Original Article

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Effect of astigmatism on refraction in children with high hyperopia

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Summary **The aim of this study was to evaluate primitively whether the extent and component of astigmatism influences regression in degree of spherical (DS) and the best corrected visual acuity (BCVA) of children with hyperopia of +5.00 diopters (D) or greater. Children were screened from the outpatient refraction database in the Wenling No. 1 People's Hospital in Zhejiang province and in Eye & ENT Hospital of Fudan University between June 2005 and December 2015. Eligible eyes were divided into three groups according to the extent of astigmatism: group of astigmatism ≤ −2 D of cylinder, group without astigmatism or with astigmatism ≥ −0.5 D of cylinder, and the group with astigmatism ≥ −0.75 D and ≤ −1.75 D of cylinder. For the component of astigmatism, eyes with astigmatism as ≤ −0.75 D of cylinder were divided into 3 groups: with the rule (WTR), against the rule (ATR) and the group with the oblique. Differences in the changes of BCVA and refractive error (RE) during follow-up terms were compared within and among groups. Differences in the mean DS or BCVA were not statistically significant between groups according to the extent of the astigmatism at the last visit (p = 0.2396 and p = 0.2131, respectively). As for the component of astigmatism, the group with oblique astigmatism had more severe hyperopia than the group of WTR (p < 0.0001) and mean BCVA in the group of ATR were better than that of the other two groups (p < 0.0001) at the first visit. However, the among-group changes were not significant at the end of the observation (p > 0.1). The regression of DS and improvement of the BCVA in children with hyperopia of +5.00D or greater may be irrespective of the component and the extent of astigmatism.**

Keywords: Astigmatism, high hyperopia, refraction, child

1. Introduction

The refraction in infants is usually hyperopic, and generally develops gradually toward emmetropia during the first years of life (*1*). However, Cambridge photoscreening program indicates that hyperopia more than +3.5 D in one or more meridians would be the most frequent refractive anomaly (5-6%) observed in a population at 9 months of age. Moreover, it is associated with a higher risk of amblyopia (almost 7 times that of the control group) and strabismus (21% versus 1.6%) at 4 years of age (*2,3*). Besides, further study concludes that young children with hyperopia greater than 5.00 D are prone to suffer from amblyopia and strabismus (*4*). Due to regression of typical neonatal hyperopia, ease of correction with spectacle lenses, and rare association with blinding disease, studies concerning the prevalence,

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incidence, and natural history of high hyperopia, and subsequent complications in children are limited (*3,5*) though subsequent amblyopia affects approximately 2-4% of the population (*6*).

During the process of emmetropization, there has been some controversy about the role of astigmatism in visual development. For one thing, some researchers speculated that persistent astigmatism may impede emmetropization with formation of a blurred image on the retina (*7-11*). Animal results in monkeys and chicks showed astigmatic defocus caused young eyes to grow slightly toward hyperopia (*10*). However, others hold the opposite view. Fulton and Shih *et al*. have suggested that an astigmatic blur induced myopia (*7-9*). Among which, against-the-rule astigmatism is agreed to predict later development of myopia and faster progression of existing myopia (*8*). So, if astigmatism has an effect on myopia on-set or its progression, then its role on emmetropization is obviously important. Nevertheless, clear signs of either hyperopic or myopic was both presented in cylinder-lens–reared monkeys (*11*).

Though numerous reports intend to disclose the role of astigmatism in visual development, no studies can well document this yet. Recently, studies have been carried out that astigmatism and high hyperopia are both risk factors for bilateral decreased visual acuity (*12*). For another, researchers found that changes in the cylinder power were almost independent of spherical equivalent over the period from 9 to 20 months in hyperopic children (*1*). Considerably less attention has been devoted to the association between astigmatism and the refractive development in children with high hyperopia. For this purpose, the present study was conducted to determine the influence of the extent and component of astigmatism on regression of typical neonatal refraction in children with hyperopia of +5.00 D or greater.

2. Materials and Methods

2.1. *Patients*

This study was conducted in accordance with the Declaration of Helsinki. Ethics Committee of Eye and ENT Hospital of Fudan University and Wenling No. 1 People's Hospital specifically approved this study. The patients included in this study were screened from outpatient refraction database in the Wenling No. 1 People's Hospital in Zhejiang province and in Eye & ENT Hospital of Fudan University between June 2005 and December 2015. Eligible children of either sex had to be no more than 10 years of age at the first visit and had hyperopia of +5.00 D or greater in at least one eye on cycloplegic refraction. We excluded patients who had glaucoma, retinal detachment, congenital cataract, nystagmus, retinopathy of prematurity or any previous ocular surgeries including laser therapy, refractive surgery, cataract surgery, and strabismus surgery, as well as those unable to cooperate with cycloplegic refraction. Finally, 890 children (1,514 eyes) were enrolled retrospectively and eligible for analysis. All children were prescribed with spectacle correction of hyperopia.

