Parapapillary Retinal Vessel Diameter in Normal and Glaucoma Eyes

I. Morphomeric Data

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The retinal blood vessels serve for nutrition of the retinal ganglion cells and their axons. This study was undertaken to evaluate the vessel diameter in normal and glaucoma eyes. The calibers of the superior temporal and inferior temporal retinal artery and vein were measured at the optic disc border and at a distance of 2 mm from the optic disc center; 473 eyes of 281 patients suffering from chronic primary open-angle glaucoma and 275 eyes of 173 normal subjects were examined. Fifteen-degree, color stereo optic disc photographs were used. In the normal eyes the inferior temporal vessels were significantly larger than the superior temporal vessels. This corresponds with: (1) the configuration of the normal neuroretinal rim, which is significantly broader in the inferior disc region than in the superior disc area; (2) the visibility of the retinal nerve fibers, which are better detectable in the inferior temporal area than in the superior temporal one; and (3) the foveola location 0.53 ± 0.34 mm inferior to the optic disc center. The retinal vessel diameter was independent of the patients’ age and optic disc and parapapillary chorioretinal atrophy size. In the glaucoma group the vessel caliber was significantly smaller than in the normal eyes. The differences were more marked for the arteries and the inferior temporal vessels, respectively. The vessel diameters decreased significantly with increasing glaucoma stage independently of the patients' age. The parapapillary retinal vessel diameter may reflect the need of vascular supply in the corresponding superficial retinal area. It may be correlated with the local ganglion cell density and retinal nerve fiber layer thickness. Invest Ophthalmol Vis Sci 30:1599–1603, 1989

The retinal nerve fiber layer and the ganglion cells depend for their nutrition on the retinal vascular system. The aim of this study was to measure and compare the vessel diameter in eyes with a presumably normal retinal ganglion cell population and in eyes with glaucomatous ganglion cell loss.

Materials and Methods

Color stereo optic disc photographs of 473 eyes of 281 patients suffering from chronic primary open-angle glaucoma and photographs of 275 eyes of 173 normal subjects were morphometrically analyzed. Consent was obtained from all patients and subjects. Mean age of the glaucoma patients (137 men, 144 women) was 63.0 ± 13.2 years (mean and standard deviation) with a minimum of 20 years and a maximum of 91 years. Their refractive error was on an average −0.27 ± 2.61 diopters (−7.35 diopters (spherical equivalent) to +12.25 diopters). Mean age of the normal subjects (66 men, 107 women) was 44.5 ± 19.0 years (3–79 years), and their mean refractive error was −0.05 ± 2.14 diopters (−7.88 diopters to +7.50 diopters). The two groups differed significantly in age; the refractive error was not significantly different. For comparison of the glaucomatous eyes with the normal eyes the latter ones were matched for age. This age-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. If both eyes had been measured only one randomly chosen eye per patient and subject was generally taken for statistical analysis. Highly myopic eyes with a myopic refractive error of more than −8.00 diopters were excluded because they have different morphometric optic disc characteristics than normal eyes.1

Criteria for the diagnosis of chronic primary open-angle glaucoma, all of which had to be fulfilled, were:
Table 1. 

