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Cataract Update

Axial length measurement techniques in pediatric eyes with cataract

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Abstract

Globe axial length (AL) in children is commonly measured using either contact or immersion technique. Office measurement of AL can be difficult in young children and infants and must often be done under anesthesia in an eye that is unable to cooperate with precise fixation and centration. Contact A-scan measurements yield shorter AL, on average, than immersion A-scan measurements in pediatric eyes. This difference is mainly the result of the anterior chamber depth rather than the lens thickness value. During intraocular lens power calculation, if globe axial length is measured by the contact technique, it will result in the use of an average 1-D stronger IOL power than is actually required. This can lead to induced myopia in the postoperative refraction. In our studied patients, there was a significant difference in prediction error between contact A-scan biometry and immersion A-scan biometry. The immersion A-scan technique is recommended for pediatric IOL power calculation. We also provide a review of biometry in pediatric eyes. The overall mean AL of pediatric cataractous eyes is significantly different than the mean AL of non cataractous eyes. More importantly, the standard deviation is higher in eyes with cataract than in those without. Three phases of eye growth in children have been documented: A *rapid, postnatal* phase from birth to 6 months of age, followed by a *slower, infantile phase* from 6 to 18 months of age, and finally a *slow, juvenile phase* from 18 months forward. In our study, girls had shorter ALs than boys and African-American subjects had longer ALs than Caucasians. Eyes with unilateral cataract had shorter ALs than eyes with bilateral cataract during the earlier years, but had longer ALs during later childhood.

Keywords: Immersion, Biometry, Prediction error, IOL power calculation

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Introduction

Intraocular lens (IOL) implantation has become a common practice for pediatric cataract surgery. However, the postoperative refraction is often different from what had been predicted or aimed for by the surgeon. Although many of the late refractive surprises in children are attributed to a myopic shift in refraction due to eye growth, early refractive surprises can be attributed to inaccuracy in IOL power calculation.[1] Error in axial length (AL) measurement is the most significant error in IOL power calculation and equates to almost 2.5 D/mm in IOL power; however, this error jumps to 3.75 D/mm in very short eyes (20 mm). Thus, every possible step should be taken to minimize errors in AL measurement. Office measurement of AL can be difficult in young children and must often be done under anesthesia in an eye that is unable to cooperate with precise fixation and centration.

Axial length measurement

A-scan ultrasound biometry is the conventional method for the measurement of AL in children (Figs. 1 and 2). Many A-scan instruments are available, and ensuring that the unit you used has been calibrated and is capable of accurate measurements is important.[2] Readers are urged to refer to the specific technical instructions of the machine they are using.

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The instrument must have an oscilloscope screen such that true echo spikes are observed in determining axiality (Fig. 2).[2] Instruments that merely report a numerical reading of the AL do not allow clinical decision making during the examination and are fraught with potential errors.

Since pediatric patients are usually operated under general anesthesia, IOL power calculations are usually performed in the operating room. The chances of having an A-scan ultrasound unit in these operating rooms for pediatric patients are low. The surgeon may need to transport the unit from the clinic to the operating room. The lack of A-scan ultrasound in operating-room settings increases the difficulty of calculating the IOL power to use for pediatric cataract surgery. While secondary IOL power can be estimated using the aphakic refraction,[3] the estimate is less accurate than primary IOL calculations, which require an A-scan unit as an essential tool.

Measuring the AL of the eye using an A-scan is dependent upon the sound velocity the instrument is set at for the measurement.[2] Some instruments use an average velocity for the entire eye while others use individual velocities for each part of the eye. Because of the inversely proportional change in the axial ratio of solid to liquid as the eye increases in length, the average phakic velocity of a short 20-mm eye is 1561 m/sec (instead of the 1555 m/sec for 23.5 mm for AL). This factor amounts to only a small (0.25 D) error in extremes of AL. Ultrasound biometry and optical biometry are two currently used ocular biometry methods that are based on different physical principles.

