Issue 2

CUTTING EDGE Glaucoma

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CUTTING **EDGE**
Glaucoma

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Traumatic Glaucoma

Zhiliang Wang, Xin Che, Jing Jiang, Yiwen Qian

Abstract

Glaucoma resulting from trauma is termed as traumatic glaucoma. Traumatic glaucoma is a branch of secondary glaucoma, so it should be called traumatic secondary glaucoma. Traumatic secondary glaucoma can be caused by penetrating, blunt, chemical, or other injuries of eye. Unlike primary glaucoma, the pathogenesis of traumatic secondary glaucoma is always complicated and the treatment is difficult. Traumatic glaucoma can be classified in different ways, but generally it is sorted by etiology. This chapter is about to introduce traumatic glaucoma induced by intraocular hemorrhage, lens dislocation, rupture of lens capsule, malignant glaucoma, neovascular, angle recession, cornea perforation, iris coloboma, and uveitis.

Keywords: Blunt trauma, Post-surgery, Intraocular hemorrhage, Lens causes, Angle lesion, Cornea perforation

Introduction

Glaucoma resulting from trauma is termed as traumatic glaucoma. Traumatic glaucoma is a branch of secondary glaucoma, so it should be called traumatic secondary glaucoma. Traumatic secondary glaucoma can be caused by penetrating, blunt, chemical, or other injuries of eye. Unlike primary glaucoma, the pathogenesis of traumatic secondary glaucoma is always complicated and the treatment is difficult. Traumatic glaucoma can be classified in different ways, but generally it is sorted by etiology. This chapter is about to introduce traumatic glaucoma induced by intraocular hemorrhage, lens dislocation, rupture of lens capsule, malignant glaucoma, neovascular, angle recession, cornea perforation, iris coloboma, and uveitis.

Glaucoma Secondary to Traumatic Intraocular Hemorrhage

Anterior chamber hemorrhage is the leading cause of traumatic ocular hypertension.

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Hyphema

Etiology

Hyphema usually occurs after ocular blunt trauma with blood mainly coming from iris. The intraocular pressure elevates due to obstruction of angle by blood cells, so it is a type of secondary open-angle glaucoma.

Clinical Manifestation

Hyphema often manifests as massive bleeding in the anterior chamber (Fig. 1) and a significant rise of IOP. In general, the IOP will not reach 30 mmHg when the blood level is under half of the anterior chamber, but the risk of glaucoma increases when rehemorrhage occurs in 20% of patients 5d after injury because of: a) severe iris damage and loss of ciliary body; b) blood in the posterior chamber and vitreous flowing into the anterior chamber.

Hemosiderin Glaucoma

Etiology

Repeated bleeding in the anterior chamber, vitreous, and retina. Usually caused by hemosiderin leading to sclerosis and obstruction of the trabecular meshwork, or iron deposits caused by the long-term retention of iron.

Clinical Manifestations

This type of glaucoma progress slowly. Brown iron particles are visible on the corneal parenchyma, lens, and retina (Fig. 2).

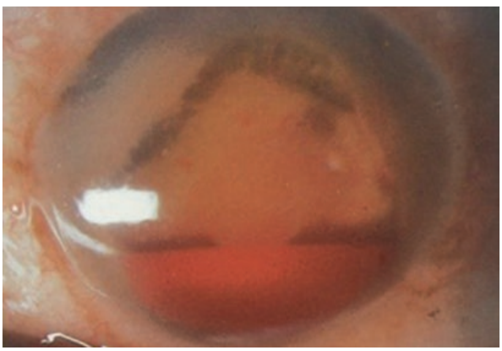


Fig. 1: Blunt injury, hyphema 1/3.

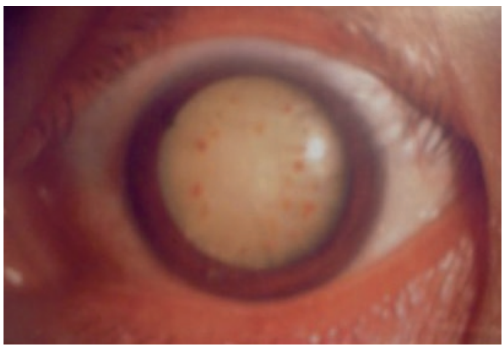


Fig. 2: Intraocular iron foreign body. Six months after trauma, brown iron particles were deposited in the angle, the posterior surface of the cornea and the anterior surface of the lens, lens opacity.

Hemolytic Glaucoma

Etiology

Hemolytic glaucoma is usually caused by vitreous hemorrhage which comes from eyeball perforation, contusion, and foreign body injury. When it occurs, the erythrocytes enter the vitreous body and erupted under the pressure of oxygen and carbon dioxide. The hemoglobin is swallowed by macrophages and entering the anterior chamber blocking the trabeculae, resulting in obstruction of the outflow of aqueous humor and a sudden increase in IOP.

Clinical Manifestations

It usually occurs about 1 week after vitreous hemorrhage (Fig. 3). Patients suddenly feel headache, eye pain, and sudden increase in IOP. Pigments and macrophages can be seen in anterior chamber angle.

Ghost-cell Glaucoma

Etiology

Ghost-cell glaucoma is an uncommon condition that occurs in association with intraocular hemorrhage. In this entity, erythrocytes degenerate in the vitreous, migrate forward to the anterior chamber through a disrupted anterior hyaloid face, and then obstruct the trabecular meshwork and cause an increase in IOP.

The RBCs in the vitreous degenerate to tan-colored spheres (ghost cells), which appear empty except for clumps of denatured hemoglobin called Heinz bodies. The ghost cells are more rigid than are normal RBCs and thus are less able to pass through the trabecular meshwork.

Fig. 3: Ocular contusion, vitreous hemorrhage for 1 week, hemocyte / Denatured hemoglobin in anterior chamber.

Clinical Manifestations

IOP depends on the number of ghost cells in the anterior chamber. Numerous brown particles can be seen in the anterior chamber. Similar to hemolytic glaucoma, but the content of aqueous humor is different.

Treatment

Glaucoma caused by intraocular hemorrhage is open-angle glaucoma. The principle is to remove intraocular hemorrhage, degenerated blood cells, and inflammatory cell components by anterior chamber irrigation or vitrectomy. Drugs can help lower the IOP.

Drug Treatment

β-Receptor blockers, α-receptor agonists, carbonic anhydrase inhibitors, hypertonic agents can be used for lowering IOP. Miotics are not recommended. Mydriatic should be used for preventing posterior synechiae.

Anterior Chamber Irrigation

Anterior chamber irrigation can be used to wash out the blood of hyphema, also the inflammatory cell components such as hemosiderin, ghost cells, and macrophages.

Vitrectomy

For patients whose IOP cannot be well-controlled through medication and anterior chamber irrigation, especially those with vitreous hemorrhage, vitrectomy is necessary.

Glaucoma Drainage Surgery

For patients with long-term intraocular hemorrhage caused by trabecular meshwork degeneration and complete obstruction of the angle outflow tract, glaucoma drainage surgery is required to control IOP.

Secondary Glaucoma by Lens Dislocation

Etiology

1. Dislocated lens in the anterior chamber (Fig. 4), causing open-angle glaucoma due to pupillary block by the synechia of lens and anterior iris.

2. Dislocated lens into the vitreous cavity (Fig. 5) makes vitreous body obstructing the anterior chamber.
3. Dislocated lens incarcerated in pupil (Fig. 6), causing angle-closure glaucoma due to elevated pressure of the posterior chamber.
4. Dislocated lens hitting ciliary body, causing excessive secretion of aqueous humor and secretory glaucoma.

Clinical Manifestation

1. Visual loss is the main symptom and iridodonesis is the typical sign. Complete lens dislocation into anterior chamber usually shows as deepened anterior chamber retroposed iris, rising IOP by vitreous body incarcerated in pupil. Narrowed or closed angle will be seen when the pupillary block occurs, which is similar to primary angle-closure glaucoma (PACG) in acute stage.
2. Repeated IOP trace is needed for diagnosis of secretory glaucoma, showing as high IOP, normal outflow facility, and vast aqueous fluid generation.

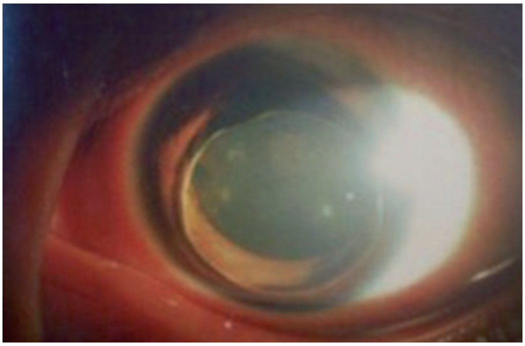


Fig. 4: Dislocated lens in the anterior chamber.

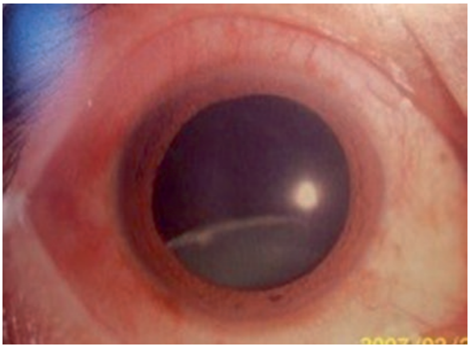


Fig. 5: Dislocated lens in the vitreous cavity.

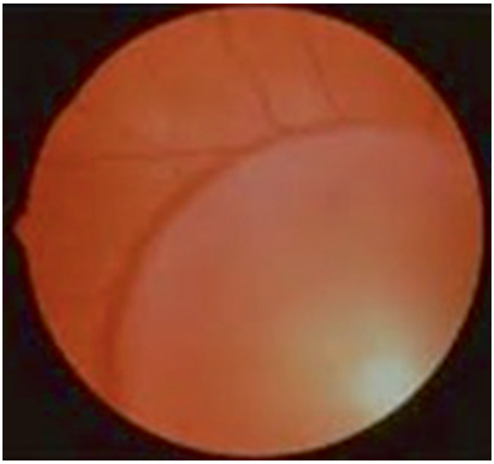


Fig. 6: Lens subluxation.

Treatment

1. Mydriasis should be performed rather than myosis.
2. IOP-lowering medication. Local use of beta-blocker, alpha receptor agonist, systemic use of hypertonic agent such as mannitol, and oral administration of carbonic anhydrase inhibitor are all optional according to the IOP level and clinical manifestations.
3. Surgery. The principle of surgery is to rebuild the aqueous humor drainage from the posterior chamber to the anterior chamber, by removing the dislocated lens and vitreous body obstructed in the anterior chamber. Based on our experience, IOL fixation to sclera without suturing (Fig. 7) is recommended.

Surgical Procedures (Video 1)

A 23-gauge vitrectomy is performed under retrobulbar anesthesia.

The conjunctiva is cut open 3.0 mm at 2 o'clock and 8 o'clock.

A 2.8 mm clear corneal incision (CCI) is made at 11 o'clock.

Two 3.0 mm long limbal parallel scleral tunnels (counterclockwise) of approximately 50% scleral thickness are created 2 mm from the limbus using a disposable syringe needle and dissected 1.0 mm from 1 side at the beginning of the scleral tunnels.

Two clockwise scleral incisions (besides the tunnel) are made using a 23-gauge needle at an angle 30 degrees above the scleral. The 2 incisions are 180 degrees from each other (usually at 2 o'clock and 8 o'clock).

3-Piece IOL is inserted into the anterior chamber.

The leading haptic is held with a forceps and then pulled out of the eye through the scleral incisions.

