Axial Elongation following Cataract Surgery during the First Year of Life in the Infant Aphakia Treatment Study

Scott R Lambert, Emory University
Michael Lynn, Emory University
Lindreth G Dubois, Emory University
George A Cotsonis, Emory University
E. Eugenie Hartmann, University of Alabama at Birmingham
M. Edward Wilson, University of South Carolina

Journal Title: Investigative Ophthalmology & Visual Science
Volume: Volume 53, Number 12
Publisher: The Association for Research in Vision and Ophthalmology | 2012-11, Pages 7539-7545
Type of Work: Article | Final Publisher PDF
Publisher DOI: 10.1167/iovs.12-10285
Permanent URL: http://pid.emory.edu/ark:/25593/f7fdx

Final published version: http://www.iovs.org/content/53/12/7539

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Accessed August 4, 2018 4:57 PM EDT
Axial Elongation following Cataract Surgery during the First Year of Life in the Infant Aphakia Treatment Study

Scott R. Lambert, Michael J. Lynn, Lindreth G. DuBois, George A. Cotsonis, E. Eugenie Hartmann, and M. Edward Wilson, for the Infant Aphakia Treatment Study Group

PURPOSE. To compare ocular axial elongation in infants after unilateral cataract surgery corrected with a contact lens (CL) or primary intraocular lens (IOL) implantation.

METHODS. Baseline axial length (AL) was measured at the time of cataract surgery (1-6 months) and at age 1 year. AL at baseline and age 1 year and the change in length/mo were analyzed in relation to treatment modality, cataractous versus fellow eye, and age at surgery using linear mixed models.

RESULTS. Mean baseline AL did not differ between the CL and IOL groups for either cataractous or fellow eyes. Eyes with cataracts were shorter than fellow eyes by an average of 0.6 mm (95% confidence interval [CI], 0.4–0.8 mm; P < 0.0001). For the operated eyes, the mean change in AL/mo was smaller in the CL group (0.17 mm/mo) than in the IOL group (0.24 mm/mo) (P = 0.0006) and was independent of age at surgery (P = 0.19). In contrast, the change in AL/mo for fellow eyes decreased with older age at surgery (P < 0.0001). At age 1 year, operated eyes treated with a CL were 0.6 mm shorter on average than operated eyes treated with an IOL (P = 0.009).

CONCLUSIONS. At baseline, eyes with cataracts were shorter than fellow eyes. The change in AL/mo was smaller in operated eyes treated with a CL than in operated eyes treated with an IOL, but was not significantly related to age at surgery. (ClinicalTrials.gov number, NCT00212134.) (Invest Ophthalmol Vis Sci. 2012; 53:7539–7545) DOI:10.1167/iovs.12-10285

One of the most challenging facets of implanting intraocular lenses (IOLs) during infancy is predicting the growth of the eye so that the desired refractive error can be achieved when the eye is fully grown. The infant eye elongates rapidly during the first year of life.1,2 Both visual deprivation and optical defocus can alter ocular growth.3,4 In addition, glaucoma during early childhood can cause excessive axial elongation.5 Postoperative refractive errors are usually corrected by spectacles or contact lenses. However, if the eye grows more than expected after IOL implantation, a large myopic refractive error may develop that in extreme cases may necessitate an IOL exchange.

The effect of removing the crystalline lens on axial elongation during early childhood is poorly understood.6–12 In a newborn rabbit model, a unilateral lensectomy has been shown to significantly decrease axial elongation.13 A similar effect has also been observed using a nonhuman primate model.14,15 The effect is age dependent, with the greatest effect occurring in neonates.16 While some series have reported a reduction of axial elongation following cataract surgery and IOL implantation in children, others have reported increased axial elongation.6,17,18 Furthermore, unilateral cataract surgery during infancy has been reported to be associated with more axial elongation in the operated eye than bilateral cataract surgery.19,20 These effects have important clinical implications in determining the optimal IOL power to implant in a child to achieve the desired refractive correction later in life.

The Infant Aphakia Treatment Study (IATS) is a randomized clinical trial comparing the effect of primary IOL implantation versus aphakia corrected with a contact lens (CL) in infants 1 to 6 months of age following unilateral cataract surgery. We previously reported that visual acuity was not significantly different between the operated eyes of the two treatment groups at age 12 months.21,22 We now report the longitudinal changes in axial length (AL) from the time of cataract surgery until an examination under anesthesia (EUA) was performed between the ages of 11 and 12 months.

