Innovations in pediatric cataract surgery

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Advances in technology have made surgery in children safer and faster. The management of pediatric cataract has made rapid progress in the past decade with the availability of safer anesthesia, newer technique’s, more predictable intraocular lens (IOL) power calculation, a better understanding of neurobiology, genetics, amblyopia management, improved IOL designs for preventing visual axis opacification, and adjuvant postoperative care. Modern vitrectomy machines with minimally invasive instruments, radiofrequency, diathermy, and plasma blades help immensely in complicated cases. Preoperative evaluation with ultrasound biomicroscopy and optical coherence tomography (OCT) allows better planning of surgical procedure. The future holds good for stem cell research, customized OCT, and Zepto (precision pulse capsulotomy).

Key words: Advances, innovations, pediatric cataract

Childhood cataract accounts for 7.4%–15.3% of childhood blindness[1] and a significant amount of avterable disability-adjusted life years. The median prevalence is about 1.03/10,000 children (0.32–22.9/10,000). The incidence ranged from 1.8 to 3.6/10,000 per year. The prevalence of childhood cataract in high-income economies was found to be 0.42–2.05 compared with 0.63–13.6/10,000 in low-income economies. There was no difference in the prevalence based on laterality or gender.[2] India has a burden of around 280,000–320,000 visually impaired children,[3] leading to an estimated lifetime loss of earning capacity of US $3500 million.[4] The management of pediatric cataract has changed dramatically in the past decade.

Preoperative Evaluation

Preoperative factors play a major role in the postoperative outcomes in children. The age of onset, type of cataract, laterality, delay in presentation, best-corrected distance visual acuity, the presence of strabismus, nystagmus, and glaucoma are all predictors of postoperative visual outcomes in children.[5] The delay in presentation to hospital for surgery is associated with poor outcomes. Congenital cataract has poorer outcomes compared to developmental cataract as it is often associated with visual deprivation in the early sensitive years of visual maturation.[6] Cataract-associated nystagmus has six times lesser chance of attaining 20/40 visual acuity compared to cataract without nystagmus.[7] Congenital cataract operated <1 year of age has the increased risk of postoperative visual axis opacification (VAO).[8] Bilateral cataract has better visual outcome than unilateral cataract, 78% of the children with bilateral cataract had more than 20/40 visual acuity.[9] Whereas unilateral cataract is often associated with microphthismolus, persistent fetal vasculature (PFV), anisometropia, and late presentation, hence has poorer visual outcomes. Preoperative good distance visual acuity has a better prognosis as it indicates amblyopia has not set in these eyes, whereas cataract associated with strabismus generally indicates that visual acuity is poor in that eye.[7] Preexisting glaucoma has the added disadvantage as these children undergo additional surgeries.

Ultrasound Biomicroscopy

Ultrasound biomicroscopy (UBM) is a noninvasive technique for imaging the anterior segment of an eye, which is extensively used in glaucoma to look for angle anomalies, iris pattern, ciliary body, and ciliary processes.[8] The probes most commonly used for the ophthalmic purpose are 10 MHz, 35 MHz, and 50 MHz, with the increase in frequency penetration decreases.[9] Higher frequency ultrasound is useful for anterior segment evaluation. In addition to its role in measuring the corneal thickness, anterior chamber depth, and angle structures, it can be used preoperatively to analyze the sulcus, sulcus-to-sulcus measurement, integrity, and the presence of anterior capsule for secondary intraocular lens (IOL) and lens thickness.[10][11] It is of prime importance in identifying anterior persistent hyperplastic primary vitreous, posterior capsular defect, and posterior polar cataract preoperatively, which helps in better planning and management of the case.[7] Ultrasound biomicroscopy also helps us in posttraumatic cases to look for cyclodialysis, subluxation, foreign body localization in anterior...
**Optical Coherence Tomography**

It is noninvasive, a noncontact technique for imaging the anterior and posterior segment of an eye with a high resolution up to 1 µm. Currently, with the advent of swept-source optical coherence tomography (OCT) using a longer wavelength of 1060 nm, imaging of choroid has improved significantly. The choroid is known to play an important role in the growth of eye; hence serial imaging of choroid over a period of time might help us in better understanding the postoperative myopic shift and the pathogenesis of myopia. Using spectrally encoded extended source, high-resolution extended source (HRES) OCT system capable of providing a transverse resolution of 4.4 µm and an axial resolution of 2.1 µm in the air have become possible. The power of lens calculation from extended depth OCT, using an improvement on the Bennett method is more accurate. Already, OCT is being extensively used for both anterior and posterior segment evaluation. The retinal nerve fibre layer thickness is different in ethnicities; it is also negatively correlated to axial length. The central macular edema can sometimes be missed on clinical examination in children, which can be captured on OCT, which is seen in around 25% of children operated for complicated cataract in juvenile idiopathic arthritis. Besides these, OCT can be used to check the vaulting of IOL, placement of anterior chamber IOL (ACIOL), angle structures, and anomalies.