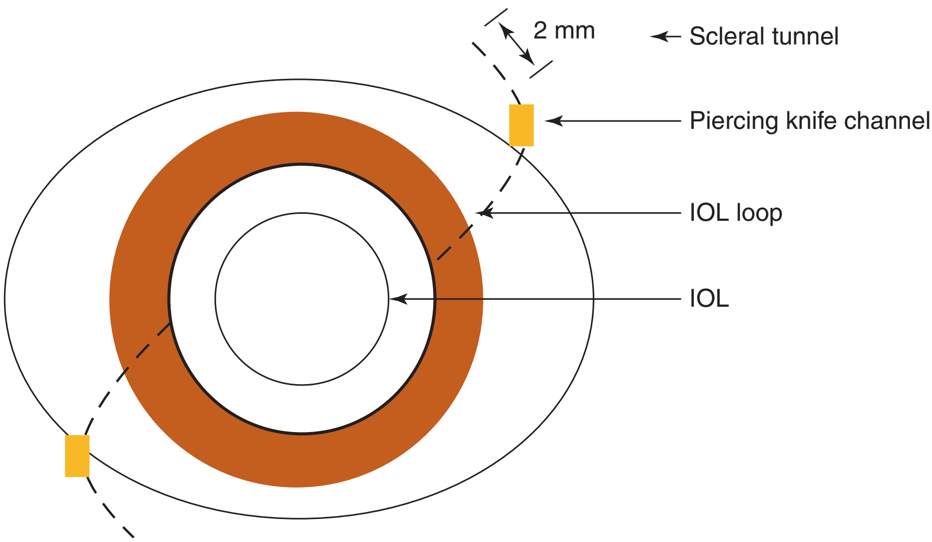


Fig. 7: Pattern diagram of IOL fixation to sclera without suturing.

The trailing haptic is held with a forceps and both haptics are externalized onto the sclera.

The haptics are inserted approximately 2.0 mm into the scleral tunnel; the IOL is centered.

At the completion of surgery, the infusion cannula is removed, and all sclerotomy sites are inspected for wound leakage.

Glaucoma Secondary to Traumatic Rupture of the Lens Capsule

Lens Allergic Glaucoma

Etiology

Lens injury may cause allergic reaction to lens substance (protein) and fibrin exudates block the angle of the chamber, or the fibrous exudative membrane forms membrane closure to exhibit the posterior aqueous humor entering into the anterior chamber, resulting in intraocular hypertension.

Clinical Manifestation

Inflammation can occur within hours or days, or as late as a few months. Uveitis can be mild or severe, with a large number of hyphema and lens fragments in the anterior chamber. When clinical signs are suspected to be allergic inflammation or severe uveitis, diagnosis of anterior chamber aspiration and diagnostic vitreous body should be performed.

Lens Particle Glaucoma

Etiology

It may be due to particles (phagocytosis of lens protein by macrophages), or the lens cortex and capsule fragments block the angle.

Clinical Manifestation

There are white lens cortex and transparent capsule fragments circulating in aqueous humor, which can also deposit on the corneal endothelium with aqueous flare and hyphema.

Phacolytic Glaucoma

Etiology

Secondary open-angle glaucoma is caused by soluble crystalline blocking the angle after trauma.

Clinical Manifestation

Red eye, pain, corneal edema, progressive increase of intraocular pressure, aqueous flare, large transparent cells (macrophages) phenomenon, small particles circulating in aqueous humor.

Treatment

On the basis of hormone and antiglaucoma drugs/IOP-lowering medicine, surgical treatment should be performed as soon as possible to remove damaged cortex and nucleus.

Traumatic Malignant Glaucoma

Etiology

1. Post-glaucoma, cataract, and other intraocular surgery, ciliary body swells and adheres with lens, causes ciliary block. As a result, aqueous humor flows into the vitreous cavity, and increases the pressure, which further pushes forward the lens-iris diaphragm, making the anterior chamber become shallow, and IOP rises sharply (Figs. 8 and 9)
2. Ciliary block glaucoma is secondary to ocular chemical injury, contusion, and perforation. Ciliary body adheres to lens due to inflammatory edema and spasm.
3. Vitreous hemorrhage, opacity, and liquefaction of traumatic vitreous are one of the conditions for aqueous humor to accumulate in vitreous body.
4. Traumatic vitreous hemorrhage, turbidity, or liquefaction is one of the conditions of aqueous humor accumulation in vitreous.

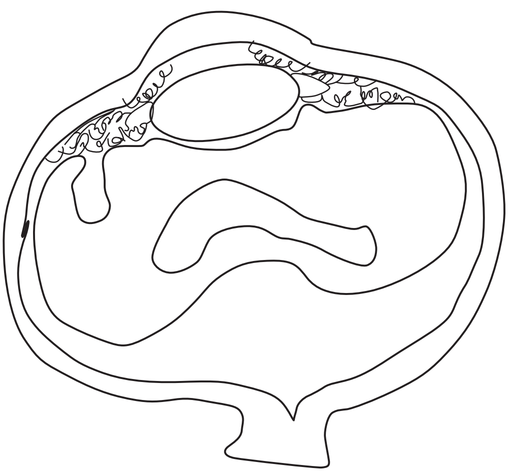


Fig. 8: Pattern diagram of malignant glaucoma.

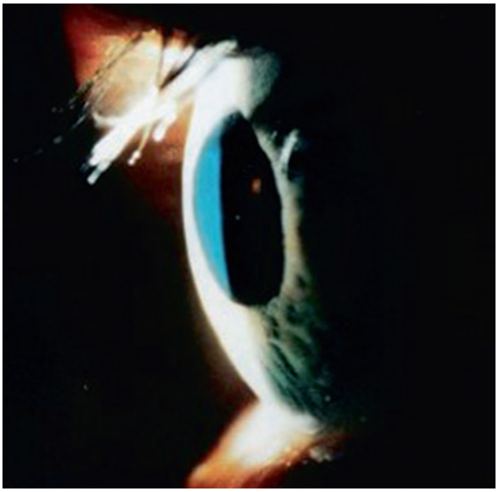


Fig. 9: Disappearance of anterior chamber.

Clinical Manifestation

1. Abnormal anatomical structures of the affected eye: Short axis, shallow anterior chamber, large lens thickness, loose suspensory ligament, and relatively anterior lens position.
2. Persistent high intraocular pressure(IOP) is an important sign. Mydriasis will increase rather than decrease the IOP. So it is called adverse glaucoma.
3. Obvious iris bombe and closed angle.

Treatment

1. The treatment of ocular trauma according to the different causes.
2. Treatment of malignant glaucoma:
   (a) IOP-lowering drugs: Atropine: dilate the pupil and prevent adhesion; hypertonic agents, carbonic anhydrase inhibitors: reduce IOP; corticosteroids: reduce inflammatory reaction. Surgery is necessary.
   (b) Laser iridotomy: promote aqueous humor drainage into the anterior chamber, but it does not relieve the pressure of lens-iris diaphragm forward. Moreover, iridotomy is easy to be blocked by inflammatory exudates.
3. Anterior vitrectomy

The principle of treatment is to reverse the aqueous humor drainage from vitreous body, lens suspension ligament, and iris terminal. Reverse the lens-iris diaphragm to anatomical position to make the posterior aqueous humor can enter the anterior chamber, and reopen the angle.

4. Glaucoma drainage

For patients with complete angle occlusion caused by malignant glaucoma, glaucoma drainage surgery should be performed on the basis of anterior vitrectomy to control IOP.

We improved the success rate of anterior vitrectomy significantly through local minimal invasive vitrectomy.

Case Presentation

The patient was treated for "eye pain with visual loss for 2 months after trabeculectomy in the both eyes."

Ophthalmic Examination

VOD: 0.15, VOS: LP TOD:30 mmHg, TOS:27 mmHg, Ocular axis: R 20.04 mm, L: 20.06 mm.

Anterior chamber disappeared, the pupil was irregular, the lens was opacity, optic papilla was pale in both eyes, C / D = 0.8 (Figs. 10, 11, 12, and 13).

Surgical Procedure (Video 2)

1. Partial PPV

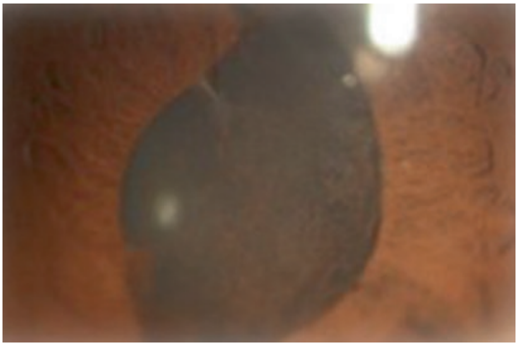


Fig. 10: Malignant glaucoma: pupilloplegia, anterior synechia (right eye).

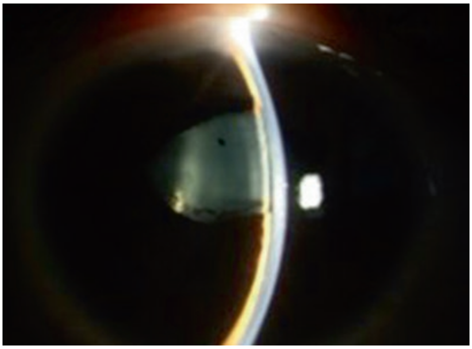
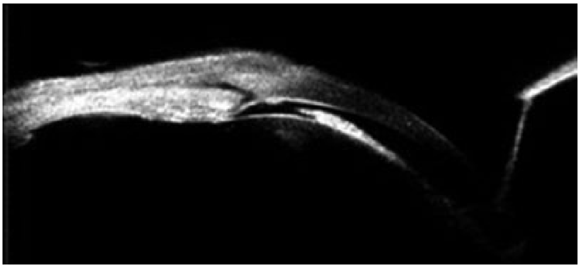


Fig. 11: Anterior chamber disappears (left eye).

Fig. 12: UBM shows that anterior chamber is very shallow, the lens-iris diaphragm moves forward, iris bombe, the anterior synechia, the angle closed (the right eye, the left eye).



After the routine disinfection and retrobulbar anesthesia, a 23-gauge vitrector was inserted into the vitreous cavity via a self-healing incision about 3.5 mm after limbus on the same median of preexisting peripheral iridectomy. No infusion or illumination was needed. Then partial vitrectomy was performed until approximately 0.5 ml vitreous was removed from the anterior vitreous cavity just behind the position of iridectomy.

2. Phacoemulsification and IOL implantation
3. Zonulohyaloidectomy and posterior capsulectomy

The partial vitrectomy was performed again to confirm that vitreous behind the peripheral iridectomy was cutted. Then the tip of the cutter was introduced carefully through this iridectomy incision forward the anterior chamber to achieve a zonulohyaloidectomy. Finally, in the central zone, the posterior capsular of about 4 mm in diameter was cut with the help of vitrector to prevent the occurrence of posterior capsular opacity.

In all eyes, we realized the significant deepening of the anterior chamber by the flow of aqueous fluid forward. Dexamethasone 2 mg was given by subconjunctival injections and a topical treatment of tropicamide was applied for 2 weeks.

Traumatic Neovascular Glaucoma

Etiology

Be common in diabetic retinopathy (DR), retinal vein occlusion (RVO), Eales disease, and other retinal ischemic diseases. Some cases were caused by trauma. Neovascularization promotes the formation of peripheral anterior synechia (PAS) and pulls the iris to the cornea. Sometimes the neovascularization membrane covers and blocks the angle (Fig. 13).

Clinical Manifestations

1. Usually a late complication of trauma, but maybe advanced when traumatic uveitis is severe.
2. Secondary to severe vascular injury, recurrent fundus hemorrhage and uncontrollable traumatic uveitis, or serious lens injury and residual cortex.
3. The main basis of diagnosis is the history of ocular trauma, persistent intraocular hypertension, and rubeosis of iris. Gonioscopy showed angle adhesion and vascular membrane formation.