2.2. *Treatment*

Subjective cycloplegic refraction (CV-3000, Topcon, Tokyo, Japan) was checked with experienced optometrists half an hour after instilling a drop of tropicamide 0.5% (Shenyang Xingqi Pharmaceutical co., Ltd., Shenyang, China) three times with five minute intervals or an hour after instilling a drop of tropicamide 0.5% five times with five minute intervals. Others were administered with atropine 0.1% (Shenyang Xingqi Pharmaceutical co., Ltd.) eye gel three times a day for three days before subjective refraction. All refractions were written using the minus cylinder convention. The axis of any cylindrical component was classified as with-the-rule (WTR) if the minus cylinder axis was within 15° of 180°, against-the-rule (ATR) for minus cylinder axis within 15° of 90°, or oblique (other than WTR or ATR) (*13*). In agreement with other studies, the standard Refractive Error in School-age Children (RESC) definitions of refractive errors were used: astigmatism as ≤ -0.75 D of cylinder in at least one eye (*14*).

2.3. *Follow-up and data collection*

Eligible eyes were divided into three groups according to the extent of the astigmatism: group of astigmatism ≤ -2 D of cylinder, group without astigmatism or with astigmatism ≥ -0.5 D of cylinder, and the group with astigmatism ≥ -0.75 D and ≤ -1.75 D of cylinder. For the component of astigmatism, eyes with astigmatism as ≤ -0.75 D of cylinder were divided into 3 groups: group of WTR, group of ATR and the group with the oblique.

Eligible patients had been followed up for at least 3 years. Measurements of refractive status and the BCVA were performed at least twice. The refraction data of the first and the last visit were collected, from which the changes of BCVA and DS between the two visits were included for analysis. Differences in changes of BCVA and DS were compared between groups. The data were collected and analyzed anonymously.

2.4. *Statistical analysis*

Analyses were performed with Stata software (Version 11.0). Both eyes were selected as the study eye when they were in accordance with the inclusion criteria. Visual acuities were converted to logarithm of minimal angle of resolution (log MAR) for data analysis. The numerical data were expressed as the mean ± S.D. Changes within groups from the first visit were analyzed using the Wilcoxon signed ranks test.

Comparisons between the group were performed using Kruskal-Wallis test or covariance analysis. A p value of < 0.05 was considered statistically significant.

3. Results

Of all the patients reviewed, 890 children (1,514 eyes) (age range, 2.47 to 10 years; mean age ± standard deviation, 6.39 ± 1.70 years) were eligible for analysis. At the first visit, the mean RE was 7.16 ± 1.70 D and the mean logarithm of BCVA was 0.23 ± 0.25 (Snellen equivalent, 0.66 ± 0.26). They had a mean follow-up time of 4.00 years (range, 3.06 to 5.3 years). Overall, there was a significant decrease of 1.91 D at the last visit in the mean DS ($p < 0.0001$) and obvious increase of 0.17 (Snellen equivalent, 0.24) in the logarithm of BCVA at the last visit ($p < 0.0001$). The mean reduction of DS was 0.48 D per year in the present study.

Figure 1 and 2 demonstrate schematically the mean DS and the mean logarithm of BCVA in the first and last visits for three groups according to the extent of the astigmatism. No statistically significant differences were seen among groups in the DS and BCVA at the first visit ($p = 0.1425$ and $p = 0.0646$, respectively). Notable improvements in the mean DS and BCVA were found for all three groups compared with the first visit ($p < 0.0001$). However, there was no favorable difference among groups either in the mean DS or in the mean BCVA ($p = 0.2396$ and $p = 0.2131$, respectively).

Of the 1,063 eyes with astigmatism as ≤ −0.75 D of cylinder, 871 eyes (81.9%) had WTR astigmatism while 23 eyes (2.2%) had ATR astigmatism. At the first visit, a significant difference was seen in the DS among groups ($p = 0.0008$). Of which, the group with the oblique astigmatism had more severe hyperopia than the group of WTR ($p < 0.0001$). Nevertheless, the differences were statistically insignificant for the group of ATR compared to the group with the oblique ($p = 0.692$) and the group of WTR ($p < 0.0001$). Both groups achieved a great reduction in mean RE at the last visit ($p < 0.0001$). However, the differences among groups were not significant ($p > 0.3$) (Figure 3).

