Neuroretinal rim width ratios in morphological glaucoma diagnosis

Jost B Jonas, Wido M Budde, Peter Lang

Abstract
Aims—To evaluate the inferior to temporal neuroretinal rim width ratio and superior to temporal rim width ratio as measures of rim shape for diagnosis of glaucoma.

Methods—Colour stereo optic disc photographs of 527 normal subjects, 100 ocular hypertensive individuals with normal visual fields, and 202 open angle glaucoma patients with a mean perimetric defect of less than 10 dB were morphometrically evaluated. Eyes with an optic cup area of < 0.2 mm² were excluded.

Results—In the normal subjects, inferior to temporal rim width ratio (0.67 (SD 0.53)) was significantly (p<0.0001) higher than superior to temporal rim width ratio (1.56 (0.49)). Both ratios were significantly (p<0.0001) higher the more vertically the optic disc was configured. In the normal eyes, both ratios were statistically independent of disc size, rim area, refractive error, age, and sex. With the differences being more marked for the inferior to temporal ratio than for the superior to temporal ratio, both rim width ratios were significantly (p<0.005) lower in the ocular hypertensive group than in the normal group. Despite the high significance of the differences, diagnostic power of the inferior ratio and the superior ratio was 59% and 58%, respectively, indicating a marked overlap between the groups.

Conclusions—Abnormally low inferior to temporal and superior to temporal rim width ratios can indicate glaucomatous optic nerve damage in some ocular hypertensive eyes. Being independent of optic disc size and ocular magnification, the rim width ratios may be taken as one among other variables for the ophthalmoscopically detected optic disc damage, taking into account, however, a pronounced overlap between normal eyes and ocular hypertensive eyes.

Patients and methods
The study consisted of 100 ocular hypertensive subjects with increased intraocular pressure and normal visual fields, 202 patients with primary or secondary open angle glaucoma with a mean visual field defect ranging between 2 dB and 10 dB, and 527 normal subjects (Table 1). Required to be included in the study was the availability of good stereoscopic optic disc photographs.

The ocular hypertensive group included eyes with intraocular pressure readings of more than 21 mm Hg or history of it, and normal visual fields (Octopus program G1). About 55% of the individuals in the ocular hypertensive group were taking antiglaucomatous treatment either because the intraocular pressure measurements had repeatedly been higher than about 25 mm Hg, because the contralateral eye not included in the study showed glaucomatous visual field defects, or because the synopsis of glaucoma risk factors such as positive family history and a rather high intraocular pressure suggested antiglaucomatous treatment.

Table 1 Composition of the study groups (mean (SD))

<table>
<thead>
<tr>
<th></th>
<th>Normal group</th>
<th>Ocular hypertensive group</th>
<th>Glaucoma group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>527</td>
<td>100</td>
<td>202</td>
</tr>
<tr>
<td>Age (years)</td>
<td>46.9 (16.2)</td>
<td>52.3 (14.9)</td>
<td>57.4 (14.0)</td>
</tr>
<tr>
<td>Range</td>
<td>4–83</td>
<td>12–79</td>
<td>23–87</td>
</tr>
<tr>
<td>Women/men</td>
<td>270/257</td>
<td>44/56</td>
<td>106/96</td>
</tr>
<tr>
<td>Refractive error (D)</td>
<td>−0.09 (2.08)</td>
<td>−0.65 (2.20)</td>
<td>−0.44 (2.27)</td>
</tr>
<tr>
<td>Range</td>
<td>−7.88 to +8.50</td>
<td>−7.50 to +4.0</td>
<td>−7.0 to +5.0</td>
</tr>
</tbody>
</table>
Neuroretinal rim width ratios in morphological glaucoma diagnosis

