23 Postoperative Complications and Management

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Abstract

The high incidence of complications after pediatric lens surgery is a bothersome issue for surgeons that may affect postoperative outcomes. Due to greater inflammatory response and immature blood-aqueous barrier, complications such as uveitis, posterior capsule opacification, secondary glaucoma, and IOL malposition are frequently seen after pediatric lens surgery. These complications may pose a serious impact on the ocular development and the visual function reconstruction of pediatric patients. This chapter will provide comprehensive and detailed information on the pathogenesis, risk factors, diagnosis, preventive strategies, and management of various postoperative complications.

Cataract extraction is the predominant method of treatment for pediatric cataracts. Due to the special anatomical structures and physiological functions of pediatric eyes, the necessary surgical techniques are demanding and different from those in adults, with a higher incidence of postoperative complications, including uveitis, posterior capsule opacification (PCO), glaucoma, and IOL decentration or dislocation. Meanwhile, the postoperative complications in pediatric patients usually have insidious onset and are prone to misdiagnosis, which leads to delayed treatment, poor surgical outcomes, and even secondary blindness. Therefore, prevention and management of postoperative complications in pediatric cataract surgeries are crucial issues for improving surgical outcomes and reducing postoperative low vision/blindness, and this poses great challenges to practicing ophthalmologists. This chapter will illustrate in detail the causes, preventions, and managements of postoperative complications for pediatric cataracts.

23.1 Complications Associated with the Cornea

23.1.1 Corneal Edema

Corneal edema is one of the early postoperative complications for pediatric cataracts (Fig. 23.1).

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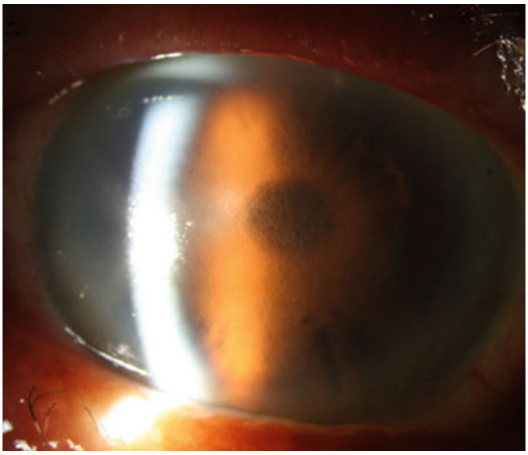

Fig. 23.1 Corneal edema after cataract surgery. A 5-year-old child develops diffuse corneal edema on postoperative day one. Slit-lamp image shows marked corneal haze

23.1.1.1 Etiology

1. Surgical trauma
   Intraoperative mechanical damage is the leading cause of postoperative corneal edema. Considering the restricted operating space due to the small eyeball and shallow anterior chamber of children, corneal endothelial injury tends to occur when surgical instruments are introduced in and out of the anterior chamber or an IOL is implanted. In addition, Descemet membrane detachment (DMD) caused by improper manipulation and excessive anterior chamber irrigation may also cause damage to the corneal endothelium. The rate of postoperative corneal endothelial cell loss is estimated to be between 5.1 and 9.2 %. Corneal edema may occur in severe cases [1, 2].
2. Postoperative inflammation
   Postoperative inflammatory response can lead to corneal endothelial pump dysfunction and a certain degree of endothelial cell apoptosis.
3. Ocular hypertension
   Ocular hypertension can occur in the early or late stages after cataract surgery. It can directly damage the corneal endothelial pump function and result in diffuse corneal edema, whereas sometimes in young children, the cornea remains clear even when the intraocular pressure (IOP) reaches 40 mmHg or above and therefore goes undetected.
4. Others
   A dislocated IOL haptic may give rise to repeated chafing of the corneal endothelium, causing progressive corneal endothelial damage and then corneal edema. The residual lens materials or vitreous strands in the anterior chamber may adhere to the corneal endothelium and disrupt its metabolism, which results in focal corneal edema. If irritation to the corneal endothelium continues, intractable corneal edema may occur. Patients with a history of corneal endothelial dystrophy, iridocorneal endothelial syndrome, and previous intraocular surgery are prone to develop postoperative corneal edema.

23.1.1.2 Clinical Manifestations

1. Local edema
   Local edema, manifesting as localized swelling and thickening of the cornea, is usually caused by surgical trauma. Residual lens matter in the anterior chamber should be considered if inferior focal corneal edema is observed.
2. Diffuse edema
   Diffuse edema usually results from postoperative inflammation, toxic anterior segment syndrome (TASS), ocular hypertension, and wide range DMD, which manifests as Descemet membrane folds, diffuse thickening, and decreased transparency of the cornea.
3. Descemet membrane curled inward
   Rupture of Descemet membrane may give rise to corneal edema. The curled Descemet membrane floating in the anterior chamber can be observed through the cornea or confirmed if necessary by anterior segment optical coherence tomography (OCT).

23.1.1.3 Management

1. Local edema
   The vast majority of focal edema after pediatric cataract surgery is caused by temporary endothelial dysfunction and may disappear within a few days without special treatment. Xiao and colleagues retrospectively analyzed

postoperative complications in 186 congenital cataract eyes (105 patients), reporting that the incidence of corneal edema in early stages after surgery is 35 % (65 eyes). The cornea edema disappeared in all cases within 3–5 days without special treatment [3]. However, anterior chamber irrigation or vitrectomy is recommended when extra amounts of lens matter or prolapsed vitreous are retained in the anterior chamber, causing persistent focal edema.

2. Diffuse edema
Diffuse or persistent cornea edema, being one of the most severe postoperative complications, should be treated promptly according to the causes. For inflammation-induced corneal edema, enhanced anti-inflammation medication should be administrated by using topical corticosteroids and nonsteroidal anti-inflammatory drugs (NSAIDs), such as prednisone acetate 1 % or dexamethasone 0.1 %. Simon JW et al. reviewed five eyes (four children) with corneal edema after cataract surgery, reporting that the edema disappeared in 5–14 days after administration of topical corticosteroids [4]. For diffuse corneal edema induced by intense anterior segment inflammation (for example, TASS), systemic corticosteroids should be added. For corneal edema resulting from DMD, urgent reattachment of the Descemet membrane is necessary for restoration of cornea clarity. Small ruptures may be cured by intracameral injection of air or inert gas, whereas wide range DMD should be reattached by suturing full-thickness cornea. If elevated IOP is detected after surgery, topical or systemic anti-glaucoma medications can be administrated (for details, see Sect. 23.5). Generally, corneal clarity will be restored after IOP returns to normal.

23.1.2 Corneal Epithelial Abrasion

Corneal epithelial abrasion often occurs in the early postoperative period and may be caused by intraoperative trauma or rubbing eyes due to the discomfort caused to the patient. Additionally, for children in need of contact lens to correct aphakic refractive error without IOL implantation, caution should be consideration given to the corneal epithelium defects that may be induced by disinfectant solutions or the daily action of wearing and removing the contact lens.

Clinical manifestations of corneal epithelial abrasion include mixed hyperemia, punctuate or flake-shaped epithelial defects, positive fluorescein staining, redness of the eye, tearing, and pain.

For mild corneal epithelial abrasion, topical medications, such as recombinant bovine basic fibroblast growth factor and preservative-free artificial tears, can be used to promote corneal epithelial healing, whereas a bandage is recommended in severe cases to reduce blinking, relieve pain, and promote corneal epithelial healing.

23.2 Complications Associated with the Uvea

23.2.1 Uveitis

Uveitis is the most common complication after pediatric cataract surgery. Other complications, such as corneal edema, ocular hypertension, IOL-related complications, and even secondary blindness, may be induced or aggravated without timely treatment.

