IOL Power Calculation for Pediatric Cataract

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Calculating and selecting an “optimum” intraocular lens (IOL) power for the small eye of a growing child presents unique challenges. The need to implant a fixed-power lens into an eye that is still growing makes it difficult to choose an “optimum” IOL power that best benefits the child’s eye. The younger the child at the time of surgery, the more difficult is the problem. This is a challenging task to the ophthalmologist of the industrial countries, but probably more so for the ophthalmologist in the developing world setting. The lack of instrumentation in many of the developing world operating-room settings, such as the handheld keratometer and the A-scan ultrasound, increases the difficulty of calculating the IOL power to use for pediatric cataract surgery. Even with the availability of the A-scan and automated keratometer in the operating room, small eyes of children possess unique challenges when calculating an IOL power. Also remember, we are using formulas that were originally designed for adult eyes.

Implanting an IOL at the calculated emmetropic power in children risks significant myopia at ocular maturity.\textsuperscript{1,12} For each individual case the IOL power needs to be customized based on many characteristics including the age, laterality (one eye or both), amblyopia status (dense or mild), likely compliance with glasses, and family history of myopia. Herein again, the developing world ophthalmologist faces additional challenges. Many patients present relatively late in their disease, and already have dense amblyopia. In addition, compliance to amblyopia therapy and required regular follow-up are also issues of concern. Thus, besides calculation, selecting an IOL power is also much more challenging to the ophthalmologist in the developing world setting.

IOL Power Calculation

**Biometry:** A-scan ultrasound and keratometry measurements on children can be very difficult or unattainable in the office. Most children need an examination under anesthesia (EUA). The NPCB in India published the 1999 results of evaluation of training for ophthalmic surgeons in extracapsular cataract extraction (ECCE) and IOL implantation. It may have changed by now, but those results showed that 14 of 66 cities did not have an A-scan ultrasound machine, and 28 didn’t have a keratometer. This was the scenario in the adult cataract surgery setup.\textsuperscript{13} The chances of having an A-scan ultrasound unit and keratometry capability in the operating room for pediatric patients are low.

Error in axial length (AL) measurement is the most significant of errors in IOL power calculation and equates to almost 2.5 D/mm. However, this error jumps to 3.75 D/mm in very short eyes (20 mm). Thus, it is crucial that we take every possible step to minimize error in AL measurement. Readers are urged to refer to the specific technical instructions of the machine they are using. Important details to keep in mind include the velocity that needs to be used for a specific eye (phakic/aphakic/pseudophakic), the A-constant for the specific IOL being used, and the characteristics of a good A-scan tracing with a spike from each layer of the eye.
ultrasound can be done with either contact or immersion methods. If contact A-scan is used, it is important to make sure that the tip does not indent the cornea. It has been reported that AL measurements made with a contact technique were, on the average, 0.24 to 0.32 mm less than measurements made using an immersion technique.\textsuperscript{14,15} We use the immersion technique. We take repeated measurements until three equal measurements are obtained with sharp retinal spikes.

For keratometry measurement, we use a Nidek Auto Keratometer, model KM-500. The measurements should be taken without the use of an eyelid speculum. To avoid the problems associated with corneal dryness, measurements should be taken as soon as possible (following IOP measurement) after induction of anesthesia. Balanced salt solution should be instilled as necessary to maintain a smooth corneal surface. Accuracy using the hand-held keratometer for the cylinder axis measurement is reported to be less reliable. However, as we are concerned here with only refractive power and not with the axis – it may be reasonable to use this instrument. Harvey and colleagues\textsuperscript{16} showed that the Alcon autokeratometer produces accurate measurements of curvature of the cornea in pediatric eyes. Therefore, to avoid inaccuracy when taking repeated measurements, it is recommended to take an average of these readings for IOL power calculation. The error is negligible this way. However, we admit that we have noted wide variation in individual keratometry values. In practice, we take multiple measurements until we get two or three readings with a difference of less than 1 D, and select one reading from that. Dahan and Drusedau\textsuperscript{7} recommended using standard adult K-readings in children, as the K-reading changes rapidly during the first year of life. However, we have noted that the keratometry value of cataractous eyes is significantly different from that of noncataractous eyes (Trivedi RH, Wilson ME et al. Axial length and keratometry in eyes with pediatric cataract. Poster presented at ASCRS, 2002), and prefer not to use standard K-values.

