallor. Vessels were considered as part of the optic cup if there was no underlying neuroretinal rim tissue; otherwise they were considered to be part of the rim. The peripapillary scleral ring of Elschnig was the often circular white band surrounding the optic nerve head. It was often better seen on the temporal disc side than on the nasal side. Juxtapapillary chorioretinal atrophy was divided into two zones: zone Alpha was characterized by an irregular hypo- and hyperpigmentation, and intimated thinning of the chorioretinal tissue layer. It was adjacent to the retina on its outer side and to zone Beta or the peripapillary scleral ring of Elschnig on its inner side. Characteristics of zone Beta were marked atrophy of the retinal pigment epithelium and of the choriocapillaris, small gray fields on a whitish background, good visibility of the large choroidal vessels, thinning of the chorioretinal tissues, and round bounds to the adjacent zone Alpha on the peripheral side and to the peripapillary scleral ring on its central side. If both zones were

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Fig. 1. Sectioning of the intra- and juxtapapillary region according to the most frequent location of glaucomatous neuroretinal rim notches at about 13° temporal to the upper and lower optic disc pole: Sectors B and C are right-angled, and their midle lines are tilted 13° (angle β) temporal to the vertical disc axis. Sector A on the temporal side (64°) and sector D on the nasal side (116°) cover the remaining area. (Reprinted with permission from Jonas JB, Gusek GC, and Naumann GOH: Die parapapilläre Region in Normal- und Glaukomaugen. I. Planimetrische Werte von 312 Glaukom- und 125 Normalaugen. Klin Mbl Augenheilk 193:52, 1988 (ref. 11)).
correlation coefficient: 0.55; slope of the regression line: 0.016; significance: < 0.00001.

Concerning the vessel diameter, the highest coefficients were calculated for the inferior temporal artery (measured at the optic disc border), followed by the superior temporal artery (measured at the disc border).

If the neuroretinal rim notch was most marked in the inferior temporal disc sector the superior temporal artery was larger in 46% and the inferior temporal artery was larger in 42%. The superior temporal artery measured on an average 0.093 ± 0.020 mm, and the inferior temporal artery 0.091 ± 0.024 mm. If the rim notch was more distinct in the superior temporal disc sector the superior temporal artery was

Results

The parapapillary retinal vessel diameters were significantly correlated with:

- the neuroretinal rim area as a whole (Fig. 2) and divided into four optic disc sectors
- the ratio of the rim area in the temporal horizontal, in the inferior temporal and in the nasal disc sector divided by the total rim area
- the neuroretinal rim width measured every 30°
- the optic cup size
- the horizontal and vertical cup/disc ratios (Fig. 3)
- the quotient of the horizontal to vertical cup/disc ratio (Table 1)
- area of zone Beta of parapapillary chorioretinal atrophy (Fig. 4)
- the area of the total parapapillary chorioretinal atrophy (zone Alpha plus zone Beta)
- the retinal nerve fiber layer score as a whole (Fig. 5) and evaluated separately in the four retinal regions, and
- the mean visual field loss per tested point (Table 2).

The correlation coefficients were not significantly different if the control group was matched for age. Concerning the tested parameters, the correlation coefficients were highest for the neuroretinal rim data, followed by the cup/disc ratios, the retinal nerve fiber layer score, the perimetric loss, area of zone Beta, and area of the total parapapillary chorioretinal atrophy (Tables 1, 2).

Concerning the vessel diameter, the highest coefficients were calculated for the inferior temporal artery (measured at the optic disc border), followed by the superior temporal artery (measured at the disc border).