23.2.1.1 Etiology

1. Immature blood-ocular barrier
Due to the immature blood-ocular barrier in pediatric eyes, surgical trauma is likely to give rise to nonspecific inflammatory response by the release of inflammatory substances such as cytokines, prostaglandins, and arachidonic acid and the bringing about of large amounts of cellulose inflammatory exudates.
2. Improper incision construction
Since young children's eyes have thin walls, iris prolapse may occur when the incision is not properly constructed. Repeated restoration of the prolapsed iris may exacerbate postoperative inflammation.
3. Failure of in-the-bag IOL implantation

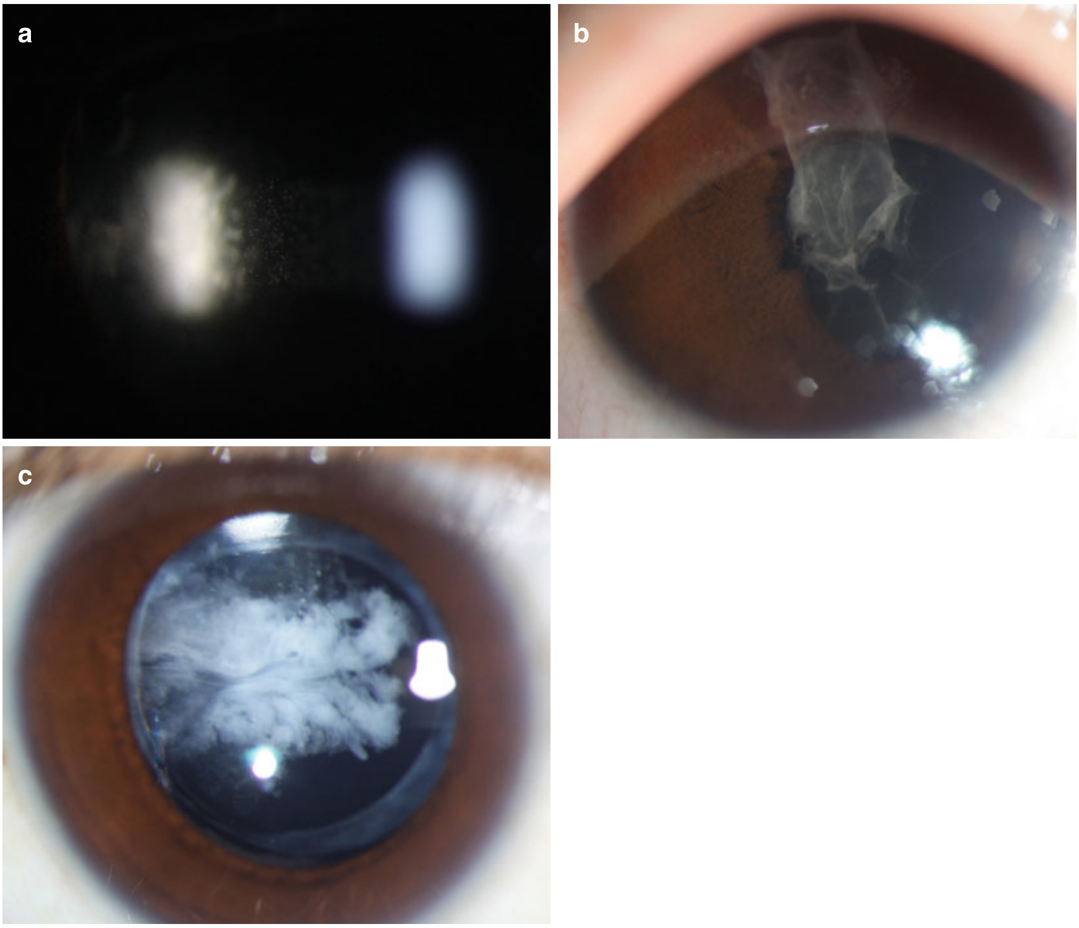

Fig. 23.2 Clinical manifestations of uveitis after pediatric cataract surgeries. (**a**) Cells in the anterior chamber; (**b**) formation of inflammatory membrane on the anterior surface of IOL; (**c**) formation of inflammatory membrane on the posterior surface of IOL

Despite the favorable biocompatibility of currently used IOLs, it is still regarded as a foreign body by nature. IOL implantation in the eye can therefore induce a series of cellular immune responses, especially when the IOL is not placed in the bag (such as in ciliary sulcus fixation and asymmetric implantation, say one haptic in the bag and the other in the sulcus). In these cases, the IOL haptics may rub the uvea and induce a significant inflammatory response.

4. Residual lens matter

   Residual lens matter in the aqueous humor can give rise to the autoimmune response and lead to phacoanaphylactic uveitis.

23.2.1.2 Clinical Manifestations

In mild cases, they show signs of aqueous flare and cells in the anterior chamber (Fig. 23.2a). In severe cases, fibrinous exudates, anterior and posterior iris synechiae, pupil deformation, and inflammatory membrane formation (Fig. 23.2b, c), as well as occlusion of the pupil, iris bombe, and secondary glaucoma, can be detected. Generally, the inflammatory response is more pronounced in pseudophakic eyes than in aphakic eyes.

23.2.1.3 Prevention and Management

1. Preoperative

The pupil should be dilated adequately and NSAIDs should be applied if necessary.

2. Intraoperative
   1. Be aware of the incision construction, to prevent irritation to the iris induced by iris prolapse.
   2. Reduce the frequency of the instruments moving in and out of the anterior chamber.
   3. Clear lens matter as thoroughly as possible.
   4. Achieve in-the-bag IOL implantation in order to reduce the contact and abrasion between IOL and the surrounding tissues. This helps to release postoperative uveal complications.
   5. Irrigate the anti-inflammatory drugs into the anterior chamber. Studies have shown that the addition of heparin in irrigating solutions reduced postoperative inflammatory responses and inflammation-related complications, including posterior iris synechiae, pupil dislocation, and IOL decentration [5]. Additionally, intracameral injection of triamcinolone acetonide could relieve anterior segment inflammation and prevent visual axis obscuration (VAO) [6]. Moreover, application of intracameral recombinant tissue plasminogen activator (r-TPA) during cataract extraction, anterior vitrectomy, and IOL implantation is effective in inhibiting the inflammatory response and preventing fibrinous membrane formation [7].
   6. Implant heparin-surface-modified (HSM) IOLs to control inflammation and pigment deposited on the surface of the IOL [8].
3. Postoperative
   In most cases of mild postoperative inflammation, a combination of the topical short-acting mydriatics, corticosteroids, and NSAIDs can control the inflammation, while in severe cases, systemic corticosteroids or NSAIDs should be added. However, potent mydriatics are not generally recommended because of the risk of pupillary capture of the IOL. When inflammatory membranes block the visual axis or cause pupillary occlusion, Nd:YAG laser may be performed to retract the membranes. If the inflammatory membranes are too thick for laser therapy, membranectomy may be considered.

23.2.2 Toxic Anterior Segment Syndrome

TASS is an aseptic inflammation following anterior segment surgeries [9]. It is associated with substances with incorrect pH, concentration, or osmolarity, gaining access to the anterior chamber, such as irrigating solutions, antibiotics, OVDs, and residue left behind by substances used during the cleaning and sterilization of instruments and resulting in cytotoxicity and tissue injuries.

The most common manifestations of TASS include acute diffuse corneal edema, pupil dilation and fixation, ocular hypertension, and anterior chamber inflammation with or without significant pain. Since children are often too young to describe their complaints properly, detailed examinations are essential and endophthalmitis should be considered in the differentiation.

The preventive methods of TASS include following standardized procedures for cleaning and sterilizing intraocular surgical instruments, avoiding preservatives during and after surgery, and ensuring rational use of intraocular drug dosage and concentration.

The main treatment of TASS is topical and systemic application of corticosteroids to control inflammation and reduce tissue damage. Huang et al. [9] reported that though corneal edema and inflammation were controlled after aggressive treatment, cornea opacity and pupil deformation still remained, which indicates that to deal with TASS, the emphasis should be put on prevention.

23.2.3 Implantation Cyst of Iris

Cases of implantation cyst of iris after cataract surgery are rare, most of them are traumatic cataract patients. Generally, this disease has a long course and progresses very slowly. It is caused by conjunctival or corneal epithelial cells growing along the wound and slowly migrating into the iris stroma (Fig. 23.3). The cysts are most likely found to grow at the root of the iris and are filled with a white sticky fluid. They seldom cause pain but could result in various degrees of visual axis occlusion, uveitis, and corneal edema. Large cysts may even cause severe complications, including obstruction of anterior chamber angle, IOP elevation, and secondary glaucoma.

For small cysts, laser treatment is feasible with a certain risk of recurrence, while for large cysts, surgical excision combined with local iridectomy is necessary. In order to prevent recurrence, the cysts should be excised integrally and completely.

23.3 Complications Associated with the Lens Capsule

23.3.1 Posterior Capsular Opacification (PCO)

PCO is one of the most common complications after pediatric extracapsular cataract extraction (ECCE) surgery and can occur as early as 1 week postoperatively. The pathogenesis and prevention of PCO are described in detail in Chap. 24.