Ultrasound biometry

Ultrasound biometry typically uses 10-MHz ultrasonic waves to obtain optical parameters such as AL, anterior chamber depth (ACD) and lens thickness (LT). Ultrasound can be done with either contact or immersion method. In the contact method, the probe touches the cornea and may result in corneal compression and a shorter AL. Corneal compression is more likely in pediatric eyes because of low corneal and sclera rigidity. Using the immersion technique, the ultrasound probe does not come into direct contact with the cornea, but instead uses a coupling fluid between the cornea and the probe preventing corneal indentation. Immersion A-scan has been shown to be superior to contact biometry in children.[1,4] If contact A-scan is used, it is important to make sure that the tip does not indent the cornea. In a randomized study, AL measurements made with a contact technique were, on the average, 0.24–0.32 mm less than measurements made using an immersion technique.[4] A consistent error could be compensated for by the addition of a constant or by formula personalization, however, this is not possible because the compression error varies from eye to eye.

Pediatric cataract surgeons use the contact technique more frequently when measuring the AL of pediatric eyes at the time of cataract surgery. This statement is based on an informal, unpublished, 2009 e-mail survey sent to all list serve members of The American Association for Pediatric Ophthalmology and Strabismus, in which 173 (82.4%) surgeons reported using contact A-scan compared with 37 (17.6%) who reported using the immersion technique.[4] Because of a lack of cooperation in the clinic setting, AL measurements in young children often must be obtained in the operating room under general anesthesia. In the operating room setting, an experienced ultrasonographer may not be available. Contact A-scan measurements are easier for the surgeon or an operating room technician to perform. Immersion A-scan requires more experience and practice and is best performed by an experienced ultrasonographer.

The ultrasound probe is placed into the solution and positioned parallel to the axis of the eye. Axiality is judged by watching for the correct spike patterns on the oscilloscope screen as the probe position is adjusted. The examiner

Figure 1. Immersion axial length measurement under general anesthesia.

Figure 2. Immersion axial length measurements under anesthesia. Note oscilloscope screen.

should be familiar with the characteristics of a good A-scan tracing with a spike from each layer of the eye. When the probe is aligned with the optical axis of the eye and the ultrasound beam is perpendicular to the retina, the retinal spike is displayed as a straight, steeply rising echo spike. When the probe is not properly aligned with the optical axis of the eye, the ultrasound beam is not perpendicular to the retinal surface and the retinal spike is displayed as a jagged, slow-rising echo spike. Repeated measurements are taken until a few equal measurements are obtained with sharp retinal spikes.

In a prospective clinical trial, we compared AL measurements by contact and immersion techniques in pediatric cataractous eyes (n = 50 eyes of 50 children).[4] AL was measured by both contact and immersion techniques for all eyes, randomized as to which to perform first to avoid measurement bias. AL measurement by contact technique was significantly shorter as compared with the immersion technique (21.36 ± 3.04 and 21.63 ± 3.09 mm, respectively; $P < 0.001$). AL measurements using the contact technique were on an average 0.27 mm shorter than those obtained using the immersion technique. Forty-two eyes (84%) had shorter AL when measured using the contact technique as compared with the immersion technique. Lens thickness measurements by the contact technique were not significantly different from those of the immersion technique (3.61 ± 0.74 and 3.60 ± 0.67 mm, respectively; $P = 0.673$). Anterior chamber depth measurements were significantly more shallow with the contact technique (3.39 ± 0.59 and 3.69 ± 0.54 mm, respectively; $P < 0.001$). Intraocular lens power needed for emmetropia was significantly different (28.68 diopters [D] vs. 27.63 D; $P < 0.001$). As mentioned above, contact A-scan measurements yielded shorter AL than immersion A-scan measurements. This difference was mainly the result of the anterior chamber depth rather than the lens thickness value. During IOL power calculation, if AL measured by contact technique is used, it will result in the use of an average 1-D stronger IOL power than is actually required. This can lead to induced myopia in the postoperative refraction.

