Background: Hyperopia is a risk factor for esotropia and amblyopia. A previous study indicated that disc areas (DAs) are reduced in patients with amblyopia.

Objective: To determine if there is a difference in the relative size of the optic disc in hyperopic eyes without strabismus or amblyopia compared with esotropic and amblyopic eyes, the relationship of axial length (AXL) to DA in subjects with hyperopia was evaluated.

Methods: Eight hundred fifty records from my private practice, which included AXL measurements and optic disc photographs or digital images, were analyzed to locate 122 subjects with bilateral refractive errors greater than +2.00 diopters. Disc areas were measured using objective techniques. Axial lengths were determined by ultrasonographic biometry. A ratio, AXL/DA, was derived by dividing the AXL in millimeters by the DA in square millimeters.

Results: The mean (SD) AXL/DA for the group with hyperopia was 9.48 (2.70) mm and 12.30 (3.45) mm for the group with hyperopic strabismus ($P=.01$). The mean (SD) AXL/DA was 15.24 (4.61) mm in the amblyopic eyes and 13.61 (3.67) mm for the nonamblyopic fellow eye ($P=.02$).

Conclusion: The optic discs of eyes with hyperopic strabismus with and without amblyopia were disproportionately and markedly reduced when compared with hyperopic eyes without amblyopia or esotropia.

Arch Ophthalmol. 2003;121:821-824

THE INCIDENTAL relationship between hyperopia, esotropia, and amblyopia is well known. Nevertheless, not all patients who have hyperopia develop esotropia and patients who have esotropia may not have amblyopia. A prior report indicated that eyes presumed to have amblyopia were characterized by reduced disc areas (DAs). Subsequently, it was suggested that since amblyopic eyes tend to be hyperopic and small that the reduced DAs were simply another aspect of small eyes. Archer stated, “The disc areas of the amblyopic eyes were significantly less than those of the control eyes, but so were the disc areas of the fellow sound eyes.” John Sloper, D Phil, FRCS, FRCPath, another clinician, recommended that the ratio between axial length (AXL) and DA would be a better indicator of disproportionate reductions in the DA (written communication, October 30, 2001).

The purpose of this retrospective study was to investigate the relationship of the AXL/DA ratio in subjects with hyperopia (spherical equivalent $>+2.00$ diopters [D]). Data obtained from routine examinations of patients with esotropia combined with amblyopia, patients with esotropia without amblyopia, and patients with hyperopia without strabismus or amblyopia were compared.
One hundred twenty-two patients met the above-mentioned selection criteria. Their data were collected and divided into the following groups. Group 1 consisted of the right eyes of 30 patients with hyperopia who had equal vision and no history of amblyopia or strabismus. They had a mean AXL of 22.68 (1.1) mm and a mean DA of 2.57 (0.71) mm². The mean AXL/DA ratio was 9.48 (2.70) mm. The distribution of the DA ratio is shown in the Figure.

Group 2 consisted of the right eyes of 24 patients who had bilateral hyperopia, equal vision, and esotropia with a mean AXL of 21.40 (1.13) mm and a mean DA of 1.88 (0.53) mm². The mean AXL/DA ratio was 12.3 (3.45) mm (Figure B).

In the 68 patients with esotropic amblyopia and bilateral hyperopia (Table 1), AXLs in eyes with better visual acuity (group 3, 21.78 [1.09] mm) were longer than their fellow amblyopic eyes, group 4, at 21.36 (1.02) mm (P= .05, paired t test). Mean DA in eyes with a better visual acuity (group 3) of 1.74 (0.47) mm² compared with fellow eyes with amblyopia (group 4) of 1.55 (0.46) mm² appear to be bigger (P= .02, paired t test). When these measures are combined into the AXL/DA ratio, the AXL/DA ratio for eyes with better acuity (group 3, 13.61 [3.67] mm) compared with the AXL/DA ratio for fellow eyes with amblyopia (group 4, 15.24 [4.61] mm) differs significantly (P= .02, paired t test) (Figure C and D). These data for the 4 groups are summarized in Table 1.