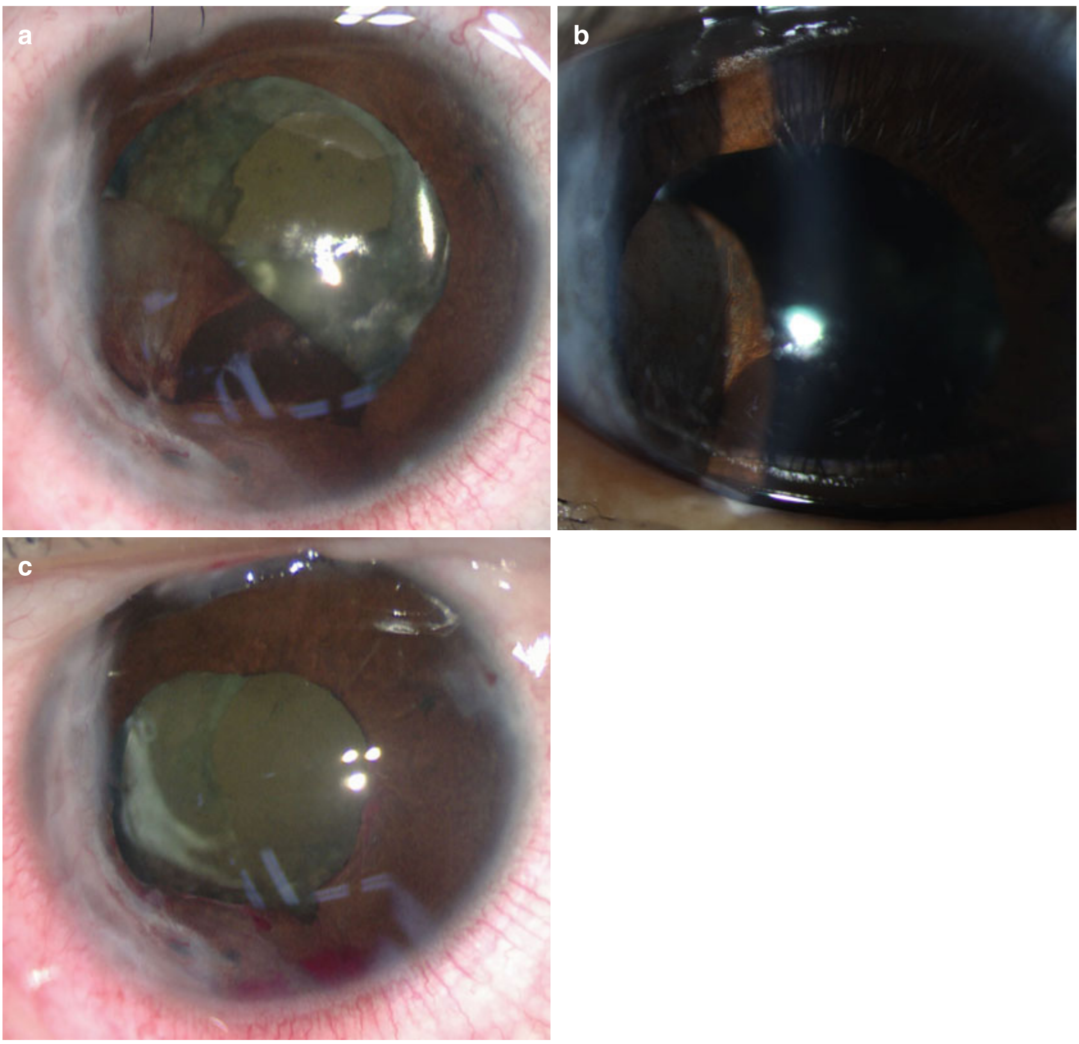

Fig. 23.3 Implantation cyst of iris. A 5-year-old boy with traumatic cataract underwent cataract extraction surgery combined with IOL implantation 1 year after surgery. (**a**) Iris cyst adherent to the nasal corneal wound; (**b**) slit-lamp examination; (**c**) 1 week after local iridectomy of the cyst

23.3.2 Capsular Shrinkage

Capsular shrinkage usually occurs 3–30 weeks after cataract surgery, manifesting as the decreasing of capsular diameter on the equator, combined with anterior capsule cystic fibrosis and diminished capsulotomy opening [10]. Factors such as surgical injuries, irritation of IOL material, inflammatory reaction, and disruption of the blood-aqueous barrier, stimulate residual lens epithelial cells to proliferate and transform into fibroblasts. These fibroblasts highly express α-smooth muscle actin and produce large amounts of collagen and other extracellular matrix which accumulates between the retained anterior capsule and IOL optic zone, leading to anterior capsule cystic fibrosis and turbidity. Additionally, α-smooth muscle actin from the fibroblasts contracts and pulls the capsulotomy opening toward the center and results in capsular shrinkage. The shrunken capsule may contribute to IOL dislocation or IOL capture, leading to postoperative diplopia, glare, and refractive errors, severely affecting the recovery of visual acuity.

The following advice may help to prevent capsular shrinkage: gentle surgical manipulation, avoidance of iris and blood-aqueous barrier damage, and the alleviation of postoperative inflammation. Furthermore, the diameter of capsulotomy openings should be controlled to around 5 mm. Small openings are prone to capsular shrinkage [11]. Moreover, IOL materials with good biocompatibility, such as acrylic IOL, can be chosen to reduce the IOL irritation to the capsule [12]. When capsular shrinkage induces IOL dislocation and affects the visual function significantly, Nd:YAG laser may be applied for anterior capsulotomy, while more severe cases will require surgical treatment.

23.4 Complications Associated with IOL

Compared with adults, inflammation responses are more severe, and the incidence of IOL-related complications is higher in children. The younger the patient, the higher the incidence of severe complications.

23.4.1 IOL Malposition

IOL malposition is associated with inflammation, incomplete openings during capsulotomy, organization and contraction of the capsule, asymmetric fixation of the IOL (a haptic in the bag, the other in the sulcus), IOL quality, residual lens matter, and lens epithelial proliferation following the cataract surgery.

Mild IOL malposition manifests as IOL decentration (Fig. 23.4a) and can only be detected after mydriasis. Generally, it requires no special treatment other than follow-up observation regarding changes in the IOL location and refractive error. Severe IOL malposition, shown as IOL dislocation (Fig. 23.4b) or IOL capture (Fig. 23.5), may contribute to monocular diplopia or high degree of astigmatism, significantly affecting the visual function. Pupillary capture of the IOL can also result in secondary increase of IOP. Surgery is often needed to reposition or remove the IOL. The indications and surgical techniques of repositioning and explantation are described in detail in Chap. 25.

23.4.2 Deposits on the IOL Surface

Deposits on the IOL surface are more common in children than adults, which may be related to the immature blood-aqueous barrier and intense postoperative inflammation. It is also associated with the size, location, and quality of the IOL. If the IOL is too small, it is movable inside the eye and may rub the uvea, resulting in IOL surface deposits. Compared with sulcus-fixated IOLs, the in-the-bag fixation of IOLs has a lower occurrence of deposits, and the severity is minimal, because in-the-bag implantation reduces the chances of abrasion between the IOL optic and the surrounding tissue. The deposits can be pigmented (Fig. 23.6) or nonpigmented. No special treatment is required if the visual acuity is not affected. However, if the visual acuity is affected, it is suggested that Nd:YAG laser be employed to eliminate the deposits.