In a subsequent study we compared prediction error (PE) and absolute prediction error (APE) using contact and immersion techniques.[1] Data from the previously described prospective study[4] of pediatric eyes that had in-the-bag implantation of an AcrySof SN60WF IOL and had refraction results available from 14 days to 3 months postoperatively were retrospectively analyzed. The contact and immersion A-scan biometry techniques had been performed in each eye and PE using each technique was compared. The mean age at surgery of the 22 patients (22 eyes) was 4.8 ± 4.1 years. There was a significant difference in PE between contact and immersion A-scan biometry in children. The mean PE was +0.4 ± 0.7 diopter (D) in the contact group and −0.4 ± 0.8 D in the immersion group ($P < 0.001$) and the mean APE was 0.7 ± 0.4 D and 0.7 ± 0.6 D, respectively ($P = 0.694$). The APE was less than 0.5 D in 5 eyes (23%) using the contact technique and in 11 eyes (50%) using the immersion technique. The mean postoperative spherical equivalent was +2.9 ± 2.5 D, which was significantly different from the mean predicted refraction for contact A-scan (3.3 ± 2.8 D; $P = 0.010$) but not immersion A-scan (2.5 ± 2.5 D; $P = 0.065$). Ben-Zion et al.[5] compared prediction errors of 138 pediatric eyes measured by the contact A-scan technique with a later group of 65 children measured with the immersion technique. They found no significant difference in APE (1.11 D and 1.03 D, respectively) and noted PE of +0.23 D and −0.32 D with the contact and immersion techniques, respectively.

Optical biometry

Optical biometry is based on partial coherence interferometry (PCI). There are currently two optical biometry devices on the market and the use of both devices in children has been reported.[6,7] The first commercially available device was the IOLMaster (Carl Zeiss Meditec, Jena, Germany) and more recently, the Lenstar (Haag-Streit AG, Koeniz, Switzerland) was introduced. Lenstar allows higher resolution compared with the IOLMaster. The measurement includes corneal thickness, ACD, LT, AL, K, white-to-white distance, pupillometry, eccentricity of the visual axis and retinal thickness at the point of fixation.

PCI has been used in cooperative children with reliability and accuracy. PCI requires patient cooperation and thus may not be a viable option in infants and young children. Claimed improvements over conventional ultrasound techniques include high reproducibility, contact-free measurements, and observer independence of the measurements. Lenhart and colleagues[6] reported PE for AL measurements obtained using partial coherence interferometry versus immersion ultrasonography in children. AL measurements in the operative eye were obtained using PCI at the preoperative clinic visit and then using immersion US in the operating room before surgery. The data were compared to determine the degree of agreement. The charts of 18 patients (27 eyes) were reviewed. Preoperative AL measurements by PCI were obtained in 21 eyes (78%). On average, the PCI-measured ALs were 0.1 mm less than the immersion US values (95% confidence interval, −0.2 to −0.1; $P = 0.002$). All eyes with an AL of 23.5 mm or less had lower PCI values than immersion US values. There was no systematic pattern of 1 measurement being greater or less than the other in eyes with an AL longer than 23.5 mm. The authors concluded that there was a systematic difference in AL measurement between PCI and immersion techniques, with PCI tending to give lower values, particularly in eyes with an AL of 23.5 mm or less.

Gursoy and colleagues[7] compared AL, ACD and LT measured with Lenstar with those obtained with A-scan contact technique. Right eyes of 565 school children were included (mean age 10.5 years). The mean differences between contact ultrasound and Lenstar were −0.72, −0.27 and +0.24 mm for AL, ACD and LT respectively.

PCI technology is not able to obtain measurements in eyes with dense cataract and in those that cannot fixate on the red light of the instrument because of inadequate vision. In children, the cataracts are often dense and fixation may be inadequate.

Axial length in eyes with pediatric cataract

We reported biometric data of pediatric cataractous eyes (randomly selected single eye in bilateral cases; cataractous eye in unilateral cases) (n = 310).[8] The mean age and AL were 45.30 ± 48.10 months and 20.52 ± 2.87 mm respectively. The results of the AL measurements from these children can be specified as within or outside the 95% CIs. For eyes that yield values outside the 95% CIs we recommend repeating the biometric examination.

The overall mean AL of pediatric cataractous eyes (20.5 ± 2.9 mm) is significantly different ($P < 0.001$) than the overall mean AL of pediatric noncataractous eyes (21.9 ± 1.6 mm) as described by Gordon and Donzis.[9] More important, the standard deviation was nearly two times more in eyes with cataract than in those without (±2.9 mm vs. ±1.6 mm). This difference is a very important factor to keep in mind; that is, these cataractous eyes are abnormal to begin with, which may also lead to variations in postoperative growth. Eyes with cataract showed a shorter AL in the first 12 months of life (cataractous, 17.9 ± 2.0 mm; noncataractous, 19.2 ± 0.7 mm). In the first 12 months of life, the standard deviation was almost three-times that of eyes without cataract (±2.0 mm vs. ±0.7 mm).

