Corneal Curvature and Axial Length Values in Children with Congenital/Infantile Cataract in the First 42 Months of Life

Paolo Capozzi,1 Cbiara Morini,1 Simone Piga,2 Marina Cuttini,2 and Pasquale Vadala1

PURPOSE. To evaluate corneal curvature (Km) and axial length (AL) of eyes of term-born children aged <3.5 years with uncomplicated congenital cataract and provide age-specific estimates.

METHODS. This was a retrospective review of patients undergoing cataract extraction from January 1994 to December 2006. Exclusion criteria were preterm birth, microphthalmia, microcornea, megalocornea, glaucoma, traumatic or complicated cataract, retinal disease. Keratometric readings were taken with an autokeratometer before surgery. Linear regression with the logarithm of the patient’s age as an independent variable was used to model the relationship between the patient’s age and biometric and keratometric readings.

RESULTS. All unilateral cataractous eyes (n = 69) and a randomly selected eye in bilateral cases (n = 111) were included in the analysis, for a total of 180 eyes. Mean age was 15.5 ± 11.8 months; mean AL, 20.03 ± 2.25 mm; mean Km, 45.07 ± 3.00 D. Km was significantly greater and AL shorter in younger children (P < 0.001). No differences according to sex were found. As a group, eyes from unilateral cataract had significantly longer AL than those from bilateral cases (P = 0.029). In a small subgroup of unilateral cataract patients for which readings from the clear lens eye were available (n = 39), Km of the affected eye was significantly greater than that of the fellow healthy eye (P = 0.007).

CONCLUSIONS. In the first 42 months of age, Km and AL are significantly different according to age. These findings have implications for the calculation of intraocular lens power in children. (Invest Ophthalmol Vis Sci. 2008;49:4774–4778) DOI:10.1167/iovs.07-1564

Progress in pediatric cataract surgery over the past 20 years now allows cataract removal and primary intraocular lens (IOL) implantation very early in life, even before 1 year of age.1–3 Early cataract removal and replacement with an IOL represents the most appropriate treatment to avoid irreversible amblyopia.4,5 Achievement of the desired refractive outcome after primary IOL implant is therefore as crucial as surgery itself to minimize anisometropia and ensure acceptable refraction for the long term.

However, the calculation of IOL power in infants below 1 year of age is prone to error, which was described as ranging from −4.06 to +3.86.6 Main reasons for suboptimal results include technical difficulties in measuring biometric parameters in small children, the use of formulas designed for the adult patient, and incomplete knowledge of the development of the eye in the first years of life. Indeed, several studies have recently appeared that were conducted to clarify the process of growth in the normal7,8 and the cataractous9,10 eye.

In ideal conditions, the IOL power for newborns or noncooperative children is selected according to individual autokeratometric and biometric measurements performed under general anesthesia. Autokeratometers, however, are still not available in most medical centers, especially in nonpediatric ophthalmology units and in the developing world, where congenital cataract is a leading cause of childhood blindness.11,12 Several clinical conditions, such as the presence of corneal opacities or posttraumatic deformations, may preclude accurate keratometric measurement. Finally, it may be necessary to predict IOL power before narcosis.13 In all these situations, the adult average keratometric values of 42.50 to 44.00 D for IOL power calculation are generally adopted also for the pediatric patient.13–18 However, serious error may occur in infants and small children, given the rapid change in corneal curvature in the first months of life.19 We retrospectively analyzed the axial length (AL) and corneal curvature (Km) measurements from a large series of cataractous eyes in children younger than 42 months, with the purpose of assessing differences according to age and providing age-specific estimates of AL and Km to be used for IOL power calculations in the absence of individual readings.

METHODS

Patients and Measurements

The study was performed at the Bambino Gesù Children’s Hospital, a tertiary pediatric referral hospital and clinical research institute in Rome, Italy.

The medical records of all consecutive patients admitted for cataract extraction from January 1994 to December 2006 were reviewed. Only patients with uncomplicated congenital cataract and age below 42 months were considered for this study. Additional exclusion criteria were preterm birth, microphthalmia, micro- or megalocornea, glaucoma, traumatic or complicated cataract, and retinal disease.

The following information was abstracted from the medical records: patient’s sex, date of birth, laterality of cataract, presurgery keratometry, AL readings, and date of surgery.

Ocular measurements were performed immediately before surgery, under the standard conditions of general anesthesia, with the subject supine and under pharmacologic mydriasis. The lids were kept open by a Barraquer wire speculum with minimal pressure on the globe. The cornea was regularly moisturized with balanced saline solution. All examinations were performed by two experienced pediatric ophthalmologists (PV and PC), and included refraction, keratometry, biometry, tonometry, and funduscopy. The autokeratometer (model KM500; Nidek, Gamagori, Japan), regularly calibrated by a trained technician, was used to measure keratometric values. These were recorded as mean of the flattest and steepest meridian in dioptrers in each eye (Km). AL was measured by Ascan ultrasonography with a biomter (Ocuscan; Alcon, Fort Worth, TX). Re-

From the 1Unit of Pediatric Ophthalmology and the 2Unit of Epidemiology, ‘Bambino Gesù’ Children’s Hospital, Rome, Italy. Submitted for publication December 6, 2007; revised May 3 and 15, 2008; accepted August 13, 2008.