If the neuroretinal rim notch was most marked in the inferior temporal disc sector the superior temporal artery was larger in 46% and the inferior temporal artery was larger in 42%. The superior temporal artery measured on an average 0.093 ± 0.020 mm, and the inferior temporal artery 0.091 ± 0.024 mm. If the rim notch was more distinct in the superior temporal disc sector the superior temporal artery was
Correlations of the retinal vessel diameter

Table 1. Correlations of the retinal vessel diameter

<table>
<thead>
<tr>
<th>Neuroretinal rim</th>
<th>Area (total)</th>
<th>Sector A</th>
<th>Sector B</th>
<th>Sector C</th>
<th>Sector D</th>
<th>Sector A/total</th>
<th>Sector B/total</th>
<th>Sector C/total</th>
<th>Sector D/total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>0.44 t</td>
<td>0.35 t</td>
<td>0.36 t</td>
<td>0.35 t</td>
<td>0.36 t</td>
<td>0.28 t</td>
<td>0.27 t</td>
<td>0.21 t</td>
<td>-0.27 t</td>
</tr>
<tr>
<td>Cup area</td>
<td>0.32 t</td>
<td>0.35 t</td>
<td>0.36 t</td>
<td>0.35 t</td>
<td>0.27 t</td>
<td>0.16 t</td>
<td>0.14* t</td>
<td>0.18 t</td>
<td>0.21 t</td>
</tr>
<tr>
<td>Cup form</td>
<td>-0.12* t</td>
<td>-0.39 t</td>
<td>-0.21 t</td>
<td>-0.34 t</td>
<td>-0.25 t</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Cup/disc ratios</td>
<td>-0.36 t</td>
<td>-0.42 t</td>
<td>-0.23 t</td>
<td>-0.25 t</td>
<td>-0.34 t</td>
<td>-0.12* t</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Hor/vertical</td>
<td>0.23 t</td>
<td>0.51 t</td>
<td>0.32 t</td>
<td>0.25 t</td>
<td>0.36 t</td>
<td>-0.16 t</td>
<td>ns</td>
<td>ns</td>
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</tr>
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<td></td>
</tr>
</tbody>
</table>

Coefficients of correlations between the intrapapillary retinal vessel diameter and intrapapillary morphometric intra- and parapapillary data. 1 = diameter of the superior temporal artery at the optic disc border; 2 = diameter of the inferior temporal artery at the optic disc border; 3 = diameter of the superior temporal artery 2 mm from the optic disc center; 4 = diameter of the inferior temporal artery 2 mm from the optic disc center; 5 = diameter of the superior temporal vein at the optic disc border; 6 = diameter of the inferior temporal vein at the optic disc border; 7 = diameter of the superior temporal vein 2 mm from the optic disc center; diameter of the inferior temporal artery 2 mm from the optic disc center. * = P < 0.01; t = P < 0.001; ns = not significant.

larger in 29%, and the inferior temporal artery was wider in 42%. In this group the diameter of the superior temporal artery was 0.090 ± 0.019 mm, and the caliber of the inferior temporal artery 0.093 ± 0.020 mm.

If the rim area in the superior temporal disc sector was larger than the rim area in the inferior temporal

![Fig. 4. Scattergram of the correlation between the total area of zone Beta of parapapillary choroidal atrophy (visible large choroidal vessels and sclera) and the diameter of the inferior temporal artery (measured at the optic disc border) in 473 eyes of 281 patients suffering from chronic primary open-angle glaucoma and in 275 eyes of 173 normal subjects. Only one randomly assessed eye per patient and subject was taken for statistical analysis. Correlation coefficient: -0.20; slope of the regression line: -0.004; significance: P < 0.0001.](https://jo...)