Statistically significant differences were found in the mean BCVA at the first visit ($p = 0.0005$). Mean BCVA in the group of ATR were better than that of the other two groups ($p < 0.0001$), however, it was uncomparable between the group of WTR and group with the oblique ($p = 0.467$). Though there were significant differences in the mean BCVA within groups from the first visit ($p < 0.001$), the among-group changes at the last visit were not notable ($p > 0.1$). (Figure 4).

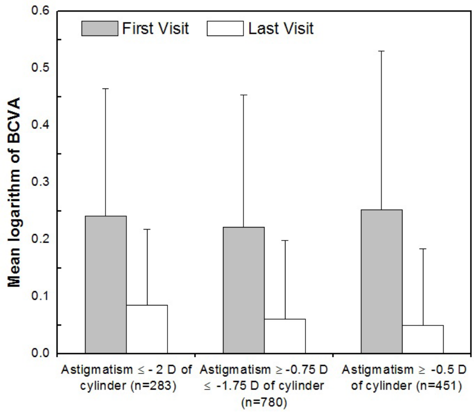

Figure 2. The BCVA improvement during the follow-up terms in all three groups divided according to the extent of astigmatism. Eligible eyes were divided into three groups according to the extent of the astigmatism. The refraction data of the first and the last visit were collected from 890 children (1,514 eyes) before and after the follow-up term. The changes of BCVA between the two visits were included for analysis. Data are expressed as the mean ± S.D (N for number of eyes).

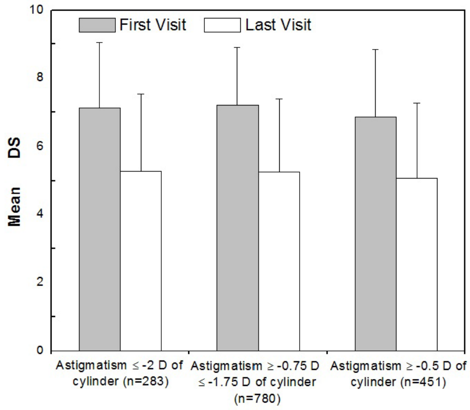

Figure 1. DS significantly decreased during follow-up terms. Eligible eyes were divided into three groups according to the extent of the astigmatism. The refraction data of the first and the last visit were collected from 890 children (1,514 eyes) before and after the follow-up term. Data are expressed as the mean ± S.D. (N for number of eyes).

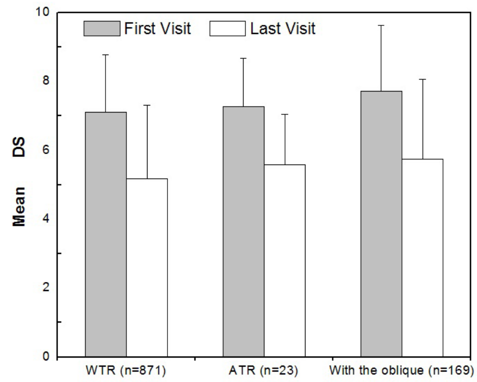

Figure 3. The group with oblique astigmatism had more severe hyperopia. The groups were divided according to the component of astigmatism into group of WTR, group of ATR and group with the oblique. The refraction data of the first and the last visit were collected from 1,063 eligible eyes with astigmatism before and after the follow-up term. Data are expressed as the mean ± S.D (N for number of eyes).

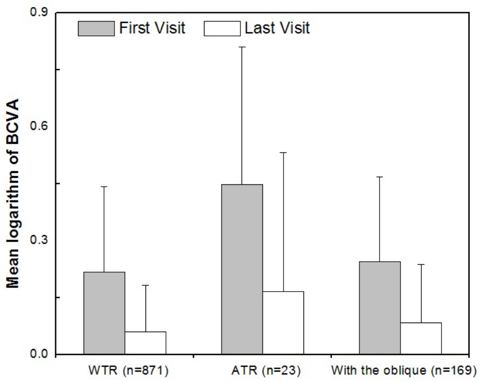

Figure 4. The group with ATR had better BCVA at the first visit but the differences become insignificant by the last visit. The groups were divided according to the component of the astigmatism into group of WTR, group of ATR and group with the oblique. The refraction data of the first and the last visit were collected from 1,063 eligible eyes with astigmatism before and after the follow-up term. Data are expressed as the mean ± S.D (N for number of eyes).

4. Discussion

In our study, for the group as a whole, a substantial alleviation of hyperopia occurs in the children, which is consistent with previous studies (*2*). Consequently, the process of emmetropization in children with high hyperopia can also be considered as a convergence of refractions toward a low hyperopic value. It was supposed that eyes with high hyperopia may reflect an intrinsic tendency to undergo less emmetropization (*15*). The mean reduction of DS was 0.48 D every year in this research. However, no comparable studies were available, thus we could not reach a final verdict in this study that whether eyes with high hyperopia may undergo less emmetropization. On the other hand, evident improvements in the BCVA were also noticed in the study, though high hyperopia (5.25 D) still existed. An achievement of 0.9 at the last visit demonstrated a definitive development of visual acuity independent of existing high hyperopia.