Disclosure: P. Capozzi, None; C. Morini, None; S. Piga, None; M. Cuttini, None; P. Vadala, None.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be marked ‘advertisement’ in accordance with 18 U.S.C. §1734 solely to indicate this fact.

Corresponding author: Paolo Capozzi, Via Francesco Grimandi 71-00146 Rome, Italy; paolocapozzi@virgilio.it.

Copyright © Association for Research in Vision and Ophthalmology
The reliability of both instruments is described elsewhere. The ultrasound velocities used were 1532 m/s for the anterior chamber, 1641 m/sec for lens, and 1532 m/s for the vitreous.

The strategy for the selection of patients is shown in Figure 1. Patients with complete data (n = 180) were older than those excluded for missing data (mean age, 15.5 ± 11.8 months vs. 9.2 ± 10.3 months; P < 0.001), but no significant differences were found as regarded sex, laterality of cataract, and AL by age group (data not shown in tables).

Among the 180 patients available for the study, 69 had unilateral cataract. In the 111 children with bilateral cataract, only one of the two affected eyes was randomly selected for the analysis, to avoid problems of nonindependence of observations. For 39 of the 69 children with unilateral cataract, Km and AL readings from the fellow healthy eye were also available.

The study was approved by the Institutional Ethical Board of the Bambino Gesù hospital and was performed in compliance with the Declaration of Helsinki.

### Statistical Analysis

All unilateral cataractous eyes and one randomly selected eye from the bilateral cases were included in the analysis. For 10 eyes, the AL measurements were missing. Descriptive statistics (mean and SD; median, range and percentiles) of Km and AL measurements were computed, together with 95% confidence interval (CI). The Pearson’s correlation coefficient was computed to assess the relationship between the patient’s age (in months) and ocular measurements. Analysis of variance (ANOVA) and unpaired t-test were used to compare means across groups of patients and eyes. A matched analysis was performed through the paired t-test to compare measurements from the unilateral cataractous eyes and unaffected fellow eye. Linear regression analysis using the logarithm of the patient’s age as an independent variable were fitted to obtain mean estimates of ocular parameters (Km and AL) by age. Statistical analyses were performed with commercial software (Stata package version 9.0; StataCorp. 2005; Stata Statistical Software: Release 9.0; College Station, TX).

### Results

All patients were Caucasian. Ninety-two (51.1%) were boys. About one third of the patients (52; 28.9%) were less than 6 months of age, and about half (88; 48.9%) were less than 1 year. The distribution of patients’ age by sex is shown in Figure 2.

Summary measurements of Km and AL by age group, together with 95% confidence intervals (CI) are shown in Table 1. One hundred eighty eyes were included in the analysis. Mean and median values of Km were greater in younger children, while the reverse was true for AL. The relationship between ocular measurements and children’s age was statistically significant (P < 0.001). No significant differences in measurements were found according to sex, whereas AL was significantly larger in eyes from unilateral compared to bilateral cataract (mean values, 20.58 vs. 19.69, P = 0.029), also after the patient’s age was accounted for.

Figure 3 shows the scatterplot of AL and Km measured within the same subject; the relationship was statistically significant (Pearson’s correlation coefficient = −0.44; P < 0.001).

The results of the linear regression analysis performed using the logarithm of the patient’s age as independent variable are given below:

\[
\text{AL} = 16.27 + (1.59 \times \text{log of age in months}); \\
R^2 = 0.47, P < 0.001.
\]

\[
K_m = 48.35 + (-1.38 \times \text{log of age in months}); \\
R^2 = 0.20, P < 0.001.
\]

A graphic representation of the observed AL and Km by patient’s age, together with the fitted curves derived from the models, is given in Figure 4. The steeper slope in the first 6 months of age indicates a more rapid change in this age span. However, change of ocular parameters continued beyond that...
age, although at a slower rate. For instance $K_m$ estimated values changed at $-0.40$ D/mo in the first 6 months, $-0.14$ D/mo in the second semester, and $-0.08$ D/mo in the second year. Estimated AL changed at 0.46 mm/mo in the first 6 months, 0.15 mm/mo in the second semester, and 0.10 mm/mo in the second year.

Table 2 shows the distribution of AL and $K_m$ estimated from the regression models by age group. The estimated mean values are close to the observed ones, indicating a good fit of the model.