**Biometry**

**Axial length**

Predicting axial length growth and hence the refractive outcome is the major remaining challenge in pediatric cataract surgery. Axial length increases rapidly in the first 6 months (0.62 mm/month), then has a relatively slower (infantile phase) growth (0.19 mm/month) till 18 months, followed by a slow (juvenile phase) growth (0.01 mm/month). Even this growth is different in different ethnicities. Rate of axial length growth in pseudophakic children is more rapid in unilateral cases compared to bilateral cases. Axial length growth postoperatively is also variable in children; hence, the absolute error in children is higher compared to the adult population. Axial length measurement has been shown to be better estimated with immersion A-scan than A-scan only because of compression of the anterior surface of the cornea. Axial length measurements made with a contact technique are on an average, 0.24–0.32 mm less than measurements made using an immersion technique. In spite of this disadvantage, indentation method is more commonly used (82.4% vs. 17.6%). Hence, if immersion scan is not possible, A-scan reading with maximum anterior chamber depth should be taken. Still, measurement of axial length can be erroneous because the child is not fixing under anesthesia, that is why there is a need for an instrument which can measure the axial length along the visual axis with fovea being imaged.

**Keratometry**

Keratometry values are typically obtained under general anesthesia using a handheld autokeratometer with a manual keratometer in older children, whenever it is possible to take awake measurements. Keratometry steeply reduces in the first 6 months, i.e., -0.40 D/month, -0.14 D/month in the second semester, and -0.08 D/month in the 2nd year. Corneal curvature reaches the adult range at about 3 years of age. Girls have steeper corneas than boys. Axial length has a linear relationship with keratometry, as the axial length increases keratometry decreases. The K values of eyes with cataract in monocular cases were steeper than those of bilateral cataracts. Keratometry is greater in the cataractous than in the fellow eyes. The mean preoperative keratometry is also different in congenital (47.78 D) than in the developmental cataract (44.35 D). Mean keratometry values are significantly associated with the mean prediction error in IOL power. Hence, obtaining the right keratometry value should never be underestimated. Keratometry readings without speculum are preferred though technically difficult, as keratometry with the speculum is known to deform the globe and give an unreliable reading.

**Intraocular Lens Power Calculation**

The full-term newborn has a mean keratometric power of 51.2 D (spherical equivalent), a mean axial length of 16.8 mm, and a mean lens power of 34.4 D which changes to 43.5 D, 23.6 mm, and 18.8 D, respectively. In the pseudophakic eye of children, there is myopic shift which is more (0.5–10.75 D) in younger (2–3 years) children compared to older (8–9 years) children (−0.75–2.5), and predicting this myopic shift is very difficult. IOL power calculation is targeted to achieve an emmetropic state in adulthood by undercorrecting the child according to age and leaving the child moderately hyperopic in the postoperative period. The initial desired refractive outcome after IOL implantation is, therefore, hypermetropia. An accurate refractive outcome after primary IOL implantation is crucial to avoid a large myopic shift in later childhood and in adulthood. In general, Enyedi’s rule of seven is followed which is validated. The suggested under correction formulae 20% for <2 years and 10% for 2–8 years does not corroborate with the axial length growth and the target refraction required for age. Hence, there is a need to develop a new under correction formulae for children. The application of adult formulae for IOL power calculation to children has given mixed results.

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**Figure 1:** Clinical picture and ultrasound biomicroscopy (a) spherophakia (b) posttraumatic anterior capsule rupture (c) developmental zonular cataract
at our institute use SRK-II formula for IOL power calculation, which is suggested to have a least predictive error.[36]

**Intraocular Lens versus Aphakia**

Infant aphakia treatment study has suggested that primary IOL implantation in children <7 months of age is associated with more chances glaucoma, added number of surgeries mainly due to VAO, and increased cost compared to contact lens use.[37] However, the visual acuity at 5 years of follow-up were comparable.[38] Although implantation of IOL in children more than 2 years of age is universally accepted as 80% of the growth of eye has already occurred, there was no clear evidence for implantation of IOL in children between 7 and 22 months of age. Recently, long-term visual outcomes in this group suggest good visual prognosis and postoperative complications comparable to children operated more than 2 years of age.[39] Primary IOL implantation in long term has better visual prognosis compared to secondary IOL implantation.[5] Aphakia in itself is a problem with issues of compliance with glasses and contact lens, especially in developing countries and lower socioeconomic status population;[40] hence, intraocular implantation is more often done[40] with child having axial length more than 17 mm and corneal diameter of more than 9.5 mm which was the lower cutoff in infant aphakia treatment study.