Treatment

1. IOP-lowering medication
2. Intravitreal injection of anti-VEGF drugs: promote the regression of NV, reduce intraocular pressure (IOP), and create conditions for subsequent surgery.
3. Glaucoma drainage surgery (Fig. 14): due to severe inflammatory reaction, trabeculectomy, which may cause scar adhesion is not recommended. The short-term effect of glaucoma valve implantation is better. Cyclocryosis is one of the effective methods at present in recent years, but it causes damage.
4. Treatment of disease causes: Vitrectomy or panretinal photocoagulation (PRP) and other treatments to reduce the ischemic state of intraocular tissue.

Glaucoma Secondary to Traumatic Angle Recession

Angle recession is quite often (81%–93%) in ocular contusion. Incidence of angle recession glaucoma accounts for 2%–10% of the total.

Fig. 13: Whole iris neovascularization.

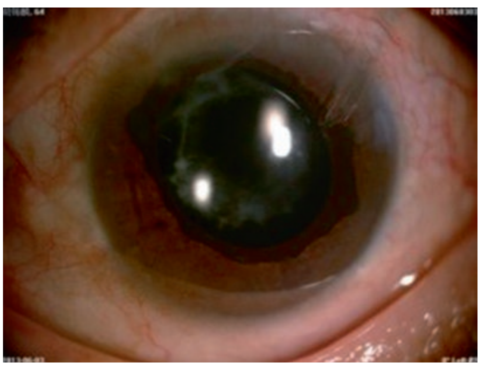


Fig. 14: Neovascularization disappeared postoperative, Valve pipe is visible.

Etiology

Traumatic angle recession is mainly caused by ocular contusion, with the separation between the circular and longitudinal muscles of the ciliary body (Fig. 15). While the longitudinal muscle is still attached to the scleral process, so the angle of the chamber is widened and deepened.

Clinical Manifestation

Gonioscopy showed the ciliary body band (CBB) widened. The peripheral anterior chamber was deepened, and the terminal of iris moved backward.

Treatment

(1) IOP-lowering.
(2) Glaucoma drainage surgery: trabeculectomy is the first choice; mitomycin C can be used to reduce the scar formation of filter valve.

Low IOP Glaucoma Secondary to Traumatic Cyclodialysis

Etiology

Due to the detachment of the whole ciliary body from the sclera after ocular contusion (Fig. 16). The adverse flow of aqueous humor into the superior ciliary cavity leads to ciliary body detachment, secondary low intraocular pressure glaucoma, macular edema, and other complications.

Clinical Manifestations

Pupil deformation, peripheral anterior chamber deepening, intraocular pressure lower than normal, retinal edema and thickening, macular edema can cause visual loss. Gonioscopy shows a gap between iris and sclera, which is distinguished from ciliary body detachment.

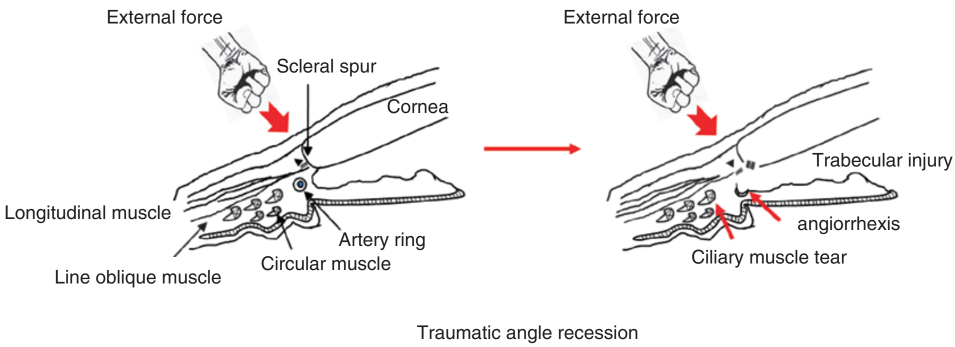


Fig. 15: Pattern diagram of traumatic angle recession.

Treatment

Local therapy can be applied to patients with mild ciliary body detachment and without significant visual loss. Surgery is necessary if macular edema happens (Fig. 17).

Medication

Corticosteroid eye drops, especially dexamethasone can help increase IOP and reduce intraocular inflammation. Mydriasis also helps to increase IOP.

Surgical Procedure (Video 3)

The surgery is performed under retrobulbar anesthesia.

After preoperative marking of the location of the cleft at the limbus, the conjunctiva is opened at the limbus with this peritomy extending 30° beyond both ends of the cyclodialysis cleft.

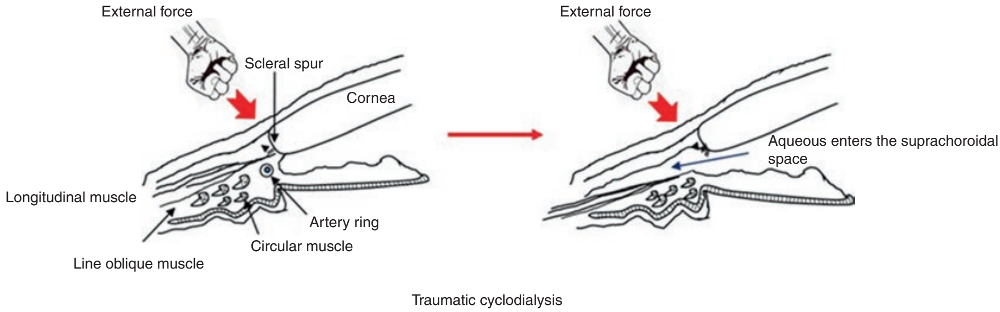
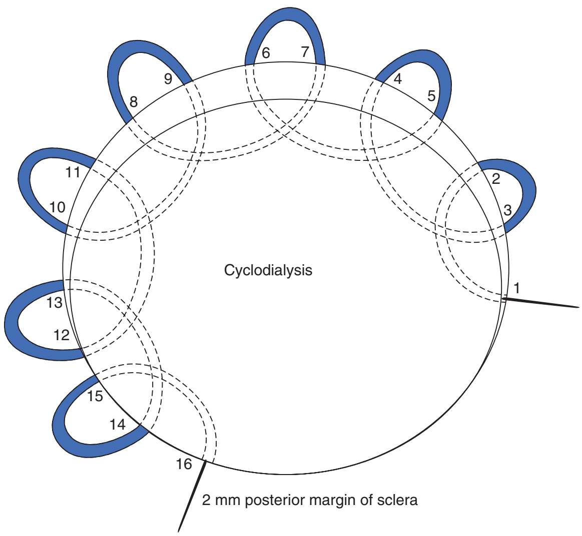


Fig. 16: Pattern diagram of traumatic cyclodialysis.

Fig. 17: Pattern diagram of the suture of cyclodialysis.



The infusion cannula is first set to maintain the intraocular pressure.

Phacoemulsification is performed under low flow rate (infusion bottle height 30 cm).

A 13-mm Morcher Type 1 L CTR, a modified Cionni type CTR with 1 eyelet, is then inserted into the capsular bag.

A foldable posterior chamber intraocular lens (IOL) (AR40e, AMO) is implanted in the capsular bag through the corneal tunnel.

Then a three-port pars plana vitrectomy is performed.

After removal of the vitreous body, one of the two long curved needles of a double-armed 10/0 polypropylene thread is pierced into the eye through the sclera 2 mm from the limbus and passing from the inside of the eye through the ciliary body and sclera to the outside of the globe.

The continuous and cerclage sutures are parallel to the limbus and we do every 3 sutures/quadrant.

After all the cyclodialysis clefts are repaired, the sutures on both ends of the cleft are fixed on the sclera.

The knots of the suture are placed on the surface of the sclera and are covered by conjunctiva. The length of the thread ends is longer than 3 mm so that the thread ends are located tensionless under the conjunctiva without great risk of piercing through the conjunctiva.

After re-fixation of the ciliary body, the retina is carefully checked and to address a retinal detachment if present.

At the completion of surgery, the infusion cannula is removed.

The conjunctival incisions are closed with 8–0 absorbable sutures.

Glaucoma Secondary to Corneal Perforation

Etiology

Corneal perforation with serious iritis is prone to peripheral anterior synechia (PAS) (Figs. 18 and 19). Iris prolapse caused by corneal perforation can cause adhesive corneal leukoplakia if not handled properly, causing secondary angle closure glaucoma.

Clinical Manifestation

1. Be similar to the symptoms of acute angle closure glaucoma attack.
2. Intraocular hypertension; corneal leukoplakia, corneal scar will affect the results of IOP.
3. PAS and anterior chamber angle occlusion.

Treatment

(1) IOP-lowering medications.
(2) Partial iridectomy or filtering operation was selected according to the synechia.

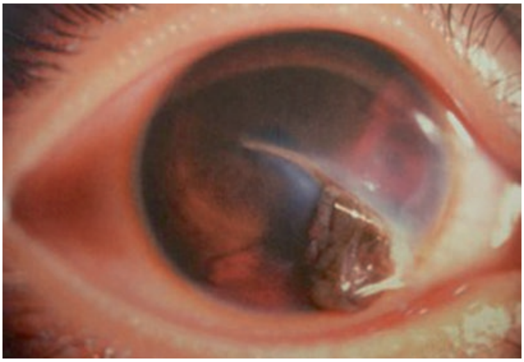


Fig. 18: Sharp injury, iris prolapses, and incarcerates into the cornea.

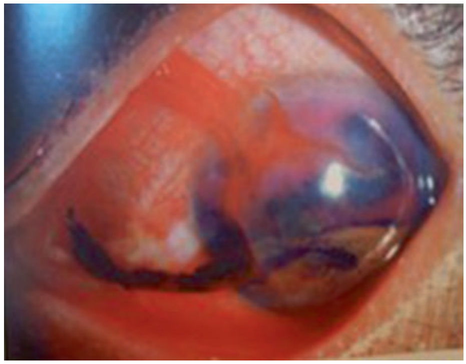


Fig. 19: Sharp injury, hyphema.

Glaucoma Secondary to Traumatic Iris Defect

Etiology

Blunt injury, sharp injury, iridectomy, and excessively broken iris are the main reasons. When the iridodialysis is over 180 degrees, iris may be curled and sinks into the angle and lead to Iris tissue necrosis, decomposition, and absorption (Figs. 20 and 21).

Pathogenesis

The residual iris in the aqueous humor, which lacks of elasticity and tension, is easy to adhere to trabeculae.

Clinical Manifestation

Acute angle-closure glaucoma can be secondary to iris defect. The patient had a sudden onset of headache, eye pain, nausea, and vomiting. Conjunctival swelling or mixed congestion, corneal edema, stubborn ocular hypertension.

Treatment

1. IOP-lowering medications.
2. Glaucoma drainage surgery such as goniotomy and trabeculectomy.

Male, 27-year old, left eye pain and blurred vision for 1 month after the blunt ocular trauma (Figs. 22 and 23).

Ophthalmic examination: VOS: 0.4, TOS: 36 mmHg.

Fig. 20: Iridodialysis occurred after blunt trauma.

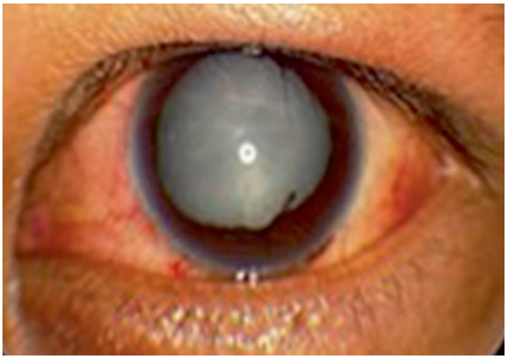


Fig. 21: Iris atrophy occurred one month after blunt trauma.

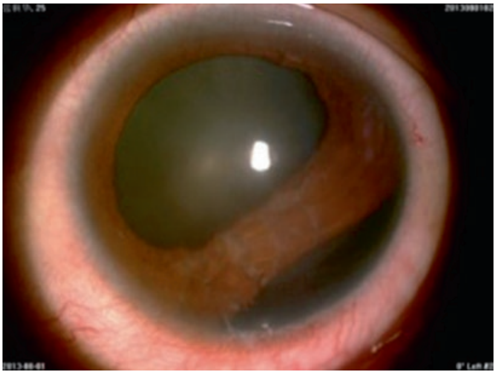


Fig. 22: Iridodialysis, pupillary deformation, and lens opacity.