Criteria for the diagnosis of open angle glaucoma were an open anterior chamber angle, maximal intraocular pressure values higher than 21 mm Hg, and glaucomatous visual field defects. Glaucomatous visual field defects were defined as an Octopus G1 field with (a) at least three adjacent test points having a deviation of equal to or greater than 5 dB and with one test point with a deviation greater than 10 dB, (b) at least two adjacent test points with a deviation equal to or greater than 10 dB, (c) at least three adjacent test points with a deviation equal to or greater than 5 dB abutting the nasal horizontal meridian, and (d) elevated global visual field indices. In the primary open angle glaucoma group, the reason for an elevation of intraocular pressure was unknown. In the group with secondary open angle glaucoma, the increase of intraocular pressure to values above 21 mm Hg was due to pseudoexfoliative glaucoma or pigmentary glaucoma. For the ocular hypertensive group and for the glaucoma group, the appearance of the optic disc was not taken into account.

The normal subjects were recruited from the administrative university staff who were asked to serve as control subjects, or they were patients who attended the hospital for diseases in the contralateral eye that was not included in the study. These diseases such as rhegmatogenous retinal detachment did not primarily affect the optic nerve.

Eyes with a myopic refractive error exceeding −8.0 dioptres were excluded because of their different optic disc morphology. To be able to measure the width of the neuroretinal rim, we excluded all eyes with an optic cup area equal to or less than 0.2 mm². Although the three study groups varied in mean age (Table 1), matching for this variable was not performed, since size and shape of the neuroretinal rim are statistically independent of age. Only one randomly selected eye per patient and subject was taken for statistical analysis. It means for the subjects in the ocular hypertensive group that the contralateral eye, which was not included in the study, could have glaucomatous visual field loss, or that intraocular pressure measurements were unknown. In the normal eyes, both rim width ratios were significantly (p<0.0001) broader at the inferior disc border than at the superior disc border (Table 2). Both neuroretinal rim ratios were significantly (p<0.0001) and positively correlated with the quotient of vertical to horizontal disc diameter: rim width ratio = 1.43 (ratio of vertical to horizontal disc diameter) + 0.13; p < 0.0001. In the normal eyes, both rim width ratios were statistically independent of optic disc size, neuroretinal rim area, refractive error, age, sex, and right or left eye (p>0.10, Pearson’s correlation coefficient R² < 0.02).

Results

In the normal subjects, the ratio of inferior to temporal rim width was significantly (p<0.0001) higher than the ratio of superior to temporal rim width (Table 2). Correspondingly, the neuroretinal rim was significantly (p<0.0001) broader at the inferior disc border than at the superior disc border (Table 2). Both neuroretinal rim ratios were significantly (p<0.0001) and positively correlated with the quotient of vertical to horizontal disc diameter: the higher were both ratios the more vertically the optic disc was configured (for inferior to temporal rim width ratio: Pearson’s correlation coefficient R = 0.23; equation of the regression line: rim width ratio = 1.43 (ratio of vertical to horizontal disc diameter) + 0.13; p < 0.0001). In the normal eyes, both rim width ratios were statistically independent of optic disc size, neuroretinal rim area, refractive error, age, sex, and right or left eye (p>0.10, Pearson’s correlation coefficient R² < 0.02).
In the ocular hypertensive group, the ratio of inferior to temporal rim width and the ratio of superior to temporal rim width were significantly smaller than in the normal group (p=0.0002 and p=0.004, respectively) (Table 2). The difference between the normal group and the ocular hypertensive group was more marked (0.19 versus 0.15) and statistically more significant (p=0.0002 versus p=0.004) for the inferior to temporal rim width ratio than for the superior to temporal rim width ratio.

Despite the high significance of the differences between the normal group and the ocular hypertensive group, the diagnostic powers of the inferior to temporal rim width ratio and the superior to temporal rim width ratio were only 59% and 58%, respectively. Diagnostic power was defined as the percentage of the area under the receiver operator curve on the total area when sensitivity was plotted against 1 − specificity. It indicates a marked overlap between both groups (Figs 3 and 4).