**Surgery**

The indications for cataract surgery include visually significant central cataracts larger than 3 mm in diameter,[41] dense nuclear cataracts, cataracts obstructing the examiner’s view of the fundus, and cataracts associated with strabismus and abnormal eye movements.

**Anesthesia**

Safe and improved drugs help in planning surgery even in neonates. Opioids are associated with adverse effects such as vomiting and respiratory depression. The subtenon block and topical lignocaine are the safe alternatives to IV fentanyl for perioperative analgesia in pediatric cataract surgery.[42,43]

**Microscope**

Callisto Eye in Zeiss Lumera 700 provides rhexis assistant which is an intraoperative projection of rings of custom sizes which can be used as guides for anterior and posterior capsulorhexis.[44] In addition, it also has a toric assistant which uses the reference axis from IOL master and target axis in the microscope eyepiece to precisely align the toric IOL without corneal marking. The noncontact fundus viewing system provides clear detailed visualization of the retina. Intraoperative continuous OCT helps in angle assessment besides cornea and retinal evaluation.[45]

**Instrumentation**

The elasticity of the anterior capsule, low scleral rigidity, and presence of formed vitreous result in upthrust in these eyes during the surgery. The need for higher molecular weight ocular vicosurgical devices (OVDs) to compensate this thrust cannot be ignored. These viscohesive (Healon GV) or viscoadaptive (Healon 5) OVDs help in performing anterior continuous curvilinear capsulorhexis and posterior continuous curvilinear capsulorhexis.[46] The development of fine 23.25 gauge instruments, especially the scissors and forceps, helps in chamber stability throughout the surgery. Anterior capsulotomy using vitrectomy cutter can be done in children <6 years.[47] Even smaller eyes can be operated on with more ease and confidence and these wounds can be left sutureless as wound integrity is better maintained. The enhanced cut rate on Centurion™ of 4000 cuts/min makes vitrectomy following posterior capsulotomy much safer. With the use of active fluidics, the chamber stability is better maintained. Although phacoemulsification energy per se is not needed in majority of cases, the higher aspiration and vacuum on these machine help in maintaining the AC. The radiofrequency endodiathermy (Kloti™) uses high-frequency (500 kHz) current to heat the probe tip to about 160° and cuts the capsule using thermal energy.[48] The Fugo’s™ plasma blade which has been approved by the US Food and Drug Administration can be used for capsulotomy, especially in cases of the PFV and posttraumatic fibrotic capsules [Fig. 2].[49]

**Choice of Intraocular Lens**

Compared to hydrophilic acrylic lenses, the hydrophobic acrylic lens shows superior reduction rates of posterior capsular opacification (PCO) and laser capsulotomy rates.[50] IOL with square edges inhibits lens epithelial cell (LEC) migration and PCO formation.[51] The “Perfect” IOL would be with a hydrophilic anterior surface and a hydrophobic posterior surface. Multifocal IOLs provide good near and distance vision[52] and also help in establishing stereopsis in unilateral cases,[53] but the brightness and contrast of the images get compromised.[54] Any decentration of lens leads to glare, halos, and deterioration in the quality of the image. Moreover, multifocal lenses cannot be used in the presence of astigmatism. Multifocal toric IOL has been used in unilateral traumatic cataract patient with a good outcome in a 7-year-old child.[54]

Femtosecond laser-assisted pediatric cataract surgery for pediatric cataract[55] becomes a very expensive proposition due to the need for general anesthesia and two patient interfaces for

![Figure 2: (a) Intraoperative continuous optical coherence tomography showing proper anterior chamber intraocular lens positioning (b) rhexis assistant for sizing anterior and posterior capsulorhexis (c) 23-gauge vitrectomy probe for membranectomy (d) retcam image showing fundal coloboma](image)
Postoperative Treatment

related to faulty IOL implantation.