**IOL Power Calculation Formulas:** Which IOL formula should be used for children? Because of the relatively large IOL formula errors demonstrated in pediatric studies, it is not clear that any formula can be considered accurate for all children.\textsuperscript{17,18} Andreo and coworkers\textsuperscript{17} reported that all formulas were slightly less accurate in eyes with a shorter AL. In this group, the Hoffer Q formula had the lowest error (1.4 D) and the SRK-II had the highest error (1.8 D). Authors concluded that in our pediatric study eyes, all four IOL power calculation formulas predicted mean refractive outcome within 1.4 D. Theoretical formulas did not outperform the regression formula. Mezer E and colleagues\textsuperscript{18} evaluated refractive outcome using 5 IOL calculation formulas to determine which best predicts refraction after pediatric cataract surgery. The authors tested SRK, SRK II, Holladay, Hoffer Q, and SRK/T formulas. Authors concluded that all 5 IOL power calculation formulas were unsatisfactory in achieving target refraction. Although no formula has been proven to have an advantage, it is preferable to use the theoretical formulas (e.g., SRK, Holladay I and Holladay II, Hoffer I and II, Hoffer Q and Haigis) because they are generally more accurate for small eyes, and in the pediatric studies they appear to be slightly more accurate overall.

**IOL Power Selection**

Children have growing eyes and rapidly developing visual systems. The eyes of normal children grow from an average of 16.8 mm at birth to 23.6 mm in adult life. Most of the axial growth occurs in the first two years of life, but there is no sharp cut-off; instead the rate of change gradually decreases throughout childhood. As eye size increases, the power of the optical component decreases proportionately. The natural lens power decreased from 34.4 D to 18.8 D.\textsuperscript{19} Pediatric cataract surgery results in loss of the natural crystalline lens prior to completion of a complex process known as emmetropization. After the crystalline lens is removed surgically, every millimeter of axial growth of the globe changes the refractive error of the eye by more than 2.5 D. In contrast to -0.9 D refractive change in normal phakic eyes, the aphakic eyes have an average myopic shift of 10 D from infancy to adulthood. Note this is a myopic shift of refraction, and not myopia. In pseudophakic eyes, the main modifiable factor is how much undercorrection to aim for at the time of surgery. Historically three major approaches have been used for IOL power selection in children: initial high hypermetropia, initial emmetropia, or initial low hypermetropia. Note that whatever option you chose, the refraction is changing, and not stable probably until 20 years of age. Thus, regular follow-up visits, and
regular change of correction of residual refraction is required with any of the options described below. Initial high hypermetropia offers the advantage that with the axial growth of an eye, the hyperopia will improve, and adult refraction would probably be at or near plano - either low myopia or low hypermetropia. However, this advantage must be balanced by the fact that the uncorrected hyperopic refractive error in children may cause or deteriorate amblyopia. To help treat amblyopia, some surgeons prefer to aim for initial emmetropia. It simplifies the battle against amblyopia. However, the price to pay is that the significant late myopia will be more and more apparent as the years pass since young children’s eyes continue to grow. Thus, a better solution may be in finding a compromise between these two extremes. Most physicians who have been implanting lenses in young children have chosen a power intermediate between what the formulas would predict for that eye at the time of implantation and what the expected adult power would be for the specific eye. Most physicians implanting an IOL consider the age at the time of surgery, status of the fellow eye, the likelihood of compliance with amblyopia therapy, etc.

**Age at cataract surgery:** When an IOL is implanted in infancy, marked axial growth must be expected over the first 1 to 2 years after surgery. Therefore, IOLs implanted in infancy are usually selected to produce a 20% or more undercorrection. The closer to birth, the more marked this undercorrection will need to be. Our recommendations to minimize late myopia based on age at surgery are shown in Table 1. However, these recommendations need to be balanced with many other variables, and thus we end up using less undercorrection than that which is recommended based on age alone, as shown in Table 1.

We recently analyzed our data (Trivedi RH, Wilson ME. Presented at World Congress of Ophthalmology, Brazil, 2006) to see how much we actually undercorrect our pediatric eyes, and found that typically we do less undercorrection than is described in Table 1. This reflects our tendency to look at multiple reasons while selecting the IOL power for a child (e.g., laterality of cataract, visual acuity, parental refractive error, etc.).

**Status of the fellow eye:** More hyperopia can be left when the surgery will be done bilaterally since non-compliance with glasses is less amblyogenic in these children, or in an eye with monocular cataract, if the fellow eye is pseudophakic – it is important to look for refractive status in the fellow eye. Attempts should be made to minimize the anisokonia in these eyes.

**Visual acuity:** Dense amblyopia may prompt a decision to leave less hyperopia (or even emmetropia) in an effort to help recover vision by emphasizing the occlusion therapy, but minimizing the need for glasses. In this instance, late myopia is acceptable to us if it helps to recover vision during the amblyopia treatment years. Current advances in ophthalmology suggest that it will be difficult to treat amblyopia. Myopia can probably be more easily handled with refractive surgery.

