Keratometry in Pediatric Eyes With Cataract

Rupal H. Trivedi, MD, MSCR; M. Edward Wilson, MD

Objectives: To report the keratometry data of pediatric cataractous eyes (randomly selected single eye of bilateral cases; cataractous eye of unilateral cases) and to compare the keratometry data of the unilateral cataractous eye with the corresponding noncataractous fellow eye.

Methods: Retrospective review of preoperative data of patients who had undergone cataract surgery before 18 years of age. Eyes with traumatic cataract or lens subluxation were excluded.

Results: Of the 299 eyes analyzed in our study, the average (SD) keratometry value was 45.39 (3.08) diopters (D) (range, 39.25-63.5 D). Age and axial length (AL) demonstrated a significant linear relationship with values ($P < .001$, $R^2$: logarithm of age, 0.31; axial length, 0.32). Keratometry values of younger children (aged 0-6 months) were significantly different from those of older children ($P < .001$). Girls had steeper corneas when compared with boys ($P = .03$). The values of eyes with cataract in monocular cases were steeper than that of bilateral cases ($P = .07$). For unilateral cataract, the eye with the cataract had a significantly steeper cornea than the fellow eye ($P = .02$).

Conclusion: The keratometry values of younger children were steeper than that of older children. In eyes with unilateral cataract, values of cataractous eyes were steeper compared with their noncataractous fellow eye.

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Implantation of an intraocular lens (IOL) in the eyes of select children having cataract surgery has become the standard of care to treat pediatric aphakia.\(^1\) Axial length (AL) and keratometry (K) values are essential in calculating the IOL power. Various publications have reported K values in eyes of children with clear lenses.\(^2\) The objective of our cross-sectional study was 2-fold: to report the K values of pediatric cataractous eyes and to compare the K values of the unilateral cataractous eye with those of the corresponding noncataractous fellow eye.

Methods: The project received an exempt status from the institutional review board of the Medical University of South Carolina (Charleston). A database search was performed for all children who had undergone cataract surgery at the pediatric ophthalmology clinic at the Storm Eye Institute between November 1991 and November 2006. We included all eyes that underwent cataract surgery at or before 18 years of age. We excluded eyes with traumatic cataract or lens subluxation. We also excluded eyes when the K value at the time of cataract surgery was not available. Data collected included age at surgery, sex, race, laterality of cataract, and K and AL values. Because race is known to influence astigmatism in children and because nearly all of our patients are either white or African American with only a few Hispanic or Asian subjects, we only included eyes of white and African American subjects to avoid confounding effects.\(^3\) For bilateral cataract cases, we randomly selected 1 eye for analysis to avoid correlation effects.

Keratometry values were typically obtained under general anesthesia using a handheld Nidek Auto Keratometer (NAK), model KM-500 (Nidek, Gamagori, Japan). However, some of the early measurements were made before the availability of a handheld keratometer. These measurements were taken with a manual keratometer and were typically in older children when it was possible to take awake measurements. Even after handheld keratometers became available, in older children these values were obtained using a manual keratometer. We attempted to obtain the measurements without the use of an eyelid speculum. To avoid the problems associated with corneal dryness, measurements were taken as soon as possible after the induction of anesthesia, and balanced salt solution was instilled as necessary to maintain a smooth corneal surface. The automated readings were recorded in diopters (D), and the average K values were calculated.

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Regression analysis and analysis of variance (ANOVA) were used for statistical analysis. To assess the adequacy of a normality assumption, we used the residuals to look at the histogram. Post hoc analysis was done using the Bonferroni test to see which groups were statistically significant. For sex, race, and laterality analysis, a t test for independence was used based on the results of the F test for equality of variance. For unilateral cataracts, we compared K values of eyes with cataract with those of the fellow eye with a clear lens using a paired t test.

RESULTS

Of the 299 eyes analyzed in our study, the median age at cataract surgery was 27.32 months (range, 0.23-203.08 months), average (SD) K value was 45.39 (3.08) D (range, 39.25-63.5 D), and average (SD) AL was 20.56 (2.86) mm (range, 14.19-29.10 mm). The results of regression analysis using K as an independent variable are shown next. Age and AL demonstrated a significant linear relationship with K values:

1. \[ K = 46.27 - (0.02 \times \text{age in months}) \] \[ (R^2 = 0.09, \; P < .001) \]
2. \[ K = 48.07 - (2.21 \times \log \text{of age in months}) \] \[ (R^2 = 0.31, \; P < .001) \]
3. \[ K = 57.98 - (0.61 \times \text{AL}) \] \[ (R^2 = 0.32, \; P < .001) \]
4. \[ K = 54.15 - (1.10 \times \log \text{of age in months}) - (0.36 \times \text{AL}) \] \[ (R^2 = 0.35; \; \text{age, } P < .001; \; \text{AL, } P < .001) \]

Although age showed a significant linear relationship with K, transformation of age to logarithm of age better fit the normality assumption for linear regression (Figure 1). The assumptions necessary for accurate inference for normality assumptions were found to be more valid for logarithm of age (Figure 1B) as compared with age (Figure 1A). The histogram appeared to be more unimodal and mound-shaped after logarithmic transformation. Logarithmic transformation of age also explained more variation in the K values than age (31% using logarithm of age and 9% using age).