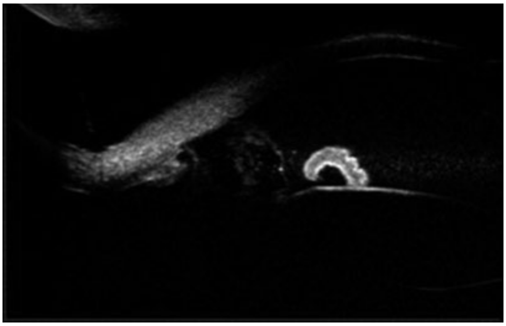


Fig. 23: UBM: Anterior chamber exudates, iris curling iris detachment.

Treatment

Surgery: Repair of iris injury; suture the broken pupillary sphincter.

Iridodialysis: Sewing machine suture of iris at the posterior border of corneal limbus (Figs. 24 and 25).

Case Presentation

Male, 27-year old, severe eye pain with blurred vision, 3 days after blunt trauma.

Examination: VOS: HM/BE, TOS: 36 mmHg, mixed congestion, whole iridodialysis (Fig. 26).

Diagnosis: Glaucoma and cataract after trauma.

Surgical Procedure (Video 4)

The surgery is performed under retrobulbar anesthesia.

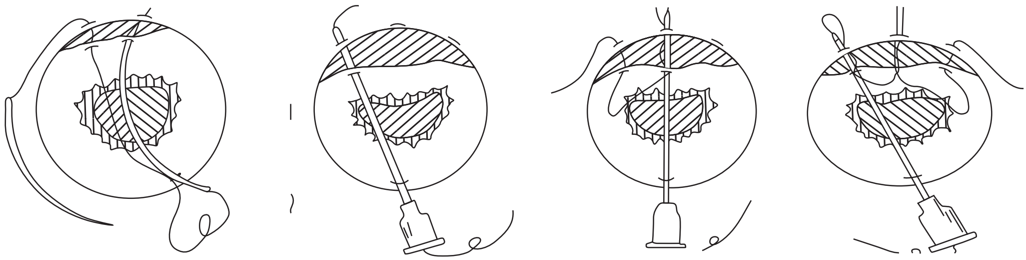


Fig. 24: Pattern diagram of sewing machine suture.

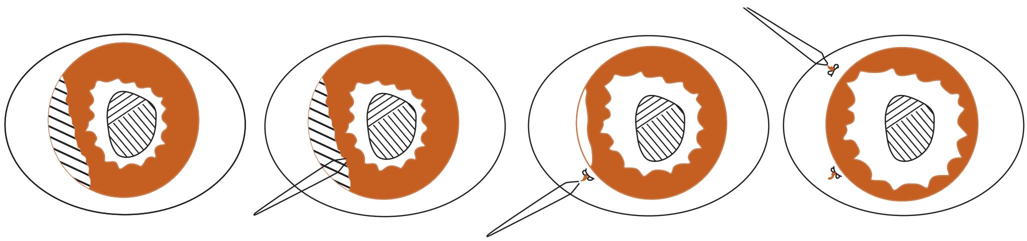


Fig. 25: Our experience of suture impaction.

A single 23-gauge port for infusion cannula to maintain IOP.

Cutting the conjunctiva along the limbus.

Making 0.5 mm sclera incision every 15° about 1.75 mm–2 mm behind the limbus.

Viscoelasticity into the anterior chamber.

Fixation of the defected iris through the sclera with 8–0 absorbable sutures (Vicryl) (suture impaction).

Cataract surgery

At the completion of surgery, the infusion cannula is removed.

The conjunctival incisions are closed with 8–0 absorbable sutures.

Glaucoma Secondary to Traumatic Uveitis

Etiology

Ocular contusion, perforating injury, and chemical injury can cause severe uveitis with serious exudates, resulting in a series of iridocyclitis, such as posterior synechia, Peripheral anterior synechia (PAS), pupillary occlusion, and iris bombé (Figs. 27, 28, and 29).

Occurs In

1. Intraocular infection due to trauma.

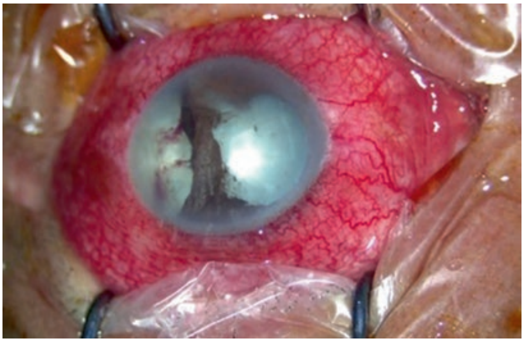


Fig. 26: Iridodialysis and cataract after blunt trauma.

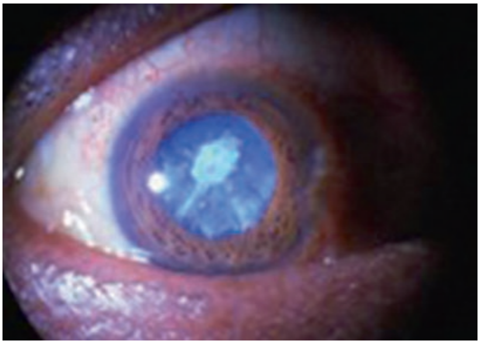


Fig. 27: About 2 months after blunt injury, lens opacity.

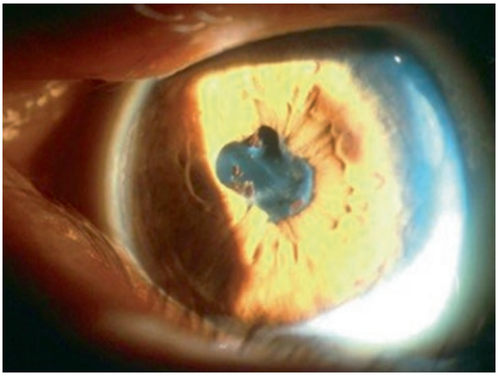


Fig. 28: About 1 month after blunt injury, PAS, iris nodules.

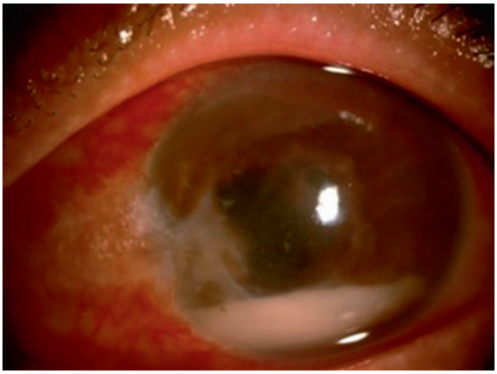


Fig. 29: About 3 days after sharp injury, hypopyon.

2. The disappearance of anterior chamber, delayed formation of anterior chamber, and wound leakage caused by trauma, lead to PAS and secondary angle closure glaucoma.
3. Traumatic lens rupture and residual cortex after lens extraction.
4. Chemical ocular trauma.

Clinical Manifestation

An acute eye pain, headache, blurred vision based on ocular trauma. Conjunctival congestion, corneal edema, shallow anterior chamber, iris bombé, PAS, intraocular hypertension.

Treatment

1. Medications: In accordance with uveitis.
2. Surgery: Treatment of primary causes.

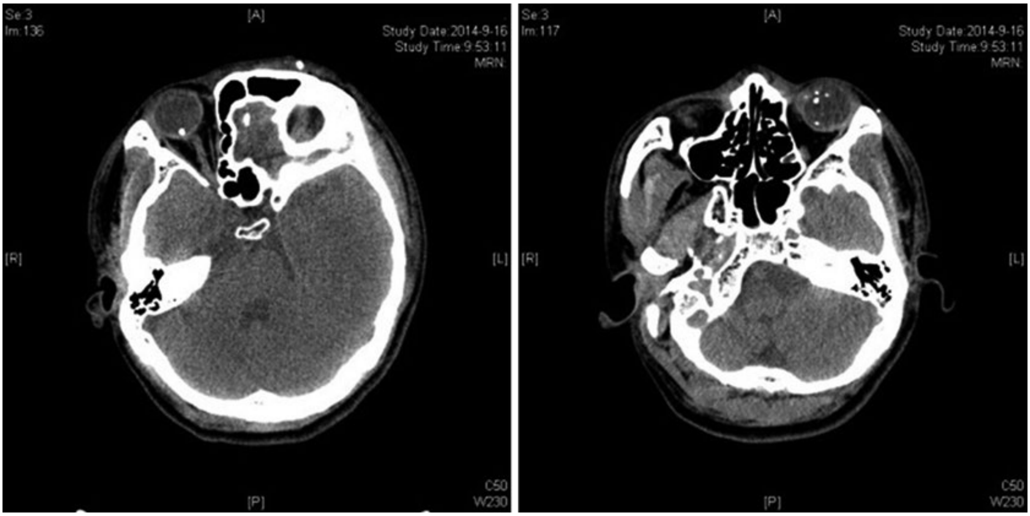


Fig. 30: Brain MRI shows: Hyper-reflective in the eyeball of both eyes.

Glaucoma Secondary to Intraocular Foreign Body

Intraocular foreign bodies, including iron, copper, zinc, and other metals, cause oxidation reaction in the eye, and damage of the angle of the eye leads to open-angle glaucoma (Fig. 30). Foreign body should be removed immediately if it damages the visual function.

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Surgical Trends in Glaucoma Management: The Current Indian Scenario

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Abstract

Objectives: To assess the current trend in the surgical management of glaucoma in India.
Methods: An anonymous online survey evaluating the preferred choices in the surgical management of glaucoma was circulated among the members of Glaucoma Society of India (GSI). Survey responses were compared to prior survey among GSI members in 2013 and members of American Glaucoma Society (AGS), 2016.
Results: A total of 175 of 879 (20%) GSI members participated in the survey of which 75.3% of the survey participants were practicing in the private sector. Trabeculectomy with or without augmentation with Mitomycin C (MMC) was the first-choice glaucoma incisional surgery for 96.6% of the survey participants. Of the participants doing tube surgery, use of valved GDD was the preferred choice (83.4%). Re-trabeculectomy was the preferred approach (60.7%) in case of trabeculectomy failure. For paediatric glaucomas, combined trabeculotomy with trabeculectomy was the preferred surgical approach for both hazy cornea (84.5%) as well as clear cornea (66%). For a POAG patient without prior incisional surgery and presenting with visually significant cataract, phacoemulsification with trabeculectomy was the preferred management approach by 58.7% of the participants.
Conclusion: Trabeculectomy continues to be the clear winner for the Indian glaucoma surgeon because of its cost effectiveness, lack of expensive instrumentation, and a more robust surgical training for trabeculectomy during residency programs. A higher proportion of angle closure disease precludes the use of minimally invasive glaucoma surgery and very often tube shunts also. Economics, ease of access and follow-up made a combined cataract and glaucoma surgery a preferred choice among Indian surgeons.

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Keywords: Trabeculectomy, Glaucoma drainage devices, Mitomycin C, Minimally invasive glaucoma surgery

Introduction

Glaucoma is a group of chronic neurodegenerative disorders characterized by a relatively selective, progressive damage to the retinal ganglion cells (RGCs) and their axons, which leads to axon loss and visual field alterations. The heterogeneity of the disease parallels the heterogeneity of treatment options chosen by glaucomatologists [1].

The worldwide overall prevalence of primary open-angle glaucoma (POAG) is 2.4%. Africa has the highest prevalence of POAG (4.0%) among all continents. The current estimated global population of POAG is 68.56 million [2]. It is expected that the number of individuals with glaucoma will reach 111.8 million by 2040 [3]. An insight in commonly adopted surgical treatment strategies may help highlight limitations and strengths of the surgical options available to glaucomatologists.