**Expected compliance of child/family to glasses/contact lens/occlusion therapy:** If compliance with glasses or contact lenses for the residual refractive error is poor, amblyopia may worsen or improve more slowly even when appropriate patching is being done. If poor compliance is expected – it is better to leave the least possible refractive error.

**Parent’s refractive error:** Last, but certainly not least, it is also important to ask about high refractive error in parents. It has been noted that if both parents are myopic, 30% to 40% of their children become myopic, whereas if only one of the parents is myopic, 20% to 25% of their offspring will become myopic. If neither of the parents is myopic, fewer than 10% of their children will become myopic. Anticipating more eye growth, these children may be left with more hypermetropia than stated in Table 1.

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Table 1. Age at cataract surgery and residual refraction: Our current (2006) recommendations*

<table>
<thead>
<tr>
<th>Age at Surgery</th>
<th>Residual Refraction</th>
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<tbody>
<tr>
<td>1st year</td>
<td>+12 to +7</td>
</tr>
<tr>
<td>1 – 2 years</td>
<td>+6</td>
</tr>
<tr>
<td>2 – 4 years</td>
<td>+5</td>
</tr>
<tr>
<td>4 - year</td>
<td>+4</td>
</tr>
<tr>
<td>5 - year</td>
<td>+3</td>
</tr>
<tr>
<td>6 - year</td>
<td>+2</td>
</tr>
<tr>
<td>7 – year</td>
<td>+1.5</td>
</tr>
<tr>
<td>8 – 10 year</td>
<td>+1</td>
</tr>
<tr>
<td>10 – 14 years</td>
<td>+0.5</td>
</tr>
<tr>
<td>&gt;14</td>
<td>Plano</td>
</tr>
</tbody>
</table>

*Other factors described here must be taken into consideration before IOL power – fellow eye status, degree of amblyopia, assumed compliance, and parental refractive error
**IOL power:** In general, the higher the IOL power the more undercorrection is needed. For example, at age 1 month, if one child has an emmetropic power of 50 D and another child at same age has an emmetropic power of 40 D, the first child will necessitate a higher residual refraction. In other words, we may use approximate expected refraction in the first child as +12 D, while in second child we would use +10 D.

**Implantation in-the-bag, sulcus, or in the anterior chamber:** If a decision regarding the site of fixation needs to be changed after opening an eye and before IOL implantation – an appropriate adjustment may need to be made. A plus-power IOL that is more anterior in the eye will have a greater refractive effect than if it were relatively posterior. Intraocular positioning of the IOL will affect the prediction error, with sulcus fixation producing a relative myopic shift from the estimated refraction. The IOL intended for capsular bag placement should be decreased by 0.75 D to 1.00 D (depending on the IOL power) when placed in the ciliary sulcus.

**Secondary IOL Implantation**

Errors in keratometry readings can occur after wearing hard contact lenses. Even 2 weeks after the use of hard contact lenses, the patient had a reported increase of 0.8 mm. Since the effect of hard contact lens wear on corneal curvature and resultant IOL calculations is variable and unpredictable, it is important that IOL calculations be made well after discontinuation of hard contact lens wear. For secondary IOLs, the power can be calculated without AL or K-values simply by using the aphakic refraction. The Pediatric IOL Calculator can also be downloaded from the AAPOS website: [http://www.aapos.org/proinfo/downloads.html](http://www.aapos.org/proinfo/downloads.html). We use axial length and keratometry readings and calculate IOL power with an “aphakic setting” on the A-scan machine. Despite all our efforts, it is not uncommon to see refractive surprises in children undergoing cataract surgery and IOL implantation. It is important to remind our readers that we are trying to take into account all known factors affecting axial growth. Besides these, several other factors (e.g., gender, race, etc.) have been reported to affect growth of the normal eye, and may also influence eye growth after cataract surgery. Surgeons who implant IOLs in young children must be prepared for a wide variance in the long-term myopic shift. Both the magnitude of the myopic shift and the variance in this shift are likely to be greatest in children having surgery in the first few years of life. Anticipation of this myopic shift, and appropriate correction or compensation, will help achieve better anatomical and functional outcomes of young eyes undergoing cataract surgery. With all that said, we must remember that an IOL implanted in a child’s eye must stay there for many years, perhaps 70 years or more. Long-term outcome will certainly remain an open question for years to come. Long-term outcome of refractive error in these eyes will help us to develop formulas specially-suited for IOL power calculation for childhood cataract.

**References**