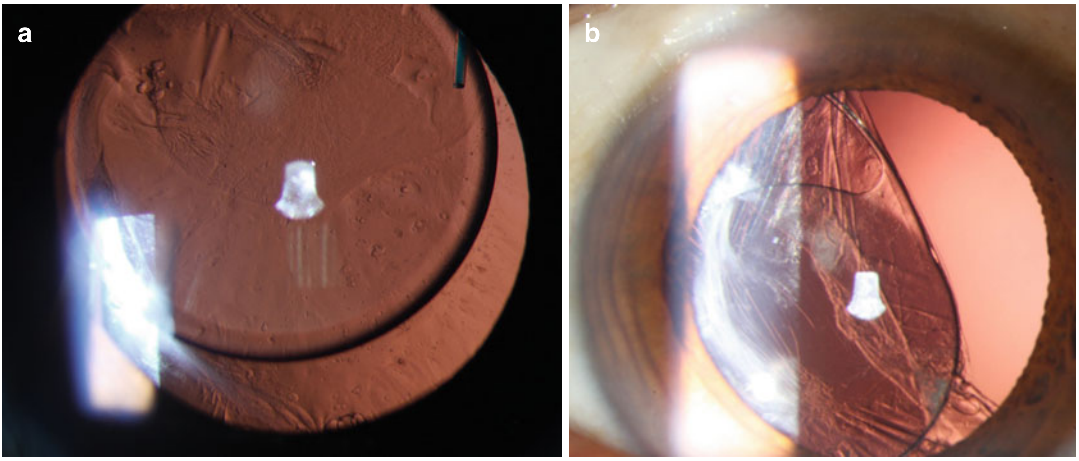

Fig. 23.4 IOL malposition. (**a**) IOL decentration; (**b**) IOL dislocation

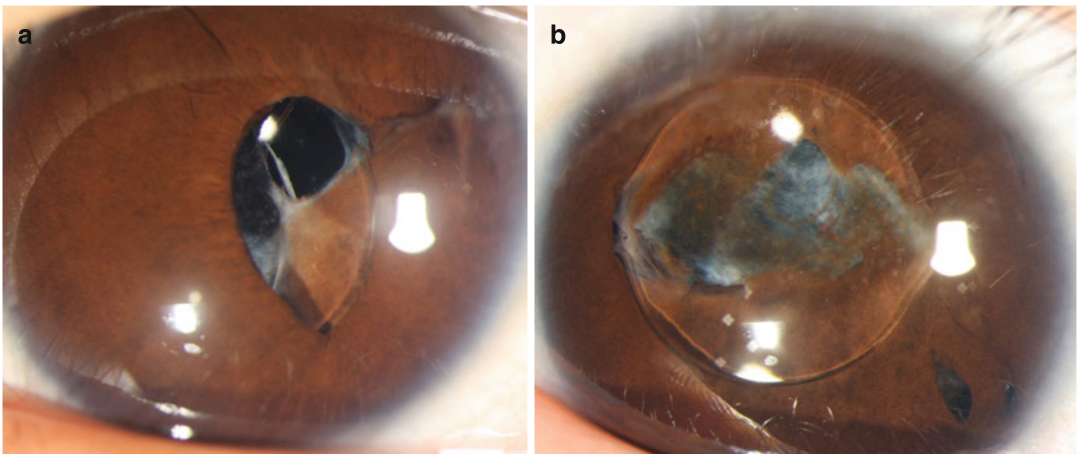

Fig. 23.5 IOL pupillary capture. (**a**) Partial pupillary capture of the IOL optic; (**b**) complete pupillary capture of the IOL optic

23.4.3 Opacification of IOL

Opacification of the IOL (Fig. 23.7) is mostly seen in silicone and hydrophilic acrylic materials [13] and is mainly associated with the biocompatibility of the IOL materials. Opaque IOL explanted from surgeries manifests calcification deposits under electron microscope examination, due to the deposition of calcium phosphate from the aqueous humor onto the surfaces or the inside of IOL. Owing to the development of IOL materials and improved production techniques over the past decades, this complication is rarely seen. Once the IOL opacification affects visual function significantly, IOL removal or exchange should be performed. Surgical techniques are detailed in Chap. 25.

23.5 Postoperative Ocular Hypertension and Secondary Glaucoma

Postoperative ocular hypertension and secondary glaucoma are major complications affecting visual function rehabilitation after pediatric cataract surgery. Postoperative ocular hypertension refers to a postoperative IOP higher than

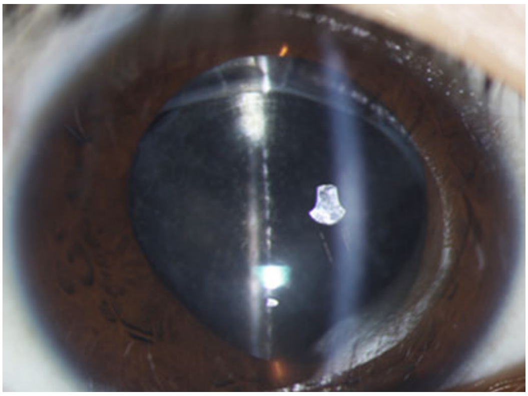

Fig. 23.6 Deposits on the surface of IOL

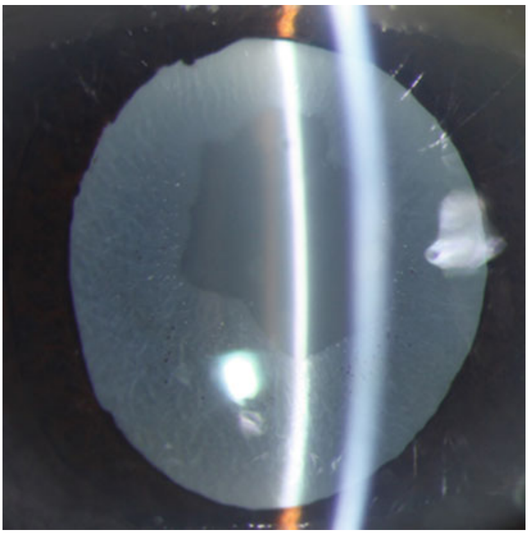

Fig. 23.7 Opacification of IOL

21 mmHg, which is a risk factor for secondary glaucoma. But apart from high IOP, the diagnosis of glaucoma also includes optic nerve damage and visual field defect. Since these children are too young to cooperate with examinations such as IOP, optic nerve, and visual field measurement, it's quite difficult to confirm diagnosis and evaluate the effect of treatments.

The reported incidence of ocular hypertension and glaucoma after pediatric cataract surgeries varies considerably (5–32 %) due to variance in the period of follow-up [14, 15]. From 2011, Zhongshan Ophthalmic Center (ZOC) has established a clinical database for pediatric cataract patients. Through follow-up observations of 206 pediatric cataract patients (379 eyes) under 10 years old for a period of 10–16 months, Lin reported that the incidence of postoperative ocular hypertension was 17.4 % [16]. Therefore, long-term follow-up of IOP measurement helps to prevent the occurrence of irreversible optic nerve damage in children following cataract surgery.

The types of secondary glaucoma following pediatric cataract surgery can be divided into two types: angle-closure and open-angle glaucoma, while the late-onset open-angle glaucoma is the most common. During the early and late postoperative period, angle-closure glaucoma can sometimes also occur.

23.5.1 Secondary Angle-Closure Glaucoma

Acute angle-closure glaucoma (Fig. 23.8) is a common complication after pediatric cataract surgery due to the limitations in surgical techniques and facilities during the past decades. With the development of surgical techniques, the incidence of this kind of complication decreases remarkably. The main cause is excessive lens cortex remnants inducing peripheral iris bombe and angle closure, while other causes are vitreous hernia and posterior synechiae (Fig. 23.9) and pupillary block due to pupillary occlusion. Francois and colleagues reviewed the causes of secondary angle-closure glaucoma after cataract surgery (Table 23.1) [17].

Chronic angle-closure glaucoma is quite rare, resulting mainly from intraocular chronic inflammation caused by residual lens matter, followed by occlusion of pupil, and finally elevation of IOP.

23.5.2 Secondary Open-Angle Glaucoma

Open-angle glaucoma is usually late onset and is the most common type of glaucoma after pediatric cataract surgery. Phelps and colleagues reviewed 18 cases with secondary glaucoma following con-

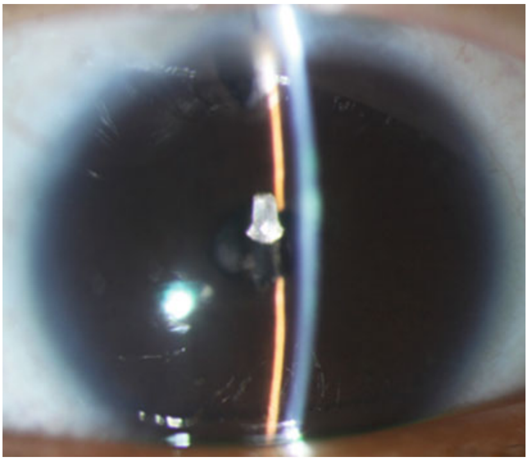

Fig. 23.8 Angle-close glaucoma after cataract surgery, showing shallow anterior chamber