The DAs of the amblyopic eyes and the fellow eyes were significantly different, but their AXLs were at the threshold of statistical significance. Analysis of variance of AXLs and optic DAs of the 4 groups showed significant differences between group 1—the hyperopic eyes without amblyopia or esotropia—and the remaining 3 groups (Table 2). The DAs and AXLs of the strabismic eyes were not significantly distinguishable from the non-amblyopic fellow eyes or the amblyopic eyes.

In a study by Gundersen et al, the DAs of 420 normal and glaucomatous eyes, using the formulas developed by Bengtsson and Krakau, averaged 2.49 (0.44) mm². Using the same formulas, Hellstrom and Svensson found that the median optic DA was 2.67 mm² in 100

**RESULTS**

One hundred twenty-two patients met the above-mentioned selection criteria. Their data were collected and divided into the following groups. Group 1 consisted of the right eyes of 30 patients with hyperopia who had equal vision and no history of amblyopia or strabismus. They had a mean AXL of 22.68 (1.1) mm and a mean DA of 2.57 (0.71) mm². The mean AXL/DA ratio was 9.48 (2.70) mm. The distribution of the DA ratio is shown in the Figure.

Group 2 consisted of the right eyes of 24 patients who had bilateral hyperopia, equal vision, and esotropia with a mean AXL of 21.40 (1.13) mm and a mean DA of 1.88 (0.53) mm². The mean AXL/DA ratio was 12.3 (3.45) mm (Figure B).

In the 68 patients with esotropic amblyopia and bilateral hyperopia (Table 1), AXLs in eyes with better visual acuity (group 3, 21.78 [1.09] mm) were longer than their fellow amblyopic eyes, group 4, at 21.36 (1.02) mm (P=.05, paired t test). Mean DA in eyes with a better visual acuity (group 3) of 1.74 (0.47) mm² compared with fellow eyes with amblyopia (group 4) of 1.55 (0.46) mm² appear to be bigger (P=.02, paired t test). When these measures are combined into the AXL/DA ratio, the AXL/DA ratio for eyes with better acuity (group 3, 13.61 [3.67] mm) compared with the AXL/DA ratio for fellow eyes with amblyopia (group 4, 15.24 [4.61] mm) differs significantly (P=.02, paired t test) (Figure C and D). These data for the 4 groups are summarized in Table 1.

The DAs of the amblyopic eyes and the fellow eyes were significantly different, but their AXLs were at the threshold of statistical significance. Analysis of variance of AXLs and optic DAs of the 4 groups showed significant differences between group 1—the hyperopic eyes without amblyopia or esotropia—and the remaining 3 groups (Table 2). The DAs and AXLs of the strabismic eyes were not significantly distinguishable from the non-amblyopic fellow eyes or the amblyopic eyes.

**COMMENT**

In a study by Gundersen et al, the DAs of 420 normal and glaucomatous eyes, using the formulas developed by Bengtsson and Krakau, averaged 2.49 (0.44) mm². Using the same formulas, Hellstrom and Svensson found that the median optic DA was 2.67 mm² in 100
healthy children and adolescents with refractive errors between -4 and +4 D. Jonas and Papastathopoulos determined the normal DA of 158 subjects to be 2.73 (0.63) mm². Hoffer measured 6950 phakic eyes and found the mean AXL to be 23.65 (1.35) mm. There is a stable and predictable relationship between AXL and refractive error that remains applicable even for variations of 3 mm in AXL. A deviation of 3 mm would be equivalent to 9 D. The AXL/DA ratio in the general population, based on these data, is 8.66 to 9.5 mm⁻¹.

