Parapapillary Chorioretinal Atrophy in Normal and Glaucoma Eyes

I. Morphometric Data

Jost B. Jonas, Xuan N. Nguyen, Gabrielle C. Gusek, and Gottfried O. H. Naumann

Glaucomatous optic nerve damage is associated with alterations of the intra- and parapapillary optic disc area. We measured and compared the parapapillary region in 582 eyes of 321 patients suffering from chronic primary open-angle glaucoma and in 390 eyes of 231 normal subjects. Only one randomly assessed eye per patient and subject was taken for statistical analysis. Highly myopic eyes with a myopic refractive error of more than –8.00 diopters had been excluded. The parapapillary chorioretinal atrophy was divided into a peripheral zone “Alpha” with irregular hyper- and hypopigmentation, and a more central zone “Beta” characterized by whitish colour, visible large choroidal vessels and visible sclera. In the normal eyes both zones were significantly (P < 0.001) largest and most common in the temporal horizontal sector, followed by the inferior temporal sector, the superior temporal sector and finally the nasal sector. In the glaucoma group both zones were significantly larger (P < 0.0001; Mann-Whitney test) and more frequent than in the normal eyes (0.40 ± 0.32 mm² versus 0.65 ± 0.49 mm² for zone Alpha, 0.13 ± 0.42 mm² versus 0.79 ± 1.17 mm² for zone Beta). The differences were significant also for the earliest glaucoma stage of this study. They were most marked for the nasal parapapillary sector. Significant differences (P < 0.001) between the normal group and the earliest glaucoma stage were: zone Alpha larger than 0.20 mm² or broader than 0.20 mm in the temporal horizontal sector, total area of zone Alpha larger than 0.30 mm², occurrence of zone Alpha in the nasal sector, and occurrence of zone Beta anywhere.

The morphologic glaucoma diagnosis has been based on the measurement and description of intra-papillary parameters, eg, the horizontal and vertical cup/disc ratios, the area and configuration of the optic cup and of the neuroretinal rim,1-14 baring of circumlinear and cilioretinal vessels,15,16 and optic disc hemorrhages.17-20 Outside of the optic nerve head the retinal nerve fiber layer has been examined and correlated with results of other morphologic and psychophysic examinations.7-21-24 The parapapillary region has generally been neglected although there have been reports on the glaucoma associated alteration of this area.25-30 In the current study the morphologic characteristics of this juxtapapillary region were measured and compared in groups of glaucomatous and normal eyes.

Materials and Methods

Glaucoma Patients

Optic disc photographs of 582 phakic eyes of 321 patients suffering from chronic primary open-angle glaucoma were the basis for one part of this study. Mean age of the 146 men and 175 women was 62.9 ± 13.3 years (mean and standard deviation) (minimum: 20 years, maximum: 91 years), mean refraction was 0.21 ± 2.62 diopters (spherical equivalent) to +12.75 diopters. Highly myopic eyes with a myopic refractive error of more than –8.00 diopters had been excluded because they have different morphometric optic disc characteristics than normal eyes.37 All patients had been examined in the period from 1980 to 1988. In all cases refractometry, keratometry, slit-lamp biomicroscopy, gonioscopy, fundus evaluation, tonometry and perimeter had been performed.

Criteria for the diagnosis of chronic primary open-angle glaucoma that had to be fulfilled by all patients...
were: (1) an open anterior chamber angle; (2) an intraocular pressure of more than 21 mm Hg or history of it; (3) alterations of the retinal nerve fiber layer according to Airaksinen and others; (4) glaucomatous morphometric changes of the intrapapillary area that were shown to be significantly different between a group of 233 glaucoma patients and a control group of 253 unselected normal subjects, such as decreased neuroretinal rim area as a whole and in four different optic disc sectors, neuroretinal rim in the inferior temporal disc sector markedly smaller than in the superior temporal one, smallest neuroretinal rim location outside of the horizontal temporal disc sector, neuroretinal rim area in the temporal inferior disc sector less than 22% of the total neuroretinal rim area, vertical cup/disc ratio larger than the horizontal one; and (5) glaucomatous visual field loss. That included paracentral isolated or arcuate, relative or absolute scotomata, nasal steps of at least 10°, and/or elevated visual field indices of the Octopus programs or Glaucoma.

If both eyes had been photographed and morphometrically analyzed only one randomly chosen eye per patient was taken for statistical analysis. Based on intrapapillary morphological criteria the optic nerve heads (one disc per patient) were divided into five subgroups: I: no apparent notch in the neuroretinal rim (96 eyes); II: notching of the neuroretinal rim in the lower temporal and/or upper temporal sector (60 eyes); III: advanced glaucomatous cupping with extensive narrowing of the neuroretinal rim at the temporal border (focal notches no longer clearly distinguishable) (40 eyes); IV: far advanced glaucomatous cupping with total loss of planimetrically evaluable neuroretinal rim at the temporal optic disc border (111 eyes); V: total loss of all neuroretinal rim (absolute glaucoma) (14 eyes).