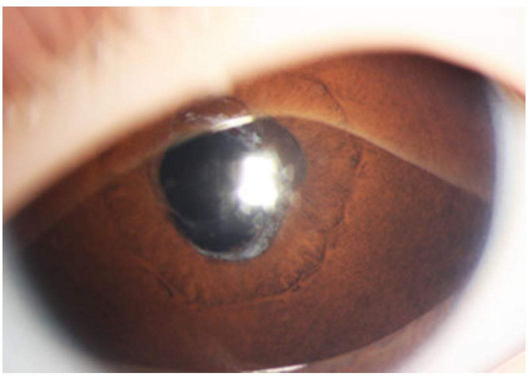

Fig. 23.9 Pseudophakic eye with pupillary posterior synechia

Table 23.1 The causes of angle-closure glaucoma after congenital cataract surgery

1. Pupillary block or peripheral anterior synechia caused by uveitis
2. Proliferative membrane and pupillary block caused by postoperative inflammation
3. Delayed formation of the anterior chamber
4. Vitreous prolapse into the anterior chamber
5. Corneal epithelium grows into the anterior chamber
6. Hyphema and intraocular hemorrhage
7. Iris prolapse
8. IOL-related glaucoma

genital cataract surgeries and reported that the IOP could elevate between 2 and 45 years following the surgeries [18]. The angle in all the above cases was open and six of them had optic nerve damage. Pathogenesis of secondary open-angle glaucoma is not yet clear. Based on present studies, it is probably associated with residual viscoelastic agents, congenital glaucoma or abnormal anterior chamber angle structure that existed preoperatively [19] and surgery-induced defects in anterior chamber angle structure and trabecular meshwork [14], combined with ocular abnormalities including microcornea, microphthalmos, poorly dilated pupils, congenital rubella syndrome, Lowe's syndrome, persistent embryonic eye vascularization, and other ocular anomalies [15]. Open-angle glaucoma is also related to surgery-induced mechanical and biochemical injuries, long-term usage of glucocorticoids, and other factors [20].

23.5.3 Examination and Evaluation

IOP elevation or glaucoma can occur months or even years after surgery and children often lack typical signs of glaucoma, such as buphthalmos, epiphora, and blepharospasm. Therefore, the postoperative IOP and the following eye conditions should be monitored regularly, especially for children with the above risk factors. Children who cannot cooperate should be checked after sedation or general anesthesia.

1. Corneal diameter measurement
   Buphthalmos or microcornea can be confirmed by measuring the corneal diameter. The IOP should be closely monitored when the corneal diameter of the affected eye is smaller than the average diameter of the same-age children. Walton et al. suggested that corneal edema, enlarged eyeball, and contact lens intolerance are early manifestations of glaucoma [21].
2. Refraction
   Drastic decrease of hyperopia may be an important sign for early diagnosis of pediatric aphakic glaucoma, as was found by Egbert. This was the earliest sign in four teenagers who subsequently developed aphakic glaucoma (six eyes). The average loss of hyperopia was 17D (9.25D to 21.00D) [22].

3. Gonioscopy
   The cause of the disease can be identified by gonioscopy examination. Open-angle glaucoma under gonioscopy shows that the root of iris is attached to the rear of the trabecular meshwork, sometimes partially covering the ciliary band or scleral crest. Pigment deposits in the trabecular meshwork may also be detected through gonioscopy. Lens fragments suggest remnant lens material.
4. Central corneal thickness
   IOP is the most important indicator for diagnosing glaucoma and is directly affected by corneal thickness. Using data from examinations of children 6 months postoperatively, Amir Faramarzi found that the central corneal thicknesses of the aphakic eyes are the largest, compared with pseudophakic eyes and normal children of the same age [23]. Although the mechanism is still unclear, the impact of corneal thickness on assessing IOP should be noted.

Regular follow-up is critical for the timely diagnosis of glaucoma after pediatric cataract surgery. It is generally recommended that a glaucoma test should be carried out every 3 months for the first postoperative year, every 6 months in the following 9 years and annually thereafter.

23.5.4 Treatment

Secondary glaucoma after pediatric cataract surgery should be treated according to its causes.

23.5.4.1 Medication

Since there are still certain risks in surgical treatment, medication is an important measure in dealing with postoperative secondary glaucoma. Compared to eyes with primary congenital glaucoma, aphakic and pseudophakic eyes are more sensitive to ocular hypotensive medication. Beta-blockers, carbonic anhydrase inhibitors (CAIs), and prostaglandin analogues are the main drugs used for lowering IOP. 1–2 % pilocarpine eye drops should be used with caution because it has a risk of inducing retinal detachment (RD) and aggravating inflammation. For IOP elevation due to postsurgical inflammation, a combination of corticosteroids, but not miotic or prostaglandin analogue drugs, is feasible.

1. Beta-blockers
   As an effective inhibitor of aqueous humor secretion, beta-blockers are the first-line drug against ocular hypertension after pediatric cataract surgery. Although beta-blockers are well tolerated by adults, it can induce severe systemic complications in infants, especially premature infants or infants with bronchospasm (asthma) or cardiovascular disorders. Therefore, before using beta-blockers in infants, clinicians should pay attention to the following aspects:
   1. A comprehensive assessment on the physical status of the child; beta-blocker is contraindicated in patients with asthma or cardiovascular disease.
   2. On the premise of effective function, use the drugs with concentrations as low as possible, for example, timolol 0.25 %.
   3. Choose the selective beta-1-blocker, for example, betaxolol 0.25 %.
   4. Minimize systemic absorption by pressing the lacrimal sac area when using eye drops.
2. Carbonic anhydrase inhibitors
   CAIs lower the IOP by inhibiting the secretion of aqueous humor. There are two modes of administration. One is oral administration. Acetazolamide (10–20 mg/kg/day), as a representative, has a stronger effect in lowering IOP and correspondingly larger side effects compared with topical CAIs. The side effects of oral acetazolamide include metabolic acidosis, diarrhea, and decreased energy levels, appetite, and weight. Therefore, the oral CAIs are only used in recurrent cases or when the topical drugs are invalid. The other mode is topical administration. Dorzolamide (Trusopt) and brinzolamide (Azopt), as representatives, may offer less systemic side effects. They are the second-line drugs for secondary glaucoma after pediatric cataract surgery and first-line drugs when beta-blocker is contraindicated.

3. Prostaglandin analogues
   Prostaglandin analogues (latanoprost and travoprost), which lower the IOP by enhancing uveo-scleral outflow, are safe and have a low incidence of systemic side effects in pediatric patients. The side effects include thickening and elongation of eyelashes, change of iris color, and eye congestion. The long-term side effects of these drugs are still not clear. They are not the first-line drugs after pediatric cataract surgeries.
4. Epinephrine agonists
   1. Alpha-2 agonist
      There are two types of alpha-2 agonist commonly used in adults: lipophilic brimonidine and hydrophilic clonidine hydrochloride. The latter goes through blood-brain barrier more easily than the former, and therefore, has larger side effects on the central nervous system. Topical brimonidine has some IOP-lowering effect in older children, especially recurrent cases in whom other IOP-lowering drugs have failed. But in infants, usage of these types of drugs may cause serious or even life-threatening systemic side effects, such as bradycardia, hypotension, hypothermia, hypotonia, apnea, and somnolence. Thus, the dosage for children should be as low as possible, such as Alphagan 0.1 % and apraclonidine 0.5 %. Side effects, such as somnolence, should be monitored.
   2. Other epinephrine agonists
   The application of adrenaline 1 % and dipivefrin hydrochloride 0.1 % is limited in pediatric cases because of their poor IOP-lowering efficacy and potential systemic toxicity (such as tachyarrhythmia and hypertension). The ocular side effects include reactive conjunctival hyperemia, melanin pigmentation deposits on the cornea and conjunctiva, and cystoid macular edema (CME).
5. Cholinergic drugs (miotic drugs)
   Cholinergic drugs lower the IOP by enhancing aqueous humor outflow in normal and high-IOP eyes; they can be used to maintain miosis before and after surgeries on anterior chamber angle or trabecular meshwork. Side effects of pilocarpine 1–2 % in aphakic or pseudophakic eyes are fewer than in phakic eyes. However, the likelihood of RD is still worth noting.
6. Hyperosmotic agents
   The glycerol 50 % solution with an oral dose of 0.75–1.5 g/kg of body weight can be added into milk, juice, and other drinks to improve adherence in children. With an intravenous dose of 0.5–1.5 g/kg of body weight and an infusion rate of 60 drops/min, mannitol 20 % solution can rapidly lower the IOP in 20–30 min, and the IOP-lowering effect can last 4–10 h. For pediatric patients, hyperosmotic agents can be used as a rapid IOP-lowering method before surgeries when conventional medications fail to control IOP.

Our present treatment protocols for ocular hypertension and glaucoma after pediatric cataract surgery are listed below.

