Visual Axis Opacification in Children Following Paediatric Cataract Surgery

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ABSTRACT

Visual axis opacification (VAO) occurs in up to 40% of pediatric patients after cataract surgery withintraocular lens implantation(IOL) even with a primary posterior capsulotomy (PPC). In both children and adult group, opacification does obscure the visual axis. However, in children after PPC, there is no capsule. Hence, the terminology VAO is used in children rather than posterior capsular opacification.

This opacification is caused by a proliferation of epithelial cells on the posterior capsule or anterior vitreous face and can hinder the optical image quality needed for normal visual development. The rate of epithelial mitotic activity is higher in children compared to adult. It can be managed by Yag laser or surgical membranectomy, the latter is preferable.

International and national published articles were systematically reviewed on aetio-pathogenesis, surgical techniques and equipment, type and material of IOL, and management of VAO in children operated for cataract. Author's experience was also included to write manuscript.

VAO is frequent complication following cataract surgery in pediatric patients. Age of cataract patients, surgical technique and type and materials of IOL are most common influencing factor for VAO. Immediate management with advance equipment of VAO reduces the incidence for development of irreversible stimulation deprivation amblyopia.

Keywords: *pediatric cataract; pediatric cataract surgery; visual axis opacification.*

INTRODUCTION

VAO occurs in 40% of pediatric patients following cataract surgery. This terminology has been coined as VAO for opacity of the media after pediatric cataract surgery, as there is no posterior capsule following surgery.[1]

The rate of epithelial mitotic activity is higher in children compared to adult. VAO results from proliferation of epithelial cells, aggressive growth of fibrous materialalongthe,the capsular remnants,andtheante riorvitreousface.[2] It hinders the optical image quality

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needed for normal visual development resulting in irreversible stimulation deprivation amblyopia.Hence early diagnoses and management of the VAO is important.[1]

Why this review?

Pediatric cataract surgeries are performed in different eye hospitals of Nepal. This article is written to outline the aetio-pathogenesis and prevention VAO in Nepalese children. This will help all the surgeons (ophthalmologists) to prevent the children from developing the VAO or manage it accordingly if it occurs.

Aetiology and Pathogenesis

Irrespective of the age, VAO is common after cataract surgery. Understanding the pathogenesis of the opacification in adult gives the good background to understand VAO in children.[3]

Pathogenesis of posterior capsular opacification (PCO) in adult

In adult cataract, pathogenesis of PCO is well understood. In the normal lens, lens epithelial cells are confined to the anterior capsule and do not proliferate and grow into the posterior capsule. In addition, germinal "E"– type epithelial cells of the lens equator undergo active mitosis throughout life to continually produce lens fibres. In the normal lens, no lens epithelial cells grow into the posterior capsule. However, in some patients undergoing cataract surgery, opacification results from proliferation of lens epithelial cells into the posterior capsule. This is likely due to anterior or equatorial epithelial cells that remain following removal of the cataract, some of which become activated. These lenticular epithelial cells proliferate posteriorly and form an opaque membrane on the posterior capsule over time. These cells acquire fibroblast–type properties with contractile capacity, thereby leading to contraction and wrinkling of the posterior capsule in some cases. Therefore, PCO is somewhat of a misnomer, since the capsule itself never opacifies; instead, it is the posterior migration of activated epithelial cells that leads to the formation of the opaque membrane on the posterior capsule. PCO results from the growth and trans-differentiation of lens epithelial cells left on the anterior capsule at the time of cataract surgery. Hence, pathogenesis can be summarized in three steps as proliferation, migration and differentiation.[4]

Equatorial differentiation of cells to fibre-like structures leads to Soemmerring's ring formation and peripheral thickening of the capsular bag. Closer to the rhexis, cell swelling can result in globular Elschnig's pearls, which may occlude the visual axis. Cells at the rhexis edge and those in the space around the optic appear to undergo epithelial-mesenchymal transition. The resulting cells are fibroblastic in morphology, express the smooth muscle isoform of actin and secrete extracellular matrix containing proteins not normally present in the lens.[4]

Pathogenesis VAO in children

In pediatric cataract, leaving the posterior capsule intact after IOL implantation in children predisposes to an unacceptably high rate of opacification known as secondary cataract formation.[5] It results from the aggressive growth of fibrous material along the posterior surface of the iris, the capsule remnants, and the anterior vitreous face that tends to develop in the healing young eye. The anterior vitreous face acts as scaffold for the epithelial cell migration.[6]

VAO is also related to the degree of postoperative inflammation. Aggressive postoperative inflammation may form secondary membranes across the pupil or over the anterior or the posterior surface of the IOL that can obscure the visual axis.