METHODS

The study design, surgical technique, follow-up schedules, patching and optical correction regimens, evaluation methods, definitions used for glaucoma and glaucoma suspect, and patient characteristics at baseline have been reported in detail previously and are only summarized in this report.21,23 The study followed the tenets of the Declaration of Helsinki, was approved by the institutional review boards of the participating institutions, and was in compliance with the Health Insurance Portability and Accountability Act. The off-label research use of the AcrySof SN60AT and MA60AC IOLs (Alcon Laboratories, Fort Worth, TX) was covered by US Food and Drug Administration investigational device exemption No. G020021.

Study Design

The main inclusion criteria were a visually significant congenital cataract (≥5 mm central opacity) in one eye, a normal fellow eye, and an age of 28 days to <210 days at the time of cataract surgery. The main exclusion criteria were an acquired cataract, persistent fetal vasculature (PFV) causing stretching of the ciliary processes, a corneal diameter <9
Am, a medical condition that might interfere with recognition visual acuity testing at age 4.5 years, an intraocular pressure (IOP) ≥25 mm Hg, and prematurity (<56 gestational weeks). Patients were randomized either to have an IOL placed at the time of the initial surgery or to be left aphakic and optically corrected with a CL.

Axial Length Measurements
Baseline AL measurements on both eyes of all patients were obtained during an EUA performed prior to cataract surgery. A second EUA was performed 2 to 4 weeks prior to the grating acuity assessment at age 1 year. Thirty minutes prior to the EUA, both eyes were dilated with 1% cyclopentolate and 2.5% Neo-Synephrine. A-scan biometry was performed using immersion or applanation. Most A-scans were performed with an Eye Cubed (Innovative Imaging, Sacramento, CA; now owned by Ellex, Eden Prairie, MN) ultrasound unit, which has a clinical accuracy of ±0.1 mm. The A-scan with the best waveforms (e.g., the highest five spikes with a perpendicular retinal spike) was recorded on a case report form, and the tracing was printed. A-scan tracings were then submitted to the Data Coordinating Center.

A-scan tracings were graded by a masked certified echographer and graded as being valid, invalid, or unreadable. A-scans were judged as valid if the gates, mode, and eye type (phakic, aphakic, or pseudophakic acrylic) were set correctly; if corneal, lens (baseline and pseudophakic eyes only), and retinal spikes were visible and of sufficient gain to be measurable; and if the leading edge of the retinal spike was perpendicular to the baseline. If an error was detected that could cause the AL measurement to be inaccurate by >0.2 mm (e.g., inappropriate mode, improper gate or caliper placement, or poor spike quality), then the scan was classified as invalid. A-scans were judged to be unreadable if the quality of the printout was degraded so that the scan could not be adequately assessed. Measurements from invalid, unreadable, and missing A-scans were not included in the analyses. A-scans from patients with glaucoma or glaucoma suspect were also excluded from the analysis because of the excessive axial elongation that occurs in infantile eyes with glaucoma.5,24

Surgical Technique
Infants randomized to the CL group underwent a lensectomy and anterior vitrectomy. Infants randomized to the IOL group had their lens aspirated followed by the implantation of an AcrySof SN60AT (Alcon Laboratories) IOL into the capsular bag. In the event that both haptics could not be implanted into the capsular bag, an AcrySof MA60AC IOL was implanted into the ciliary sulcus. The IOL power was calculated based on the Holladay 1 formula targeting an 8 diopter (D) undercorrection for infants 4 to 6 weeks of age and a 6 D undercorrection for infants older than 6 weeks. Following IOL placement, a posterior capsulotomy and an anterior vitrectomy were performed through the pars plana/plicata.

Optical Correction
Within a week after cataract surgery, patients randomized to the CL group were fit with a Silsoft (Bausch and Lomb, Rochester, NY) or a rigid gas-permeable contact lens with a 2.0 D overcorrection to provide adequate optical correction for infants older than 6 weeks. Following IOL placement, the prescribed optical correction was rigid gas-permeable contact lens with a 2.0 D overcorrection to provide adequate optical correction for infants older than 6 weeks. After cataract surgery, patients randomized to the IOL group were fit with a Silsoft (Bausch and Lomb, Rochester, NY) or a rigid gas-permeable contact lens with a 2.0 D overcorrection to provide adequate optical correction for infants older than 6 weeks. Following IOL placement, the prescribed optical correction was a rigid gas-permeable contact lens with a 2.0 D overcorrection to provide adequate optical correction for infants older than 6 weeks.