![Fig. 5. Scattergram of the correlation between the retinal nerve fiber layer score and the diameter of the inferior temporal artery (measured at the optic disc border) in 137 eyes of 79 patients suffering from chronic primary open-angle glaucoma and in 127 eyes of 72 normal subjects. Only one randomly assessed eye per patient and subject was taken for statistical analysis. Correlation coefficient: 0.41; slope of the regression line: +0.002; significance: P < 0.00001.](https://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/933378/ on 11/14/2018)
disc sector, the artery diameter was larger in 54% in the superior temporal sector and larger in 38% in the inferior temporal sector. Mean artery caliber was superior temporally \(0.100 \pm 0.020\) mm and inferior temporally \(0.094 \pm 0.031\) mm. If the rim area was larger in the inferior temporal disc sector than in the superior temporal disc sector, the artery was wider in 12% in the superior temporal sector and in 53% in the inferior temporal sector wider. Mean artery caliber was superior temporally \(0.094 \pm 0.019\) mm and inferior temporally \(0.104 \pm 0.028\) mm.

If the retinal nerve fiber layer score was larger in the superior temporal retinal area than in the inferior temporal one, the artery was wider in 57% in the superior temporal sector and in 35% in the inferior temporal sector. Mean artery caliber was superior temporally \(0.100 \pm 0.020\) mm and inferior temporally \(0.094 \pm 0.031\) mm. If the retinal nerve fiber layer of the inferior temporal area was higher, the superior temporal artery was wider in 12% and the inferior temporal artery in 53%. Mean diameter of the superior temporal artery was \(0.094 \pm 0.019\) mm and of the inferior artery \(0.104 \pm 0.028\) mm.

If the neuroretinal rim area was larger or if the retinal nerve fiber layer score was higher in the left eye than in the left eye, the vessels were significantly \((P < 0.01)\) larger in the right eye than in the left eye. If the neuroretinal rim area was larger or if the retinal nerve fiber layer score was higher in the left eye, the vessels were significantly \((P < 0.01)\) larger in the left eye.

No correlations were found with age, refraction, sex and side.

**Discussion**

The retinal vessel diameter decreased with increasing glaucoma stage. The reduction of the vessel diameter was correlated with morphologic and perimetric glaucomatous changes. The correlation coefficients were highest for the diameter of the inferior temporal artery (measured at the optic disc border), followed by the diameter of the superior temporal artery (measured at the disc border). This corresponds with:

1. The significantly higher frequency of glaucomatous neuroretinal rim notches in the inferior temp-

**Table 2. Correlations of the retinal vessel diameter**

<table>
<thead>
<tr>
<th>Parapapillary chorioretinal atrophy zone Alpha</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector A</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Sector B</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Sector C</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Sector D</td>
<td>ns</td>
<td>ns</td>
<td>-0.23 t</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>-0.16* ns</td>
</tr>
</tbody>
</table>

| Zones Beta                                    | Total | -0.15 t | -0.20 t | -0.13* | -0.19 t | -0.13* | -0.16 t | -0.13* | -0.16 t |
| Sector A                                      | -0.17 t | -0.19 t | -0.12* | -0.19 t | -0.13* | -0.17 t | -0.12* | -0.12* | -0.18 t |
| Sector B                                      | -0.14* | -0.19 t | -0.14* | -0.16 t | -0.14* | -0.13 t | -0.13* | -0.13* | -0.13* |
| Sector C                                      | -0.15 t | -0.18 t | ns | -0.18 t | -0.12* | -0.17 t | ns | -0.16 t | ns |
| Sector D                                      | ns | -0.16 t | ns | -0.15* | ns | ns | -0.12* | ns | ns |

| Zones Alpha and Beta                          | Total | -0.20 t | -0.33 t | ns | -0.20 t | -0.20 t | -0.27 t | -0.21 t | -0.21 t |
| Sector A                                      | -0.17 t | -0.20 t | -0.14* | -0.20 t | ns | -0.17 t | -0.13* | -0.15* | -0.15* |
| Sector B                                      | -0.14* | -0.20 t | -0.14* | -0.17 t | -0.12* | ns | -0.17 t | -0.13* | -0.13* |
| Sector C                                      | -0.17 t | -0.21 t | -0.13* | -0.20 t | ns | -0.18 t | ns | -0.18 t | ns |
| Sector D                                      | -0.15* | -0.30 t | ns | -0.16* | -0.18* | -0.17* | -0.22 t | -0.19* | ns |