<table>
<thead>
<tr>
<th>Glaucoma stage</th>
<th>Number</th>
<th>I</th>
<th>p(I)</th>
<th>II</th>
<th>p(II)</th>
<th>III</th>
<th>p(III)</th>
<th>IV</th>
<th>p(IV)</th>
<th>V</th>
<th>p(V)</th>
<th>I-V</th>
<th>p(I-V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior temporal disc border</td>
<td>0.104 ± 0.018</td>
<td>0.099 ± 0.019</td>
<td>0.12</td>
<td>0.095 ± 0.014</td>
<td>0.0009</td>
<td>0.096 ± 0.022</td>
<td>0.095 ± 0.019</td>
<td>0.091 ± 0.020</td>
<td>0.091 ± 0.020</td>
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</tr>
<tr>
<td>Parapapillary</td>
<td>0.110 ± 0.019</td>
<td>0.108 ± 0.018</td>
<td>0.16</td>
<td>0.101 ± 0.017</td>
<td>0.0032</td>
<td>0.104 ± 0.018</td>
<td>0.097 ± 0.018</td>
<td>0.090 ± 0.022</td>
<td>0.101 ± 0.019</td>
<td></td>
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</tr>
<tr>
<td>Inferior temporal disc border</td>
<td>0.109 ± 0.019</td>
<td>0.107 ± 0.019</td>
<td>0.16</td>
<td>0.093 ± 0.017</td>
<td>0.0000</td>
<td>0.094 ± 0.021</td>
<td>0.081 ± 0.022</td>
<td>0.073 ± 0.020</td>
<td>0.092 ± 0.023</td>
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</tr>
<tr>
<td>Parapapillary</td>
<td>0.112 ± 0.016</td>
<td>0.107 ± 0.023</td>
<td>0.20</td>
<td>0.103 ± 0.030</td>
<td>0.0000</td>
<td>0.100 ± 0.016</td>
<td>0.094 ± 0.020</td>
<td>0.085 ± 0.018</td>
<td>0.100 ± 0.023</td>
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<tr>
<td>Superior temporal vein disc border</td>
<td>0.129 ± 0.025</td>
<td>0.132 ± 0.024</td>
<td>0.48</td>
<td>0.129 ± 0.024</td>
<td>0.7480</td>
<td>0.132 ± 0.022</td>
<td>0.118 ± 0.022</td>
<td>0.117 ± 0.027</td>
<td>0.126 ± 0.024</td>
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</tr>
<tr>
<td>Parapapillary</td>
<td>0.140 ± 0.025</td>
<td>0.139 ± 0.022</td>
<td>0.57</td>
<td>0.136 ± 0.022</td>
<td>0.3724</td>
<td>0.141 ± 0.022</td>
<td>0.129 ± 0.021</td>
<td>0.119 ± 0.024</td>
<td>0.134 ± 0.022</td>
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</tr>
<tr>
<td>Inferior temporal vein disc border</td>
<td>0.137 ± 0.020</td>
<td>0.130 ± 0.029</td>
<td>0.11</td>
<td>0.132 ± 0.021</td>
<td>0.2998</td>
<td>0.125 ± 0.020</td>
<td>0.119 ± 0.023</td>
<td>0.120 ± 0.029</td>
<td>0.125 ± 0.025</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Parapapillary</td>
<td>0.145 ± 0.021</td>
<td>0.138 ± 0.028</td>
<td>0.06</td>
<td>0.134 ± 0.024</td>
<td>0.0056</td>
<td>0.136 ± 0.024</td>
<td>0.131 ± 0.023</td>
<td>0.124 ± 0.024</td>
<td>0.134 ± 0.023</td>
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</table>

Diameter (mm) (mean and standard deviation) of the superior temporal and inferior temporal retinal artery and vein at the optic disc border and 2 mm from the optic disc centre in 473 eyes of 281 patients with chronic primary open-angle glaucoma and in 275 eyes of 173 normal subjects. Only one randomly chosen eye per patient and subject was taken for statistical analysis. The glaucoma group were divided into five stages (I-V) according to the intrapapillary photomorphology: p(I): significance (Mann-Whitney test) of difference control group-glaucoma stage I; p(II): significance of difference control group-glaucoma stage II; p(III): significance of difference control group-glaucoma stage III; p(IV): significance of difference control group-glaucoma stage IV; p(V): significance of difference control group-glaucoma stage V; p(I-V): significance of difference control group-total glaucoma group. In the normal group the inferior temporal artery (measured at the disc border) was significantly (P = 0.0037; Wilcoxon test) larger than the superior temporal artery (measured at the optic disc border), and the inferior temporal vein (measured at the disc border and 2 mm from the disc center) was significantly larger (P = 0.0004 and P = 0.0024 respectively; Wilcoxon test) than the superior temporal vein (measured at the disc border and parapapillary, respectively).