With the revolutionary addition of several newer devices and techniques in the surgical armamentarium of a glaucoma surgeon, there has been a shift in the preferred surgical practice patterns from filtering surgeries to minimally invasive glaucoma surgery (MIGS) [4]. Trabeculectomy has been the 'gold standard' glaucoma incisional surgery performed so far, with the primary goal of the surgeon being sustained control of intraocular pressure (IOP) together with a favorable bleb morphology and minimal bleb-related complications. However, with the advent of glaucoma drainage devices (GDD), an inclination towards the same has been seen [5].

Over the last decade, the MIGS space has grown tremendously and has become a major part of the glaucoma surgical paradigm in many countries. Fundamentally, this growth has enabled glaucoma surgeons to provide more nuanced, patient-centric care. One of the chief changes in the surgical practice has been the use of tubes as a primary procedure. As per the treatment outcomes of Tube Versus Trabeculectomy (TVT) study, tube surgery had a higher success rate compared to augmented trabeculectomy at the end of 5-year follow-up [6]. However, according to the recent outcomes of Primary Tube Versus Trabeculectomy (PTVT) study, there is no significant difference in the rate of surgical failure at the end of 3-year follow-up. Likewise, the frequency of vision threatening complications was comparable in both the groups according to PTVT study [7].

Surgical trends in the management of glaucoma have been documented and published using surveys by the members of American Glaucoma Society (AGS) from time to time [8-12]. Four such surveys by the AGS in 1996, 2002, 2008 and 2016 highlighted a shift from trabeculectomy to GDD among the glaucoma surgeons practicing in America.

The current survey was designed to ascertain the current preferred surgical practice patterns for glaucoma surgery among practicing glaucomatologists in India, who are registered members of the Glaucoma Society of India (GSI).

Subjects and Methodology

This survey was conducted among the glaucoma surgeons practicing in India who are members of GSI, after seeking formal permission from the current GSI President and Secretary. The GSI which was established in 1990 is a group of Indian ophthalmologists, who are glaucoma centric or have a special interest in glaucoma. A list of registered GSI members with valid email id's was sought in December 2020. An anonymous survey was created using the online platform Google forms and the link of the same was distributed to the 879 GSI members using electronic mail. The survey was available for 4 weeks.

The study followed the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines [13].

Full confidentiality of the particulars of the participants was maintained. Participation in the study was anonymous and voluntary. No personal data were collected. The survey's instructions informed the enrollees that, by completing the survey, they consented to take part in the survey and the data obtained were processed anonymously in aggregate statistical summaries.

Designing the Survey and Logic Operations

The online survey was pretested on 10 general ophthalmologists who were performing glaucoma surgeries but were not a member of GSI. The average time for filling the survey was 5 min. These pretest data were not analysed in the final results. The link for the same was emailed to the surgeons using the mail address of the principal investigator.

The survey was open to all participants, who fulfilled the two eligibility criteria: currently a member of GSI, and secondly regularly performing glaucoma surgeries. No incentives were offered to improve response rate. No participant was personally contacted outside this internet-based survey. The participants had an option to review their responses before submitting. The survey was open for responses for 1 month after which it was closed and the data analysed. Six reminders were sent over the month to those who had not completed the survey.

Anonymous responses to the questionnaire were recorded from all participants who willingly undertook it. Only one submission per surgeon was allowed. Website used authentication cookies at log in and no IP addresses were collected. Anonymity was assured by password protection of the survey account.

All analyses and statistical tests were conducted using SPSS version 21.0 (SPSS Inc., Chicago, Il, USA). Simple descriptive statistics was used to generate frequencies, percentages, and proportions. Data generated were analysed for correlations between multinomial categorical variables using chi-square test. Residuals were calculated to understand the nature of correlations between the variables. Significance was assumed for p value < 0.05.

Results

Only 175 of 879 (20%) GSI members participated in the survey of which 49.1% were female glaucoma surgeons. 75.3% survey participants were practicing in the private sector, 21.7% in government, academic setting and remaining 3% in government, non-academic setting.

57.1% of the survey respondents were fellowship trained glaucoma surgeons whereas 12% participants had done senior residency (3-year duration) in glaucoma. Remaining (30.9%) were non-formally trained glaucoma surgeons. Sixty-nine (39.4%) participants had more than 20 years of surgical experience, 55 (31.4%) between 10 and 20 years, 39 (22.3%) between 5 and 10 years and 12 (6.9%) participants had < 5 years of surgical experience.

Close to half (52.6%) of the survey participants examined < 200 glaucoma patients per month, 28.3% between 200 and 400 patients per month whereas 19.1% participants examined more than 400 patients per month. Trabeculectomy with or without augmentation with Mitomycin C (MMC) was the first-choice glaucoma incisional surgery for 96.6% of the survey participants.

Annual number of trabeculectomies performed was around 50 for 65% of the survey participants and > 100 for 16.7% of the participants. Peribulbar anaesthesia was the preferred mode of anaesthesia by 87.4% of the survey responders, followed by subtenon/intracameral anaesthesia by 8% and topical anaesthesia by 4.6%. In terms of stay suture, 48% of the participants preferred superior rectus bridle stay suture, 37% corneal stay suture and remnant 15% preferred no stay suture. 87.4% preferred fornix based conjunctival incision and the remainder 12.6% preferred limbal-based conjunctival incision. Triangular scleral flap was preferred by 69.7% of the participants, while 29.7% participants preferred rectangular flap.

MMC on sponge was the preferred choice of intraoperative anti-metabolite for 86.3% of the survey participants as opposed to subconjunctival MMC by 9.1% participants. Only 4% preferred not to use any anti-metabolite. 66.7% of the participants using MMC preferred a dose of 0.2 mg/ml (0.02%) while 24% preferred 0.4 mg/ml (0.04%) of MMC intraoperatively. A 2-minute application (60.6%) was the most popular duration of MMC.

The preferred mode for sclerostomy was Kelly's Descemet punch for 64% of the survey participants. The most popular method of scleral flap closure was combination of both interrupted and releasable suture by 64.6% of the survey participants. Only 2.3% preferred an adjustable suture. Nearly half (51.2%) participants preferred continuous mattress suture for conjunctival closure whereas 44.8% preferred interrupted mattress suture. Only 10.3% preferred to leave a viscoelastic agent at the end of trabeculectomy for a well-formed anterior chamber.

Indiana Bleb Appearance Grading Scale (IBAGS) was the most popularly used scale for post-operative bleb grading (36%) whereas 33% participants did not use any grading scale. AS-OCT as a method of post-operative bleb imaging was preferred by only 17.2% of the participants. In terms of use of anti-metabolite of choice postoperatively, 5-Flurouracil (5-FU) was the agent of choice (52%). Nearly half (46.5%) of the participants preferred to remove the releasable suture 2 weeks post-operatively whereas 21.1% preferred a later period. Needling under microscope was the preferred method of bleb revision post-operatively (71.6%) whereas re-trabeculectomy was the preferred approach (60.7%) in case of bleb failure.

Of the participants doing tube surgery, use of valved GDD was the preferred choice (83.4%). The scleral patch graft was the most popular method for covering the tube (51.3%), whereas corneal patch graft was preferred by only 7.8% of the participants. Only 10.3% of the participants preferred to use a viscoelastic agent during tube surgery. A second tube shunt surgery (GDD) was the preferred approach (66.4%) in case of failure of tube shunt surgery.

Of the 75.3% of the survey participants practicing in the private sector 95.2% preferred trabeculectomy, 3.2% preferred valved GDD and $<1\%$ preferred non-valved GDD and minimally invasive glaucoma surgery (MIGS), whereas all the participants practicing in academic as well as government non-academic institutions preferred trabeculectomy as their preferred mode of incisional surgery. Of the 30.9% non-formally trained glaucoma surgeons, 96.2% of the surgeons preferred trabeculectomy whereas 3.6% preferred either valved GDDs or MIGS.

For paediatric glaucomas, combined trabeculotomy with trabeculectomy (CTT) was the preferred surgical approach for both hazy cornea (84.5%) as well as clear cornea (66%). Goniotomy was the surgery of choice for 22.7% of the participants presenting with clear cornea. Nearly half (49.3%) of the participants preferred Sevoflurane as the anaesthetic agent of choice for paediatric glaucoma surgery followed by combination of two anaesthetic agents (28.7%).

For a POAG patient without prior incisional surgery and presenting with visually significant cataract, phacoemulsification with trabeculectomy was the preferred management approach by 58.7% of the participants whereas phacoemulsification alone was preferred by 39.5% of the participants.

Younger surgeons (age range, 30–40 years) performed significantly lower number of trabeculectomy surgeries in comparison to older surgeons (age >40 years) as indicated by the high negative residuals (50–100 surgeries $= -2.142$; >100 surgeries $= -0.896$; p value $= 0.036$). Surgeons with age more than 50 years performed significantly smaller number of tube surgeries as compared to younger physicians (age <50 years) as denoted by high negative residuals (50–100 surgeries $= -1.118$; >100 surgeries $= -0.803$; p value $= 0.041$). Non-trained glaucoma surgeons were much less likely to perform >50 tube surgeries as indicated by the high negative residuals (50–100 surgeries $= -1.095$; >100 surgeries $= -0.796$; p value $= 0.029$). The residuals for salient categorical variables along with the corresponding p values are summarized in Table 1.

Discussion

The holy grail of the surgical treatment of glaucoma remains a surgical option that is as safe as it is effective, and to date, it remains elusive. Therefore, in the absence of a clear best choice, glaucoma surgical practice patterns may be influenced by a number of factors. These include access to equipment, resources and training, and economic constraints along with hyperendemic geographical factors. With newer surgeries emerging as safer options, the learning curve as well as surgeon training are also becoming important determinants for the surgeons' choice, when it comes to the glaucoma surgical treatment paradigm. Even though most of these novel surgical techniques which target either the aqueous production and/ or outflow pathways are not available in India, the trabectome and the indigenously developed Baerveldt like implant, the Aurolab aqueous drainage device (AADI), are the latest additions to the Indian glaucoma surgeon's armamentarium. Survey of GSI members, thus, is a valuable tool to assess the practice patterns followed by the Indian glaucoma surgeons.

An on-site survey was conducted during the annual conference of the GSI in 2013 and revealed that most of the ophthalmologists (88.5%) preferred trabeculectomy as their surgery

Table 1: Residuals for salient categorical variables along with the corresponding p values.

Parameter	Pearson's Chi-Square residuals			*p* value
	Age (in years)			
	30–40	41–50	51–60	
Number of trabeculectomy surgeries				
< 20	0.741	−0.67	0.094	0.036
20–50	1.446	−0.805	−0.365	
51–100	−2.142	1.921	−0.258	
> 100	−0.862	0.048	0.691	
Number of tube surgeries				
< 20	1.029	−0.536	−0.329	0.041
20–50	−1.868	0.093	1.59	
51–100	−0.254	1.194	−1.118	
> 100	−0.729	1.298	−0.803	
Choice of intraoperative antimetabolite				
MMC Injection	−1.507	−1.37	2.781	0.007
MMC Sponge	0.655	0.605	−1.219	
5-Fluorouracil	−0.501	−0.637	1.122	
None	−0.573	−0.498	1.033	
Use of postoperative standard bleb grading system				
IBAGS	−0.616	−1.066	1.687	0.039
MBGS	0.428	0.741	−1.172	

MMC Mitomycin-C; *IBAGS* Indiana Bleb Appearance Grading Scale; *MBGS* Moorfields Bleb Grading System

of choice for adult glaucoma [14]. As many as 44.8% for general ophthalmologists, and 24.4% of glaucoma specialists, did not favor usage of antifibrotics during filtration surgery ($P < 0.01$). More than 90% of glaucoma surgeons preferred MMC during trabeculectomy. Most glaucoma specialists (73%) preferred a fornix-based conjunctival flap; while a little over half of general ophthalmologists (57.5%) preferred the same during trabeculectomy in their study, while almost 90% of the respondents preferred the fornix-based conjunctival flap in ours.

