Optic Disc Rim Area Is Related to Disc Size in Normal Subjects

Joseph Caprioli, MD, Joseph M. Miller, MD

- Measurements of optic disc rim area are used to quantitatively evaluate the optic nerve head in open angle glaucoma. It has been suggested that disc rim area (neuroretinal rim area) is independent of disc size, unlike measurements of cup-disc ratio that co-vary with measurements of disc size. To test the relationships between topographic optic disc measurements and disc size, we used computerized image analysis (Rodenstock analyzer) of the optic nerve head to measure total disc area, cup area, disc rim area, and disc cup volume in 38 normal subjects. Magnification-corrected measurements of cup area, disc rim area, and cup volume were positively correlated with measurements of disc area. Measurements of disc rim area were therefore not independent of disc size in this group of normal subjects. A normal range of values for disc rim area can be predicted for an eye depending on the area of its optic disc. Sensitive predictions require further refinement based on the patient’s age, race, and sex.


Clinical studies indicate that, in some patients, structural changes of the optic nerve head can be detected in early glaucoma before the visual field becomes abnormal. Significant loss of ganglion cell axons has been documented in patients with elevated intraocular pressure before visual field abnormalities were detected. An accurate clinical assessment of the number of nerve fibers contained in the optic nerve head may provide a means with which to detect early glaucomatous optic nerve damage.

Bengtsson found a strong covariation between the size of the normal optic disc and its cup, while measurements of “rim breadth” were relatively independent of disc diameter. Measurements of rim breadth, then, might be more useful than measurements of cup-disc ratio to detect the presence of early glaucomatous optic nerve damage. Airaksinen and coworkers suggested that measurements of disc rim area (neuroretinal rim area) in early glaucoma would be useful for the same reason. They argued that the disc rim area reflects the number of nerve fibers in an eye and is not influenced by the size of the optic disc or by the cup-disc ratio. Radius and Pederson demonstrated a strong correlation between the amount of rim tissue and the number of axons present in the optic nerves of primate eyes with experimentally induced glaucoma.

This study investigates quantitatively the normal relationships between topographic measurements of the optic nerve head and disc size. We used a system of computerized image analysis to obtain measurements of total disc area, disc cup area, disc rim area, and cup volume in normal subjects.

**SUBJECTS AND METHODS**

A computerized image analysis system (Rodenstock analyzer, G. Rodenstock Instrumente GMBH, Munich) was used to make quantitative structural measurements of the optic nerve head. Descriptions of this instrument have been published.

The optical head provides a simultaneous stereoscopic videographic image of the optic disc with a high-sensitivity, image-intensified video camera. A computer digitizes the fundus image (256 x 256 pixels) and “freezes” it on the monitor for evaluation by the operator. Images may then be rejected or saved on a floppy or fixed disk. To obtain depth measurements across the optic nerve surface, a set of seven parallel stripes is projected onto the fundus; two such images are processed to make depth measurements, providing 14 vertical stripes along which measurements are obtained. Approximately ten of these stripes span an optic nerve head with an average diameter of 1.4 mm. The stripes provide features on otherwise featureless areas of the optic disc so that effective image analysis can be performed.

To obtain depth measurements, the instrument simultaneously records a pair of stereoscopic images with striped patterns that contain small deformations caused by variations in nerve head topography. The computer selects corresponding line segments within the two stereoscopic disc images and computes their cross-correlation function. This results in approximately 1600 calculated depth values along the stripes. These depth measurements are further processed to extract structural measurements after the disc edge is defined by the operator. The operator subjectively identifies and marks the edge of the optic disc. A computer algorithm objectively identifies the margin of the “cup” by locating the point on each of 360 radial profiles lying 150 μm below and nearest the disc edge. The disc rim area is the area between the cup rim margin and the disc edge. The overall cup-disc ratio is the average of all cup-disc ratios calculated for each of the 360 radial profiles. All dimensions are corrected for image magni-
fication and minification using ultrasonographic measurements of axial length or keratometry and refraction.\(^\text{11}\)

Normal subjects were volunteers from the hospital staff or spouses of patients. None had a history of eye disease and all had normal results of an ophthalmologic examination. The inclusion criteria were reasonably clear media and pupillary dilation to 5 mm or more. Patients with high refractive errors were included.

**RESULTS**

The average (± SD) age of the normal subjects was 36 ± 12 years. The mean spherical equivalent of refractive error was −0.9 ± 2.5 diopters (D) with a range of +1.50 to −9.00 D; no patient had more than 1.50 D of astigmatism.

