Cycloplegic Refractions of Infants and Young Children:
The Axis of Astigmatism

Velma Dobson,* Anne B. Fulton,† and S. Lawson Sebris*

Review of the cycloplegic refractions of all children who were first examined at Children's Hospital Medical Center in Boston between 1968 and 1978 revealed that 281 children between the ages of 0 and 9.5 years had astigmatism of 1 diopter (D) or greater but no other ophthalmological or neurological problems. In the 85 children under 3.5 years of age, against-the-rule astigmatism was 2.5 times more common than with-the-rule astigmatism, whereas in the 103 children over 5.5 years of age, with-the-rule astigmatism was three times as common as against-the-rule astigmatism. Eleven children who had been astigmatic as infants were recalled; follow-up refraction at ages 5–11 years revealed that all but three had at least a 0.75 D decrease in astigmatism. The remaining three had astigmatism equal in magnitude and axis to the astigmatism they had as infants. Thus, there is a high prevalence of against-the-rule astigmatism in infants and toddlers, which disappears by the time the children reach school age. Invest Ophthalmol Vis Sci 25:83-87, 1984

Many reports indicate that, among astigmatic subjects, the axis of astigmatism varies with age. For example, the prevalence of against-the-rule astigmatism (minus cylinder axis at 90°) increases with each decade after age 40°-5° (see Hirsch2 for a review of early literature). Much less is known about the prevalence of with- and against-the-rule astigmatism in children, but age-related changes in the axis appear to take place. Hirsch6 found that the ratio of with- to against-the-rule astigmatism was approximately 5:1 at age 6 but only 2:1 at age 12, due to an increase in against-the-rule astigmatism across this age range. Woodruff7 found a predominance of with-the-rule astigmatism in 3- to 6-year-olds, and Lyle8 reported that with-the-rule astigmatism was much more common than against-the-rule astigmatism in children 5–10 years of age.

A high prevalence of astigmatism among infants has recently been rediscovered.8°-16° In the studies in which axis of astigmatism was examined,8°,11°,13°-15° the proportion of astigmatic infants who had against-the-rule astigmatism was found to be much greater than that proportion in school-age children or adults. For infants, the ratio of against-the-rule to with-the-rule astigmatism reported in the various studies ranged from 8:1 among 101 preterm infants less than 8 weeks of age14 to 1:1 among 62 11- to 20-week-old, full-term infants.8° Thus, the data indicate that against-the-rule astigmatism is common during infancy and in later life, but uncommon in school-age children and young adults. However, there are no published data that indicate when during the period between infancy and childhood the decline in against-the-rule astigmatism occurs. Furthermore, there are no longitudinal data that indicate whether changes in astigmatic axes occur in individual subjects from infancy to childhood.

The purpose of the present study was to examine more closely the prevalence of against-the-rule, with-the-rule, and oblique-axis astigmatism between infancy and childhood. In addition, through a follow-up study of children who were astigmatic at 18 months of age or younger, we hoped to learn whether the infants who showed predominantly against-the-rule astigmatism were the same children who had with-the-rule astigmatism during the school years.

Materials and Methods

The subjects for this study were obtained from a review of 5,042 consecutive patients examined by three staff ophthalmologists at the Children's Hospital Medical Center in Boston between 1968 and 1978. Included in this study were refractive data from the first eye examination of all children who were (1) 9.5 years of age or less at the time of the eye examination, (2) full-term at birth, (3) had no ocular or systemic abnormalities at the time of the eye examination, and (4) had 1 diopter or more of astigmatism in either eye. Table 1 shows the number of subjects in ten age groups who met criteria 1 through 3 and the proportion of
Table 1. Percentage of subjects with astigmatism ≥ 1 diopter

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>0-6 mo</th>
<th>.05-1.5</th>
<th>1.5-2.5</th>
<th>2.5-3.5</th>
<th>3.5-4.5</th>
<th>4.5-5.5</th>
<th>5.5-6.5</th>
<th>6.5-7.5</th>
<th>7.5-8.5</th>
<th>8.5-9.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects*</td>
<td>46</td>
<td>187</td>
<td>98</td>
<td>97</td>
<td>105</td>
<td>108</td>
<td>87</td>
<td>93</td>
<td>90</td>
<td>68</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right eyes</td>
<td>17</td>
<td>19</td>
<td>11</td>
<td>32</td>
<td>37</td>
<td>50</td>
<td>41</td>
<td>45</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>Left eyes</td>
<td>17</td>
<td>20</td>
<td>10</td>
<td>31</td>
<td>42</td>
<td>50</td>
<td>34</td>
<td>45</td>
<td>17</td>
<td>12</td>
</tr>
</tbody>
</table>

* First refraction data of subjects who had no ocular or systemic abnormalities and were born at term.

these children in each age group who had 1 diopter or more of astigmatism in one or both eyes. The high proportion of astigmatic subjects in the middle age groups is undoubtedly due to the fact that our sample of subjects is a clinical sample; it is likely that such a sample would contain a high proportion of children with refractive errors, especially at ages where these refractive errors would interfere with a child's daily activities (eg, reading or watching television).