| Retinal nerve fiber layer                      | Total | 0.33 t | 0.41 t | ns | ns | 0.25* | 0.34 t | 0.32 t | 0.33 t |
| Sector A                                      | 0.29 t | 0.37 t | ns | ns | 0.27 t | 0.35 t | 0.34 t | 0.31 t | 0.31 t |
| Sector B                                      | 0.35 t | 0.39 t | ns | ns | 0.23* | 0.32 t | 0.31 t | 0.32 t | 0.32 t |
| Sector C                                      | 0.30 t | 0.39 t | ns | ns | 0.24* | 0.35 t | 0.31 t | 0.35 t | 0.35 t |
| Sector D                                      | 0.30 t | 0.40 t | ns | 0.22* | 0.28 t | 0.30 t | 0.30 t | 0.30 t | 0.30 t |

| Visual field loss (mean loss per test point)   | -0.28 t | -0.39 t | -0.16* | -0.23 t | -0.30 t | ns | -0.24 t | ns |

Coefficients of correlations between the parapapillary retinal vessel diameter and intrapapillary morphometric intra- and parapapillary data. 1 = diameter of the superior temporal retinal area at the optic disc border; 2 = diameter of the inferior temporal retinal area at the optic disc border; 3 = diameter of the superior temporal artery at the optic disc border, 4 = diameter of the inferior temporal artery at the optic disc center; 5 = diameter of the superior temporal vein at the optic disc center; 6 = diameter of the inferior temporal vein at the optic disc center; diameter of the inferior temporal artery 2 mm from the optic disc center; diameter of the inferior temporal vein 2 mm from the optic disc center.

* = \(P < 0.01\); \(t = P < 0.001\); ns = not significant.
Fig. 6. (top) Optic disc with unilateral glaucomatous optic nerve damage (glaucoma stage III–IV) due to secondary open-angle glaucoma. Optic disc: area: 1.82 mm², horizontal diameter: 1.38 mm, vertical diameter: 1.65 mm. Optic cup: area: 1.50 mm², horizontal diameter: 1.22 mm, vertical diameter: 1.52 mm. Cup/disc ratio horizontal: 0.88, vertical: 0.91, horizontal/vertical: 0.97. Neuroretinal rim: area: 0.32 mm², width at the upper disc pole: 0.10 mm, at the lower disc pole: 0.04 mm, nasal: 0.10 mm, temporal: 0.06 mm. Zone Alpha (arrowheads) of parapapillary chorioretinal atrophy: 1.71 mm²; zone Beta (arrows) of parapapillary chorioretinal atrophy: 0.54 mm². Retinal vessel diameter (measured at the optic disc border): superior temporal artery: 0.07 mm, inferior temporal artery: 0.06 mm, superior temporal vein: 0.13 mm, inferior temporal vein: 0.12 mm. Note: No parapapillary retinal nerve fiber bundles detectable, in contrast to Figure 7.

Fig. 7. (bottom) Normal optic nerve head (contralateral eye of Fig. 6). Optic disc: area: 1.69 mm², horizontal diameter: 1.38 mm, vertical diameter: 1.56 mm. No optic cup. Cup/disc ratio: 0.00. Neuroretinal rim: area: 1.69 mm². Zone Alpha (arrowheads) of parapapillary chorioretinal atrophy: 0.30 mm², no zone Beta of parapapillary chorioretinal atrophy. Retinal vessel diameter (measured at the optic disc border): superior temporal artery: 0.12 mm, inferior temporal artery: 0.13 mm, superior temporal vein: 0.16 mm, inferior temporal vein: 0.19 mm. Note: parapapillary retinal nerve fiber bundles very distinct.