Figure 2 shows the frequency distribution of K values. Table 1 lists descriptive statistics of K values in different age groups. Results of the ANOVA test revealed that these results of K in different age groups were statistically significantly different (P < .001). Post hoc analysis revealed that K values of younger children (0-6 months of age) were significantly different from all other age groups (P < .001 with all age groups). Keratometry values of older children (>6 months) were not significantly different from each other. Figure 3 shows scatterplots of various age categories vs K values. Note that the trend line shows linear decrease in the K value only up to age 6 months (Figure 3B and C). Figure 4 shows a scatterplot of AL vs K values, suggesting a linear relationship. Table 2 lists the mean K values of unilateral cataractous eyes and that of their fellow eyes with a clear lens.

COMMENT

Investigators have previously reported K values in non- cataractous pediatric eyes. In this study, we report K values of cataractous pediatric eyes. Most eyes in this series had K measurements made using an automated handheld keratometer. Handheld keratometry offers the convenience of obtaining K measurements in children under anesthesia. Noonan and colleagues found that the Nidek automated keratometer was accurate, reliable, and easy to use, and its results compared favorably with that of the manual Zeiss keratometer (Carl Zeiss Vision, Jena, Germany) when measuring corneal curvature.

It is well documented in the literature that infantile eyes have a significantly steeper K value. The results of our study suggest that eyes with pediatric cataracts also have significantly steeper K values from birth to 6 months of age when compared with older children. Ehlers and colleagues obtained 47.50 D as a mean value for mature infants and 43.69 D for children aged 2 to 4 years. They concluded that corneal curvature reaches the adult range at about 3 years of age. Gordon and Donzis noted their average K values of full-term infants as 45.2 D. In-
agaki9 followed the change in corneal curvature over time in 8 newborns. He reported a rapid change in mean curvature from 49.01 D to 45.98 D during the first 2 to 4 weeks of life, which slowed after 8 weeks (44.60 D) and then stabilized at 44.05 D at 12 weeks after birth. Asbell and colleagues13 noted their mean corneal curvature of 45.03 D at birth, 44.0 D at 3 months, and 43.0 D at 6 months. Hof-fer10 recorded K values of 7500 phakic adult eyes, not-

Table 1. Descriptive Statistics of Mean Keratometry Values of Pediatric Cataractous Eyes in Different Age Groups

<table>
<thead>
<tr>
<th>Evaluation Categories</th>
<th>Keratometry Value, Mean (SD), Diopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 6 Months of Age</td>
<td>Aged 6-18 Months</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>(n=48)</td>
</tr>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td></td>
<td>(n=42)</td>
</tr>
<tr>
<td>P value</td>
<td>.44</td>
</tr>
<tr>
<td>Laterality</td>
<td>Unilateral cataract</td>
</tr>
<tr>
<td></td>
<td>(n=70)</td>
</tr>
<tr>
<td></td>
<td>Bilateral cataract</td>
</tr>
<tr>
<td></td>
<td>(n=20)</td>
</tr>
<tr>
<td>P value</td>
<td>.07</td>
</tr>
<tr>
<td>Race</td>
<td>White</td>
</tr>
<tr>
<td></td>
<td>(n=71)</td>
</tr>
<tr>
<td></td>
<td>African American</td>
</tr>
<tr>
<td></td>
<td>(n=19)</td>
</tr>
<tr>
<td>P value</td>
<td>.93</td>
</tr>
<tr>
<td>Total</td>
<td>47.99 (3.61)</td>
</tr>
<tr>
<td></td>
<td>(n=90)</td>
</tr>
</tbody>
</table>

aSignificant at *P* < .05.

than boys (0.74 D steeper in the vertical meridian and 0.63 D steeper in the horizontal meridian, *P* < .001). These authors studied children from 6 to 14 years of age (average, 10 years). We, too, found a significant difference after 5 years of age. In our study, the variation of K values was also noted to be higher in female subjects compared with male (SD 3.45 vs 2.67 D, respectively).