This glaucoma staging has been proven to be useful by statistically significant correlations (P < 0.0001) between the glaucoma stage and intrapapillary parameters, eg neuroretinal rim area, width and configuration, horizontal and vertical cup/disc ratios, the quotient of horizontal to vertical cup/disc ratios, prevalence of optic disc hemorrhages, and parapapillary retinal vessel diameter, parapapillary retinal nerve fiber alterations, and visual field indices.

Normal Subjects

The glaucomatous optic nerve heads were compared with 390 normal optic discs of 231 normal subjects (98 men and 133 women). Mean age in the control group was 44.4 ± 18.7 years (3-81 years), mean refraction −0.07 ± 2.18 diopters (−7.88 diopters (spherical equivalent) to +7.50 diopters). The subjects came to the Eye Hospital for an ocular check-up without special pathologic findings, for eyeglass prescriptions, or for treatment of an ocular disease in the contralateral eye that did not primarily affect the optic nerve. If both eyes had been photographed and morphometrically analyzed only one randomly chosen eye per subject was taken for statistical analysis.

Method

All optic disc photographs (color 15° stereo diapositives) had been taken with a telecentric Zeiss fundus camera. The slides were projected 15 times magnified. The outlines of the intra- and parapapillary structures were plotted on paper and morphometrically evaluated (Zeiss Morphomat 30).

The intra- and parapapillary area was divided into four sectors (Figure 1): the inferior temporal and superior temporal sectors "B" and "C" were right-angled and their middle lines were tilted 13° temporal to the vertical optic disc axis. Sector "A" on the temporal side and sector "D" on the nasal side covered the remaining area (64° and 116°, respectively). The reason for this optic disc sectioning was due to the location of notches on the neuroretinal rim that were found in a preceding study at about 13° temporal to the superior and inferior optic disc poles.
Parapapillary chorioretinal atrophy was evaluated in these four sectors separately. Its total area was given as the sum of the areas measured in the four sectors. The mean width per sector was calculated as the ratio of the structure's area in that sector divided by the optic disc circumference in that sector. For this calculation the optic nervehead form was considered to be circular.

The photographic magnification was corrected according to Littmann.40-42 Indirect evidence for the usefulness of Littmann's method is that 457 unselected normal optic discs (mean area 2.69 ± 0.70 mm²) determined intravitally using Littmann’s method43 did not differ significantly (Mann-Whitney test) in size from 107 optic nerve scleral canals (mean area 2.59 ± 0.72 mm²) that had been measured post-mortem in unfixed, unselected human donor eyes.44 A similar area of the optic nerve scleral canal for a North American population (2.56 mm²) has been reported by Straatsma et al,45 while Ishii46 measured a size of 2.10 mm² in Japanese enucleated globes.

Definition of the Intra- and Parapapillary Structures

Intrapapillary: The optic disc was the area inside of the white peripapillary scleral ring of Elschnig.47 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. This topographic definition of the intrapapillary optic disc structures has already been used by Betz,2,3 Airaksinen,5-7 Drance,5,10 Cloux-Fey,5 Britton,48 and the authors themselves.13,14,39,43,49

Parapapillary: The peripapillary scleral ring of Elschnig47 was the white, often circular band surrounding the optic nervehead. It was often better seen on the temporal disc side than on the nasal side. It separated the optic disc area from the parapapillary chorioretinal atrophy and the retina, respectively.

The parapapillary chorioretinal atrophy was divided into two zones: zone “Alpha” (Figs. 2–5) 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 parapapillary scleral ring of Elschnig on its inner side. Characteristics of zone Beta (Figs. 2–5) were: marked atrophy of the retinal pigment epithelium and of the choriocapillaris, small grey fields on a whitish background, good visibility of the large choroidal vessels, thinning of the chorioretinal tissues, round bordering to the adjacent zone Alpha on the peripheral side and to the parapapillary scleral ring on the central side. If both zones were present in the same sector, zone Beta was always closer to the optic disc than zone Alpha. The histologic equivalent of zone Beta might be a complete loss of the retinal pigment epithelium and of the choriocapillaris; the ophthalmoscopic appearance of zone Alpha might be caused by irregularities of the retinal pigment epithelium and of the parapapillary chorioid.31,34,47,50

Reproducibility

The intra- and interobserver variation coefficients had been determined in a recent study.39 Photographs of five unselected normal and of five unselected glaucomatous optic nerveheads had been reevaluated five times each by two investigators (GG and JJ) independently. The intraobserver variation coefficients were for zone Alpha 0.159 and 0.167 and for zone Beta 0.096 and 0.067. The interobserver coefficients were for zone Alpha 0.164 and for zone Beta 0.084.

