Astigmatism in Children: Changes in Axis and Amount from Birth to Six Years

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Noncycloplegic refractions of 1,000 children aged 0–6 years revealed a high incidence of astigmatism, especially in the first 2 years of life. Before age 4½ years, most of the astigmatism was against-the-rule and after that age most was with-the-rule. Of 19 children who did not show astigmatism in the first year, only one acquired it by 4 years. Of 29 children who had large amounts of astigmatism in the first year, all showed elimination or a large reduction in the amount of the cylindrical error by 4 years. These results are relevant to the etiology of astigmatism. Invest Ophthalmol Vis Sci 25:88–92, 1984

It is now well documented that infants have a high incidence of clinically significant astigmatism.1–5 Mohindra and colleagues,3 using noncycloplegic retinoscopy, found that 45% of a sample of 276 infants showed significant astigmatism (≥1.0 diopters [D]) in the first year of life. Similar findings have been reported using cycloplegic retinoscopy1,4,5 and photorefraction.2 Most of the astigmatism in the first year is against-the-rule, ie, minus cylinder axis 90°.1,5

Refraction data from school-aged children, on the other hand, show a much lower incidence of astigmatism, and most of it is with-the-rule, ie, minus cylinder axis 180°.1,5 For example, Hirsch6 reported that between the ages of 6 and 12 years, 4% to 7% of the children showed more than 0.75 D of astigmatism, almost exclusively with-the-rule. Based on his longitudinal data, Hirsch concluded that there is not much change in astigmatism during the school years. If a child is going to have a large amount of astigmatism, he or she will have it by 6 years of age.

The high incidence of astigmatism in infancy and the much lower incidence in school-aged children imply that much of the early astigmatism must be eliminated between 1 and 6 years. And, since infants tend to have against-the-rule astigmatism and older children have with-the-rule, changes in axis must also be occurring during this time. However, the few refraction studies that cover this age range present conflicting findings. Atkinson et al7 reported that the incidence of astigmatism (≥0.75 D) declined to adult levels, 8–10%, by 18 months of age. Mohindra and Held,8 on the other hand, found that the incidence of astigmatism (≥1.0 D) was still high, almost 40%, as late as 5 years of age. Neither study reported data on the axis of astigmatism. Woodruff9 reported both the axis and amount of astigmatism compiled from the refractions of 631 children between the ages of 1 and 6 years. His results showed a trend to more astigmatism with increasing age. Three percent of 2-year-old children showed 0.75 D or more of astigmatism, while by 6 years of age, 10% showed this amount. Most of the astigmatism was with-the-rule. Larger amounts (≥2.25 D) of against-the-rule astigmatism were never seen.

Studies of early astigmatism are important in order to understand the development of the human visual system. Some adult astigmats show optically uncorrectable losses of acuity (meridional amblyopia) for edges in the orientations that are presumed to have been blunted by their astigmatism since early childhood. The amblyopia is assumed to be produced by the habitual blurring.10 Tracking the refractions of young children during development will provide more information about the timing of a sensitive period, during which astigmatism may have deleterious effects on the development of the visual nervous system. The refraction data are also relevant to the etiology of astigmatism and its prognosis.

In this study we report cross-sectional refraction data obtained from a group of 1,000 children aged 0–6 years. In addition, we report longitudinal changes in refractions in a group of 48 children who were followed for a period of at least 4 years beginning shortly after birth. This is the first time that refractions have been tracked in very young children.
Materials and Methods

One thousand children aged 0–6 years comprised the cross-sectional sample. Ninety-seven percent were white, 2% were black, and 1% Oriental. Informed consent of the parents was obtained prior to undertaking the study. Upon initial refraction, 609 children had less than 1 D of astigmatism, and 391 had 1 or more D. In the first year, 63% of the children had mean spherical refractions between -1.0 and +1.0 D, with a mean of +0.5 D. Over years 1–6, 90% of the children had mean spherical refractions between -1.0 and +1.0 D, with a mean of +0.5 D. Children with phoria, tropia, or ocular disease were excluded from the sample. Infants were recruited by a letter describing the MIT research program in infant vision sent to parents in the Cambridge, Massachusetts area. Names and addresses were obtained from the birth records on file in the Cambridge City Hall. Responses to the letters that resulted in participation in the study averaged 10%. Older children were recruited from day care centers, nursery schools, and camps in the Cambridge area. Forty-eight of the children were refracted from 4–20 times in the first year, and periodically thereafter, until they reached at least 4 years of age. These children comprised the longitudinal sample.