Although the mean K value of our African American subjects was flatter than that of white subjects (45.14 vs 45.47 D), the difference was not statistically significant (*P* = .42). The AL of our pediatric cataractous population is significantly longer in African American eyes compared with white eyes; therefore, we expected compensatory flatter K values in the eyes of the African American subjects. In children younger than 6 months, K values for African American subjects were flatter than those of white subjects in the same age group (47.93 vs 48.01 D, *P* = .07). In the absence of compensatory changes in K values beyond 6 months of age, it is possible that additional factors (eg, change in lens power) may have also changed significantly to keep the refractive state constant. Overall, we have fewer numbers of African American subjects compared with white subjects, which reflects the patient distribution at our institute.

Our data show a borderline, significantly steeper mean K value in eyes with unilateral cataract as a group (*P* = .07) and in children younger than 6 months (*P* = .07). However, in children older than 5 years, our data show significantly flatter corneas in eyes with unilateral cataract when compared with bilateral cataract (*P* = .02). Knowing that corneal changes generally occur within the first 6 months of age, it is difficult to explain this difference in K change.

We noted in unilateral cases that the eye with a cataract had a significantly steeper cornea compared with the
fellow eye (P = .02). Further analysis revealed that this difference was significant only up to age 6 months (P = .01). The K values of cataractous eyes (45.39 [3.08] D, n=299) in our study were significantly different from the K values of noncataractous eyes as reported by Gordon and Donzis2 (44.1 [1.1] D, n=77), calculated from data from their birth to 20 years of age. Not only do the mean values differ, but the standard deviation is almost 3 times greater in cataractous eyes (3.08 vs 1.1 D).14 We have proportionately more eyes in the younger age groups as compared with the Gordon and Donzis data, which may partially explain the steeper corneal values in our series. Asbell and colleagues7 noted no significant difference between eyes with cataract and eyes without cataract. However, between birth and 6 months of age, their mean K values were 46.82 D in normal eyes as opposed to 48.01 D in eyes with cataract.7 Furthermore, they analyzed a group of 11 eyes that had persistent hyperplastic primary vitreous, now commonly known as persistent fetal vasculature (PFV). Of these 11, 6 had K readings higher than the average of the non-PFV eyes for their specific age group. Although they are from a small sample, these data suggest that corneas from eyes with PFV are steeper than the average for normal eyes at that age. The authors did not include these 11 eyes for statistical analysis. Had they been included, their reported K values might have reflected steeper corneas. We have not done separate analysis for PFV eyes; however, it is interesting that 1 patient with a K value of 63.5 D had PFV. We failed to find such steep corneal curvature in any of the published literature.

Limitations of the current retrospective study include that measurements were made by 2 different technicians during the 15-year review and that published accuracy of the handheld keratometer compared with the manual keratometer was compiled from adults who were awake and able to fixate.15 We measured corneal curvature under anesthesia, and the lack of fixation might have affected our results. However, because of poor cooperation in children, handheld keratometry under anesthesia is the best possible practical approach to getting K values. Some of the older children and those undergoing operations before the availability of handheld keratom-
ters had K measurements using the manual keratometer. Considering the limitations of a retrospective study and reports that both instruments give comparable K values, and to be more reflective of a true-life scenario, we have reported K values as a group. Also, because this was a cross-sectional study, it is not possible to provide a definitive conclusion regarding when K values stabilize. However, because each congenital cataract needs to be removed as early as detected to provide the best possible visual outcome, preoperative K values cannot be studied in a longitudinal manner. Future studies of longitudinal change in K values after cataract surgery are being planned. The use of parental self-reporting for assessment of the ethnicity of children in this study is a common approach for determining ethnicity and is currently used by the US Census Bureau. This reflects the concept that race reflects self-identification by people according to the race or races with which they most closely identify; however, inherent in this is also the potential for error in the case of families with parents of different ethnicities.

Despite these limitations, certain conclusions can be drawn. The K values of younger children were steeper than older children. The K values of female subjects were significantly steeper than male subjects. Logarithmic transformation of age can explain 31% of the variation in K values. Axial length has a linear relationship with keratometry. The K values of eyes with cataract in monococular cases were steeper than those of bilateral cataracts. In eyes with unilateral cataract, K values of cataractous eyes were steeper compared with their noncataractous fellow eyes. The K values of cataractous eyes were significantly different from noncataractous eyes, and the standard deviation of K values in pediatric eyes with a cataract was large in contrast with a normal age-matched population. These data are pertinent to IOL power calculation in children.

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Author Contributions: Dr Trivedi had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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REFERENCES