Results

Normal Eyes

Zone Alpha of the parapapillary chorioretinal atrophy measured in normal eyes on an average 0.41 ± 0.37 mm² (mean and standard deviation) with a minimum of 0.00 mm² and a maximum of 2.21 mm² (Fig. 6). It was significantly (P < 0.00001; Wilcoxon test) larger and more frequent (P < 0.001, Chi-square test) than zone Beta, with a mean total area of 0.13 ± 0.42 mm² (0.00 mm²-3.65 mm²) (Fig. 7). Both zones Alpha and Beta and the total parapapillary chorioretinal atrophy as sum of zones Alpha and Beta were significantly (P < 0.001; Wilcoxon test) broadest and most frequent in the temporal horizontal sector, followed by the inferior temporal sector, the superior temporal sector, and finally the nasal sector (Tables 1–3).

Because highly myopic eyes with a myopic refractive error of more than −8.00 diopters were excluded, no significant correlations were found between the refraction and the total area of zone Alpha, zone Beta, and the total parapapillary chorioretinal atrophy, respectively. Age was significantly (P < 0.001) correlated only with the area of zone Beta in the temporal horizontal sector. Considering that this sector was the least important one in differentiating normal and glaucomatous optic nerveheads, and regarding the low correlation coefficient (R square = 0.045), we did not match the control group for age. Concerning the optic disc area, significant correlations with low correlation coefficients existed with the area of zone Alpha and zone Beta in the temporal horizontal sec-
Fig. 2. (top left) Optic nervehead with glaucomatous optic nerve damage (stage III–IV); optic disc area: 2.38 mm²; horizontal disc diameter: 1.65 mm; vertical disc diameter: 1.79 mm; optic cup area: 1.88 mm²; horizontal cup diameter: 1.50 mm; vertical cup diameter: 1.59; neuroretinal rim area: 0.50 mm²; cup/disc ratio horizontal: 0.91; vertical: 0.89; horizontal/vertical: 1.02; peripapillary scleral ring of Elschnig (small arrows); zone Alpha (long arrows) of the parapapillary chorioretinal atrophy, total area: 1.30 mm²; zone Beta (arrowheads) of the parapapillary chorioretinal atrophy, total area: 0.84 mm².

Fig. 3. (top right) Optic nerve head with glaucomatous optic nerve damage (stage I); optic disc area: 2.25 mm²; horizontal disc diameter: 1.59 mm; vertical disc diameter: 1.77 mm; optic cup area: 0.92 mm²; horizontal cup diameter: 0.99 mm; vertical cup diameter: 1.16; neuroretinal rim area: 1.33 mm²; cup/disc ratio horizontal: 0.62; vertical: 0.66; horizontal/vertical: 0.95; peripapillary scleral ring of Elschnig (small arrows); zone Alpha (long arrows) of the parapapillary chorioretinal atrophy, total area: 1.88 mm²; no zone Beta of the parapapillary chorioretinal atrophy. Note: Neuroretinal rim area at the inferior disc pole smaller and parapapillary chorioretinal atrophy larger than at the superior disc pole.

Fig. 4. (bottom left) Optic nerve head with glaucomatous optic nerve damage (stage III–IV); optic disc area: 3.02 mm²; horizontal disc diameter: 1.88 mm; vertical disc diameter: 2.08 mm; optic cup area: 2.13 mm²; horizontal cup diameter: 1.49 mm; vertical cup diameter: 1.80; neuroretinal rim area: 0.89 mm²; cup/disc ratio horizontal: 0.79; vertical: 0.87; horizontal/vertical: 0.91; zone Alpha (long arrows) of the parapapillary chorioretinal atrophy, total area: 1.41 mm²; zone Beta (arrowheads) of the parapapillary chorioretinal atrophy, total area: 0.86 mm². Note: Neuroretinal rim area at the inferior disc pole smaller and parapapillary chorioretinal atrophy larger than at the superior disc pole.