Baseline Characteristics
The mean (± standard deviation) age at surgery among the 79 patients included in the analysis was 2.6 ± 1.6 months (range,
0.9–6.8); 45 (57%) were female and 68 (86%) were white. The mean patient age was not significantly different between treatment groups (CL, 2.5 ± 1.7 months; IOL, 2.6 ± 1.7 months; P = 0.81). The mean age among the 14 patients excluded for glaucoma or glaucoma suspect was 1.7 months versus 2.6 months for both the 21 patients excluded because of missing, unreadable, or invalid A-scans and the 79 patients included in the analyses (P = 0.17).

P values for the linear mixed model analysis of baseline AL are shown in Table 2. As expected because of randomization, baseline AL was not significantly related to treatment (P = 0.62). This was demonstrated in an analysis of least squares means, which showed that mean AL adjusted for age was not significantly different between the treatment groups for either the cataractous eyes (CL, 18.1 mm; IOL, 17.9 mm; P = 0.46) or the fellow eyes (CL, 18.5 mm; IOL, 18.7 mm; P = 0.23). The treatment groups were compared for cataractous and fellow eyes separately since the linear mixed model analysis showed that baseline AL differed according to the type of eye (P < 0.0001, Table 2). Mean AL adjusted for age for fellow eyes (18.6 mm) was significantly greater than for cataractous eyes (18.0 mm) (mean difference, 0.6 mm; 95% confidence interval [CI], 0.4–0.8 mm; P < 0.0001).

Baseline AL was strongly associated with age at surgery (P < 0.0001, Table 2). We examined this relationship in detail for the cataractous eyes. Since baseline AL was not related to treatment, we combined the cataractous eyes from the two treatment groups. Figure 1 demonstrates the strong association between baseline AL and age (n = 75, r = 0.69; P < 0.0001). On average, the AL increases 0.5 mm (95% CI, 0.4–0.6 mm) per month among patients in the age range studied (1–7 months of age). The estimated mean AL at 1 month of age was 17.2 mm (95% CI, 16.9–17.5) and increased to 19.9 mm at age 6 months (95% CI, 19.4–20.4).

### Table 1. Number of Patients Included in the Analyses

<table>
<thead>
<tr>
<th>Category</th>
<th>Treatment</th>
<th>Contact Lens, No. of Patients</th>
<th>IOL, No. of Patients</th>
<th>Total, No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomized</td>
<td>57</td>
<td>57</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Without glaucoma</td>
<td>52</td>
<td>48</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Axial length available</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both eyes</td>
<td>37</td>
<td>25</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Operated eye only</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Fellow eye only</td>
<td>5</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>34</td>
<td>79</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. P Values for Linear Mixed Model Analyses

<table>
<thead>
<tr>
<th>Effect</th>
<th>Baseline AL*</th>
<th>Change in AL per Month</th>
<th>Age 1 Year AL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (CL vs. IOL)</td>
<td>0.62</td>
<td>0.91</td>
<td>0.23</td>
</tr>
<tr>
<td>Eye (cataractous vs. fellow)</td>
<td>&lt;0.0001</td>
<td>0.0002</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age at surgery</td>
<td>&lt;0.0001</td>
<td>0.0002</td>
<td>0.0012</td>
</tr>
<tr>
<td>Interaction: treatment × eye</td>
<td>0.34</td>
<td>0.042</td>
<td>0.23</td>
</tr>
<tr>
<td>Interaction: treatment × age</td>
<td>0.67</td>
<td>0.32</td>
<td>0.64</td>
</tr>
<tr>
<td>Interaction: eye × age</td>
<td>0.049</td>
<td>0.0072</td>
<td>0.001</td>
</tr>
<tr>
<td>Interaction: treatment × eye × age</td>
<td>0.99</td>
<td>0.73</td>
<td>0.58</td>
</tr>
</tbody>
</table>

* AL, axial length.