Finally, in the 39 patients with unilateral cataract for which readings from the clear lens fellow eye were available, a matched comparison between the cataractous and the healthy eye was performed (data not shown in tables). $K_m$ was greater in the cataractous than in the fellow eyes (mean $K_m = 44.89 \pm 2.78$ vs. $43.91 \pm 1.71$), and the difference was statistically significant ($P = 0.007$). In contrast, mean AL measurements were not significantly different (20.72 ± 1.89 vs. 20.29 ± 1.54, $P = 0.12$).

**DISCUSSION**

We analyzed biometry and keratometric values in a large population of term born children with uncomplicated congenital/infantile cataract aged below 42 months. Cases of preterm birth, and other ocular abnormalities such as microphthalmia, micro- or megalocornea, glaucoma, and retinal disease were excluded. Thus, we were able to study a remarkably homogeneous population.

Consistently with previous studies, we found the expected pattern of AL elongation and corneal flattening with increasing age.21–24 AL, but not $K_m$, was significantly greater in eyes from unilateral versus bilateral cataract. In the subsample of cases of unilateral cataract where readings from the fellow eye were available, AL was significantly greater in the cataractous than in the unaffected fellow eye. No differences in AL and $K_m$ were found according to sex.

Several studies have been published on corneal development in infants. The older ones were pathologic studies on cadaveric eyes25 or were performed in vivo with obsolete techniques24 or manual keratometers.19,28 Others were limited by the small sample size25,26 or were designed with different purposes. Flitcroft et al.’s investigated keratometry in a pediatric population with congenital cataract, but the study was aimed at describing differences in corneal curvature before and after cataract surgery, and separate values by patients’ age were not reported. More recent studies are focused on refractive development in preterm infants, keratometric readings for full-term infants are reported only for comparison purposes, and sample size is usually small and not stratified by age.30,31 $K_m$ for the first months of life may also be derived from studies exploring the development of the major optical components during emmetropization.7,8 However, these studies include only normal subjects whose age is not specifically relevant to cataract surgery. Direct comparisons between the results of these studies and our findings are difficult because of the previously mentioned methodologic differences. Besides, since corneal and axial growth are influenced by preterm

**Table 1.** Measurements of AL and $K_m$ by Patient Age in Unilateral and Randomly Selected Single Eyes of Patients with Bilateral Cataract

<table>
<thead>
<tr>
<th>Age Group (mo)</th>
<th>Patients (n)</th>
<th>Mean ± SD</th>
<th>95% CI</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL (mm)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–3</td>
<td>25</td>
<td>17.86 ± 2.11</td>
<td>16.99–18.73</td>
<td>17.52</td>
<td>14.22–23.85</td>
</tr>
<tr>
<td>3–6</td>
<td>23</td>
<td>17.97 ± 1.81</td>
<td>17.19–18.76</td>
<td>17.90</td>
<td>15.11–22.38</td>
</tr>
<tr>
<td>6–12</td>
<td>36</td>
<td>19.73 ± 1.52</td>
<td>19.21–20.24</td>
<td>19.79</td>
<td>16.05–25.57</td>
</tr>
<tr>
<td>12–18</td>
<td>23</td>
<td>20.56 ± 1.38</td>
<td>19.96–21.16</td>
<td>20.23</td>
<td>17.71–25.51</td>
</tr>
<tr>
<td>$K_m$ (D)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–3</td>
<td>25</td>
<td>47.89 ± 3.47</td>
<td>46.45–49.31</td>
<td>46.50</td>
<td>42.12–54.50</td>
</tr>
<tr>
<td>3–6</td>
<td>27</td>
<td>45.90 ± 3.13</td>
<td>44.67–47.14</td>
<td>45.75</td>
<td>39.50–54.50</td>
</tr>
<tr>
<td>6–12</td>
<td>36</td>
<td>45.06 ± 2.55</td>
<td>44.19–45.92</td>
<td>44.81</td>
<td>40.37–51.50</td>
</tr>
<tr>
<td>12–18</td>
<td>25</td>
<td>44.86 ± 2.69</td>
<td>43.74–45.97</td>
<td>44.63</td>
<td>39.25–50.00</td>
</tr>
<tr>
<td>18–30</td>
<td>41</td>
<td>43.64 ± 2.43</td>
<td>42.87–44.41</td>
<td>43.88</td>
<td>38.00–48.63</td>
</tr>
<tr>
<td>30–42</td>
<td>26</td>
<td>44.00 ± 1.97</td>
<td>43.21–44.80</td>
<td>44.13</td>
<td>40.63–48.75</td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>45.07 ± 3.00</td>
<td>44.63–45.52</td>
<td>44.88</td>
<td>38.00–54.50</td>
</tr>
</tbody>
</table>

* Measurements missing in 10 patients.
comparisons between our data and those studies that analyze preterm and full-term infants together are fraught with difficulties. More recently, Trivedi and Wilson studied a large series of cataract patients whose age ranged from less than 1 month to 18 years. One hundred eighty-eight eyes were from children below 4 years. Cases of traumatic cataract and subluxation were excluded. However, they did not differentiate according to preterm birth or presence of other abnormal ocular conditions besides cataract.