Fig. 5. (bottom right) Optic nervehead with glaucomatous optic nerve damage (stage III); optic disc area: 2.42 mm²; horizontal disc diameter: 1.61 mm; vertical disc diameter: 1.83 mm; optic cup area: 1.70 mm²; horizontal cup diameter: 1.39 mm; vertical cup diameter: 1.53; neuroretinal rim area: 0.72 mm²; cup/disc ratio horizontal: 0.86; vertical: 0.83; horizontal/vertical: 1.04; peripapillary scleral ring of Elschnig (small arrows); zone Alpha (long arrows) of the parapapillary chorioretinal atrophy, total area: 1.08 mm²; zone Beta (arrowheads) of the parapapillary chorioretinal atrophy, total area: 0.88 mm². Note: Neuroretinal rim area at the inferior disc pole smaller and parapapillary chorioretinal atrophy larger than at the superior disc pole.

tor ($P < 0.001$ and correlation coefficient $R^2$ = 0.01 for zone Alpha, and $P < 0.01$ and $R^2$ = 0.03 for zone Beta). Eyes with chronic primary open-angle glaucoma and normal globes, however, are not significantly different in optic disc size,$^{32}$ so that matching was not necessary. In this study the mean optic nervehead area in the control group was $2.69 \pm 0.69$ mm² (mean and standard deviation)
relative frequency

Fig. 6. Histogram of the total area of zone Alpha of the parapapillary chorioretinal atrophy (irregular hypopigmentation and hyperpigmentation) in 390 eyes of 231 normal subjects. Only one randomly chosen eye per subject was taken for statistical analysis. Mean: 0.41 mm$^2$; median: 0.00 mm$^2$; standard deviation: 0.37 mm$^2$.

(relative frequency = 912)

Fig. 7. Histogram of the total area of zone Beta of the parapapillary chorioretinal atrophy (visible large choroidal vessels, visible sclera) in 390 eyes of 231 normal subjects. Only one randomly chosen eye per subject was taken for statistical analysis. Mean: 0.13 mm$^2$; median: 0.00 mm$^2$; standard deviation: 0.42 mm$^2$.

(minimum: 0.86 mm$^2$; maximum: 5.54 mm$^2$) and in the glaucoma group 2.64 ± 0.60 mm$^2$ (0.98 mm$^2$-5.53 mm$^2$). No correlations were detected for sex and side. The largest mean width of zone Alpha was found in 229 cases (229/231 = 99.1%) inside and in two cases (2/231 = 0.9%) outside of the temporal horizontal sector. Zone Beta was in 226 (226/231 = 97.8%) eyes widest inside and in five eyes (5/231 = 2.2%) broadest outside of the temporal sector. A circular parapapillary zone Alpha existed in eight eyes (8/231 = 3.5%) and a circular zone Beta in 11 eyes (11/231 = 4.8%) of the control group. In 19 eyes (19/231 = 8.2%) a circular ring of zone Alpha and/or zone Beta was seen.
Table 1. Morphometric data of zone Alpha

<table>
<thead>
<tr>
<th>Glaucoma stage:</th>
<th>Number</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>I-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (mm²)</td>
<td>231</td>
<td>96</td>
<td>60</td>
<td>40</td>
<td>111</td>
<td>14</td>
<td>321</td>
</tr>
<tr>
<td>Sector A</td>
<td>0.22 ± 0.18</td>
<td>0.29 ± 0.23</td>
<td>0.28 ± 0.22</td>
<td>0.30 ± 0.21</td>
<td>0.32 ± 0.30</td>
<td>0.17 ± 0.20</td>
<td>0.30 ± 0.25</td>
</tr>
<tr>
<td>Sector B</td>
<td>0.06 ± 0.07</td>
<td>0.11 ± 0.15</td>
<td>0.14 ± 0.22</td>
<td>0.09 ± 0.10</td>
<td>0.11 ± 0.16</td>
<td>0.07 ± 0.08</td>
<td>0.11 ± 0.16</td>
</tr>
<tr>
<td>Sector C</td>
<td>0.10 ± 0.11</td>
<td>0.13 ± 0.15</td>
<td>0.16 ± 0.13</td>
<td>0.15 ± 0.10</td>
<td>0.16 ± 0.16</td>
<td>0.12 ± 0.16</td>
<td>0.15 ± 0.15</td>
</tr>
<tr>
<td>Sector D</td>
<td>0.05 ± 0.13</td>
<td>0.09 ± 0.19</td>
<td>0.08 ± 0.13</td>
<td>0.05 ± 0.09</td>
<td>0.11 ± 0.23</td>
<td>0.17 ± 0.26</td>
<td>0.09 ± 0.19</td>
</tr>
<tr>
<td>Total</td>
<td>0.41 ± 0.37</td>
<td>0.62 ± 0.56</td>
<td>0.60 ± 0.33</td>
<td>0.59 ± 0.39</td>
<td>0.70 ± 0.50</td>
<td>0.54 ± 0.59</td>
<td>0.65 ± 0.49</td>
</tr>
<tr>
<td>Frequency (%)</td>
<td>82.7%</td>
<td>85.4%</td>
<td>87.3%</td>
<td>90.0%</td>
<td>81.1%</td>
<td>57.1%</td>
<td>83.7%</td>
</tr>
</tbody>
</table>

Area, width and frequency (mean and standard deviation) of zone Alpha of the chorioretinal atrophy in 582 eyes of 321 patients suffering from chronic primary open-angle glaucoma and in 390 eyes of 231 normal subjects. Only one randomly chosen eye per patient and subject has been taken for statistical analysis. 0: normal subjects; I-V: glaucoma stages; sector A: horizontal temporal (64°); sector B: superior temporal (90°); sector C: inferior temporal (90°); sector D: nasal (116°).