### Change in Axial Length

Longitudinal changes in AL for the operated and fellow eyes are shown in Figure 2. Age at the time of the first measurement varied among patients but was relatively similar for the second measurement. Table 2 shows the P values associated with the various terms in the linear mixed model. Figure 3 shows the mean change in AL/mo estimated from the model versus age at surgery according to treatment group (CL versus IOL) and eye (operated versus fellow). The notable results are the significant two-way interactions. One of these was eye × age (0.0072), indicating that the change in AL/mo decreased significantly with increasing age at surgery in the fellow eyes but not in the operated eyes. This is demonstrated in Figure 3, where the slopes of the lines are greater for the fellow eyes than for the operated eyes. The second significant two-way interaction was treatment × eye (0.042), suggesting that the difference
between operated and fellow eyes was not the same for the two treatment groups. This can be seen in Figure 3, as the operated and fellow eyes are more similar in the IOL group than in the CL group.

Separate models were fit for the operated and fellow eyes that included treatment, age at surgery, and the interaction of treatment and age. The interaction was not significant for either (operated: \( P = 0.47 \); fellow: \( P = 0.71 \)). For the no-interaction model for operated eyes, age was not significant (\( P = 0.19 \)), but the mean change in AL/mo was significantly different between treatments (estimated means: CL, 0.17 mm/mo; IOL, 0.24 mm/mo; \( P = 0.0006 \)). For the no-interaction model for fellow eyes, treatment was not significant (\( P = 0.13 \)), but age was significant (\( P < 0.0001 \)). In a linear regression model with age as the only variable, the estimated mean change in AL/mo was 0.28 mm/mo at 1 month of age (95% CI, 0.26–0.30) and 0.14 mm/mo at 6 months of age (95% CI, 0.11–0.18).

Axial Length at 1 Year of Age

In the linear mixed model for AL at 1 year of age, there was a significant interaction for eye and age at surgery (Table 2), indicating that the effect of age at surgery on the AL at 1 year of age differed between operated eyes and fellow eyes (\( P = 0.0012 \)). Separate models were fit for the operated and fellow eyes that included treatment, age at surgery, and the interaction of treatment and age.

For the operated eyes, the interaction was not significant (\( P = 0.54 \)). For the model without interaction, age at surgery was significant (\( P < 0.0002 \)) with a trend for significance with treatment (\( P = 0.1 \)). Therefore, we report the mean AL at 1 year of age estimated from the model for different values of age at surgery for the two treatment groups. The mean AL was 19.0 mm for aphakic and 19.5 mm for pseudophakic eyes having surgery at 1 month of age and 20.6 mm for aphakic and 21.1 mm for pseudophakic eyes having surgery at 6 months of age (Fig. 4).

For fellow eyes, neither treatment (\( P = 0.65 \)), age at surgery (\( P = 0.46 \)), nor the interaction (\( P = 0.89 \)) was statistically significant. Since none of these factors were significant, we
eyes. At 12 months of age, the mean ALs of the pseudophakic eyes were significantly shorter than their fellow eyes. At 5 weeks of age, both the aphakic and the implanted were included, which suggests that factors related to age, such as prematurity, ocular growth,31,32 a second possibility is that axial elongation was altered for optical reasons. Defocusing with plus and minus lenses has been shown to alter axial elongation in a nonhuman primate model.4,5,3. However, this seems unlikely since the operated eye in both treatment groups was focused to a near point and since compliance with contact lens and spectacle use was quite good.21 Finally, there may have been a difference in the IOP between the operated eyes in the two treatment groups. However, this is unlikely since all eyes that were judged to have glaucoma or glaucoma suspect were excluded from the analyses.

As expected, we found that the mean change in AL/mo for patients enrolled at a younger age. Others have reported a deceleration of axial elongation during the first year of life in normal eyes,1,2 Second, the quality of the A-scans used in the analyses. Studies using a nonhuman primate model have also reported a retardation of axial elongation following a lensectomy during infancy. Lambert et al.15 simulated a unilateral congenital cataract by placing a translucent contact lens on the right eye of a cohort of infant Rhesus monkeys. When the monkeys were 11 to 16 days of age, a lensectomy was performed on their right eyes. Some of the eyes had an IOL implanted while others were left aphakic and corrected with a contact lens. At 5 weeks of age, both the aphakic and the pseudophakic eyes were significantly shorter than their fellow eyes. At 12 months of age, both the aphakic and the pseudophakic eyes were significantly shorter than their fellow eyes. The retardation of axial elongation that occurs following a lensectomy has been shown to be age dependent. While a large reduction in axial elongation was noted in monkeys undergoing a lensectomy at 4 days and 2 weeks of age, only a small effect was noted after a lensectomy at 7.5 months and 1 year of age.16 We did not find the retardation of AL to be age dependent in our study. However, we studied only infants 1 to 6 months of age. Bradley and coworkers50 have also reported that axial elongation in the untreated eye can be affected by the treatment of the fellow eye in a nonhuman primate model. In our study, we did not find that the type of treatment of the operated eyes had an effect on axial elongation of the untreated fellow eyes.