Analysis of the data derived from the nonamblyopic, nonesotropic hyperopic group 1 showed that the AXL/DA ratio of 9.68 (2.54) mm⁻¹ was similar to the value for the healthy population. The mean AXL for this group was about 1 mm longer than the other 3 groups (Table 1). Nevertheless, the AXL/DA ratio was the lowest for the hyperopic group 1 because the mean DA was 30% to 40% larger than the DAs of the other groups.

The AXLs and DAs in 24 right eyes of patients with esotropia and hyperopia without amblyopia, group 2, were less than those of the patients without esotropia. Their mean AXL/DA ratio of 12.30 (3.45) mm⁻¹ indicates that the DA was reduced compared with the healthy population and the nonesotropic subjects.

The AXL/DA ratio for the fellow eyes, group 3, was 13.61 (3.67) mm and the AXL/DA ratio for the amblyopic eyes, group 4, was 15.24 (4.61) mm⁻¹ (P = .02, paired t-test). Disc areas were smaller in relation to AXL for amblyopic eyes despite their reduced AXLs.

These results indicate that reductions in DA are consistently found in eyes with esotropia with and without amblyopia. In addition, it seems that in patients with amblyopia, although both eyes demonstrate increased AXL/DA ratios, the eyes with poorer vision have a greater relative reduction in DA.

Disc area generally relates directly to the number of nerve fibers in the optic nerve. Quigley et al stated, "The number of fibers increased linearly with an increasing disc area." Jonas et al noted that "a significant correlation was found between the optic fiber count and the area of the inner aperture of the optic nerve sceral canal." Papastathopoulos et al noted that "Eyes with long diameters had a large retinal surface and large optic disc." Conversely, small hyperopic eyes have smaller optic discs. A paucity of nerve fibers may be a factor in the explanation for decreased visual acuity in amblyopic eyes and reduced visual functions in the fellow eye.

CONCLUSIONS

Archer noted that amblyopic eyes have small optic discs, that amblyopic eyes tend to be hyperopic, and that hyperopic eyes are smaller, and hence, may be expected to have smaller optic discs. Thus, to find out if the optic discs of patients with amblyopia are unexpectedly small, it was necessary to examine the AXL/DA ratio. This has been done and the result shows that in comparison to eyes with hyperopia (group 1) eyes with hyperopia and esotropia (group 2), eyes with hyperopia and amblyopia (group 4), and nonamblyopic fellow eyes with hyperopia and esotropia (group 3) all have significantly a higher AXL/DA ratio. It is, therefore, concluded that the optic discs of eyes with hyperopia and esotropia with and without amblyopia are disproportionately and significantly smaller than eyes with hyperopia without amblyopia or esotropia. Reduced optic DA may be a factor in the explanation of impaired visual functions found in patients with amblyopia who have esotropia.

Submitted for publication April 16, 2000; final revision received December 23, 2002; accepted February 12, 2003.

Corresponding author and reprints: Philip Lempert, MD, Park View Health Care Campus, Cornell University, 10 Brentwood Dr, Ithaca, NY 14850 (e-mail: EYECARTPLUS @AOL.COM).
REFERENCES

17. Hess RF, Field DJ. Is the spatial deficit in strabismic amblyopia due to loss of cells or an uncalibrated disarray of cells? Vision Res. 1994;34:3397-3406.

Call for Papers

The ARCHIVES and the National Eye Institute will be publishing a special theme issue on epidemiology of blinding diseases and blindness prevention. Barbara Blodi, MD, and Frederick Ferris III, MD, will be guest editors for this special issue. We invite all investigators to submit important research addressing issues concerning blindness such as diabetic retinopathy, age-related macular degeneration, cataract, glaucoma, refractive error, low vision, and blindness. Early receipt ensures the best chance for acceptance for this special issue. Accepted manuscripts not included in this issue will be published in other issues of the ARCHIVES. All manuscripts are subject to peer review. Please note in the cover letter that the submission is for the “epidemiology of blinding diseases and blindness prevention” theme issue.