Despite these differences in the patient’s characteristics, their results are broadly consistent with our findings. They showed steeper corneas and shorter ALs in girls than in boys. However, the differences disappeared after stratification for patient’s age, suggesting a possible confounding effect by this variable. They also reported shorter AL in unilateral versus bilateral cases, but the difference was not significant below 60 months of age. After that time, unilateral cataractous eyes had longer ALs, a finding similar to our own.

In the small subsample of 59 patients with unilateral cataract, we were able to confirm the finding of Trivedi and Wilson of steeper corneas in the cataractous eye than in the noncataractous fellow eye, but we found no significant difference in AL. Duration and entity of the visual deprivation may influence biometric parameters, but unfortunately the information on type and severity of cataract and age of onset were not available for our patients. We used the same ultrasound velocity for the cataractous and the healthy eye. Thus, although congenital/infantile cataract is usually not very hard, the faster ultrasound propagation through the cataractous lens may lead to some underestimation of AL in the affected eye, minimizing the difference with the healthy eye.

According to Trivedi and Wilson, while AL elongation continues beyond the first year of life, Kstabilizes by 6 months of age. In our study, we found that modifications in K continue over the second semester and also the second year of life, although at a lower rate: a finding more similar to the pattern described by Ehlers et al. in a sample of neonates and children without cataract. This study has limitations. Similarly to previous ones, it was cross-sectional and based on a retrospective review of clinical records. We therefore were not able to include in the analysis the children’s anthropometric measures such as weight, height, and head size, nor elements such as type of lens opacity and time of cataract onset, which might influence the axial and keratometric development of the eye. A prospective longitudinal study taking into account these additional factors would provide more reliable normative values. Also, the contact technique used to measure AL may lead to 0.10 to 0.24 mm shorter readings compared with the immersion one.

Yet, to our knowledge, this is the largest study providing reference biometric and keratometric values from a homogeneous series of infants and small children with congenital/infantile cataract. Exclusion of preterm births and other patho-

<table>
<thead>
<tr>
<th>Age (mo)</th>
<th>AL (mm)</th>
<th>Kst (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5</td>
<td>17.35 ± 0.53</td>
<td>47.43 ± 0.46</td>
</tr>
<tr>
<td>3–6</td>
<td>18.63 ± 0.27</td>
<td>46.30 ± 0.23</td>
</tr>
<tr>
<td>6–12</td>
<td>19.65 ± 0.26</td>
<td>45.42 ± 0.23</td>
</tr>
<tr>
<td>12–18</td>
<td>20.55 ± 0.17</td>
<td>44.63 ± 0.14</td>
</tr>
<tr>
<td>18–24</td>
<td>20.99 ± 0.13</td>
<td>44.25 ± 0.12</td>
</tr>
<tr>
<td>24–30</td>
<td>21.50 ± 0.08</td>
<td>43.80 ± 0.07</td>
</tr>
<tr>
<td>30–36</td>
<td>21.84 ± 0.09</td>
<td>43.52 ± 0.07</td>
</tr>
<tr>
<td>36–42</td>
<td>22.08 ± 0.08</td>
<td>43.30 ± 0.07</td>
</tr>
<tr>
<td>Total</td>
<td>20.03 ± 1.53</td>
<td>45.09 ± 1.33</td>
</tr>
</tbody>
</table>

Data are the mean ± SD
* AL predicted by logarithm of age
† Kst predicted by logarithm of age.
logic accompanying eye conditions allowed us to identify precisely the type of patients to whom our results may be generalized: Caucasian, term-born children with uncomplicated congenital/infantile cataract, without accompanying pathologic eye conditions, and aged up to 42 months. This age range was selected because manual keratometry measurement presents technical difficulties primarily in this period. Moreover, after 3 years of age, the radius of corneal curvature shows little if any variations, as indicated by previous studies.21–23

In conclusion, our data on children with congenital/infantile cataract showed that, over the first years of life, corneal curvature and AL are significantly different in children of different ages, but not between girls and boys. In unilater al cataract, the \( K_m \) of the affected eye is significantly greater than the \( K_m \) of the eye with a clear lens. These data may be useful in pediatric ophthalmic surgery in the absence of biometry and keratometry readings, or when only AL is known, since the use of an average adult \( K_m \) for the IOL calculation in children below 42 months of age.

Our results may contribute to our knowledge regarding optical refraction in congenital/infantile cataractous eyes, with the perspective of establishing new pediatric-specific formulas for the IOL calculation in children below 42 months of age.

References