When the IOP is lower than 25 mmHg, treatment should be performed according to the cause. For example, if the elevation of IOP is due to inflammation, NSAIDs should be applied.

When the IOP is between 25 and 30 mmHg, one of the IOP-lowering drugs, such as carteolol, should be added.

When the IOP is between 30 and 40 mmHg, two kinds of IOP-lowering drugs, such as carteolol and brinzolamide, should be used.

If the IOP is higher than 40 mmHg, three kinds of IOP-lowering drugs should be employed at the same time, for example, carteolol, brinzolamide, and brimonidine tartrate.

23.5.4.2 Laser Therapy

Nd: YAG laser peripheral iridectomy is effective in treating pupillary block glaucoma. Before laser, IOP should be controlled as low as possible. The initial laser iris hole is apt to close when intense inflammation occurs, so laser treatment may be repeated after one week to reopen it.

23.5.4.3 Surgery

1. Peripheral iridectomy
   Due to the widespread application of Nd:YAG laser, surgical peripheral iridectomy has

become the second choice of treatment. Surgical peripheral iridectomy is taken into consideration only if repeated laser peripheral iridectomy fails or severe inflammation occurs.

2. Filtration surgery with anti-fibrotic drugs
Currently, trabeculectomy is still a mainstream surgical method for aphakic or pseudophakic glaucoma. The previous reported success rate of trabeculectomy varies a lot. For children, the major cause of surgical failure is the relatively thick Tenon's capsule, active proliferation, after surgical trauma, and rapid healing of the wound. Therefore, the younger the child, the more likely they are to receive a failed surgery. The same as trabeculectomy in adults, the success rate may be improved by adding anti-fibrotic drugs intraoperatively. Mitomycin C (MMC) and 5-fluorouracil (5-FU) are commonly used anti-fibrosis drugs. However, due to the requirement of multiple postoperative subconjunctival injections for 5-FU and general anesthesia for injection in children, 5-FU is not suitable for anti-fibrosis therapy in pediatric glaucoma surgery. The dosage and duration of using MMC is still under debate. Although most clinicians believe that 0.2–0.4 mg/ml MMC for 2–3 min is safe and effective, large randomized controlled clinic trials with long-term follow-up are needed to further clarify the best dosage/duration and possible ocular/systemic complications. The intraoperative MMC-related complications include postoperative shallow anterior chamber, corneal epithelial defects, ocular hypotension with or without choroidal detachment, and severe late-onset infection. Therefore, clinicians should monitor the children regularly after surgery and teach the parents to be aware of and observe for the signs of complications.
3. Glaucoma drainage devices
For glaucoma children, glaucoma valve implantation may be considered when medications and traditional surgeries fail. The valve is designed to divert aqueous humor by making a track, usually behind the limbus or near the equator, between the anterior chamber and subconjunctival/sub-Tenon's space to lower the IOP. This surgical method effectively avoids some bleb-related and medication-related complications.
4. Cyclodestructive surgery
Cyclodestructive surgery can be used for refractory glaucoma when all the other therapies fail or in eyes with poor visual acuity [24, 25]. There are two ways to destroy the ciliary body: cyclophotocoagulation (more commonly used) and cyclocryotherapy. As an adjuvant therapy to surgery, repeated cyclophotocoagulation can be applied in the cases which are not suitable for surgery. However, the long-term success rate of cyclodestructive surgery is low and it might lead to sight-threatening complications.

23.6 Posterior Segment Complications

23.6.1 Cystoid Macular Edema

CME, the pathological change with characteristic cystoid spaces, is the retinal thickening of the macula caused by the blood-retinal barrier disruption, perifoveal retinal capillary leakage, and fluid accumulation in the inner retina of the macula area (outer plexiform layer and inner nuclear layer). Possibly due to the tight vitreoretinal adherence in children, the incidence of CME after pediatric cataract surgeries is relatively low. However, CME should be taken seriously because it is harder to be monitored in children than in adults, and once it happens, the rehabilitation of the visual function will be affected considerably.

23.6.1.1 Etiology

Pathogenesis of CME after cataract surgery is not yet clear. The major influencing factors include vitreomacular traction, intraocular inflammation, and postoperative ocular hypotension. Intraoperative posterior capsule rupture and disturbance to the vitreous are both definite risk factors for postoperative CME. While preventing the PCO, a postoperative complication with very high incidence, prophylactic posterior capsulotomy and anterior vitrectomy increase the incidence of CME. In order to explore the impact of phacoemulsification combined with posterior capsulotomy and anterior vitrectomy on macular thickness in children with congenital cataract, we tested macular thickness in 60 children during surgeries (tested under general anesthesia immediately after surgeries) and one week after surgeries by OCT examination. This study showed that 15 % (9/60) patients had remarkably increased macular thickness or even macular edema in 1 week postoperatively and indicated that the congenital cataract surgery combined with anterior vitrectomy may have a certain degree of influence on the patients' macular region.

23.6.1.2 Clinical Manifestation

Mild CME patients may show no obvious symptoms or just mild decreased visual acuity. Except for loss of the foveal reflex, no sign will be found under ophthalmoscopy examination. For severe cases, significant decrease in visual acuity, central scotoma, metamorphopsia, micropsia, and characteristic signs of retinal thickening and edema of the macula may be shown. But for infants, the symptoms and signs are hard to detect in the early period because of their vague complaints and poor adherence. The possible presence of amblyopia in children themselves may further enhance the difficulty in evaluating the visual function.

Usually, the CME occurs 4–16 weeks after cataract surgeries. There are also some late-onset cases with CME occurring in postoperative 7–16 years.

23.6.1.3 Examination

1. Direct/indirect ophthalmoscopy
   Retinal thickening of the macula and the characteristic cystoid spaces caused by accumulation of fluid can be observed in typical cases.
2. Fundus fluorescence angiography (FFA)
   FFA is used to assess the permeability of the blood-retinal barrier. Usually, sodium fluorescein is taken intravenously. But for infants and young children, there are two options:
   1. Intravenous administration
      It is the same as adults.
   2. Oral administration
      Oral administration may be chosen to avoid the potential risk of systemic complications caused by intravenous administration in children. For children weighing less than 25 kg, 0.5 g of fluorescein is suggested to be added into 50 ml juice (fluorescein 10 %) and taken orally. For children weighing 25–50 kg, 1 g of fluorescein in 100 ml juice (fluorescein 10 %) is prescribed. The plasma fluorescein concentration at about 30 min after oral administration is close to the level at late venous phase with intravenous administration, and it will last for about 2 h. For children with CME, macular fluorescein leakage can be observed by cobalt blue filter of direct ophthalmoscopy with the most significant leakage occurred in 45–60 min after oral administration. Many studies had already confirmed the safety and effectiveness of oral administration of fluorescein for examination in children.
3. Optical coherence tomography
   OCT is a tomography imaging method with high resolution and scanning speed. With the help of OCT, retinal microstructure and changes to the macula can be observed from a two-dimensional or a three-dimensional perspective view, the retinal thickness of the macula can be quantitatively measured, and the characteristic structural changes of the retinal layers can be qualitatively described (Fig. 23.10). In essence, OCT provides a theoretical basis for diagnosis and treatment of macular disease during the early period after cataract surgery.

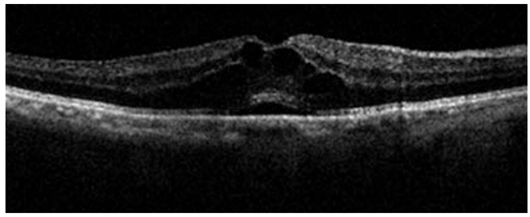

Fig. 23.10 OCT image of CME after cataract surgery. Patient, 6 months old, 1 week after phacoemulsification combined with anterior vitrectomy, OCT examination showed CME

23.6.1.4 Prevention and Management

Intraoperative vitreous disturbances and postoperative inflammation can both induce the occurrence of CME, but some perioperative managements may lower its incidence.