The use ofintracameraltriamcinoloneintra-operatively reduces the anterior segment inflammation and VAO after cataract surgery with IOLimplantation.[7]

Factors of VAO

1. Ocular Abnormalities and Timing of surgery

VAO is mostcommonineyeswithassociatedocular anomalies.[8] Young age is a significant risk factor for VAO, and its occurrence is a virtual certainty in pediatric patients.[9-11] VAO after cataract surgery in the first year of life occurs more frequently when ocular abnormalities like anterior segment dysgenesis and persistent fetal vasculature, are present. Based on study done in children with single acrylic intra- ocular lens (IOL), one-third of the patients who developed VAO required a secondary surgical intervention at a mean of five months. The mean age of patients whose eyes opacified was 3.8 months, compared with a mean age of five months for patients whose visual axis remained clear for a longer duration. Of those eyes operated on before six months of age, 43.7% opacified. Just 18.2% of patients older than six months during the time of surgery experienced VAO.[8]

When cataract and IOL surgery was undertaken within the first year of life, a secondary surgical procedure was required in 37.9% of eyes to maintain a clear

visual axis. Most secondary surgery for VAO occurred within the first six months after surgery. Proliferation of cortex was the most common form of VAO, followed by mixed-type with predominantly fibrous, fibrous alone, or Elschnig's pearls. When secondary surgery was required, it occurred primarily during the first six months (i.e. 9 of 11 patients) after the initial cataract surgery.[8]

1. IOL implantation

IOL implantation in children is associated with higher perioperative complications and an increased risk of subsequent VAO compared to adults

[12].IOL implantation in a growing eye of a young child brings several problems including opacification of the posterior capsule, if remained intact, interferes with visual rehabilitation in children. PPC and anterior vitrectomy provides the clarity of visual axis[13].

Prevention

1. Continuous Curvilinear Casulorhexis(CCC)

The creation of a CCC was found to delay the development of central visual obscuration by facilitating the mechanism of fusion between the edges of the continuous curvilinear capsulorhexis to the posterior capsule, forming a Soemmering's ring. Persistent residual LECs are the main reason for PCO and VAO.[14]

2. Role of anterior vitrectomy to prevent VAO

PCO is almost an unavoidable complication in children's eyes if the posterior capsule is left intact. Several methods have been proposed in order to keep the optical axis clear in infants and young children. The rate of PCO is up to 100% when the posterior capsule remains intact It reflects greater tissue reactivity of lens epithelial cells in children.[5]

Comparison of posterior capsulectomy with and without anterior vitrectomy showed that PCO rates are diminished only after combined posterior capsulectomy and anterior vitrectomy and not after capsulectomy alone. Other surgical manoeuvres to maintain a clear visual axis after pediatric posterior chamber IOL implantation have been tried; eg, primary posterior capsulotomy, epilenticular IOL implantation with pars planalensectomy, secondary pars plana or limbalcapsulotomy and/or anterior vitrectomy, primary posterior CCC with or without anterior vitrectomy, and primary posterior CCC and posterior optic capture of a capsular-bag-fixated IOL with or without anterior vitrectomy. PPC and anterior vitrectomy is a required step in congenital IOL surgery to prevent VAO. Alternatively, posterior CCC with anterior vitrectomy can also be done to prevent VAO.Anteriorvitrectomy and posterior capsulotomy reduce the scaffolding for lens epithelial cell migration to the anterior hyaloid face and decrease the incidence of VAO.[15,16]

Atkinson and Hilesin 1994 recommended leaving the posterior capsule intact, even in very young children and performing Nd:YAG laser posterior capsulotomy under a second general anaesthesia in the early post operative period before opacification occurs. Subsequently, however, they reported a 41% closure of the laser capsulotomy when this protocol laws followed.[17,18]

However, long-term complications such as vitreous or macular changes or retinal detachment several decades after anterior vitrectomy performed during pediatric IOL surgery have not been studied extensively. It might be desirable to avoid this surgical step. One advantage of posterior optic capture described by Gimbel and DeBroff might be the prevention of VAO without an anterior vitrectomy.[19] Vasavada and co-authors report on optic capture with or without anterior vitrectomy in children between five and 12 years of age. With a 5.25 mm optic-captured IOL, they found that the visual axis remained clear in all eyes with an anterior vitrectomy but in only 30% of eyes without an anterior vitrectomy. VAO was described as "reticular fibrosis of the anterior vitreous phase." Although visual acuity and high-contrast acuity were almost the same in both groups, low-contrast sensitivity was better in the vitrectomized eyes, a finding that should be examined.[20]

