Axial Length–Disc Area Ratio in Esotropic Amblyopia

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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.

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THE COINCIDENTAL relationship between hyperopia, esotropia, and amblyopia is well known.1,2 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).3 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.4 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.”4 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.

METHODS

Eight hundred fifty records were extracted on the basis of availability of AXL measurements and optic disc images from about 20,000 medical records of patients examined in my office. This included the vast majority of patients with amblyopia encountered which constitutes 2.14% of the total patient population. From this group all records of patients with a bilateral spherical equivalent of +2.00 D or more and without amblyopia or strabismus were extracted (group 1, n=30). Amblyopia is defined as a difference of at least 2 lines on the Snellen letter chart with the poorer eye no better than 20/40 with best correction. Additionally, all records of patients with hyperopia of greater than +2.00 D with esotropia without amblyopia were extracted (group 2, n=24); all records for patients with hyperopia with esotropia and amblyopia were...
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.

### RESULTS

Data obtained for the right eyes of patients with hyperopia (group 1) and patients with hyperopia and esotropia (group 2) were collected and analyzed. The eyes of amblyopia-affected patients were separated into 2 groups—eyes with amblyopia (group 4) and their fellow eyes (group 3). The information derived from each group was analyzed separately.

Axial length measurements had been performed using an ultrasound biometer (model 4000; Sonomed, Lake Success, NY) or a laser interferometer (Zeiss IOL Master; Zeiss-Humphrey Systems, Dublin, Calif) on both eyes of all subjects. Disc area measurements were carried out on 35-mm slides or digitized images. Calculations for the magnification factor of the eye-camera combination and the absolute size of the optic nerve used formulas developed by Bengtsson and Krakau.²,³ These formulas use AXL, as the most important factor, and refractive error. Calculations of magnification factors and optic disc size as well as analysis of these data were conducted using computer software programs (Lotus Approach 3.08; Lotus Development Corp, Cambridge, Mass). Data are given as mean (SD). The study protocol was approved by the institutional review board of Cayuga Medical Center, Ithaca, NY.

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**COMMENT**

In a study by Gundersen et al,⁶ the DAs of 420 normal and glaucomatous eyes, using the formulas developed by Bengtsson and Krakau,¹⁹ averaged 2.49 (0.44) mm². Using the same formulas, Hellstrom and Svensson⁶ found that the median optic DA was 2.67 mm² in 100
Table 1. Summary of Mean Values for 4 Groups Who Had Hyperopia Greater Than +2.00 D in Each Eye*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, F/M</td>
<td>15/15</td>
<td>13/11</td>
<td>30/38</td>
<td>30/38</td>
</tr>
<tr>
<td>Age, y</td>
<td>57.6 (27.1)</td>
<td>28.3 (21.5)</td>
<td>39.8 (24.5)</td>
<td>39.8 (24.5)</td>
</tr>
<tr>
<td>Spherical equivalent, D</td>
<td>3.10 (1.35)</td>
<td>4.30 (1.88)</td>
<td>3.95 (1.97)</td>
<td>5.10 (1.82)</td>
</tr>
<tr>
<td>AXL, mm</td>
<td>22.67 (1.10)</td>
<td>21.40 (1.13)</td>
<td>21.78 (1.09)</td>
<td>21.36 (1.02)</td>
</tr>
<tr>
<td>DA, mm²</td>
<td>2.57 (0.71)</td>
<td>1.88 (0.53)</td>
<td>1.74 (0.58)</td>
<td>1.55 (0.55)</td>
</tr>
<tr>
<td>AXL/DA ratio, mm⁻¹</td>
<td>9.48 (2.70)</td>
<td>12.30 (3.45)</td>
<td>13.61 (3.67)</td>
<td>15.24 (4.61)</td>
</tr>
</tbody>
</table>

Abbreviations: AXL, axial length; D, diopters; DA, disc area.

*Data are given as mean (SD) unless otherwise indicated. Group 1 consisted of the right eyes of 30 patients with hyperopia who had equal vision and no history of amblyopia or strabismus; group 2, the right eyes of 24 patients with bilateral hyperopia, equal vision, and esotropia; group 3, 68 patients with hyperopia, esotropia, and no amblyopia in the fellow eye; and group 4, 68 patients with hyperopia, esotropia, and amblyopia. For further details see the “Results” section.

Comparisons of the data derived from the nonamblyopic, nonesotropopic 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 nonesotropopic 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 nerve fiber count and the area of the inner aperture of the optic nerve scleral canal.” 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. 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 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 MA may be a factor in the explanation of impaired visual functions found in patients with amblyopia who have esotropia.

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