In an attempt to increase the diagnostic power, the rim width ratios were corrected for their dependence on the optic disc shape. We used two formulas: corrected rim width ratio = (measured rim width ratio)/(mean of rim width ratio in the normal group), and: rim width ratio defect = expected rim width ratio − measured rim width ratio.

Expected inferior to temporal rim width ratio and expected superior to temporal rim width ratio, respectively, were calculated as: 1.43 (1.22, respectively) × (ratio of vertical to horizontal disc diameter) + 0.13 (0.24, respectively). These were the equations of the regression lines when the rim width ratios were correlated with the vertical to horizontal disc diameter ratio.

Using these two formulas, the diagnostic power to separate normal eyes from ocular hypertensive eyes did not change.

In the glaucoma group with visual field loss, both rim width ratios were significantly (p<0.0001) smaller than in the normal group (Table 2). The differences between both groups were more marked for the ratio of inferior to temporal rim width (difference 0.29) than for the ratio of superior to temporal rim width (difference 0.18). Correspondingly, the differences between the ocular hypertensive group without visual field defects and the glaucoma group with visual field defects were more marked for the ratio of inferior to temporal rim width (difference 0.10) than for the ratio of superior to temporal rim width (difference 0.03) (Table 2).

Disc area and, consequently, the cup to disc diameter ratios in the normal eyes were higher in the present study than in previous reports. The reason is that, in the present investigation, eyes with an optic cup area of equal to or less than 0.2 mm² were excluded.

Discussion
Both neuroretinal rim width ratios in the ocular hypertensive group without visual field defects were significantly lower than in the normal group (p<0.0001) (Table 2).
Neuroretinal rim width ratios in morphological glaucoma diagnosis

1369

optic disc regions (Figs 1 and 2).

superior, and temporal disc regions pointing at

rim width is possibly even in the inferior,

in the inferior and superior disc regions

on the optic nerve. The reason for this is that

open angle glaucoma, the neuroretinal rim is

shape and the magnification by the

anterior inferior, middle, and posterior inferior
disc sector, the nasal disc area, and finally

and superior disc regions (Table 2). This also

neuroretinal rim in the inferior and superior
disc regions, and consequently to higher

neuroretinal rim shape. Instead of being broad-

configurations with the rim width being broadest

the inferior and superior disc regions, the

Overall measurements are independent of the

shape of the optic disc. The reason for this is

and the nasal disc area, and finally

optic nerve damage. In the latter, the neuroretinal

attachment between the study groups (Figs 3

neuroretinal rim notches.23 Rim

predominantly in the inferior and superior disc

horizontally oval discs. This leads to a broader

typical shape of the optic disc. It is the reason

partially depends on the position of the central

in horizontally oval optic discs. Correspondingly,

latter, the neuroretinal rim depends on the type

neuroretinal rim is preferentially lost in the

progression of neuroretinal rim notches.23 Rim

But within the optic disc, the local susceptibility

focal normal pressure glaucoma in which the

neuroretinal rim typically shows localised defects in

the optic disc. It is the reason why the inferior

in vertically oval optic discs. Correspondingly, the

overlap between the groups (Figs 3 and 4). Despite

within the optic disc. The local susceptibility for

form of the optic disc. Within the optic disc, the

shape.24 This also accounts for eyes with an

neuroretinal rim is the reason why the inferior

i.e. with the focal normal pressure glaucoma than

in eyes with high pressure glaucoma.