Glucomatous Eyes

The area of zone Alpha, both as a whole and divided into the four parapapillary sectors, enlarged with increasing glaucoma stage (Table 1, Fig. 8). The differences between the normal eyes and the eyes of glaucoma stage I (P < 0.005 or smaller; Mann-Whitney test; exception: area of zone Alpha in the inferior temporal sector), and the differences between the normal eyes and the total glaucoma group (P < 0.001; Mann-Whitney test) were significant. The enlargement of zone Alpha was most marked in the nasal parapapillary sector (Fig. 9) for which the increase in frequency from 7.3% in the normal group to 23.1% in glaucoma stage I was also statistically proven (Chi-square test) (Table 1). The mean width of zone Alpha was largest outside of the temporal horizontal sector in one eye of glaucoma stage I (1/96 = 1.04%) and in 12 patients of the total glaucoma group (12/321 = 3.7%). In nine eyes of glaucoma stage I (9/96 = 9.4%) and in 45 eyes of the total zone Alpha, both as a whole and divided into the four parapapillary sectors, enlarged with increasing glaucoma stage (Table 1, Fig. 8).

Table 2. Morphometric data of zone Beta

<table>
<thead>
<tr>
<th>Glaucoma stage:</th>
<th>Number</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>I-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (mm²)</td>
<td>231</td>
<td>96</td>
<td>60</td>
<td>40</td>
<td>111</td>
<td>14</td>
<td>321</td>
</tr>
<tr>
<td>Sector A</td>
<td>0.05 ± 0.15</td>
<td>0.11 ± 0.18</td>
<td>0.13 ± 0.19</td>
<td>0.27 ± 0.30</td>
<td>0.38 ± 0.39</td>
<td>0.20 ± 0.15</td>
<td>0.23 ± 0.31</td>
</tr>
<tr>
<td>Sector B</td>
<td>0.02 ± 0.10</td>
<td>0.06 ± 0.16</td>
<td>0.08 ± 0.15</td>
<td>0.15 ± 0.16</td>
<td>0.27 ± 0.41</td>
<td>0.16 ± 0.18</td>
<td>0.15 ± 0.29</td>
</tr>
<tr>
<td>Sector C</td>
<td>0.04 ± 0.14</td>
<td>0.09 ± 0.15</td>
<td>0.11 ± 0.22</td>
<td>0.25 ± 0.32</td>
<td>0.35 ± 0.41</td>
<td>0.34 ± 0.55</td>
<td>0.21 ± 0.34</td>
</tr>
<tr>
<td>Sector D</td>
<td>0.02 ± 0.09</td>
<td>0.07 ± 0.16</td>
<td>0.08 ± 0.19</td>
<td>0.21 ± 0.35</td>
<td>0.33 ± 0.54</td>
<td>0.33 ± 0.70</td>
<td>0.19 ± 0.40</td>
</tr>
<tr>
<td>Total</td>
<td>0.13 ± 0.42</td>
<td>0.33 ± 0.55</td>
<td>0.40 ± 0.67</td>
<td>0.88 ± 0.97</td>
<td>1.32 ± 1.55</td>
<td>1.03 ± 1.50</td>
<td>0.79 ± 1.17</td>
</tr>
<tr>
<td>Frequency (%)</td>
<td>14.7%</td>
<td>41.7%</td>
<td>45.0%</td>
<td>67.5%</td>
<td>77.7%</td>
<td>55.6%</td>
<td>59.6%</td>
</tr>
<tr>
<td>Sector A</td>
<td>13.4%</td>
<td>33.3%</td>
<td>41.7%</td>
<td>65.0%</td>
<td>69.6%</td>
<td>78.6%</td>
<td>53.1%</td>
</tr>
<tr>
<td>Sector B</td>
<td>14.3%</td>
<td>40.6%</td>
<td>43.3%</td>
<td>70.0%</td>
<td>75.9%</td>
<td>85.7%</td>
<td>59.0%</td>
</tr>
<tr>
<td>Sector C</td>
<td>4.8%</td>
<td>21.9%</td>
<td>26.7%</td>
<td>45.0%</td>
<td>53.6%</td>
<td>71.4%</td>
<td>38.8%</td>
</tr>
<tr>
<td>Sector D</td>
<td>15.2%</td>
<td>44.8%</td>
<td>50.0%</td>
<td>70.0%</td>
<td>78.6%</td>
<td>85.7%</td>
<td>62.4%</td>
</tr>
<tr>
<td>Total</td>
<td>0.05 ± 0.15</td>
<td>0.11 ± 0.18</td>
<td>0.13 ± 0.20</td>
<td>0.28 ± 0.33</td>
<td>0.39 ± 0.39</td>
<td>0.20 ± 0.14</td>
<td>0.24 ± 0.31</td>
</tr>
<tr>
<td>Sector A</td>
<td>0.02 ± 0.07</td>
<td>0.05 ± 0.11</td>
<td>0.06 ± 0.11</td>
<td>0.11 ± 0.12</td>
<td>0.19 ± 0.28</td>
<td>0.12 ± 0.12</td>
<td>0.11 ± 0.20</td>
</tr>
<tr>
<td>Sector B</td>
<td>0.03 ± 0.10</td>
<td>0.06 ± 0.11</td>
<td>0.08 ± 0.16</td>
<td>0.18 ± 0.23</td>
<td>0.25 ± 0.29</td>
<td>0.24 ± 0.35</td>
<td>0.15 ± 0.24</td>
</tr>
<tr>
<td>Sector C</td>
<td>0.01 ± 0.05</td>
<td>0.04 ± 0.08</td>
<td>0.05 ± 0.11</td>
<td>0.12 ± 0.19</td>
<td>0.18 ± 0.29</td>
<td>0.18 ± 0.36</td>
<td>0.10 ± 0.22</td>
</tr>
<tr>
<td>Sector D</td>
<td>0.02 ± 0.07</td>
<td>0.06 ± 0.10</td>
<td>0.07 ± 0.13</td>
<td>0.16 ± 0.18</td>
<td>0.24 ± 0.27</td>
<td>0.18 ± 0.24</td>
<td>0.14 ± 0.21</td>
</tr>
</tbody>
</table>