To control for the fact that children of different ages are often brought to the ophthalmology clinic for different reasons, data analysis was also conducted on the retinoscopies of a subset of the above group who came to the clinic for the same reason. This subset included 12 2.5- to 3.5-year-olds and 14 7.5- to 8.5-year-olds who were brought to the ophthalmologist because poor vision was suspected based on parents' observations or poor performance on a school or preschool vision screening.

In order to obtain longitudinal data concerning changes in axis of astigmatism, an attempt was made to conduct a follow-up refraction of the 43 children who were less than 18 months of age at the time of the first refraction. Five to 11 years after the initial examination, the parents of the 43 children were sent a letter that asked them to bring the child back to the ophthalmology clinic for a free follow-up eye examination. The parents of 13 of the children were located, and 11 of them agreed to come in for the follow-up examination. After the study had been explained to the parents of the 11 participants, informed consent was obtained. One of us (AF), who was unaware of the axis of the child's astigmatism at the previous visit, conducted an examination of each child that included assessment of alignment and motility, binocular function (TNO and Bagolini glasses), slit-lamp biomicroscopy, and indirect ophthalmoscopy, as well as cycloplegic retinoscopy. All of the children had good and equal corrected vision, except one who appeared to have a mildly amblyopic right eye (20/25) but normal vision (20/20) in the fellow eye. We suspect the amblyopia was refractive; retinoscopy in infancy revealed right eye: +3.00-3.00 × 90; left eye: +2.00 S. At follow-up, retinoscopy revealed right eye: +2.25-1.25 × 90; left eye: +0.50 S. This was the only patient who showed any deficit of acuity; however, he was orthophoric and had good binocular function (TNO test: fused targets having 60 seconds of arc disparity; Bagolini glasses: normal retinal correspondence and no suppression). All other patients also had normal alignment and motility and normal anterior and posterior segments assessed by slit-lamp biomicroscopy and indirect ophthalmoscopy.

For all subjects, the cycloplegic agent was cyclopentolate 1%. Retinoscopies were performed in a dimly lighted room using a Copeland streak retinoscope, with the child fixating the light of the retinoscope. The refractionists used the minus cylinder convention. We classified the axis of the cylindrical component of each refraction as with-the-rule (direct) if the minus cylinder axis was at 180 degrees ±15, against-the-rule (indirect) for minus cylinder axis at 90 degrees ±15, or oblique (other than with- or against-the-rule).

Results

The proportion of subjects in 10 age groups who had with-the-rule, against-the-rule, and oblique axis astigmatism of 1 diopter or greater is shown in Figure...
1. Consistent with previously published reports\textsuperscript{8,11,13-15} and recent data,\textsuperscript{17,18} the infants and young children studied here had a much higher prevalence of against-the-rule astigmatism than that seen in older children (right eye: $\chi^2 = 482$, df = 9, $P < 0.001$; left eye: $\chi^2 = 449$, df = 9, $P < 0.001$). For this group of children, the transition between the predominance of against-the-rule astigmatism to the predominance of with-the-rule astigmatism occurred between 3.5 and 5.5 years postnatal.

Figure 2 shows the data of the subset of children who came to the clinic because they showed evidence of poor visual acuity. These data show that even if subjects were selected only on the basis of complaints of poor vision, a greater proportion of children in the younger age group had against-the-rule astigmatism than in the older age group. Thus, it is clear from the cross-sectional data presented in Figures 1 and 2 that there are age-related differences in the prevalence of with- and against-the-rule astigmatism.

The results of the retinoscopies of the 11 children who participated in the longitudinal follow-up are presented in Figure 3. Each data point represents retinoscopic data from one eye. Brackets indicate data from the two eyes of an individual. Two subjects were anisometropic at the time of the first refraction; only the data from the astigmatic eye of each are shown. Filled circles indicate with-the-rule astigmatism and open circles indicate against-the-rule astigmatism. None of these subjects showed oblique-axis astigmatism. The dashed lines indicate 1 diopter of astigmatism; subjects whose data points fall between these lines would have been classified as nonastigmats in our study.

Figure 3 shows several features of the longitudinal data. First, all but one subject (two eyes) who returned for the follow-up study had against-the-rule astigmatism as infants. This is not surprising because a high proportion of children in the 0–18-month age group in the original study had against-the-rule astigmatism (see Figure 1). Second, only six of the 22 eyes that were refracted in this study had more than a diopter of astigmatism at the follow-up refraction. These results are in agreement with the results of previous longitudinal studies that have found that most of the astigmatism seen in infants disappears as these children grow older.\textsuperscript{12,15} Third, for the six eyes that had astigmatism of 1 diopter or more at the follow-up refraction, the axes of the astigmatism were identical to the axes that were present at the child's first refraction. Thus, although the number of subjects is small, we have no evidence that children who were against-the-rule astigmats as infants later develop with-the-rule astigmatism of 1 diopter or more. Instead, the tendency appears to be for the amount of the astigmatism to decrease with age, while the axes remain constant. It should be noted, however, that one subject (two eyes) in the present study who had considerable against-the-rule astigmatism at 8.5 months (+2.50-2.50 X 90 O.U.) was found to have a slight with-the-rule astigmatism at 9.5 years of age (+0.50-0.50 X 180 O.U.). This patient had 20/20 acuity (Snellen chart) in each eye and good binocular function.