Another factor which has to be taken into

the finding that in the normal group of the

significant differences between the normal eyes

the diagnostic power of the inferior to temporal

the superior to temporal rim width ratio was

and 58%, respectively, indicating a marked

visually normal.7 11–22 Correspondingly, the dif-

the pattern of normal pressure loss of

normal group of the present study was

inferior disc sector, the nasal disc area, and finally

focal normal pressure glaucoma and the

inferior disc region, followed by the superior
disc area. However, the inferior disc region can

rim width ratios depend on the shape of the

20% to 60%, broader than in the temporal disc

pattern of loss of neuroretinal rim in glaucoma-

the finding in normal eyes7 (Fig 1), and the

pattern of loss of neuroretinal rim in normal eyes

In normal eyes, the rim has a characteristic

in the inferior disc region, followed by the su-

the inferonasal quadrant, the inferonasal disc

is reflected in abnormal rim

optic nerve damage in glaucomatous eyes.

Correspondingly, the difference between

the normal group and the ocular hypertensive

development of neuroretinal rim notches.23 Rim

Another aspect to consider is that the pattern

the optic disc. Within the optic disc, the local

temporal superior disc region and the inferior
disc sector than the normal disc sectors.

between the normal group and the ocular

in eyes with an abnormal optic disc shape, how-

optic disc width.26 The difference in rim width

neuroretinal rim notches in eyes with the focal

rim width ratios depend on the shape of the

the central retinal vessel trunk is the temporal

optic disc width ratios depend on the shape of

neuroretinal rim in the inferior and superior

deformity of neuroretinal rim notches.23 For

in normal eyes6 (Fig 1), and the

neuroretinal rim in normal eyes6 (Fig 1), and the

physiological shape of the neuroretinal rim

shape of the optic disc. It is the reason why

horizontal cup to disc diameter ratio than for the

inferior to temporal rim width ratio was signifi-

broad rim width ratios.26 This also accounts

neuroretinal rim notches.23 Rim notches are present

in some ocular hypertensive eyes with normal

perimetric results. In view of the overlap

optic disc width ratio will be less helpful for an

optic disc shape, the optic disc region with the

within the optic disc, the local susceptibility

spectrum and high pressure glaucoma by the

anterior inferior, middle, and posterior inferior
disc sector, the nasal disc area, and finally

the finding that in the normal group of the

the optical media of the eye, the

nearly normal5 (Fig 1), and the

neuroretinal rim is reflected in abnormal rim

because of the physiological shape of the

inferior and superior disc regions (Table 2). This

neuroretinal rim in normal eyes6 (Fig 1), and the

neuroretinal rim in normal eyes6 (Fig 1), and the

horizontal cup to disc diameter ratio than for the

inferior to temporal rim width ratio was signifi-

INVESTIGATION OF NEURORETINAL RIM IN NORMAL EYES
various techniques for measuring the optic disc area in the normal population when the interindividual variability of the optic disc size is usually located in the nasal region of the optic disc, the differences in neuroretinal rim measurement between both methods are largest in the nasal disc region, while in the inferior, superior, and temporal disc areas both methods almost show congruent results. This suggests that the findings of the present study may be transferred to studies using a confocal scanning laser tomograph.

The statistically high significance of the difference in the rim width ratios between the ocular hypertensive group and the normal group may not be exaggerated since the individuals in the ocular hypertensive group were highly preselected being referred to a university hospital. The subjects in the ocular hypertensive group had a relatively high risk of eventually developing glaucomatous perimetric defects, which is already shown by the high frequency of antiglaucomatous treatment, might have changed the optic disc morphology to a smaller optic cup and a larger area of neuroretinal rim. This serves to underline the following present study that the inferior to temporal rim width ratio and the superior to temporal rim width ratio are helpful for early detection of glaucomatous optic nerve damage in some ocular hypertensive eyes without glaucomatous visual field defects. In view of the pronounced overlap between the normal subjects and the ocular hypertensive group (Figs 3 and 4), however, one must take into account that the inferior to temporal neuroretinal rim width ratio and the superior to temporal neuroretinal rim width ratio are not at all sufficient for an early glaucoma diagnosis in all eyes with preperimetric glaucomatous optic nerve damage, and that the rim width ratio is only one among several other variables for the recognition of glaucomatous changes.

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