Intraocular Lens Insertion

Vitreorhexis

Superior incision protects the wound by lids and Bell’s phenomenon. Three incisions and two side ports 180° apart give 360° movements. The first incision by nondominant hand should be done, if chamber gets shallow after 1 or 2 side ports, stop and inject OVD. Preservative-free adrenaline (1:100,000) is injected for pupillary dilation, trypan blue dye (0.06%) under air stains the capsule which is washed out from all incisions for better marking of an incision. Then, a cystitome is used to give nick on anterior lens capsule; anterior capsular rhesis is completed with the help of utrata or intravitreal 23-gauge forceps through 2.2 mm entry. Anterior capsulorhexis can also be done by push and pull technique.[58] Multiquadrant hydrodissection (at least three quadrants) is the preferred method in pediatric group, following which bimanual lens aspiration is completed to remove the lens matter. This is followed by partially underfilling the anterior chamber with high viscosity, cohesive viscoelastic substance, again cystitome is used to give nick over the posterior capsule and posterior capsulorhexis is completed using intravitreal forceps. The rapidly dividing LECs result in high incidence of VAO necessitating primary management of the posterior capsule. Anterior vitreous face acts as a scaffold for proliferating LECs and metaplastic pigment cells. Anterior vitrectomy breaks this scaffold, thus preventing VAO formation. Posterior capsulorhexis and vitrectomy are based on the age of the patient at surgery. A posterior capsulotomy is a must for all patients <6 years of age. Vitreectomy can be deferred after 5 years of age. In children, the surgical incisions need to be sutured using 10-0 monofilament nylon because of increased risk of anterior chamber collapse and endophthalmitis.

Vitreorhexis

Instead of doing the posterior capsulorhexis from the anterior route, posterior capsulorhexis can be done using minimally invasive and sutureless 25-gauge vitreotomy cutter through pars plana route after IOL implantation which has been shown to be equally stable with less postoperative reaction.[57] Anterior capsulorhexis can also be done using vitreotomy cutter, but the tensile strength is usually lower than anterior curvilinear capsulorhexis. Vitreorhexis has the advantage of better anterior chamber stability and less postoperative astigmatism.[58]

Intraocular Lens Insertion

Inserting the IOL in the bag when posterior capsular rhesis is already made is difficult. After making a 2.75 mm entry wound, IOL is inserted by pushing the leading haptic against the back surface of the anterior capsule, and then pushing down the trailing haptic followed by tucking of the trailing haptic into the bag. This is a safe method and results in no complications related to faulty IOL implantation.[59]

Postoperative Treatment

Early literature quotes these eyes to have a more intraocular reaction, which includes anterior chamber cells, flare, fibrinous reaction, pupillary membrane formation, and posterior synechiae formation. This is mainly due to the immaturity of the blood-aqueous barrier, insufficient fibrinolytic activity by trabecular meshwork, and foreign body reaction to IOL,[60] Heparin surface-coated IOL in uveitis cases, a subconjunctival injection of dexamethasone with or without triamcinolone, enoxaparin, and heparin in infusion fluid, has been documented to have a less postoperative reaction.[61] Postoperative single injection of hydrocortisone 5 mg/kg and dexamethasone 0.1 mg/kg have been shown to be equally effective, without the complication of increase in intraocular pressure seen with depot steroid and hyphema seen with heparin.[62] Recently, phase 3b multicentric trials, dufiprednate 0.05% four times a day have shown safety and efficacy profiles similar to prednisolone acetate 1% in children 0–3 years undergoing cataract surgery.[63]

Follow-up management

Surgery is only a part of the management process, and success of the surgery depends on the postoperative follow-up, compliance for multiple examinations under anesthesia, amblyopia management, early detection, and treatment of complications.

Amblyopia Therapy

Amblyopia is frequently seen in childhood cataract; it is a form of cortical visual impairment, for which no organic cause can be attributed.[64] The inhibition of neurological signals in visual pathway leads to anatomic changes which are visible in the lateral geniculate nucleus and occipital cortex.[65] Amblyopia generally develops during the critical period of eye development, which extends up to 9 years of age. Although recent evidence suggests that the cortical plasticity can extend well beyond the postulated age.[66] Besides the basic management of amblyopia by correcting the underlying cause, appropriate optical correction, occlusion, and penalization of the dominant eye during the critical period, there is emerging evidence for the use of perceptual learning, video gaming, dichoptic training, transcranial magnetic stimulation, and drugs such as carbipoda, levodopa, and citicoline.[67] Functional magnetic resonance imaging has emerged as a modality for researching the new techniques for amblyopia management.[68] Amblyz™ liquid crystal occlusion glasses are a good alternative to traditional patching.[69]