The normal subjects came to the Eye Hospital for an ocular check-up, having no pathology findings, for an eye glass prescription, or because of an ocular disease in the contralateral eye. All optic disc photographs (15° color stereo diapositives) were taken with a telecentric Zeiss fundus camera. The diapositives were projected X15 magnified. We plotted the superior temporal and inferior temporal retinal artery (12 eyes), inferior temporal retinal vein (12 eyes), and superior temporal retinal vein (12 eyes) of all normal control eyes. Based on intrapapillary photomorphologic criteria the optic nerve heads (one disc per patient) were divided into five subgroups: I: no apparent notch in the neuroretinal rim (80 eyes); II: notching of the neuroretinal rim (80 eyes); III: advanced glaucomatous cupping with extensive narrowing of the neuroretinal rim (102 eyes); IV: far advanced glaucomatous cupping with total loss of the neuroretinal rim (68 eyes); V: total loss of all neuroretinal rim (absolute glaucoma) (17 eyes).

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2 mm from the optic disc center. The method of the optic disc morphometry, the definition of the intra- and parapapillary structures and the correction of the photographic magnification have been described in detail previously.\textsuperscript{6-9}

**Results**

**Normal Eyes**

In the normal eyes the diameter of the inferior temporal artery measured at the optic disc border 0.109 ± 0.019 mm (mean and standard deviation) with a minimum of 0.060 mm and a maximum of 0.160 mm. It was significantly larger (P < 0.005; Wilcoxon test) than the caliber of the superior temporal artery (0.104 ± 0.018 mm) (Table 1). The inferior temporal vein measured at the disc border 0.137 ± 0.020 mm (0.60-0.190 mm) and was significantly larger (P < 0.005; Wilcoxon test) than the superior temporal vein (0.129 ± 0.025 mm) (Table 1). The vessel diameters were not correlated with refraction, age, sex and size and form of the optic disc and parapapillary chorioretinal atrophy.

**Glaucoma Eyes**

The vessel diameters were significantly smaller in the glaucomatous eyes than in the unmatched and age-matched normal control groups, respectively (Table 1). The differences were most marked for the inferior temporal retinal artery, followed by the superior temporal artery, the inferior temporal vein and finally the superior temporal vein. They were significant also for the glaucoma stages II–V, when compared separately with the control group. The vessel diameters decreased significantly (P < 0.00001) with increasing glaucoma stage (Tables 1, 2; Figs. 1, 2). If each glaucoma stage was divided up into a younger and an older group respectively, the groups within each glaucoma stage did not differ significantly in vessel diameter. In the older group of a lower glaucoma stage the artery diameters were always larger but not always significantly larger than in the younger group of the next following glaucoma stage (Table 2). This indicates that the vessel diameter reduction in glaucoma was independent of age.

The correlation coefficients were larger for the arteries than for the veins. This corresponds with the larger differences in artery diameter than in vein diameter between the normal and glaucomatous eyes.

**Discussion**

In the normal eyes the inferior temporal vessels were significantly broader (P < 0.005, Wilcoxon test) than the superior temporal vessels. This correlates with: (1) the configuration of the neuroretinal rim that in normal eyes is significantly broader at the inferior optic disc pole than at the superior disc pole; (2) the visibility of the retinal nerve fiber layer bundles that are better detectable in the inferior temporal arcade than in the superior temporal region; and (3) the location of the foveola 0.53 ± 0.34 mm inferior to the optic disc center.\textsuperscript{10}

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**Table 2.**

<table>
<thead>
<tr>
<th>Age group</th>
<th>Normal subjects</th>
<th>Glaucoma stage I</th>
<th>Glaucoma stage II</th>
<th>Glaucoma stage III</th>
<th>Glaucoma stage IV</th>
<th>Glaucoma stage V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Superior temporal artery</td>
<td>Inferior temporal artery</td>
<td>Superior temporal vein</td>
<td>Inferior temporal vein</td>
<td>Superior temporal artery</td>
<td>Inferior temporal artery</td>
</tr>
<tr>
<td>&lt;65 years</td>
<td>0.106 ± 0.018</td>
<td>0.098 ± 0.020</td>
<td>0.095 ± 0.018</td>
<td>0.093 ± 0.017</td>
<td>0.086 ± 0.017</td>
<td>0.074 ± 0.015</td>
</tr>
<tr>
<td>&gt;65 years</td>
<td>0.132 ± 0.022</td>
<td>0.134 ± 0.022</td>
<td>0.133 ± 0.027</td>
<td>0.130 ± 0.019</td>
<td>0.130 ± 0.022</td>
<td>0.123 ± 0.020</td>
</tr>
</tbody>
</table>