The mean (± SD) disc area was 1.70 ± 0.37 mm²; mean (± SD) disc rim area, 1.13 ± 0.37 mm²; mean (± SD) cup area, 0.57 ± 0.31 mm²; and mean (± SD) cup volume, 0.35 ± 0.18 mm³. Statistically significant positive correlations with disc area were found for cup area (\(r = .53, P = .0006\)) and for cup volume (\(r = .65, P = .00001\)), such that (1) cup area = 0.42 × disc area −0.15 mm² (Fig 1), and (2) cup volume = 0.34 mm³ × disc area −0.23 mm³ (Fig 2). There was also a statistically significant correlation (\(r = .65, P = .00001\)) between disc rim area and total disc area, such that rim area = 1.36 × disc area −1.19 mm² (Fig 3). The 95% prediction interval for individual measurements of disc rim area as a function of disc area in normal subjects was also determined (Fig 3).

**COMMENT**

The earliest measurable abnormalities of glaucomatous optic nerve damage, whether psychophysical or structural, have not yet been completely defined. There is considerable clinical evidence to suggest that structural changes of the optic nerve head may be detected in some patients before the visual field becomes measurably abnormal.\(^\text{14}\) An accurate clinical estimate of the number of ganglion cell axons in a living eye may provide valuable information regarding early and interval glaucomatous damage to the optic nerve head.

Clinical estimates of cup-disc ratio are limited in their value to detect the earliest optic disc changes in patients with glaucoma.\(^\text{15}\) Careful examination of stereo disc photographs may be the best routine method by which to recognize subtle interval changes of the optic disc.\(^\text{16}\) The qualitative and subjective nature of these comparisons, however, has initiated a search for more quantitative methods.

Airaksinen and colleagues\(^\text{16}\) manually measured the disc rim area of the optic nerve head in 33 normal individuals, 50 individuals with suspected glaucoma, and 51 patients with glaucoma. The mean measurements were statistically significantly different among the groups. The authors speculated that disc rim area may not be affected by the size of the optic disc, and that such measurements would be independent of both optic disc size and cup-disc ratio. Measurements of the disc rim area might then be used as a measure of the number of ganglion cell axons present in the optic nerve. However, a recent report by Britton et al\(^\text{19}\) indicates that manual measurements of disc rim area are a function of disc size; eyes with larger discs have larger measured disc rim areas.

The Rodenstock analyzer, a system using videographic computerized image analysis, has been used to obtain quantitative measurements of optic nerve head topography. With this instrument, the edge of the disc is defined subjectively, while the edge of the cup is defined objectively by the computer. Measurements of cup volume are entirely objective and are independent of operator input. The reproducibility of these measurements and comparisons with manual tracing techniques have been published.\(^\text{12-15}\) Mikelberg and coworkers\(^\text{16}\) found a highly significant correlation of vertical and horizontal cup-disc ratio, disc rim area, and disc area measurements obtained with this videographic image analysis system with similar measurements obtained using manual tracing techniques. Correlation coefficients of measurements of disc rim area and optic disc area for the manual and automated techniques were .72 (\(P = .0000\)) and .89 (\(P = .0000\)), respectively. Caprioli and Miller\(^\text{19}\) found a strong linear correlation between manual measurements of disc rim area and more objective measurements obtained with recent software modifications to the Rodenstock analyzer (\(r = .76, P < .00001\)).

In the present study, measurements of cup area and cup volume positively correlated with measurements of disc area; these were not surprising results. However, measurements of disc rim area were also positively correlated with the total area of the optic disc. A prediction interval (Fig 3) can be used to establish, with 95% confidence, whether the rim area for a given size optic disc lies within a normal range. The scatter of the values, and therefore the width of the prediction interval, might be further reduced by studying a larger number of normal subjects and by controlling for age, sex, and race.

The results of this study agree with those of Britton et al,\(^\text{19}\) who manually traced the disc rim. We have additionally shown that objective measurements of cup volume correlate with disc size. It cannot be assumed a priori that measurements of disc rim area reflect the number of retinal ganglion...
cell axons present in the nerve head. There are three possible explanations for co-variation of disc size and disc rim area. First, larger discs may have a larger supporting framework or a greater volume of nonneural elements that contribute to the measurement of disc rim area. Second, and much less likely, eyes with larger discs may carry a greater number of ganglion cells than do smaller eyes. Third, there may be some artifact of the measurement that overestimates disc rim area in large discs, underestimates disc rim area in small discs, or both. There is no basic information currently available to either support or refute these alternative hypotheses.

Additional normal data are being accumulated, and it may be possible to make more accurate predictions of expected disc rim areas from measurements of optic disc size. Estimates from age-, sex-, and possibly race-matched normal controls may be required. If an accurate estimate of normal disc rim area for an individual eye can be made, then clinical measurements of this parameter might be used to detect early glaucomatous optic nerve damage.

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