Stem Cell Research

Recently, endogenous stem cells (lens epithelial/progenitor cells) were isolated to regenerate the lens. Lin et al. have described a novel technique, in which children <2 years of age received lensectomy with an eccentric, smaller capsulorhexis leaving LECs intact. The residual cells regenerated a lens structure with refractive power and accommodative ability. This must be studied in more eyes before it can be an adopted technique.[70] Congenital cataract is hereditary in 8.3%–25% of cases, with the most being autosomal dominant in inheritance.[71] Congenital cataract with more than forty genes and loci has been isolated.[72]

Challenging Situations

Spherophakia

Spherophakia was first described by Hartridge in 1886, it is due to the defective development of the zonules.[73] On

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ultrabiomicroscopy (UBM), shallow anterior chamber, steep anterior lens curvature, iridolenticular contact, elongated zonules, increased distance between the lens equator, and the ciliary processes can be seen.\(^\text{[13]}\)

Intralenticular bimanual irrigation and aspiration with ACIOL or scleral fixated IOL with or without trabeculectomy can be done.\(^\text{[74]}\)

Technique

Surgical management of ectopia lentis in subluxation of more than 270° is challenging, which cannot be managed with capsular support rings and in-the-bag placement of IOL. The technique of intralenticular lens aspiration through a small incision came into practice in cases where capsular bag removal was deemed necessary. Sinha \textit{et al.}\(^\text{[75]}\) used bimanual irrigation-aspiration followed by vitrectomy cutter to remove the capsular bag. We modified this technique, two nicks are made in the anterior capsule of the lens, with the help of a 23-guage MVR, irrigation cannula was inserted from one opening to stabilize the bag, and through another opening, the cutter was inserted. The lens matter was aspirated with the help of vitrectomy cutter itself in irrigation-aspiration cut mode followed by the removal of the bag in anterior vitrectomy mode [Fig. 3].

**Persistent Fetal Vasculature**

The reported visual acuity results after surgery for PFV are variable (0%–71%). If the PFV does not cover the visual axis during the 1st year of life, the prognosis for patient’s vision is excellent, provided that surgery and treatment for amblyopia of the affected eye takes place as soon as possible.\(^\text{[76]}\) Ultrasound and color Doppler imaging are informative screening and diagnostic tools that show characteristic flow patterns in the PFV.\(^\text{[77]}\) The new echographic finding of a double linear echo on high-frequency ultrasound was observed in the region of the pars plana or plicate consistent with a thickened adherent anterior hyaloid face and not to be an anteriorly inserted peripheral retina.\(^\text{[78]}\) The intraoperative presence of “salmon patch sign” eccentric pink hue is suggestive of active vasculature within the PFV.\(^\text{[79]}\) The Fugo’s\(^\text{TM}\) plasma blade can be used to avoid intraoperative bleeding using pulses of plasma that are generated around the tip to cut and cauterize tissue without extensive collateral tissue damage [Fig. 4].\(^\text{[80]}\) IOL implantation should be tried in unilateral cataract to decrease the chance of developing amblyopia.\(^\text{[81]}\)

**Conclusion**

Advancement in technology has remarkably improved the surgical outcome. Zepto (precision pulse capsulotomy)\(^\text{[82,83]}\) and HRES OCT\(^\text{[17]}\) will be the future-driving technology. The biggest hurdle remaining is precise IOL power calculation in children.

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**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Rahi JS, Sripathi S, Gilbert CE, Foster A. Childhood blindness in India: Causes in 1318 blind school students in nine states. Eye (Lond) 1995;9(Pt 5):545-50.
2. Sheeladevi S, Lawrenson JG, Fielder AR, Suttle CM. Global

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**Figure 3**: (a) Subluxated lens (b) mid-peripheral microvitreoretinal entry (c) 2 microvitreoretinal entries made (d) bag stabilized with irrigation probe (e) lens aspiration on irrigation/aspiration mode with vitrectomy cutter (f) anterior vitrectomy at 4000 cuts/sec (g) pupil constricted with pilocarpine and air injected (h) anterior chamber intraocular lens and suture placed

**Figure 4**: Persistent fetal vasculature (a) hemostasis using diathermy (b) Fugo’s\(^\text{TM}\) plasma blade (c) persistent fetal vasculature stalk on ultrasonography (d) color Doppler showing flow in persistent fetal vasculature
prevalence of childhood cataract: A systematic review. Eye (Lond) 2016;30:1160-9.