**Discussion**

The results of the present study provide both cross-sectional and longitudinal data concerning with-the-
rule, against-the-rule, and oblique-axis astigmatism in infancy and childhood. The cross-sectional data indicate that in astigmatic children less than 3½ years of age, against-the-rule astigmatism is more common than with-the-rule astigmatism, whereas after age 5½, with-the-rule astigmatism is more common than against-the-rule astigmatism. These cross-sectional data, obtained by cycloplegic retinoscopy, are consistent with recent data obtained by noncycloplegic retinoscopy and photorefraction.

The longitudinal data (Figure 3) are also consistent with noncycloplegic results, obtained with retinoscopy and photorefraction, which indicate that the astigmatism of many infants decreases as the infants grow older. As was true in Gwiazda et al.'s results, our data showed that children with a diopter or more of against-the-rule astigmatism in infancy did not have a diopter or more of with-the-rule astigmatism at school age. However, we also found, as did Gwiazda et al., that there are cases of children whose axes switch from large amounts of against-the-rule astigmatism in infancy to small amounts (≤0.5 D) of with-the-rule astigmatism by school age.

Given that the cross-sectional data show that the predominant form of astigmatism changes from against-the-rule during infancy to with-the-rule at school age, what might be the mechanisms that cause this change? Two mechanisms that have been invoked most frequently to explain the increased prevalence of against-the-rule astigmatism in old age may also contribute to axis changes during the preschool years. These two mechanisms are (1) changes in eyelid pressure against the cornea and (2) the amount of pressure exerted on the eye by the horizontal rectus muscles.

It has been suggested that the high proportion of with-the-rule astigmatism present in school-age children and young adults is due to the force applied to the cornea by the eyelids, and that after age 40, eyelid pressure relaxes, resulting in an increase in against-the-rule astigmatism as the cornea returns to its natural form (greater curvature in the horizontal than in the vertical meridian). If the eyelids of the infant are as weak as the eyelids of elderly individuals, then lack of pressure by the eyelids could result in the high frequency of against-the-rule astigmatism seen in infants. This explanation assumes that the changes in astigmatism that occur between infancy and childhood are predominantly corneal, an assumption supported by the recent keratometric data of Howland, which indicate that there is a high correlation between the corneal and total astigmatism of young infants.

Another factor that may contribute to the high proportion of against-the-rule astigmatism in infancy and old age is the influence of the horizontal extraocular muscles on the shape of the eye. Assuming that the tonic forces of the horizontal recti remain the same with respect to the tonic forces of the other eye muscles with increasing age, decreased eyelid pressure in infancy and old age could result in an increase in the curvature of the horizontal meridian and therefore an increased frequency of against-the-rule astigmatism at these ages.

Thus, two mechanisms may contribute to a decrease in against-the-rule astigmatism and an increase in with-the-rule astigmatism during the preschool years. The cross-sectional data presented in the present paper are consistent with such mechanisms. The apparent contradiction of the longitudinal and cross-sectional data may be the result of the small number of subjects who could be followed longitudinally in the present sample. Alternatively, it may be that the children who show large amounts of against-the-rule astigmatism in infancy are not the same children who show large amounts of with-the-rule astigmatism at school age.

Finally, given that a high proportion of infants have against-the-rule astigmatism, how does the astigmatism affect their vision? In young infants, the astigmatism may have little effect on their vision because of their poor visual acuity and large depth of focus. In support of this hypothesis, Dobson and co-workers found no evidence that 3-month-old astigmatic infants accommodate differentially to vertical versus horizontal gratings. In infants over 3 months of age, behavioral evidence concerning the effect of astigmatism on vision is scarce. Teller and co-workers tested an infant with 2.5 D of astigmatism who showed a difference in visual acuity for vertical and horizontal gratings at 4 and 5 months that was eliminated when her astigmatism was corrected with glasses at 6 months. Held and co-workers, in a study of visual preference in infants under 13 months of age, found that the presence of astigmatism can affect an infant's preference for vertical versus horizontal gratings. Thus, there is evidence that the defocus produced by astigmatism can have a measurable effect on an infant's vision. Recently, Gwiazda and co-workers have reported that infantile astigmatism may have long-term effects on visual acuity that persist even when the astigmatism is no longer present.

In summary, the cycloplegic retinoscopy data reported in the present study indicate that before age 3½ the predominant form of astigmatism is against-the-rule, whereas after age 5½, the predominant form is with-the-rule. Longitudinal data from individual infants showed a general trend for the amount of astigmatism to decrease with age but little evidence for changes in axis with age.

Key words: astigmatism, axis of astigmatism, infants, children, cycloplegic retinoscopy, refraction
Acknowledgments

We thank Dr. Luisa Mayer and Mrs. Dorothy Rodier for assistance in patient evaluation, and Dr. Davida Y. Teller for comments on an earlier version of the manuscript.

References