With regards to the extent of astigmatism, no statistical differences among groups were seen in this study. From studies concerning the response of the eye to blur imposed by cylindrical lenses, little attention was drawn to the influence of the extent of astigmatism on refractive development. For one thing, it was hypothesized that chicks with highly astigmatic lenses with their image quality sufficiently degraded might experience form deprivation effects (myopia shift) (*16*). Also, some researchers showed that higher astigmatism was associated with more myopic refraction and more myopic shift, but also suggested that astigmatism was related to longer axial length and axial length growth (*17*). For another, a study of hyperopic children found that changes in the cylinder power were almost independent of spherical equivalent over the period from 9 to 20 months of each other, indicating the extent of the astigmatism would not interfere with the regression of hyperopia in the early months of life (*1*). As it is worth noting that even though the subjects here are much older than those in the published paper, similar results were observed consistent with Ehrlich's conclusion. This suggests that the amount of astigmatic defocus could not produce any difference in the DS and BCVA, or even in the process of emmetropization in the children with high hyperopia. In contrast, numerous reports have linked the component of astigmatism to refractive development and emmetropization. As in most reports, WTR astigmatism occupied the major portion in preschool children (*1,17*), which was also applicable to children with high hyperopia in the present study. For animal experiments with different orientation of the imposed astigmatism in chicks and monkeys, no consistent conclusion was obtained about the influence of a component of astigmatism on emmetropization as signs of either hyperopic or myopic growth were both shown (*12,16*). In fact, the association between astigmatism and myopia is controversial. On one hand, Fulton *et al*. described the relations between increasing myopic spherical equivalent refraction (SER) and an increase in astigmatism in their study of 298 children (aged from 0-10 years) (*7*). On the other hand, the results in older children (> 10 years) from Parssinen did not support the causal relation between astigmatism and myopic progression (*18*). However, the disparity of age may account for the dispute because the development of the older children was more or less completed. One finding determined that the outcome of amblyopia treatment seems to be less favorable in patients with either hyperopic or myopic ATR astigmatism (*19*). In their study, there was statistically significant less line gain of BCVA among patients with hyperopic ATR astigmatism compared with patients with hyperopic WTR astigmatism and myopic ATR patients compared with myopic WTR patients. A number of factors may have affected our results differently from the previous study (*19*). Of which, the enrolled patients all had unilateral amblyopia due to anisometropia without strabismus, whereas we did not gather systematic data. Further research should be directed concerning those parameters. However, Mutti and associates held the opinion that astigmatism in infancy appeared to be unrelated to emmetropization of spherical equivalent refractive error (*20*). Though we experienced a large age range (2.47-10 years), the regression of children's high hyperopia should be irrespective of the component and the extent of astigmatism.

This study has a number of limitations. First, the study was retrospective, resulting in incomplete data including information on spectacle correction. A review of the ophthalmic literature fails to show any consistent guidelines for the level of hyperopic refractive error that warrants a prescription. Whether spectacle wear would impede emmetropization or not is not well established yet. Although Smith and Hung noted that fully correcting the hyperopic refractive errors of juvenile monkeys induced a hyperopic shift (*21*). In a randomized clinical trial, Atkinson *et al*. found that refractive error correction for +3.50 D or more of hyperopia significantly reduces the risk of strabismus and amblyopia, and they also found that refractive error correction does not alter the emmetropization process in hyperopic children (*2*). Nevertheless, they cannot be sure how refractive correction might affect the development of very large hyperopic errors, which showed very variable degrees of emmetropization in their observations. Of note, children with hyperopic refractive errors with or more than +5 D would be taken into consideration for optical correction as general guidelines for most practitioners to improve visual acuity (*22*). Therefore, it would have been instructive to have studied matched groups of children with corrected and uncorrected refraction who have high hyperopic refractive errors. Second, our study's lack of information on amblyopic training prevented us from definitively evaluating the role that astigmatism may play in altering the natural history of hyperopia. Children with confirmed 3.75 D hyperopia usually had a high prevalence and incidence of amblyopia and strabismus (*3*) and called for treatment of occlusions and special trainings which could interfere with the reduction of refractive errors and improvement of the BCVA.

Notwithstanding the above limitations, this report primitively documented that the regression of spherical refractive errors and improvement of the BCVA in children with hyperopia of +5.00 D or greater may be irrespective of the component and the extent of astigmatism.

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