1. Preoperative preparation
   Preoperative usage of topical NSAIDs is effective in prevention of intraoperative miosis and postoperative CME. However, there is still a lack of evidence about using it in children. For children with preexisting glaucoma, preoperative withdrawal of some antiglaucoma drugs, such as pilocarpine for 2 weeks and latanoprost for 8 weeks before surgery, is also a useful approach for prevention. For children with preexisting uveitis, cataract surgery should not be performed during the active inflammatory period.
2. Intraoperative precautions
   1. Tunnel incision, closed surgery, and stable anterior chamber can minimize the incidence of intraoperative ocular hypotension, iris prolapse, and damage.
   2. If anterior vitrectomy is performed in the first-stage operation, posterior capsule continuous circular capsulorhexis (PCCC), compared with other methods of posterior capsulotomy, is the best method for maintenance of the stability of the vitreous. It plays a role in restricting the movement of vitreous, preventing vitreous prolapse into the anterior chamber or even incision incarceration and, thereby, ameliorating the vitreomacular traction during vitrectomy.
   3. In-the-bag implantation of IOL can form a barrier between anterior and posterior segments and, therefore, maintains the stability of the posterior segment. Additionally, the in-the-bag IOL can reduce the IOL's mechanical abrasion to its surrounding tissue which consequently lessens postoperative uveal reaction. Therefore, it is effective in lowering the incidence of CME.
   4. Ensure the incision is sealed at the end of surgery.
3. Postoperative managements

Anti-inflammatory treatment is the key in prevention and management of CME.

1. Steroids
   Although there are some side effects associated with the application of steroids in children, short-term topical usage is still necessary. For cases with persistent postoperative macular edema, oral or intravenous steroids are both feasible. Intravitreal injection of long-acting corticosteroids, such as triamcinolone acetonide, has a certain effect on CME. But IOP should be monitored regularly, and once it elevates, treatment should be taken.
2. NSAIDs
   Topical application of NSAIDs, such as diclofenac sodium 0.1 %, ketorolac 0.5 %, and indomethacin 1.0 %, can effectively reduce the incidence of CME. They are first-line medications for CME.
3. Cycloplegic drugs
   Cycloplegic drugs can inhibit postoperative uveitis, thereby reducing the chance of CME. Especially for children with bag-fixated IOLs, topical atropine, a strong cycloplegic drug, is still safe and effective.

23.6.2 Retinal Detachment

RD is one of the most serious complications after pediatric cataract surgery. It can occur at any time, even several decades after surgery. Owing to the development of modern cataract surgical techniques, the incidence of RD has decreased markedly. However, once it happens, it will notably affect the postoperative rehabilitation of visual function in children.

23.6.2.1 Etiology

The incidence of RD after pediatric cataract surgeries is about 1 %, without clear pathogenesis. The risk factors are high myopia, periphery retinal degeneration, intraoperative posterior capsular rupture, and vitreous prolapse.

23.6.2.2 Clinical Manifestations

The postoperative clinical manifestations of RD in children are similar to adults. However, it is harder to identify in children in the early stages because of their vague complaints and poor adherence to examination. Furthermore,

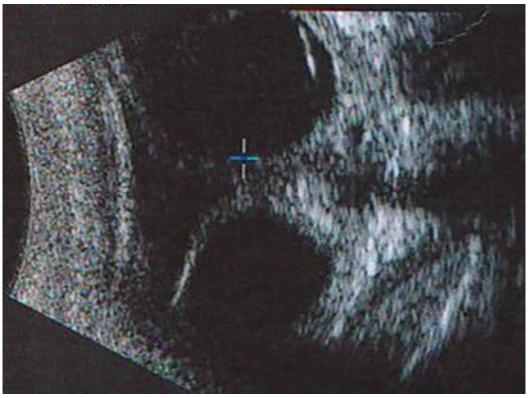

Fig. 23.11 B-scan image of choroidal detachment after cataract surgery. Patient, 8 years old, congenital glaucoma and cataract, day 1 postoperatively, B-scan image of severe choroidal spherical bulge

the formation of PCO and secondary proliferative membrane affects the fundus examination as well. Therefore, B-scan should be performed on potential RD eyes.

23.6.2.3 Management and Prognosis

Surgical methods include scleral buckling, vitrectomy with silicone oil or gas tamponade, or combinations of these techniques. Although the retina can usually be reattached, recovery of the function is influenced by many factors. The indications for poor prognosis include preoperative poor visual acuity, RD involving the macula, and severe proliferative vitreoretinopathy (PVR).

23.6.3 Choroidal Detachment (CD)

CD is an uncommon complication after pediatric cataract surgery and may occur immediately or 1 week to several months after surgery. Ocular hypotension and decreased external pressure of the choroidal vessels cause choroidal vasodilatation, and the increased permeability of the vessels thereby leads to the occurrence of CD. In eyes with concomitant congenital glaucoma and cataract, rapid reduction of IOP after surgery gives rise to a much higher occurrence of CD than in eyes without concurrent glaucoma (Fig. 23.11). Additionally, the surgical trauma and IOL irritation can induce acute uveitis, decreased production of aqueous humor, intraocular tissue edema, leakage of choroidal vessels, and therefore occurrence of CD. The major symptoms of CD are decreased vision and eye pain which cannot be precisely expressed by children. Fortunately, a B-scan can help confirm the diagnosis. Corticosteroids and hyperosmotic agents are two major medications for CD. The use of cycloplegic drugs, hyperosmotic agents, and systemic and topical corticosteroids can facilitate resolution of inflammation, recovery of aqueous humor secretion, and elevation of IOP. Then, the subchoroidal space will be closed gradually (Fig. 23.12).

23.6.4 Vitreous Hemorrhage (VH)

VH is a rare complication after cataract surgery and occurs mainly in children with persistent hyperplastic primary vitreous (PHPV) which is a disease caused by failure of fetal primary vitreous and hyaloid vasculature to regress and is often concurrent with cataract. The surgical treatment for PHPV requires vitrectomy which may induce the bleeding from the remaining vessels in the proliferative membrane and lead to postoperative VH.

Claudia reviewed the postoperative complications of 43 congenital cataract patients (65 eyes) with different medical histories, reporting that 12/65 eyes are complicated with PHPV [26]. Various degrees of VH were observed in seven eyes (58.3 %) postoperatively. Among them, fundus examinations can be performed in two eyes with mild VH, and a B-scan is required to assess the vitreous and retinal condition in five eyes with moderate to severe VH. The authors suggest that the presence of PHPV is strongly associated with the occurrence of postoperative VH.

For mild VH, the blood can clear by itself without special treatment, while vitrectomy should be performed urgently in the cases with severe VH combined with retinal hemorrhage or RD.

23.7 Infectious Endophthalmitis

Infectious endophthalmitis is a rare but devastating postoperative complication with the incidence between 0.071 and 0.45 % [27–29]. 82 % of the cases had signs of endophthalmitis presented

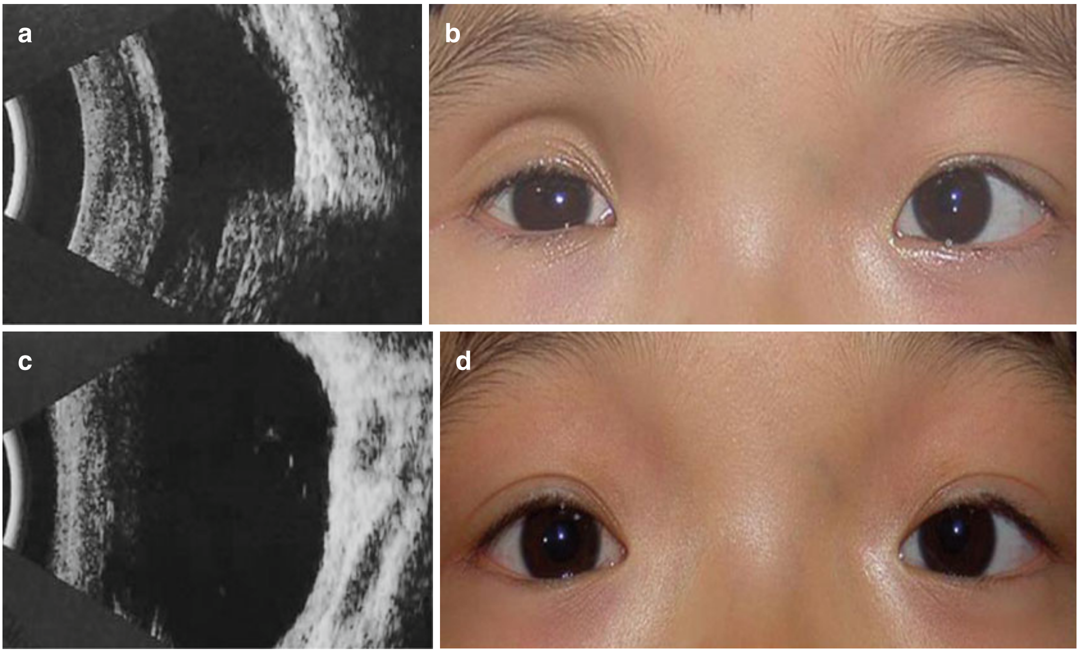

Fig. 23.12 Choroidal detachment after cataract surgery. Female patient, 8 years old, congenital cataract in the right eye, accepted phacoemulsification and IOL implantation. (**a**) Day 1 postoperatively, B-scan image of choroidal detachment; (**b**) hypotension (5 mmHg) of the right eye and enophthalmos; (**c**) day 3 postoperatively, B-scan shows ameliorative choroid detachment area and severity after being treated with corticosteroids and hyperosmotic agents; (**d**) recovery of IOP (15 mmHg) in the right eye, no apparent enophthalmos