Area, width and frequency (mean and standard deviation) of zone Beta of the chorioretinal atrophy in 582 eyes of 321 patients suffering from chronic primary open-angle glaucoma and in 390 eyes of 231 normal subjects. Only one randomly chosen eye per patient and subject has been taken for statistical analysis. 0: normal subjects; I-V: glaucoma stages; sector A: horizontal temporal (64°); sector B: superior temporal (90°); sector C: inferior temporal (90°); sector D: nasal (116°).
Table 3. Morphometric data of the total parapapillary chorioretinal atrophy

<table>
<thead>
<tr>
<th>Glaucoma stage:</th>
<th>0</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>I-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>231</td>
<td>96</td>
<td>60</td>
<td>40</td>
<td>111</td>
<td>14</td>
<td>321</td>
</tr>
<tr>
<td>Area (mm²)</td>
<td>0.27 ± 0.26</td>
<td>0.40 ± 0.30</td>
<td>0.40 ± 0.27</td>
<td>0.56 ± 0.36</td>
<td>0.70 ± 0.51</td>
<td>0.36 ± 0.23</td>
<td>0.53 ± 0.41</td>
</tr>
<tr>
<td>Sector A</td>
<td>0.08 ± 0.12</td>
<td>0.17 ± 0.21</td>
<td>0.21 ± 0.25</td>
<td>0.24 ± 0.17</td>
<td>0.38 ± 0.47</td>
<td>0.23 ± 0.17</td>
<td>0.26 ± 0.34</td>
</tr>
<tr>
<td>Sector B</td>
<td>0.14 ± 0.20</td>
<td>0.22 ± 0.21</td>
<td>0.27 ± 0.23</td>
<td>0.40 ± 0.33</td>
<td>0.51 ± 0.43</td>
<td>0.46 ± 0.54</td>
<td>0.36 ± 0.36</td>
</tr>
<tr>
<td>Sector C</td>
<td>0.03 ± 0.09</td>
<td>0.13 ± 0.17</td>
<td>0.14 ± 0.16</td>
<td>0.26 ± 0.15</td>
<td>0.44 ± 0.52</td>
<td>0.50 ± 0.82</td>
<td>0.26 ± 0.44</td>
</tr>
<tr>
<td>Sector D</td>
<td>0.51 ± 0.41</td>
<td>0.92 ± 0.70</td>
<td>1.02 ± 0.70</td>
<td>1.47 ± 0.70</td>
<td>2.02 ± 1.35</td>
<td>1.57 ± 1.74</td>
<td>1.42 ± 1.16</td>
</tr>
<tr>
<td>Total</td>
<td>84.8%</td>
<td>93.7%</td>
<td>94.8%</td>
<td>95.0%</td>
<td>97.3%</td>
<td>100%</td>
<td>95.6%</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>0.26 ± 0.25</td>
<td>0.41 ± 0.33</td>
<td>0.42 ± 0.27</td>
<td>0.56 ± 0.40</td>
<td>0.71 ± 0.49</td>
<td>0.38 ± 0.23</td>
<td>0.54 ± 0.41</td>
</tr>
<tr>
<td>Sector A</td>
<td>0.06 ± 0.08</td>
<td>0.12 ± 0.15</td>
<td>0.16 ± 0.19</td>
<td>0.17 ± 0.12</td>
<td>0.27 ± 0.31</td>
<td>0.17 ± 0.12</td>
<td>0.19 ± 0.23</td>
</tr>
<tr>
<td>Sector B</td>
<td>0.10 ± 0.14</td>
<td>0.16 ± 0.16</td>
<td>0.20 ± 0.17</td>
<td>0.28 ± 0.25</td>
<td>0.36 ± 0.29</td>
<td>0.32 ± 0.25</td>
<td>0.26 ± 0.25</td>
</tr>
<tr>
<td>Sector C</td>
<td>0.02 ± 0.03</td>
<td>0.07 ± 0.10</td>
<td>0.08 ± 0.09</td>
<td>0.14 ± 0.08</td>
<td>0.20 ± 0.29</td>
<td>0.28 ± 0.42</td>
<td>0.14 ± 0.24</td>
</tr>
<tr>
<td>Sector D</td>
<td>0.09 ± 0.07</td>
<td>0.17 ± 0.13</td>
<td>0.18 ± 0.11</td>
<td>0.26 ± 0.18</td>
<td>0.36 ± 0.25</td>
<td>0.28 ± 0.28</td>
<td>0.25 ± 0.21</td>
</tr>
<tr>
<td>Total</td>
<td>0.36 ± 0.23</td>
<td>0.40 ± 0.27</td>
<td>0.42 ± 0.27</td>
<td>0.56 ± 0.40</td>
<td>0.71 ± 0.49</td>
<td>0.38 ± 0.23</td>
<td>0.54 ± 0.41</td>
</tr>
</tbody>
</table>