Refractions were obtained by the near-retinoscopy procedure, performed by two experienced refractionists (MS and IM) without pre-knowledge of any earlier findings obtained from children in the longitudinal sample. It has been shown that near-retinoscopic refractions of children are highly correlated with their cycloplegic refractions and that repeated near-retinoscopic measurements of the same children made within a short period of time rarely deviated by more than ±0.5 D.3

In the near-retinoscopy procedure, the child fixated the light of the retinoscope in an otherwise dark room. Retinoscopy was performed at a fixed distance of 50 cm without cycloplegia. The streak was moved quickly between the two principal meridians to determine the cylindrical power and axis. The vergence of the retinal reflection was neutralized through the use of a graded set of lenses mounted in a bar for easy manipulation.

An adjustment factor of —1.25 D was added to the spherical component at neutrality to obtain the static distance refraction of the eye. This factor was used rather than the —2.0 D, which would be correct for the working distance of 50 cm, because it has been determined that an average tonus adjustment of +0.75 D must be added to the static refraction obtained by near-retinoscopy.13 In experiments with both infants and adults, Owens and colleagues showed that the beam of a retinoscope, when viewed in a dark room, does not stimulate accommodation.14 They further showed that, in this situation, the eye focuses for an intermediate distance, referred to as the dark focus or resting state of accommodation. On average, this effect can be compensated for by applying a standard tonus adjustment of +0.75 D. Thus, —2.0 D (working distance) +0.75 D (average tonus adjustment for dark focus) = —1.25 D, the adjustment factor applied to the spherical component of the refraction.

All refractions were written using the minus cylinder convention. The axis of the cylindrical component was classified as with-the-rule if the minus cylinder axis was at 180° ± 15°, against-the-rule for minus cylinder at 90° ± 15°, or oblique (other than with-the-rule or against-the-rule; usually either 45° in one eye and 135° in the other, or 30° in one eye and 120° in the other).

Results

Figure 1 shows the proportion of 1,000 children aged 0–6 years who had 1 D or more of astigmatism. These data are based on the initial refraction of the right eye of each child. Results of a chi square test showed that the distribution of amounts of astigmatism, including <1 D of astigmatism, varied as a function of age ($\chi^2 = 123$, df = 15, $P < 0.001$). It can be seen in Figure 1 that both the incidence and amounts of astigmatism are highest in the first two years and decline thereafter:

Data from the children with clinically significant astigmatism shown in Figure 1 are divided by axis in Figure 2. In the first three years of life (0–35 months), the proportion of children who have against-the-rule astigmatism is not significantly different from the proportion who have with-the-rule ($\chi^2 = 1.4$, df = 1, n.s.). However, for older children (3–6 years), there is a higher prevalence of against-the-rule astigmatism be-
fore 4½ years (54 months), and a higher prevalence of with-the-rule after that age \( (x^2 = 4.45, \text{df} = 12, P < 0.05) \). Over all ages, only a small proportion of children ever show oblique axis astigmatism.

Table 1 shows the change in amount and axis as a function of age for the children in the longitudinal sample who had significant astigmatism at 6 months of age. Of these, 16 children had against-the-rule astigmatism at 6 months, 8 children had with-the-rule astigmatism at 6 months, and 5 children had oblique axis astigmatism at 6 months. All 29 children showed a significant reduction in the amount of astigmatism between 6 months and 4–6 years of age \( (t = 13.4, \text{df} = 28, P < 0.001) \). Of the children who had large amounts of against-the-rule astigmatism at 6 months (Table 1a), by 6 years of age, one third of the children had small amounts of against-the-rule astigmatism, one third had shifted axis to small amounts of with-the-rule astigmatism, and one third had no astigmatism. It should be noted that only one of the 6-year-olds had greater than 1 D of astigmatism, and the axis remained against-the-rule.

For the children who had large amounts of with-the-rule astigmatism at 6 months (Table 1b), there was a shift to smaller amounts of with-the-rule astigmatism or to no astigmatism at all with increasing age. None of the children acquired against-the-rule astigmatism. Three of the 5 children who had large amounts of oblique axis astigmatism at 6 months (Table 1c) shifted to small amounts of with-the-rule at 5 years. Overall, then, much of the early astigmatism was either eliminated or reduced in amount, with an indication of a shift in axis to with-the-rule.

