Axial Length–Disc Area Ratio in Esotropic Amblyopia

Philip Lempert, MD

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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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.
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 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 nerve fiber count and the area of the inner aperture of the optic nerve scleral canal." Papastathopoulos et al noted that "Eyes with large 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.

### 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.

### Table 2. Statistically Significant Values for ANOVA Comparison

<table>
<thead>
<tr>
<th>Group</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>&lt;.009</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Group 2</td>
<td>.03</td>
<td>&lt;.002</td>
<td>&lt;.02</td>
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<td>Group 3</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Abbreviation: ANOVA, analysis of variance.

*Data were obtained using Fisher protected least significant difference to determine the ratio of axial length over disc area. These express the probabilities of obtaining observed differences by chance. 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.

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.

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