Area, width and frequency (mean and standard deviation) of the total chorioretinal atrophy in 582 eyes of 321 patients suffering from chronic primary open-angle glaucoma and in 390 eyes of 231 normal subjects. Only one randomly chosen eye per patient and subject has been taken for statistical analysis. 0 = normal subjects; I-V: glaucoma stages; sector A: horizontal temporal (64°); sector B: superior temporal (90°); sector C: inferior temporal (90°); sector D: nasal (116°).

glaucoma group (45/321 = 14.0%) zone Alpha was present in all four parapapillary sectors.

Zone Beta significantly increased in area and frequency with the glaucoma stage (Fig. 10). The differences between the normal group and glaucoma stage I and the total glaucoma group respectively were significant (P < 0.0001, Mann-Whitney test; Chi-square test) (Table 2). Again, the differences were most marked for the nasal parapapillary sector (Fig. 11). Zone Beta was broadest outside of the temporal horizontal sector in 13 eyes of glaucoma stage I (13/96 = 13.5%) and in 61 eyes of the total glaucoma group (61/321 = 19.0%). In 16 eyes of glaucoma stage I (16/96 = 16.7%) and in 107 eyes of the total glaucoma group (107/321 = 33.3%) zone Beta was found in all parapapillary sectors.
The total parapapillary chorioretinal atrophy increased with the glaucoma stage in a way similar to zone Alpha and zone Beta, and it was also significantly larger in glaucoma stage I ($P < 0.0001$; Mann-Whitney test) than in the control group (Table 3). The difference in frequency was significant for the nasal parapapillary sector. In 15 eyes of glaucoma stage I (15/96 = 15.6%) and in 89 eyes of the total glaucoma group (89/321 = 27.7%) zone Alpha and/or zone Beta were found in all sectors.
Differentiation of Control Group versus Glaucoma Stage I

The area of zone Alpha in the temporal horizontal sector was larger than 0.20 mm² in 44.2% of the normal eyes and in 65.6% of the eyes of glaucoma stage I. In the nasal sector zone Alpha was present in 7.3% in the normal group and in 23.7% in glaucoma stage I. Zone Beta was present in the temporal horizontal sector in 14.7% of the normal eyes and in 41.7% of the eyes of glaucoma stage I; in the nasal sector it was present in 4.8% of the normal subjects and in 21.9% of the patients of glaucoma stage I. The total parapapillary chorioretinal atrophy was in the temporal horizontal sector larger than 0.20 mm² in 48.1% of the normal group and in 77.1% of the eyes of glaucoma stage I. In the nasal sector it was present in 9.2% in the normal subjects and in 43.7% of patients of glaucoma stage I.