Glaucoma specialists also favored releasable suture techniques during trabeculectomy (51.1%) in 2013, while the most popular method of scleral flap closure was combination of both interrupted and releasable suture by 64.6% in 2021. Interestingly, only about 2% of the respondents preferred an adjustable suture in our study. Almost 28% glaucoma specialists reported that they were implanting GDDs, as compared to about 8% of other ophthalmologists.

This implies that trabeculectomy continues to be the first choice, with its popularity unaffected from 2013 to 2021, with almost the same number of ophthalmologists choosing it to be their first choice of surgery. With almost 38% of the respondents preferring a GDD implantation in case of failure of the primary trabeculectomy in 2021, the acceptability of the same seems to be almost constant as well.

Trabeculectomy has been the gold standard for surgical management of glaucoma, and in the Indian context, it continues to be the first choice for the management of medically uncontrollable glaucoma. In fact, nearly 96.6% of the surgeons preferred trabeculectomy as their first choice, despite the evidence that both tube shunts and trabeculectomy are equally efficacious. However, our results differ from the preferred practice patterns by the members of AGS where an increasing trend for the tube surgery was seen as published in their latest survey. Vinod *et al.* reported that the most common initial surgery for POAG was trabeculectomy with MMC (59%), followed by GDD (23%), and MIGS (14%) [12]. Our results were not limited to patients of POAG, and the fact that a large proportion of Indian patients have primary angle closure disease (PACD), our results could be skewed towards trabeculectomy. The cost of GDD implantation could be one deterrent: India is a developing country with a large proportion of people having low per capita income, making GDD unaffordable for most. Another reason for preferring trabeculectomy could be lack of surgeon training for GDD, with most residency programs not teaching the surgery routinely.

Interestingly, even for a more developed nation like Japan, trabeculectomy remains the surgical choice for most glaucomatologists: with trabeculectomy being the first choice even for previously once-failed trabeculectomy (76.0%); and secondary glaucomas (Neovascular glaucoma (NVG) for non-operated eyes 63.8%, and prior vitrectomized eyes 49.8%; Uveitic glaucoma for non-operated eyes 71.6%, and once failed trabeculectomy 64.2%) [15].

Trabeculectomy augmented with MMC is almost considered standard of care in current glaucoma practice. Bleb-related infections and hypotony-related complications have led to decrease in duration and dose of MMC use [16-18]. Two thirds (66.7%) of our participants preferred to use 0.2 mg/ml of MMC, while the most popular choice (48%) for the participants of the AGS survey was 0.4 mg/ml of MMC. In our survey, 86.3% participants used MMC on sponge in contrast to 9.1% who preferred MMC injection. The results of our survey differ from the AGS survey where 31% surgeons preferred MMC injection [12]. This is despite the fact that there is evidence of superior IOP control with fewer glaucoma medications at 3 years in the injection group, with comparable complications in both groups, other than more frequent tense, vascularized blebs in the sponge group [19]. A possible reason could be the ease of use with sponges, better perceived safety, and continued teaching of the traditional methods of MMC application.

Trabeculectomy may be ineffective in many cases, as IOP undergoes dynamic changes due to continuous wound modelling, therefore, traditionally, when trabeculectomy failed GDDs were considered [20]. In fact, GDDs were reserved for high-risk glaucomas, including uveitic and neovascular glaucoma, and also for surgical failures. Over a third (38.7%) of the survey respondents preferred a GDD in case of trabeculectomy failure, but re-trabeculectomy remained the surgery of choice for the majority. This is unlike the AGS survey trend, where the usage of GDD (71%) surpassed the practice of re-trabeculectomy in 2016(20%) [12]. This dramatic increase in GDD use may be attributed to the results of the TVT study, in which the former had comparable IOPs, and lower rates of reoperation compared to patients who underwent trabeculectomy with MMC at five years of follow-up [6]. However, the results of the more recent PTVT study, which used MMC for two minutes as against the four minutes in the TVT study, showed that the IOP achieved following trabeculectomy with MMC was lower, as compared to GDD, with use of fewer glaucoma medications, and similar complication rates at the end of three years of follow-up [7]. Thus, in the Indian scenario, where use of GDD may not be a pocket friendly option, a trabeculectomy may actually be the better alternative with near comparable results.

Another interesting observation made in the present survey was the increased usage of GDD by young fellowship trained surgeons as opposed to non-formally trained glaucoma surgeons. This mirrors the 2016 AGS survey, which also reported that older surgeons preferred trabeculectomy with MMC, while the younger surgeons chose GDD in most clinical settings. This may be due to the increased focus on GDD training in residency and fellowship programs.

It must also be noted that there are only two tube shunts available in India: the more expensive Ahmed Glaucoma Valve (AGV), and the relatively newer, non-valved, AADI [21]. A possible explanation could be an increase in the number of fellowship training programs in the recent past, with better surgical training, especially with tube shunts. While the current survey does not depict the change in practice patterns, or the increased use of tube shunts, the provision of a low cost indigenously produced glaucoma shunt may result in greater acceptance of the same, over time. The same also reflects in the fact that the valved GDD was the preferred choice in 83.4% of the respondents, with the others preferring the recently introduced indigenous non-valved shunt. Its low cost and surgical training in some of the more popular fellowship programs may be reason for its rapid popularity, despite being a two-step surgical procedure.

MIGS has captured the imagination of glaucoma surgeons worldwide, with its promise of minimal tissue trauma, greater safety, rapid visual recovery and efficacy less than conventional incisional surgeries, but comparable to a single glaucoma medication [22].

It can be, moreover, performed alone or in conjunction with phacoemulsification cataract surgery using the same clear corneal incision, as a cataract plus procedure. The conjunctiva is spared, which does not compromise the success of future incisional glaucoma surgery if adequate reduction in IOP is not achieved after MIGS [23, 24].

In the present survey, less than 1% of the respondents preferred MIGS in comparison to the AGS survey where MIGS was preferred by 14% of the surgeons [12]. In an almost startling revelation, Iwasaki et al. reported that in 2019, Japanese glaucoma surgeons preferred MIGS (79.0%) for non-operated eyes with mild OAG associated with cataract, as compared to conventional trabeculotomy (4.6%) [15].

The Indian scenario, of course, is remarkably different with none of the MIGS being approved for use by the regulatory authorities [25]. The limitations of MIGS in the Indian context therefore include nonavailability of most MIGS devices, additional cost, a steep learning curve and their limited utility for early glaucoma with open angles.

Because of similar age predilections, cataract and glaucoma frequently coexist in the elderly. Cataract surgery alone has been shown to reduce IOP in eyes with glaucoma [23]. In the present survey, cataract surgery alone was preferred by 40% of the surgeons. The results were comparable to the AGS survey where 44% of the surgeons preferred alone cataract surgery. The respondents of the AGS survey preferred to perform a cataract extraction combined with trabeculectomy with MMC in 24%, with MIGS in 22% and with GDD in 9% [12]. The majority (60%) of the surgeons in our survey preferred a single stage combined glaucoma and cataract surgery. Even though the

IOP-related results are found to be better in a staged procedure, a combined surgery remains the procedure of choice for two very important reasons: economics, ease of access and follow-up. For most patients, especially in rural and small-town India, a combined surgery is more affordable than two surgeries, and the decreased number of follow-up visits make it more feasible as well. Most surgeons are also apprehensive that a cataract-first would mean restoration of central vision, and the patient would thereafter be lost to follow-up, leading to eventual detrimental clinical outcomes.

The preferred approach for treating paediatric glaucoma in the current survey was CTT by 84% of the surgeons. Preventing blindness due to childhood glaucoma is challenging in developing nations like India. Most of the paediatric glaucoma surgeries require microscopic surgical expertise and specialized equipment and as most new technologies have first world markets in their sights, less affluent and developing countries do not always enjoy their benefits. [26].

There is marked variability in the preferred surgery for paediatric glaucoma across the globe. [27].

In a recent Indian study too, the primary surgical procedure for majority of eyes with paediatric glaucoma was CTT (78.5%) [28].

Our current study has several limitations. Our survey had a poor response rate, with only one in five of the members of the glaucoma society members responding. While a general disregard for online surveys may be a reason for this, a more rational cause could be the fact that most members of the GSI are not glaucoma specialists. Since the membership is open for all the practicing ophthalmologists in India, a significant proportion of members were comprehensive ophthalmologists, perhaps hesitant to reveal their preferred practice to the ophthalmic community at large. It is, however, of interest to note that even the aforementioned survey by the AGS had a response rate similar to ours: a total of 252 of 1,091 (23%) members participated in that survey, even though the survey was available online for 6 weeks [12]. The AGS survey respondents were all fellowship trained glaucoma surgeons, unlike the GSI membership which is open to general ophthalmologists also. The anonymized nature of the survey did not allow us to compare characteristics of GSI members who did and did not participate to assess for non-response bias. The fellowship-trained GSI members may not be representative of all surgeons who perform glaucoma surgery, which could also affect the generalizability of results. The severity and type of glaucoma were not specified in our survey which could potentially affect the surgical choices. Future surveys that better delineate treatment options in different clinical scenarios may help in consolidating our findings.

While the exciting world of MIGS and GDDs complicates surgical choices for the developed world, trabeculectomy continues to be the clear winner for the Indian glaucoma surgeon. Its cost effectiveness, lack of expensive instrumentation, and a more robust surgical training for trabeculectomy during residency programs are perhaps the most obvious reasons for this. It also must be kept in mind that India, like most of South East Asia, has a much higher proportion of angle closure disease, which precludes the use of most MIGS, and very often tube shunts also. Lack of access to the implants, lack of surgical training as well as definite evidence establishing their superior clinical efficacy are also important contributory factors. In the current Indian scenario, appropriate surgical intervention at appropriate time by appropriately trained surgeons is not available to all glaucoma patients.

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Lens Extraction in PACG

Noel Ching-Yan Chan, Clement C. Y. Tham

Abstract

With the advancement of technology and the development of phacoemulsification, lens extraction can now be performed through smaller corneal incisions with minimal conjunctival manipulation and intraoperative intraocular pressure fluctuations. For different stages of Primary Angle Closure diseases, phacoemulsification alone or combined with glaucoma procedures are important surgical treatment options in the control of intraocular pressure and disease progression. This chapter will illustrate the algorithm in the choice of surgery in different scenarios with the display of recent evidence. We will also discuss the potential perioperative risk and complications aside from its preventive measures in this group of patients.

Keywords: Lens extraction, Angle closure, Cataract, Small pupil, Glaucoma

Introduction

In newly diagnosed primary angle closure diseases, the management principle is to first re-open all appositionally closed portions of the drainage angle by eliminating the key mechanism(s) of angle closure, with the aim of normalizing intraocular pressure (IOP), and preventing further glaucomatous progression. Traditionally, laser peripheral iridotomy (with or without subsequent laser peripheral iridoplasty) is the mainstay in opening up the drainage angle. In this era when phacoemulsification has become a relatively safe and widely practiced procedure, lens extraction has become one of the initial surgical options as well (Fig. 1).