The vein diameters were generally less well correlated with the glaucomatous changes than the artery diameters. The inferior temporal vein decreased from 0.137 ± 0.020 mm in the normal eyes to 0.125 ± 0.025 mm in the glaucoma group. Presuming a tube-like form, this represents a decrease of the vessel cross-section area of 16.7% compared with 28.8% for...
the cross-section reduction of the inferior temporal artery (diameter in normal eyes: 0.109 ± 0.019 mm; glaucomatous eyes: 0.092 ± 0.023 mm). The discrepancy between the decrease of artery and vein cross-section might be caused by a clinically asymptomatic engorgement of the venous blood flow in glaucoma. The impendiment might be responsible for the higher frequency of central retinal vein occlusion in eyes with chronic primary open-angle glaucoma.18

Concerning the tested parameters, the correlation coefficients were highest for the neuroretinal rim area (Fig. 2, Tables 1, 2). When the rim area was measured in four different disc sectors separately (Fig. 1) or if its width was determined every 30° in a clockwise fashion, the coefficients were relatively higher if the vessel diameter was compared with the rim area and width of the corresponding disc sector (Table 1). This might also be taken as evidence for the spatial relationship between the glaucoma damage and the local vessel diameter.

The correlation coefficients were second highest for the cup/disc ratios in spite of their dependence on the optic disc size.2,19 The vertical cup/disc ratio (Fig. 3) was generally better correlated than the horizontal cup/disc ratio. This corresponds with the higher clinical value of the vertical ratio, and with its better correlation to intra- and parapapillary morphometric and perimetric data.15,17,20 The quotient of the horizontal to vertical cup/disc ratio also was significantly correlated with the vessel diameter. This parameter is larger than 1.0 in normal eyes because normally the horizontal cup/disc ratio is higher than the vertical one.6 In the course of glaucomatous optic nerve damage the neuroretinal rim loss takes place predominantly at the vertical disc poles so that the vertical cup/disc ratio enlarges more than the horizontal one. The quotient of the horizontal to vertical cup/disc ratio then becomes less than 1.0.6,17

Similar to the neuroretinal rim size and the cup/disc ratios, the retinal nerve fiber layer score (Fig. 5) was best correlated with the inferior temporal artery diameter followed by the superior temporal artery caliber and the vein width (Table 2). Again, the coefficients were relatively higher if the regional nerve fiber layer score was compared with the corresponding vessel diameter.

Lowest correlation coefficients were calculated for zone Beta (Fig. 4) and for total parapapillary chorioretinal atrophy. The significance of this relationship, however, shows the importance of evaluating the parapapillary region in glaucoma.11,15

If the glaucoma group was divided up into eyes with neuroretinal rim notches, rim area loss and decreased retinal nerve fiber layer score predominantly in the superior temporal or in the inferior temporal sector, respectively, the retinal arteries were significantly wider in that sector in which the rim area was larger, in which the rim notch was more distinct, and in which the retinal nerve fiber layer score was higher. This also indicates a spatial correlation between reduction of the vessel diameter and glaucomatous damage in the corresponding region. This is similar to the spatial relationship between the glaucomatous neuroretinal rim loss inside of the optic disc and the increase of parapapillary chorioretinal atrophy outside of the optic nerve head.11,15 If both eyes of the same patient were compared, the vessels were significantly smaller in that globe in which the neuroretinal rim area was smaller and the retinal nerve fiber layer score was lower (Figs. 6, 7).

The retinal vessel diameter has been evaluated already in recent studies21-26 in which, however, mostly only relative size units were used. The reduction of the vessel caliber in glaucoma observed in this study and its correlation in time and location with the morphologic and perimetric data show the importance of measuring the retinal vessel diameter in absolute size units for glaucoma diagnosis and possibly also for follow-up.

Key words: neuroretinal rim, optic disc morphometry, parapapillary chorioretinal atrophy, retinal nerve fiber layer, retinal vessel diameter

References

10. Jonas JB, Gusek GC, Guggemoos-Holzmann I, and Naumann GOH: Size of the optic nerve scleral canal and compari-