In spite of the improvements in the microsurgical techniques, with lens aspiration, PPC and anterior vitrectomy, VAO is common complication of the pediatric cataract surgery. Pars plana capsulotomy with pars plana anterior vitrectomy is a safe, effective method of managing the posterior capsule in pediatric cataract surgery with IOL implantation.[21] Posterior CCC as a single technique did not show any decrease in the incidence of VAO. Posterior CCC together with anterior vitrectomyis required to prevent VAO and to decrease reoperation rate.[22] In younger children, cataract surgery with posterior capsulorhexis and anterior vitrectomy was advantageous, whereas in older children a clear visual axis was achieved without vitrectomy.[23] Primary posterior capsulorhexis with anterior vitrectomy in pediatric cataract surgery who are between two and five years old is necessary and effective procedure with low VAO rate.[24]

3. Other Per-operative approach to minimize the VAO

A surgery-related factor to reduce PCO and VAO is

discussed in the following paragraphs.

4. Hydro dissection-enhanced cortical cleanup

Similar to the adult cataract surgery, cortical "clean-up" is important step during the surgery. Theoretically, since activated anterior capsular and equatorial lens epithelial cells are responsible for the opacification, and then removing them at the time of surgery should lead to lower rates of VAO.

5. In-the-bag (capsular) fixation

The second approach depends on forming an optic/haptic – bag barrier, and requires in-the-bag capsular fixation. This allows direct contact of the IOL with the posterior capsule rim, thereby preventing any activated epithelial cells migration ("no space, no cells"). In case one or both haptics are not placed in the bag, a potential space is created, allowing an avenue for cells to grow posteriorly toward the visual axis.

6. Capsulorhexis edge on IOL surface

A less obvious, but significant addition to precise in-the-bag fixation, is creating a CCC diameter slightly smaller than that of the IOL optic. For example, if the IOL optic were 6.0 mm, the capsulorhexis diameter would ideally be slightly smaller, perhaps 5.0-5.5 mm. This places the cut anterior capsule edge on the anterior surface of the optic, providing a tight fit (analogous to a "shrink wrap") and helping to sequester the optic in the capsular bag from the surrounding aqueous humour.

There are surgery and IOL-related factors that are particularly important in the prevention of PCO and VA.[25-29]

7. Lens design, material

Advances in lens design and biocompatibility have greatly reduced rates of PCO in adult cataract. This fact is again valuable in pediatric cataract too. Silicone lenses have good anti-proliferative properties. One piece PMMA lenses are not as effective in preventing PCO as the silicone lenses. In general, compared to PMMA lenses, hydrophobic acrylic intraocular lenses have demonstrated even lower rates of PCO. A recent study comparing the rates of capsular opacification following surgery between silicone and acrylic intraocular lenses found no statistical difference in opacification or Nd:YAG capsulotomy rates; other studies have shown that acrylic lenses have the lowest opacification rates when compared with PMMA and silicone lenses.[30]

Importantly, the above study used lenses constructed in a particular geometrical pattern: rectangular optic with sharp edges. In fact, optic geometry likely plays a very important role; studies have suggested that square, truncated edges may decrease the rates of capsular opacification by virtue of the geometry itself. Furthermore, the sharp posterior edge not anterior edge - of the optic seems to be the important factor in reducing opacification. This is true in pediatric cataract as well. The concept of the barrier effect goes back to the original Ridley lens.[31] If accurately implanted in the capsular bag, it provides an excellent barrier effect, with almost complete filling of the capsular bag and contact of the posterior IOL optic to the posterior capsule ("no space, no cells"). A lens with one or both haptics "out-of-the-bag" has much less of a chance to produce a barrier effect. In pediatric age group too, in the bag IOL implantation is hence advised. A truncated, square-edged optic rim appears to cause a complete blockade of cells at the optic edge, preventing epithelial ingrowth over the posterior capsule. In a study done in pediatric cataract with hydrophobic IOL, early 25% of operated eyes of infants required a secondary surgical procedure for VAO; the rate was higher in eyes of female infants but did not differ between IOL models.[32] It is the management of the posterior capsule rather than IOL design and material that influences the incidence of VAO after cataract surgery in children. Development of VAO in the postoperative period was delayed with a hydrophobic acrylic IOL with square edges compared with a PMMA lens without square edges.[33]

8. IOL biocompatibility

Implantation of acrylic IOLs significantly lowers the incidence of PCO. Acrysof IOL implantation with appropriate management of the posterior capsule provided a clear visual axis in pediatric cataract surgery.[34]