It is uncertain why aphakic eyes in our study experienced less ocular growth than pseudophakic eyes. One possibility is that the pseudophakic eyes had an increased number of additional intraocular surgeries, which we have reported previously.21,22 Most of these surgeries were performed to clear visual axis opacities. These additional intraocular surgeries may have elevated the level of chemical mediators in these eyes, such as prostaglandins, which may have altered ocular growth.31,32 A second possibility is that axial elongation was altered for optical reasons. Defocusing with plus and minus lenses has been shown to alter axial elongation in a nonhuman primate model.4,5 However, this seems unlikely since the operated eye in both treatment groups was focused to a near point and since compliance with contact lens and spectacle use was quite good.21 Finally, there may have been a difference in the IOP between the operated eyes in the two treatment groups. However, this is unlikely since all eyes that were judged to have glaucoma or glaucoma suspect were excluded from the analyses.

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Our findings are clinically important because they suggest that cataract surgery coupled with IOL implantation is associated with increased axial elongation compared to cataract surgery without IOL implantation during infancy. In our study, we targeted an undercorrection in the operated eye for infants undergoing IOL implantation of 8 D for infants 6 weeks or younger and 6 D for infants older than 6 weeks, which was based on data from a pilot study. After these patients have been followed over a longer time period, we will be able to evaluate the long-term accuracy of our targeted undercorrection.

Acknowledgments

Cynthia Kendall graded the A-scan tracings and provided training to the IATS investigators on how to perform biometry.

References

APPENDIX

The Infant Aphakia Treatment Study Group

Administrative Units and Participating Clinical Centers: Clinical Coordinating Center (Emory University): Scott R. Lambert, MD (Study Chair); Lindreth DuBois, MEd, MMSc (National Coordinator).

Data Coordinating Center (Emory University): Michael Lynn, MS (Director), Betsy Bridgman, BS; Marianne Celano, PhD; Julia Cleveland, MSPH; George Cotsonis, MS; Carey Drews-Botsch, PhD; Nana Freret, MSN; Lu Lu, MS; Seegar Swanson; Thandeka Tutu-Gxashe, MPH.

Visual Acuity Testing Center (University of Alabama, Birmingham): E. Eugenie Hartmann, PhD (Director); Clara Edwards; Claudio Bussettini, PhD; Samuel Hayley, BS.

Steering Committee: Scott R. Lambert, MD; Edward G. Buckley, MD; David A. Plager, MD; M. Edward Wilson, MD; Michael Lynn, MS; Lindreth DuBois, MEd, MMSc; Carolyn Drews-Botsch, PhD; E. Eugenie Hartmann, PhD; Donald F. Everett, MA.

Contact Lens Committee: Buddy Russell, COMT; Michael Ward, MMS.

Participating Clinical Centers (in order by the number of patients enrolled): Medical University of South Carolina; Charleston, South Carolina (14): M. Edward Wilson, MD; Margaret Bozic, CCRC, COA.

Harvard University; Boston, Massachusetts (14): Deborah K. Vanderveen, MD; Theresa A. Mansfield, RN; Kathryn Bisceglia Miller, OD.

University of Minnesota; Minneapolis, Minnesota (13): Stephen P. Christiansen, MD; Erick D. Bothun, MD; Ann Holleschau, BA; Jason Jedlicka, OD; Patricia Winters, OD; Jacob Lang, OD.

University of Texas Southwestern; Dallas, Texas (6): David R. Weakley, MD; David R. Stager Jr, MD; Joost Felius, PhD; Clare Dias, CO; Debra L. Sager; Todd Brantley, OD.

Data and Safety Monitoring Committee: Robert Hardy, PhD (Chair); Eileen Birch, PhD; Ken Cheng, MD; Richard Herte, MD; Craig Kollman, PhD; Marshalyne Yergin-Allsopp, MD (resigned); Cyd McDowell; Donald F. Everett, MA.

Medical Safety Monitor: Allen Beck, MD.