Logarithmic transformation of age explained more variation in AL than does age (70% when log of age is used and 41% with age). Linear regression analysis revealed that during the first 6 months of life, AL increased by 0.62 mm per month. From 6 to 18 months of age, it increased by 0.19 mm per month and after 18 months, by 0.01 mm per month or 0.12 mm per year. The mean AL during the first month of age was 16.01 mm, which increased to 23.20 mm in children 10–18 years of age, showing 7.19 mm in axial growth. Our finding suggested a *rapid, postnatal* phase from birth to 6 months of age, followed by a *slower, infantile phase* from 6 to 18 months of age, and finally a *slow, juvenile phase* from 18 months forward. At the younger ages, eyes with cataract had a shorter AL compared with their normal fellow eyes or data of the pediatric population without cataract. With advancing age, eyes with cataract had a longer AL than did their normal fellow eyes.

Sex-linked differences in the AL have been reported in the literature.[10,11] Larsen[11] reports shorter mean AL in noncataractous eyes of girls than the mean AL in noncataractous eyes of boys (23.92 mm vs. 24.36, $P < 0.001$). Isenberg et al.[10] noted that the eyes of male infants grow faster than those of the female infants ($P < 0.001$).

In our study of cataractous eyes, the girls had a shorter AL than did the boys (20.23 vs. 20.78 mm, $P = 0.09$).[8]

In our study, significantly longer eyes were found in African-American patients than in Caucasian patients (21.66 vs. 20.14 mm, $P < 0.001$). Kleinstein et al.[12] note significant differences in the prevalence of refractive error among ethnic groups (African-American, Asian, Hispanic, and Caucasian), even after controlling for age and sex.

We found that eyes with unilateral cataracts overall had a shorter mean AL than those with bilateral cataracts (20.15 vs. 21.10 mm, $P = 0.003$).[8] This effect was seen until 60 months of age. Eyes with cataract may also be associated with ocular anomalies (e.g., microphthalmos) leading to shorter AL. However, in children beyond 60 months of age, unilateral cataractous eyes were longer than bilateral cataractous eyes (23.06 vs. 22.25 mm) perhaps due to elongation caused by deprivation amblyopia. Lorenz et al.[13] have reported that in unilateral cataract, there is a trend toward an increased AL. In bilateral cataract, the eyes were shorter than normal, especially when surgery was performed during the first 6 months of life. Eyes between 6 and 12 months of age tended to have normal to increased AL at the time of surgery. Lorenz et al.[13] further reported that in unilateral cataract, 5 of 12 eyes examined at the time of surgery were 7% to 16% longer than their age-matched control eyes. Griener et al.[14] reported that in unilateral cases, between 2 and 6 months of life the mean AL was 18.7 mm. Moore[15] reported that in eyes at a mean age of 3.7 months (range, 1.3–6) the mean AL was 18.41 mm (range, 16.49–20.09). They reported that the AL in all but one patient was greater than the average AL of normal neonates in their practice. Kugelberg et al.[16] reported their results in 12 children with unilateral congenital cataract (age range, 4–418 days). All these eyes had a shorter AL (median, 17.54 mm) than did their fellow eyes (median, 19.04 mm).

Summary

Measuring globe axial length in children can be challenging. If performed in the clinic setting, poor cooperation and poor fixation may lead to errors. Often, measurements are done in the operating room under general anesthesia. However, experienced technicians and modern A-scan ultrasound units may not be available in these operating room settings. Immersion A-scan is more accurate in children but it requires experience and knowledge of the ideal pattern of ultrasonic spikes. Pediatric eyes with cataract vary considerably from the non-cataract eyes. Early in life, microphthalmia is common when cataract is present. In older children, deprivation amblyopia can lead to abnormally long axial length. Pediatric surgeons must measure the eyes carefully and predict eye growth as much as possible in order to implant the IOL best suited for each patient at the time of surgery and well into the future.

Conflict of interest

The authors have no financial or proprietary interest in any product mentioned herein.

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