Retinal vessel diameter in 473 eyes of 281 patients with chronic primary open-angle glaucoma in 275 eyes of 173 normal subjects. Only one randomly chosen eye per patient and subject was taken for statistical analysis. The glaucoma group was divided into five stages according to the intrapapillary morphology, and each glaucoma stage was divided into a younger group with an age of less than 65 years and an older group of more than 65 years.
Fig. 1. Scattergram between the diameter of the inferior temporal retinal artery (measured at the optic disc border) and the glaucoma stage 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. 0 = normal eyes; I–V: glaucoma stages according to the intrapapillary pathomorphology of the optic nerve head. Correlation coefficient: −0.51; slope of the regression line: −0.007; significance: \( P < 0.00001 \).

It can be speculated that in the inferior temporal arcade more retinal ganglion cells and more retinal nerve fibers are located that need more vascular supply than the fewer ganglion cells in the superior temporal arcade. This can be taken as a hint for a correlation between the retinal vessel diameter and the ganglion cell density and retinal nerve fiber layer thickness, respectively.

Fig. 2. Scattergram between the diameter of the inferior temporal retinal vein (measured at the optic disc border) and the glaucoma stage 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. 0 = normal eyes; I–V: glaucoma stages according to the intrapapillary pathomorphology of the optic nerve head. Correlation coefficient: −0.31; slope of the regression line: −0.004; significance: \( P < 0.00001 \).

Vessel diameter was not significantly correlated with age. The considerable interindividual size variability of retinal vessel diameter due to the variation of vessel bifurcation could have masked a relationship to the age-related loss of retinal ganglion cell axons that has been reported to range from no significant decline to a loss of approximately 400,000 out of 1.648 million axons for a span of 70 years.

The parapapillary retinal vessel diameters were significantly smaller in the glaucoma eyes than in the control eyes (Table 1). This also held true when the glaucoma eyes were compared with an age-matched control group. Similar findings were reported in a previous study in which either the inferior temporal or the superior temporal retinal vessels were measured. Independently of age the vessel diameters decreased with increasing glaucoma stage (Tables 1, 2; Figs. 1, 2). This indicates a correlation between the vessel diameter and the retinal ganglion cell population. It can be assumed that the vessels decreased in diameter because there was less need of oxygen in the inner retinal layer after optic nerve damage and the loss of retinal ganglion cells had occurred. Further evidence for this hypothesis is that in eyes with nonglaucomatous optic nerve damage the retinal vessel caliber is significantly smaller than in normal ones. This points to the presumed autoregulation of the retinal blood vessels. A theoretical alternative is to consider the decrease of the retinal vessel caliber as the reason for ganglion cell loss.

In the glaucoma group and the normal control group the presence and severity of diabetes mellitus, arterial hypertension and intake of vasoactive drugs had not been evaluated systematically. In intraindividual bilateral comparison, however, the retinal vessels were smaller in that eye with larger glaucomatous optic nerve damage, and within the same eye the vessel diameter reduction was more marked in that arcade that showed more severe retinal nerve fiber layer changes and neuroretinal rim loss, respectively. This indicates that vessel diameter reduction in glaucoma is at least partially associated with glaucomatous changes in the inner retinal layers.

From a diagnostic point of view, the decreased vessel diameter in eyes with chronic primary open-angle glaucoma can be taken as an ophthalmoscopic feature for optic nerve damage.

Key words: glaucoma, neuroretinal rim, optic disc morphometry, retinal nerve fiber layer, retinal vessel diameter

References