3. Titilay JS, Pal N, Murthy GV, Gupta SK, Tandon R, Vajpayee RB, et al. Causes and temporal trends of blindness and severe visual impairment in children in schools for the blind in North India. Br J Ophthalmol 2003;87:941-5.

4. Shamanna BR, Dandona L, Rao GN. Economic burden of blindness in India. Indian J Ophthalmol 1998;46:169-72.

5. Bonaparte LA, Trivedi RH, Ramakrishnan V, Wilson ME. Visual acuity and its predictors after surgery for bilateral cataracts in children. Eye (Lond) 2016;30:1229-33.

6. Mwende J, Bronsard A, Mosha M, Bowman R, Geneau R, Courtwright P. Delay in presentation to hospital for surgery for congenital and developmental cataract in Tanzania. Br J Ophthalmol 2005;89:1478-82.

7. Spanou N, Alexopoulos L, Manta G, Tsamadou D, Drakos H, Paikos P. Strabismus in pediatric lens disorders. J AAPOS 2011;15:163-6.

8. Pavlin CJ, Harasiewicz K, Sherar MD, Foster FS. Clinical use of ultrasound biomicroscopy. Ophthalmology 1991;98:287-95.

9. Silverman RH. High-resolution ultrasound imaging of the eye – A review. Clin Exp Ophthalmol 2009;37:54-67.

10. Dada T, Gadia R, Sharma A, Ichhpuijani P, Bali SJ, Bhartiya S, et al. Ultrasound biomicroscopy in glaucoma. Surv Ophthalmol 2011;56:433-50.

11. Gupta V, Jha R, Srinivasan G, Dada T, Sihota R. Ultrasound biomicroscopic characteristics of the anterior segment in primary congenital glaucoma. J AAPOS 2007;11:546-50.

12. Kucukceviçilgin M, Hurmeric V, Ceylan OM. Preoperative detection of posterior capsule tear with ultrasound biomicroscopy in traumatic cataract. J Cataract Refract Surg 2013;39:289-91.

13. Macken PL, Pavlin CJ, Tuli R, Trope GE. Ultrasound biomicroscopic features of spherophakia. Aust N Z J Ophthalmol 1995;23:217-20.

14. Fujimoto JG. Optical coherence tomography for ultrahigh resolution in vivo imaging. Nat Biotechnol 2003;21:1361-7.

15. Hirata M, Tsuikjawa A, Matsumoto A, Hangai M, Ooto S, Yamashiro K, et al. Macular choroidal thickness and volume in normal Hong Kong Chinese children measured with optical coherence tomography. Invest Ophthalmol Vis Sci 2011;52:4971-8.

16. Fujiwara T, Imamura Y, Margolis R, Slakter JS, Spaide RF. Enhanced depth imaging optical coherence tomography of the choroid in highly myopic eyes. Am J Ophthalmol 2009;148:445-50.

17. Yu X, Liu X, Chen S, Luo Y, Wang X, Liu L. High-resolution extended source optical coherence tomography. Opt Express 2015;23:26399-413.

18. Hernandez VM, Cabot F, Ruggeri M, de Freitas C, Ho A, Yoo S, et al. Calculation of crystalline lens power using a modification of the Bennett method. Biomed Opt Express 2015;6:4501-15.

19. Leung MM, Huang RY, Lam AK. Retinal nerve fiber layer thickness in normal Hong Kong Chinese children measured with optical coherence tomography. J Glaucoma 2010;19:95-9.

20. Pang Y, Goodfellow GW, Allison C, Block S, Frantz KA. A prospective study of macular thickness in ambyopic children with unilateral high myopia. Invest Ophthalmol Vis Sci 2011;52:2444-9.

21. Paroli MP, Spinucci G, Fabiani C, Pavetti-Pezzi P. Retinal complications of juvenile idiopathic arthritis-related uveits: A micropimetry and optical coherence tomography study. Ocul Immunol Inflamm 2010;18:54-9.

22. Baikoff G, Lutun E, Wei J, Ferraz C. Contact between 3 phakic intraocular lens models and the crystalline lens: An anterior chamber optical coherence tomography study. J Cataract Refract Surg 2004;30:2007-12.

23. Wilson ME, Trivedi RH. Axial length measurement techniques in pediatric eyes with cataract. Saudi J Ophthalmol 2012;26:13-7.

24. Capozzi P, Morini C, Piga S, Cuttini M, Vadala P. Corneal curvature and axial length values in children with congenital/infantile cataract in the first 42 months of life. Invest Ophthalmol Vis Sci 2008;49:4774-8.