IOLs with a high adhesion property and sharp optic edge will prevent proliferation of LECs thus mitigating PCO.[35] Incidence of VAO and post-operativeuveal inflammation is significantly less with acrylic lenses and was safe to use in pediatric eyes. In the comparative study between the acrylic and PMMA lenses, twenty-five children with bilateral cataract, five years and older, underwent cataract surgery and implantation of an acrylic in one eye and PMMA IOL in the other eye of each patient. They were followed up for an average of 11.1 +/- 9.5 months to assess the incidence of clinically significant VAO and occurrence of postoperative complications. Post-operatively, 22(95.6%) patients with acrylic IOLs and 20 (86.9%) patients with PMMA IOLs either maintained or improved their vision. In the acrylic and PMMA IOL groups respectively, the incidence of

clinically significant PCO was 21% (4) and 75% (12) (P =0.002), with a median onset at 2.9 months and 0.7 months.[36]

Hydrophilic foldable IOLs have excellent uveal biocompatibility, are resistant to surface alterations or damage during folding and insertion, and have low potential to damage corneal endothelial cells in case of contact.[37] However, according to the 2001 pediatric cataract surgery and IOL survey of ASCRS and AAPOS members, this type of IOL was preferred by only 2.4% and 1% of the responders, respectively.[38]

Lack of enthusiasm for hydrophilic acrylic IOLs may be due to lower capsular biocompatibility in comparison to other biomaterials; this type of IOLs are associated with higher rates of lens epithelial cell (LEC) outgrowth, anterior capsule contracture, PCO and surface calcification as experienced in adult cataract surgery.[39-41] The latter complication can be severe enough to necessitate IOL explanation in some patients.[42]

Hydrophobic acrylic material binds more firmly to fibronectin, a plasma protein that is also secreted by LECs, compared with PMMA, silicone and hydrophilic acrylic materials.Therefore, it has been established that hydrophobic acrylic materials bind more firmly with the capsule.[43]

9. Maximal IOL Optic-Posterior Capsule Contact: Other contributing factors in reducing PCO are posterior angulation of the IOL haptic and posterior convexity of the optic. This is due to the creation of a "shrink wrap", a tight fit of the posterior capsule against the back of the IOL optic. The relative "stickiness" of the IOL optic biomaterial probably helps produce an adhesion between the capsule and IOL optic. There is preliminary evidence that the hydrophobic acrylic IOL biomaterial provides enhanced capsular adhesion or "bio adhesion".[44-52]

Why prevention of VAO is necessary ?

VAO can causeirreversible stimulation deprivation amblyopia hence prevention of VAO is necessary.[53] Repeated treatments may be required in some cases. Surgically, the approach can be anterior via the limbus or posteriorly (pars plana).Some factors that may reduce the incidence of VAO include in-the-bag IOL placement, thorough removal of lens substance, hydro dissection, type of IOL, PPC and anterior vitrectomy (especially in the ambylogenic age group), minimal iris trauma, and minimizing postoperative inflammation.[54]

Treatment of VAO

VAO can be managed with either pars planavitrectomy and capsulotomy or YAG capsulotomy which can be performed under general anaesthesia in uncooperative children.[35] VAO can be treated by Neodymium: Yttrium Aluminium Garnet (Nd:YAG) laser in cooperative children who can sit in the slit lamp. It is acceptable in the management of PCO after AcrySof IOL implantation in children.[55] However, unlike in the adults opacification is tougher in children. Most of the time yag laser may not cut the fibrous opacification.

Even though laser is a relatively simple procedure, it is difficult to perform in all children. Moreover, it is unavailable in all the hospitals.

Following yag laser, combination of steroid antibiotic drop is given four times a day for one week. Patients are then followed up in one week time for refraction and prescription of the glasses.In small children surgical membranectomy needs to be done. Capsulectomy and vitrectomy is safe and effective in thick VAOs in pseudophakic children.[56]

In aphakic children membranectomy can be done through the corneal approach. In pseudophakic children membranectomy can be done through sclera approach or the corneal approach. If surgical membranectomy is done, the combination of steroid antibiotic drop is given frequently for one week and drop is continued for 4-6 weeks. Posterior capsulotomy using 25-G vitrectomy system is safe and effective in management of PCO in pseudophakic children. There is ease of manipulation with smaller instruments in these small eyes.[57]

CONCLUSIONS

VAO still remains the mostfrequent complication of pediatric cataract surgery. The most critical factor influencing the occurrence of VAO is age. VAO in children causes stimulation deprivation amblyopia. Hence VAO must be managed immediately, either by Yag or surgically. While opacification is nearly universal in infantile eyes, the incidence decreases with increasing age. Primary management of the posterior capsule and anterior vitrectomy are effective in preventing re- opacification of visual pathways. The type and material of the IOL is another factor affecting the incidence of VAO. Appropriate vitrectomy set up, surgical procedures, skills, and appropriate IOLs help to reduce VAO.

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