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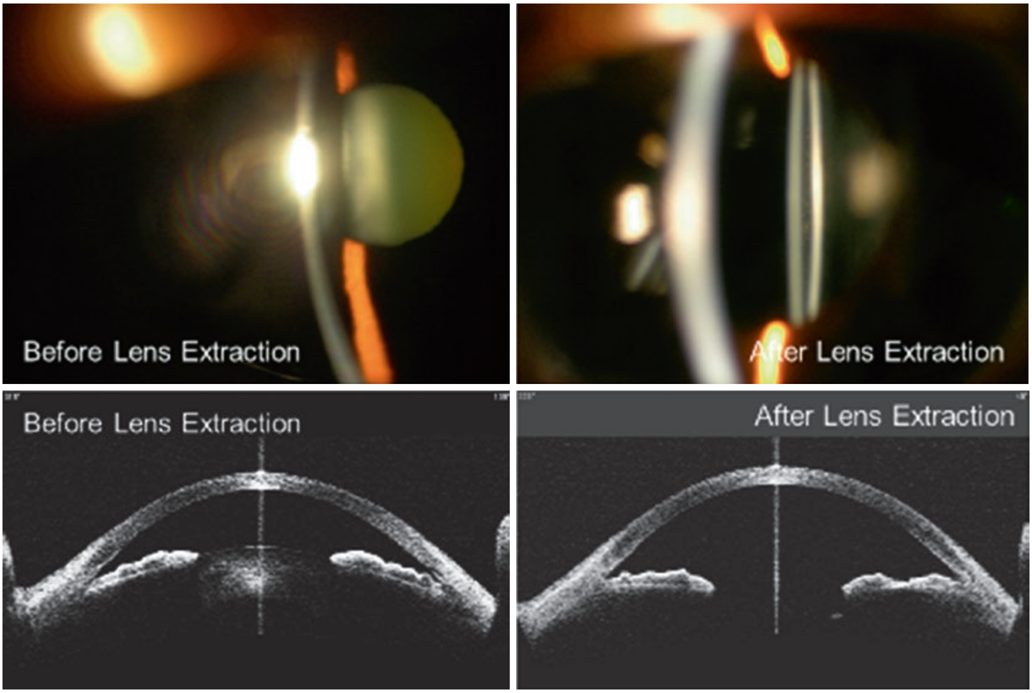


Fig. 1: Lens extraction results in deepening of the anterior chamber, opening of appositional angle closure, and reduction of pupillary block.

Lens Extraction in Angle Closure Glaucoma

Besides reversing one important anatomical predisposition to angle closure and lowering IOP, there are other potential benefits of lens extraction in Primary Angle Closure Glaucoma (PACG). It may decrease the need for subsequent glaucoma surgery. It also decreases the risk of complications (including cataract formation) associated with glaucoma surgery. The consensus now is that lens extraction is a beneficial initial or early surgical intervention in most PACG patients [1].

The question of interest comes down to the timing of this intervention and when to consider it in different scenarios requiring surgical intervention:

(a) IOP uncontrolled with drugs + coexisting cataract
(b) IOP controlled with drugs + coexisting cataract
(c) IOP uncontrolled with drugs + no cataract
(d) Newly diagnosed PAC/PACG with high IOP + no cataract
(e) Acute primary angle closure (APAC)

IOP Uncontrolled with Drugs with Coexisting Cataract

In this scenario, the main surgical options include phacoemulsification alone versus combined phaco-trabeculectomy, both of which can reduce IOP in PACG eyes. Trabeculectomy alone has a limited role in this case, because of the known pathogenic role of the lens in PACG, and also because of the relatively higher perioperative risk of complications of performing trabeculectomy in PACG eyes. Furthermore, a significant proportion of patients will soon need cataract extraction after trabeculectomy, and future cataract extraction may result in loss of the functioning filter. Studies have reported that 30–100% of previously functioning blebs will require glaucoma medications to control IOP after subsequent cataract surgery.

A randomized controlled trial revealed that combined surgery resulted in better IOP control than did phacoemulsification alone over a 24-month follow-up period, as suggested by a lower mean IOP and the requirement of 1.2 fewer topical glaucoma medications [2]. However, this difference was not statistically significant at 5 years after surgery [3]. 11.1% and 29.6% of phacoemulsification-alone eyes subsequently required trabeculectomy for IOP control within the 2-year and 5-year period, respectively [2]. There was no significant difference between the two groups in terms of visual acuity or glaucomatous progression at 2 or 5 years follow-up [2, 3]. Yet, combined phaco-trabeculectomy resulted in more postoperative complications, and 25% of these eyes required additional surgical procedures such as laser suture lysis or needling to maintain filtration [2, 3].

Phacoemulsification alone is still a viable first-line surgical option in this setting, but combined phaco-trabeculectomy should be considered in those patients requiring greater IOP reduction or maximum drug reduction. Either approach may be adopted depending on patient factors. For example, phacoemulsification alone may be considered in patients who are more prone to the risk of trabeculectomy complications or in eyes that carry higher surgical risk when subjected to combined surgery (such as eyes with lower endothelial cell count). On the other hand, combined phaco-trabeculectomy would be a good option for patients with poor compliance or accessibility to medications, or those with multiple drug allergies.

IOP Controlled with Drugs with Coexisting Cataract

The major surgical options are again phacoemulsification alone and combined phaco-trabeculectomy. The efficacy of phacoemulsification alone in widening anterior chamber angles, reducing IOP and drug requirement, has been long studied [4]. In PACG eyes, phacoemulsification alone resulted in greater opening of drainage angle and greater deepening of the anterior chamber than combined phaco-trabeculectomy [5]. A randomized controlled trial has shown that phacoemulsification alone can result in 9.82% IOP reduction and 59.2% drug reduction. Although combined phaco-trabeculectomy resulted in 1.67 mm Hg more IOP reduction and 0.8 fewer topical glaucoma drug requirements, it came with a higher risk of complications [6]. At 5 years after surgery, only 8.6% of the phacoemulsification group required additional glaucoma surgery [3]. Therefore, in this scenario, the benefit of combined phaco-trabeculectomy is probably not sufficient to justify the additional risk of complications and postoperative interventions. Phacoemulsification may be the surgery of choice.

IOP Uncontrolled with Drugs and with No Cataract

"Clear lens extraction" is the term commonly used to describe the extraction of an optically clear lens when there is no visually significant cataract. The word "clear" emphasizes that the visual acuity is not sufficiently affected by the lens status. However, the pathophysiology of PACG often includes an abnormally thick and anteriorly positioned lens, which results in an exaggerated pupillary block (Fig. 1). The lens is thus a crucial component in the pathogenesis of PACG and should be considered pathological in PACG, despite its clarity. Therefore, in this scenario, the surgical options may include trabeculectomy alone or phacoemulsification alone.

For this group of patients, it has been shown that clear lens extraction resulted in a significant reduction in synechial angle closure, and an increase in anterior chamber angle width and anterior chamber depth compared to trabeculectomy alone [7]. A randomized controlled trial has shown that phacoemulsification alone is effective in reducing IOP by 34% and glaucoma drug requirement by 59.5% [8]. Over the first 24 months, trabeculectomy has a similar IOP lowering effect as phacoemulsification alone and can lead to 1.06 fewer glaucoma medications. Eyes receiving trabeculectomy have a higher surgical complication rate of 45.8% as compared to 3.8% in the phacoemulsification alone group. Within 2 years, 19.2% of eyes receiving phacoemulsification alone eventually received trabeculectomy, while 25% of eyes receiving trabeculectomy required subsequent cataract surgeries or additional surgical intervention to maintain filtration. This difference was statistically insignificant.

Potential benefits of "clear lens extraction" include lower risk of damage to the corneal endothelium with a lower ultrasound energy requirement, lower risk of complications of subsequent glaucoma surgery, and no risk of cataractous progression after future glaucoma surgery. It can be considered in patients who are significantly hyperopic or presbyopic, in view of the additional refractive benefits from intraocular lens implantation. In situations where drug reduction is a high priority, trabeculectomy may be a more suitable option.

Newly Diagnosed PAC/PACG with High IOP but No Cataract

The benefit of eliminating the mechanistic role of the crystalline lens at an earlier stage has been further studied in a multicenter randomized controlled trial—the EAGLE study, in which 155 subjects with PAC and 263 patients with PACG at age 50 or above were randomized to receive either traditional laser peripheral iridotomy or clear lens extraction as the initial therapy upon diagnosis [9]. In the clear lens extraction group, 9% received concomitant viscosynechialysis, while in the laser iridotomy group, 5% received concomitant argon laser iridoplasty. Results have shown that clear lens extraction has a greater efficacy and cost-effectiveness than did laser iridotomy as the initial treatment. The group receiving clear lens extraction had a lower mean IOP (1.18 mm Hg lower), lower percentage of subjects requiring topical glaucoma medications (21% versus 61%), a lower percentage of subjects requiring glaucoma surgery (1 versus 24 operations), and a better quality of life score assessed with European Quality of Life-5 Dimensions questionnaire. Although lens extraction may be associated with potential severe intraoperative and postoperative complications, irreversible visual loss occurred in one participant in the clear lens extraction group as compared with three participants in the laser iridotomy group.

Above all, since "clear lens extraction" is not an established conventional treatment and there is no consensus yet on its use, informed consent and excellent rapport between physician and patient are of paramount importance before proceeding. Besides, patients have to be aware that cataract extraction in PACG eyes may be associated with higher surgical risk than with routine cataract surgery. Upon discussing the optimal surgical procedure for each individual patient, risks should be personalized and potential risks such as transient IOP spike or steroid-induced ocular hypertension after lens extraction have to be thoroughly explained. It is also important to understand that there is a possibility of preexisting trabecular meshwork damage in PACG eyes, which may limit the efficacy of IOP reduction by lens extraction alone in these eyes.

Lens Extraction in Acute Primary Angle Closure (APAC)

Argon laser peripheral iridoplasty (ALPI) or medical treatment, depending on facilities and expertise, remains the first-line intervention for patients suffering from acute primary angle closure (APAC). The role of early lens extraction as an alternative to laser peripheral iridotomy (LPI) has been studied in two randomized controlled trials [9-11]. In both of the trials, subjects were randomized to receive either early phacoemulsification or LPI after medically aborted APAC. Lam *et al*. found that treatment with LPI was associated with a significantly increased risk of subsequent IOP rise, while early phacoemulsification was associated with consistently lower IOP at all time points and required fewer medications [10]. Husain *et al.* showed a higher 2-year cumulative survival for the phacoemulsification group in terms of IOP control. Compared with laser iridotomy, the better IOP control after phacoemulsification in post-APAC eyes was secondary to a greater degree of opening of drainage angle and possibly flushing of the trabecular meshwork.

Despite the clear benefit of early lens extraction after APAC, the optimal timing of lens extraction after medically aborted APAC remained uncertain. Some surgeons suggest earlier lens extraction (within days) to prevent peripheral anterior synechiae (PAS) formation, but most surgeons advocate operating weeks after the resolution of the attack upon reduction of ocular inflammation and improvement of corneal clarity. To balance between PAS formation and increased operative risk, the best time window for performing lens extraction after APAC attack may be as soon as the inflammation associated with the attack has largely resolved. During the interim period, an interim LPI may be considered, especially when earlier surgery would not be possible because of logistical constraints. Although a previous trial demonstrated that the endothelial cell count did not differ significantly between LPI and phacoemulsification in this subgroup, one must consider the combined effect of the two sequential procedures if this happens.

Other IOP Lowering Procedures to be Combined with Lens Extraction in PACG

Lens extraction also provides a good opportunity where additional glaucoma procedures can be performed with the corneal wound created during lens extraction. Examples of such include combining cataract extraction with goniosynechialysis (GSL) and endocyclophotocoagulation (ECP). Combining GSL with phacoemulsification has certain advantages, including better visualization and access to the drainage angle intraoperatively, better IOP/drug reduction, a lower possibility of recurrent angle closure and PAS formation, as well as the elimination of the risk of lens damage or cataract formation after the surgery (Fig. 2). Combining ECP with lens extraction allows safe and easy access to the ciliary process with no requirement for additional incisional wound. Apart from reducing aqueous production, ECP has also been postulated to impose additional IOP lowering effect by widening anterior chamber angles, particularly in PACG eyes, by shrinking ciliary processes. A case series of five patients using intraoperative anterior segment OCT has shown a significant widening of the anterior chamber angle in eyes with plateau iris syndrome after combined phacoemulsification and ECP as compared to phacoemulsification alone [12].