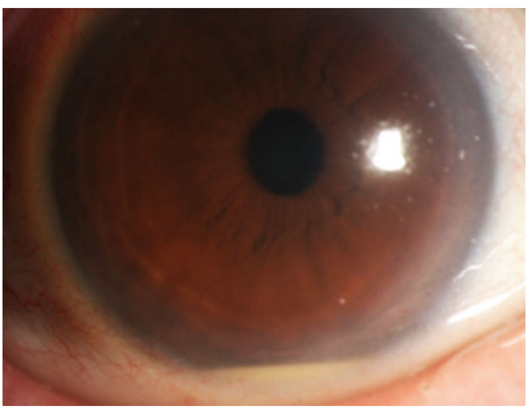

Fig. 23.13 Endophthalmitis and hypopyon after cataract surgery

within 3 days after surgery (Fig. 23.13). 65 % of the cases finally lost light perception. The difficulty in communicating with children and in differential diagnosis from uveitis,retinal tumor and other retinal diseases makes thorough postoperative examinations extremely important for early diagnosis of infectious endophthalmitis. The most common causative organism for postoperative endophthalmitis was gram-positive bacteria which accounted for 94 % of the infections. Among them, *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Streptococcus*, *Enterococcus*, and other gram-positive bacteria accounted for 70 %, 9.9 %, 9 %, 2.2 %, and 3 % infections, respectively. Only 5 % of the endophthalmitis were caused by gram-negative bacteria [30].

23.7.1 Risk Factors

1. Ocular and systemic infectious factors
   The infectious factors include nasolacrimal duct obstruction, dacryocystitis, blepharitis, upper respiratory tract infection, meningitis, urinary tract infections, and other endogenous infectious factors.
2. Incision construction
   As the surgical incision provides an entry for the pathogens, it plays a key role in the occurrence of postoperative endophthalmitis. There

were studies reported that transparent corneal incision increased the risk of infectious endophthalmitis. Since children are physically active and vulnerable to trauma, willing to rub their eyes, and have a poor adherence to medications, the construction of a watertight incision is particularly essential for them. The scleral tunnel incision from a superior approach with suture closure is preferred in pediatric cataract surgery because it makes the incision under multiple protections from suture, conjunctiva, upper eyelid, and Bell's phenomenon.

3. Surgical operation and intraoperative complications
Long-duration surgery, frequent movement of surgical instruments in and out of the eyes, repeated iris prolapse and posterior capsule rupture, and other intraoperative complications can increase the likelihood of postoperative inflammation.

Pediatric postoperative endophthalmitis has its own characteristics: lack of complaints, easy misdiagnosis, high blindness rate, and various infection routes. Good and colleagues reported three cases of postoperative endophthalmitis. All of them had symptoms of nasolacrimal duct obstruction and upper respiratory tract infection [28]. This indicated that systemic examination of upper respiratory tract and nasolacrimal duct before surgery is essential for children. Additionally, surgeons should be aware of that surgeries on both eyes at the same time may increase the likelihood of endophthalmitis. Therefore, two eye surgeries should be prepared and sterilized as two separate operations.

23.7.2 Prevention

Endophthalmitis is a disaster once it occurs. Therefore, prevention, with the aim of minimizing the ocular surface flora, is essential in the perioperative period

1. Preoperative usage of topical antibiotics
Although it is still under debate whether the preoperative usage of antibiotics decreases the incidence of postoperative infection, topical antibiotics are used routinely before surgery. Commonly used antibiotic eye drops include lincomycin, ofloxacin, levofloxacin, and tobramycin. According to research [31], bacterial clearance rates for conjunctival sac after using topical antibiotics were 70.59 %, 94.74 %, 100 %, and 89.47 %, respectively.
2. Povidone iodine
Preoperative povidone-iodine preparation is a recognized procedure in preventing postoperative infection. With povidone-iodine10 % sterilization for skin around the operation area and topical povidone-iodine 5 % maintenance in conjunctival sac for several minutes before balanced salt solution (BSS) washout, ocular causative organisms can be effectively killed without severe corneal complications. Domestic and international studies showed that application of povidone-iodine reduced the incidence of postoperative endophthalmitis [31, 32].
3. Intracameral injection of antibiotics at the end of operation
Intracameral injection of antibiotics at the end of an operation is an efficient way in preventing the postoperative infectious endophthalmitis. But the toxicity and antibiotic resistance should be taken into consideration. The widely used intracameral antibiotics are cephalosporins and vancomycin. Cephalosporins mostly consist of cefazolin, cefuroxime, and ceftazidime. As the first generation of cephalosporin, cefazolin possesses strong antibacterial activity against gram-positive bacteria. But it is utilized less and less today due to its narrow antimicrobial spectrum. Cefuroxime, the second generation of cephalosporin, is the most widely used cephalosporin at present. Compared with the first generation of cephalosporins, it has stronger antibacterial activity against pneumococcus and gram-negative bacteria but weaker ability against *Staphylococcus aureus*. Generally, the concentration for intracameral delivery is 1.0 mg/0.1 mL. To date, several studies reported that intracameral injection of cefuroxime lower the incidence of postoperative endophthalmitis from 0.42 to

0.13 % [33–36]. Ceftazidime, the third generation of cephalosporins, is largely applied in controlling gram-negative bacteria infection. Vancomycin is usable for serious penicillin- and cephalosporin-resistant gram-positive bacterial infections. *Staphylococcus epidermidis*, *Staphylococcus aureus*, and *Streptococcus* are all sensitive to it. The standard concentration for intracameral delivery is 0.4–1.0 mg. There was a study reported that intracameral injection of 0.4–0.8 mg vancomycin can reduce the incidence of endophthalmitis from 0.06 to 0.00 % [37].

23.7.3 Management

The treatment principle for endophthalmitis in children after cataract surgery is the same as in adults. Broad-spectrum antibiotics, rapid diagnosis, and prompt surgical intervention are crucial factors affecting the prognosis. Once the occurrence of infectious endophthalmitis is suspected, use topical and systemic broad-spectrum antibiotics after taking and testing the aqueous humor for the pathogen. If the diagnosis of infectious endophthalmitis is confirmed, topical and systemic sensitive antibiotics should be prescribed. Prompt vitrectomy and vitreous injection of sensitive antibiotics should be performed when the inflammation progresses rapidly.

It is difficult to achieve effective antimicrobial concentrations in the eyes through systemic administration, topical administration, or subconjunctival injection. The most effective way is intravitreal injection. Before injection, 0.2 ml vitreous is aspirated, smeared, cultured, and tested for antibiotic sensitivity. The popular medication for intravitreal injection is 1 mg vancomycin in 0.2 ml BSS, while intravitreal injection of 2 mg ceftazidime in 0.2 ml solution is also optional. After 24 h, sensitive antibiotic can be injected again according to the antibiotic sensitivity test.

As an adjuvant therapy, systemic usage of broad-spectrum antibiotic against gram-positive bacteria should be combined with the ones against gram-negative bacteria. Change the antibiotics if the used drugs are different from the result of the antibiotic sensitivity test or the treatment is invalid in 3 days. In addition to the systemic high dose combination antibiotics, intravenous corticosteroids should be used to lessen the retinal toxicity caused by inflammation.

23.8 Summary

The distinct developmental and structural characteristics of children's eyes make the complications after pediatric cataract surgery complex and volatile, such as almost ubiquitous PCO and the remarkably high incidence of secondary glaucoma. The choice of surgical method and IOL implantation time are also associated with the occurrence of postoperative complications. Therefore, for prevention and management of complications after pediatric cataract surgery, higher surgical techniques and thorough understanding of the various complications based on postoperative examinations are required to achieve early diagnosis, early treatment, and good postoperative curative effect.

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