Nineteen children in the longitudinal sample never showed significant astigmatism in the first year. They were periodically refracted until at least 4 years of age, and in that time, only one acquired significant astigmatism. This child acquired 1.5 D of with-the-rule astigmatism at 6 months. All 29 children showed a significant reduction in the amount of astigmatism between 6 months and 4–6 years of age \( (t = 13.4, \text{df} = 28, P < 0.001) \). Of the children who had large amounts of against-the-rule astigmatism at 6 months (Table 1a), by 6 years of age, one third of the children had small amounts of against-the-rule astigmatism, one third had shifted axis to small amounts of with-the-rule astigmatism, and one third had no astigmatism. It should be noted that only one of the 6-year-olds had greater than 1 D of astigmatism, and the axis remained against-the-rule.

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astigmatism in his right eye at age 2 years and has kept it until age 6 years.

Discussion

Results of the present study indicate that the large amounts of astigmatism shown before 2 years of age are greatly reduced or eliminated by 4 years of age. With respect to the axis of astigmatism, 4–5 years is a time of transition. Before age 4½ years, most children have against-the-rule astigmatism and after that age, with-the-rule. These findings have been confirmed using cycloplegic retinoscopy15 and photorefraction.16 Longitudinal data from Dobson and colleagues15 agree with our findings in showing that the large amounts of astigmatism seen in infancy are greatly reduced or eliminated by school age. In addition, the axes of astigmatism of individual children may shift from large amounts of against-the-rule or oblique in the first year to small amounts (<0.5 D) of with-the-rule by school age. There is no indication of a shift in axis in those children who initially have with-the-rule astigmatism.

With-the-rule astigmatism predominates until at least 9 years of age. Inspection of patients’ records at the New England College of Optometry (Boston, Massachusetts) revealed that of 47 patients aged 5–9 years with significant astigmatism, 80% showed with-the-rule.

The changes in astigmatism with age documented in the present study are relevant to the etiology of astigmatism. The fact that much of the early astigmatism is against-the-rule and then is either gradually eliminated or becomes with-the-rule may reflect increased eyelid pressure with age.17,18 It has been shown that changes in lid pressure can produce changes in the amount of astigmatism. Robb19 found that patients who had hemangiomas of the eyelid as infants showed astigmatism in the involved eye at a later age. Since the axis of the astigmatism varied systematically with the location of the hemangioma, the pressure of the lesion is inferred to have changed the corneal curvature.

Wilson and colleagues20 showed that retracting the eyelids of young adults with a lid speculum for at least 10 sec produced less with-the-rule astigmatism in corneas that had more than 1.0 D of with-the-rule astigmatism. The same mechanism could account for the increase in against-the-rule astigmatism shown by older (more than 40 years old) patients.21,22 Results of a study by Baldwin and Mills,22 examining both keratometry readings and refraction data, indicate that most of this increase could be accounted for by steepening of the cornea in the horizontal meridian, most likely due to decreased eyelid pressure in later years.

An analogous explanation can be offered for the increase in with-the-rule astigmatism seen after 4½ years. This explanation presumes that most of the early astigmatism is corneal and is supported by Howland, who recently found in young infants a high correlation between total astigmatism measured by photorefractometry and corneal astigmatism measured by photokeratometry.23,24 According to Gullstrand,17 the natural form of the cornea is against-the-rule. This is the most prevalent type of astigmatism found in young children. After 4½ years, the increase in with-the-rule astigmatism could reflect increased eyelid pressure, which would produce greater flattening of the cornea in the horizontal meridian, since maintained pressure must be greater along the horizontal.

Since most of the early astigmatism is either eliminated or greatly reduced in amount, one wonders whether there are any lasting effects. Gwiazda and colleagues25 found that children who had a large amount of myopic astigmatism as infants and later lost it, showed reductions in acuity for the edges oriented along the formerly myopic focus when tested at 4 to 7 years of age. No such reductions were found in formerly hyperopic children. This finding may account, in part, for the unusual patterns of orientational anisotropy shown by some 5–10-year-old nonastigmatic children.25,26 However, given that most infant astigmas have relatively small amounts of hyperopic astigmatism, there should not be a large number of older children and adults with meridional anisotropia resulting from early uncorrected astigmatism.

One final conclusion emerges from the longitudinal results. If a child does not have astigmatism in infancy, he or she is unlikely to acquire it at a later age, at least up to 4–6 years of age.

Key words: astigmatism, axis of astigmatism, refractions, near-retinoscopy, visual development

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References