25. Vasavada AR, Raj SM, Nihalani B. Rate of axial growth after congenital cataract surgery. Am J Ophthalmol 2004;138:915-24.

26. Vasavada V, Shah SK, Vasavada VA, Vasavada AR, Trivedi RH, Srivastava S, et al. Comparison of IOL power calculation formulae for pediatric eyes. Eye (Lond) 2016;30:1242-50.

27. Ehlers N, Sorenson T, Bramsen T, Poulsen EH. Central corneal thickness in newborns and children. Acta Ophthalmol (Copenh) 1976;54:285-90.

28. Zadnik K, Manny RE, Yu JA, Mitchell GL, Cotter SA, Quiralt JC, et al. Ocular component data in schoolchildren as a function of age and gender. Optom Vis Sci 2003;80:226-36.

29. Trivedi RH, Wilson ME. Keratometry in pediatric eyes with cataract. Arch Ophthalmol 2008;126:38-42.

30. Filicrt DL, Knight-Nanan D, Bowell R, Lanigan B, O’Keete M. Intraocular lenses in children: Changes in axial length, corneal curvature, and refraction. Br J Ophthalmol 1999;83:263-9.

31. Olsen H, Ehlers N, Hjortdal JO. Value of intraoperative keratometry in predicting outcome of radial keratotomy. Acta Ophthalmol Scand 1997;75:398-400.

32. Gordon RA, Donzis PB. Refractive development of the human eye. Arch Ophthalmol 1985;103:785-9.

33. Plager DA, Kipfer H, Sprunger DT, Sondhi N, Neely DE. Refractive change in pediatric pseudophakia: 6-year follow-up. J Cataract Refract Surg 2002;28:910-5.

34. Sachdeva V, Katukuri S, Kakunaya R, Fernandes M, Ali MH. Validation of guidelines for undercorrection of intraocular lens power in children. Am J Ophthalmol 2017;174:17-22.

35. Dahan E, Drusedau MU. Choice of lens and dioptic power in pediatric pseudophakia. J Cataract Refract Surg 1997;23 Suppl 1:618-23.

36. Kakunaya R, Gupta A, Sachdeva V, Rao HL, Vaddavalli PK, Om Prakash V. Accuracy of intraocular lens power calculation formulae in children less than two years. Am J Ophthalmol 2012;154:13-19.e2.

37. Infant Aphakia Treatment Study Group, Hartmann EE, DuBois L, Drews-Botsch C, et al. Comparison of contact lens and intraocular lens correction of monocular aphakia during infancy: A randomized clinical trial of HOTV optotype acuity at age 4.5 years and clinical findings at age 5 years. JAMA Ophthalmol 2014;132:676-82.

38. Weakley DR, Lamberts SR, Wilson ME, Plager DA, Buckley EG, Lynn M. Refractive error and anisometropia after unilateral intraocular lens implantation in infants under 7 months of age-results at 5 years of age from the Infant Aphakia Treatment Study (IATS). J AAPOS 2016;20:e10. Available from: http://www.jaapos.org/article/S1091-8531(16)30163-X/abstract. [Last accessed on 2017 Apr 17].

39. Hussain MH, Reid HM, Clinch SJ, Egan MS, Sivasundar I, Croney D, et al. Comparison of contact lens and intraocular lens correction of anisometropia in children: Results of a randomized clinical trial. J Cataract Refract Surg 2004;30:2007-12.

40. Wilson ME, Pandey SK, Thakur J. Paediatric cataract blindness in the developing world: Surgical techniques and intraocular lenses in the new millennium. Br J Ophthalmol 2003;87:14-9.

41. Vasavada AR, Nihalani BR. Pediatric cataract surgery. Curr Opin Ophthalmol 2006;17:54-61.

42. Ghai B, Ram J, Makkar JK, Wig J, Kaushik S. Subtenon block compared to intravenous fentanyl for perioperative analgesia in pediatric cataract surgery. Anesth Analg 2009;108:1132-8.
43. Sinha R, Subramaniam R, Chhabra A, Pandey R, Nandi B, Jyoti B. Comparison of topical lignocaine gel and fentanyl for perioperative analgesia in children undergoing cataract surgery. Paediatr Anaesth 2009;19:371-5.

44. Binder AP. Intra-operative OCT devices for ophthalmic use: An overview. Spectrum of Ophthalmology 2014;28:2-5. Available from: http://www.springer.com/medicine/ophthalmology/journal/717. [Last accessed on 2017 Apr 13]

45. Ehlers JP, Dupps WJ, Kaiser PK, Goshe J, Singh RP, Petkovsek D, et al. The Prospective Intraoperative and Perioperative Ophthalmic Imaging with Optical Coherent Tomography (Pioneer) study: 2-year results. Am J Ophthalmol 2014;158:999-1007.