Discussion

In the literature there are only a few reports on parapapillary glaucomatous changes. Primrose examined 52 glaucoma eyes. He found that a “peripapillary halo was present in more than half often quite early in the disease, and was also present in many fellow eyes as yet free from cupping.” “Only three out of 52 cases showed no juxtapapillary signs.” Primrose suggested that the presence of a peripapillary halo might be a useful diagnostic sign for early glaucoma diagnosis. Wilensky and Kolker graded the parapapillary changes in 164 nonglaucomatous and 55 glaucomatous eyes. According to the description of the Figure on page 342 of their paper, they defined the “peripapillary halo” as the peripapillary scleral ring of “Elschnig.” For this structure they found no statistical significant difference between the glaucomatous and nonglaucomatous eyes. For what they called “peripapillary atrophy” there was a significant difference in grade and frequency between the glaucoma and control group. Furthermore, they observed that in patients with bilateral glaucoma the peripapillary atrophy was more common than in patients with unilateral glaucoma. They suggested that in these patients the duration of the glaucomatous disease was not yet long enough. Naumann described the parapapillary chorioretinal atrophy in a clinical-histopathologic correlation as loss of the retinal pigment epithelium and obliteration of the smaller parapapillary choroidal vessels. Anderson and Heijl reported on a significant correlation between the location of the widest parapapillary atrophy and the sector of greatest cupping and the direction of the visual field defect, respectively. Airaksinen correlated parapapillary atrophy with the neural optic disc tissue and found only a “weak correlation of peripapillary atrophy over time.” We differentiated parapapillary chorioretinal atrophy into a peripheral zone Alpha with irregular hypopigmentations and a more central zone Beta characterized by the features of a complete chorioretinal atrophy (Figs. 2–5).
Normal Eyes

In normal eyes parapapillary chorioretinal changes were significantly (P < 0.001) broadest and most frequent in the temporal horizontal sector, followed by the inferior temporal sector, the superior temporal sector, the temporal nasal region and the nasal sector (Tables 1–3). This is in contrast to the configuration of the normal neuroretinal rim, which is largest in the inferior temporal sector followed by the superior temporal sector, the nasal sector, and the horizontal temporal region. With the exclusion of highly myopic eyes, area and frequency of the parapapillary chorioretinal atrophy were not significantly correlated with refraction. Also, no correlations were found with sex or side. Zone Alpha was significantly (P < 0.00001) larger and significantly (P < 0.00001) more frequent than zone Beta (Figs. 6, 7). Zone Alpha occurred in 84.4% and zone Beta in 15.2% of normal eyes. Both were most common and widest in the temporal horizontal region and least common and smallest in the nasal sector.

Glaucomatous Eyes

Parapapillary atrophy as a whole and both zones Alpha and Beta were significantly (P < 0.00001) larger and zone Beta was significantly (P < 0.00001) more frequent in the glaucoma group than in the control group (Tables 1–3). This difference was also significant for the earliest glaucoma stage of this study. It was more distinct for zone Beta than for zone Alpha, and it was most marked for the nasal sector followed by the inferior temporal sector, the superior temporal sector, and the temporal horizontal region (Tables 1–3; Figs. 8–11).

The size and frequency of parapapillary atrophy were significantly (P < 0.0001) correlated with the glaucoma stage (Figs. 8–11); the more advanced the optic nerve damage the larger the area and the higher the frequency of parapapillary atrophy.

Differentiation of Normal and Glaucomatous Eyes

Significant (P < 0.001) differences between the normal eyes and those of the earliest glaucoma stage of this study (stage I) were:

1) Zone Alpha:
   - total area larger than 0.30 mm² or mean width broader than 0.05 mm;
   - area in temporal horizontal sector larger than 0.20 mm² or mean width broader than 0.20 mm;
   - occurrence in the nasal sector;
   - occurrence of a circular zone Alpha in all four sectors (P < 0.05).
2) Zone Beta:
   - occurrence anywhere;
   - total area larger than 0.30 mm² or mean width broader than 0.05 mm;
   - area in the temporal horizontal sector larger than 0.20 mm² or mean width broader than 0.20 mm;
   - occurrence in the nasal sector;
   - occurrence of a circular parapapillary atrophy (zone Alpha and/or zone Beta).

If all glaucoma eyes and not only those of stage I were considered, the significance of the differences got higher and additional parameters (eg, broadest location of zone Alpha outside of the temporal horizontal sector) became significant.

The parapapillary chorio-pigment epithelio-retinal atrophy was significantly larger and more frequent in eyes with chronic primary open-angle glaucoma than in normal globes. It deserves special attention in glaucoma diagnosis and follow-up. It might be an interesting point in the pathogenesis of glaucomatous optic nerve fibre loss.

Key words: optic disc morphometry, optic nervehead, neuroretinal rim, parapapillary chorioretinal atrophy, glaucoma

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