46. Wilson ME Jr. Anterior lens capsule management in pediatric cataract surgery. Trans Am Ophthalmol Soc 2004;102:391-422.

47. Wilson ME, Trivedi RH, Bartholomew LR, Pershing S. Comparison of anterior vitrectorhexis and continuous curvilinear capsulorhexis in pediatric cataract and intraocular lens implantation surgery: A 10-year analysis. J AAPOS 2007;11:443-6.

48. Krag S, Thim K, Corydon L. Diathermic capsulotomy versus capsule phacoemulsification: A biomechanical study. J Cataract Refract Surg 1997;23:86-90.

49. Singh D. Use of the Fugo blade in complicated cases. J Cataract Refract Surg 2002;28:573-4.

50. Li Y, Wang J, Chen Z, Tang X. Effect of hydrophobic acrylic versus hydrophilic acrylic intraocular lens on posterior capsule opacification: Meta-analysis. PLoS One 2013;8:e77864.

51. Ness PJ, Werner L, Maddula S, Davis D, Zaugg B, Stringham J, et al. Pathology of 219 human cadaver eyes with 1-piece or 3-piece hydrophobic acrylic intraocular lenses: Capsular bag opacification and sites of square-edged barrier break. J Cataract Refract Surg 2011;37:923-30.

52. Jacobi PC, Dietlein TS, Konen W. Multifocal intraocular lens implantation in pediatric cataract surgery. Ophthalmology 2001;108:1375-80.

53. Lapid-Gortzak R, van der Meulen IJ, Jellema HM, Mourits MP, et al. Comparison of transcorneal and pars plana routes in pediatric cataract surgery. J Cataract Refract Surg 2002;28:593-5.

54. Lin H, Ouyang H, Zhu J, Huang S, Liu Z, Chen S, et al. Lens regeneration using endogenous stem cells with gain of visual function. Nature 2016;531:323-8.

55. Hejtmancik JF. Congenital cataracts and their molecular genetics. Semin Cell Dev Biol 2008;19:134-49.

56. Churchill A, Graw J. Clinical and experimental advances in congenital and paediatric cataracts. Philos Trans R Soc Lond B Biol Sci 2011;366:1234-49.

57. Farnsworth PN, Burke PA, Blanco J, Maltzeman B. Ultrastructural abnormalities in a microspherical ectopic lens. Exp Eye Res 1978;27:399-408.

58. Nelson LB, Maumenee IH. Ectopia lentis. Surv Ophthalmol 1982;27:143-60.

59. Sinha R, Sharma N, Vajpayee RB. Intralenticular bimanual irrigation: Aspiration for subluxated lens in Marfan's syndrome. J Cataract Refract Surg 2005;31:1283-6.

60. Miltra RA, Huyhn LT, Ruttmeyer MS, Mieler WF, Connor TB, Han DP, et al. Visual outcomes following lensectomy and vitrectomy for combined anterior and posterior persistent hyperplastic primary vitreous. Arch Ophthalmol 1998;116:1190-4.

61. Hu A, Pei X, Ding X, Li J, Li Y, Liu F, et al. Combined persistent fetal vasculature: A classification based on high-resolution B-mode ultrasound and color Doppler imaging. Ophthalmology 2016;123:19-25.

62. Mackeen LD, Nischal KK, Lam WC, Levin AV. High-frequency ultrasonography findings in persistent hyperplastic primary vitreous. J AAPOS 2000;4:217-24.

63. Khokhar S, Gupta S, Gogia V, Nayak B. Salmon pink patch sign: Diagnosing persistent fetal vasculature. Oman J Ophthalmol 2016;9:68-9.

64. Sinha R, Bali SJ, Kumar C, Shekhar H, Sharma N, Titival JS, et al. Results of cataract surgery and plasma ablation posterior capsulotomy in anterior persistent hyperplastic primary vitreous. Middle East Afr J Ophthalmol 2013;20:217-20.

65. Chang DF, Mamalis N, Werner L. Precision pulse capsulotomy: Preclinical safety and performance of a new capsulotomy technology. Ophthalmology 2016;123:255-64.

66. Thompson VM, Berdahl JP, Solano JM, Chang DF. Comparison of manual, femtosecond laser, and precision pulse capsulotomy edge tear strength in paired human cadaver eyes. Ophthalmology 2016;123:265-74.