Tackling Specific Operative Risks and Complications During Lens Extraction

Preoperative

High IOP should be adequately controlled before any surgical intervention. In selected cases, systemic acetazolamide or mannitol may be required. Corneal endothelial status should be evaluated using specular microscopy upon clinical examination and particularly in cases after acute primary angle closure or previous difficult or multiple laser procedures. Preoperative miotics should be terminated with IOP monitoring a week before surgery.

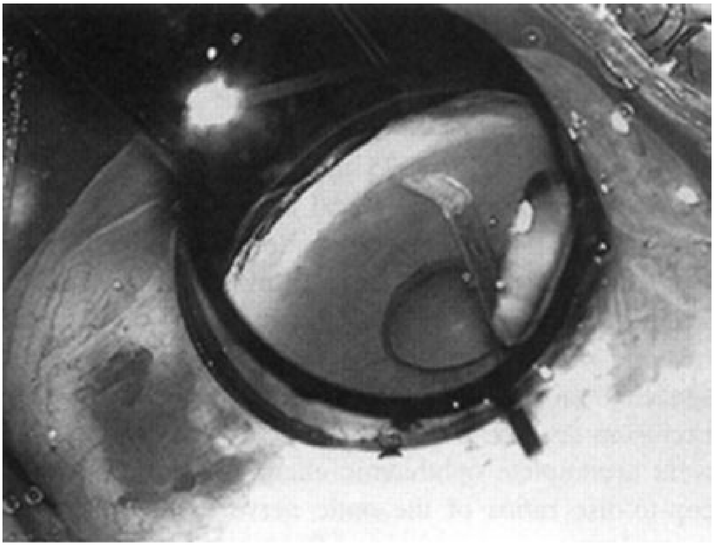


Fig. 2: During goniosynechiolysis, the angle can be visualized using a Swan Jacob direct gonio lens. Visible PAS can be broken down by pushing the peripheral iris down gently with a flat spatula inserted via a paracentesis wound. Caution is taken not to damage the iris or induce iridodialysis.

Intraoperative

Main surgical wound using three-step incisions and tight-angled side port paracentesis will help prevent iris prolapse. Small pupil can be tackled using various techniques, including Kuglen iris hooks, iris retractors, or Malyugin ring (Fig. 3). Specialized, heavy-weighted viscoelastics (such as Healon GV/5) can be used to maintain the anterior chamber during capsulorhexis, as it helps to tamponade the anterior bulging curvature of the lens, as well as prevent iris movement. High lens vault may increase the risk of runaway capsulorhexis; therefore, surgeons should take caution in maintaining a centripetal force and may require a second instrument to depress the lens. Excessive hydrodissection should be avoided as it might induce iris prolapse and, in extreme cases, inadvertent posterior capsule blowout with drop nucleus. Adequate hydrodelineation is very helpful in cases with small pupil and large lens. During phacoemulsification, extra anterior chamber pressurization may be necessary to maintain the anterior chamber and to prevent endothelial damage. After implanting the intraocular lens, viscoelastics should be removed thoroughly to prevent a postoperative IOP spike. Intracameral miotics can be instilled to reverse pupil dilatation and prevent immediate peripheral anterior synechiae formation.

Postoperative

Additional intraoperative iris maneuvers require additional topical steroid therapy to control ocular inflammation and prevent the development of cystoid macular edema. For patients with advanced glaucomatous damage, oral acetazolamide is a good option to prevent overnight IOP spike and wipeout. Upon follow-up, surgeons should be aware of possible malignant glaucoma in this subset of patients which may require immediate YAG hyaloidotomy or vitrectomy combined with iridectomy, hyaloidectomy, and zonulectomy [13].

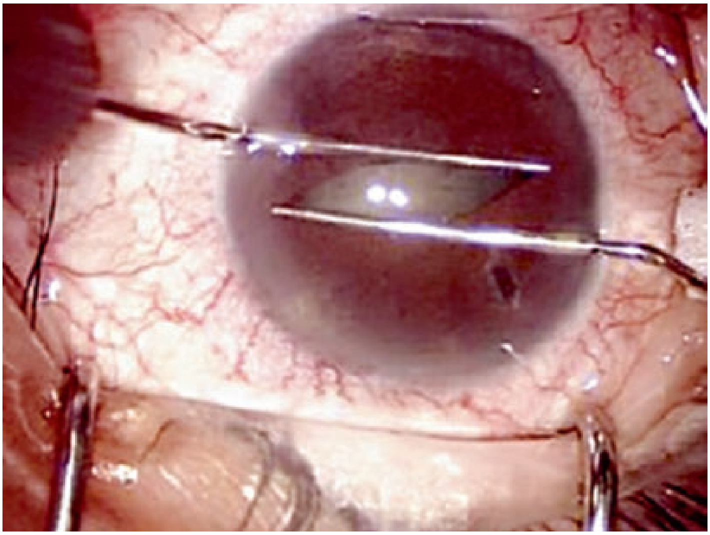
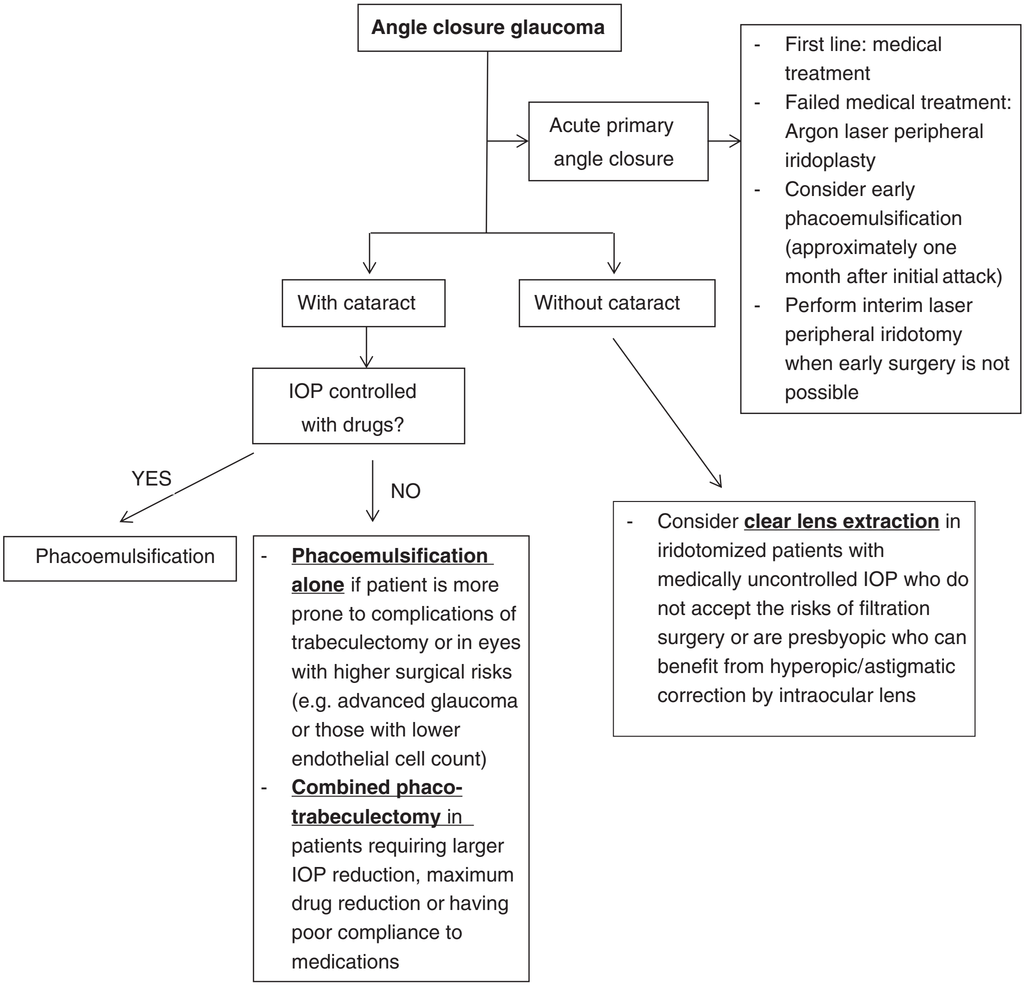


Fig. 3: Small pupil is not uncommonly encountered in patient with PACG. Kuglen hooks can be used to enlarge the pupil intraoperatively. Alternatively, iris retractors or Malyugin ring can be employed.



Algorithm 1: Cataract/Clear lens extraction as treatment strategy for angle closure and angle closure glaucoma (Abbreviations: *AC* angle closure, *ACG* angle closure glaucoma, *IOP* intraocular pressure).

Conclusion

Lens extraction has a specific role in treating angle closure glaucoma. It should be considered as one of the treatment options in PACG eyes with cataracts, medically uncontrolled PACG eyes, as well as in APAC eyes after abortion of the acute episode. Concomitant filtration surgery may be considered if drug reduction is a top priority, but surgical complications should be thoroughly discussed with patients. Other adjunctive IOP-lowering procedures such as GSL or ECP can also be combined with lens extraction in suitable candidates to achieve maximal IOP lowering.

An algorithm for considering cataract or clear lens extraction as a treatment strategy in angle closure diseases is provided (Algorithm 1).

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CLINICAL VIGNETTE

Traumatic Cyclodialysis Cleft Treatment Combined with Cataract Surgery: An Original Triple Procedure

Mariana Leuzinger-Dias, Mário Lima-Fontes, Cláudia Oliveira-Ferreira, João Paulo Macedo, Fernando Falcão-Reis, Paulo Freitas-da-Costa, António Benevides-Melo

Abstract

Introduction: To describe a "triple" surgical procedure, which combined traumatic cataract extraction by phacoemulsification with gas endotamponade and cyclocryotherapy in the successful treatment of a traumatic cyclodialysis cleft.

Methods: A 44-year-old man who suffered severe left eye blunt trauma with an elastic band developed a 4-hour extent cyclodialysis cleft with consequent hypotony. After 7 weeks of persistent hypotonic maculopathy unresponsive to medical treatment, and with an evolving traumatic cataract, the patient underwent cataract surgery combined with intravitreal gas endotamponade (20% SF_6) and cyclocryotherapy.

Results: Two weeks after the procedure the intraocular pressure increased to 12 mmHg and remained steady during the next 14 months of follow-up. Hypotonic maculopathy resolved and successful closure of the cyclodialysis cleft was confirmed by gonioscopy and ultrasound biomicroscopy.

Conclusion: Gas endotamponade and cyclocryotherapy constitute a promising option in the treatment of cyclodialysis clefts unresponsive to medical therapy. In our case, this minimally invasive technique was innovatively combined with cataract surgery. Despite early postoperative intraocular inflammation, a successful outcome was achieved.

Keywords: Cyclocryotherapy, Cyclodialysis Cleft, Gas Endotamponade, Hypotonic Maculopathy, Traumatic Cataract Surgery

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Key Summary Points
Cyclodialysis is a rare disorder that results from disinsertion of the longitudinal ciliary muscle fibers from the scleral spur, creating an alternative route for aqueous humor outflow, which may lead to severe hypotony.
Blunt ocular trauma is the most frequent cause of cyclodialysis cleft formation.
Closing a cyclodialysis cleft is a true therapeutic challenge. There are many treatment modalities (ranging from laser therapy to surgical interventions), but there is no obvious gold-standard technique.
We report a case of traumatic cyclodialysis cleft and cataract, successfully treated with gas endotamponade and cyclocryotherapy combined with phacoemulsification and intraocular lens (IOL) implantation.
To the best of our knowledge, this “triple” procedure is the first of its kind reported in the literature, with promising outcomes.

Introduction

A cyclodialysis cleft formation is a rare clinical event that results from disinsertion of the longitudinal ciliary muscle fibers from the scleral spur, thus creating a direct communication between the anterior chamber and the suprachoroidal space [1]. The free outflow of aqueous humor through this alternative route may lead to chronic hypotony and secondary associated complications, such as refractive changes, cataract formation, flat anterior chamber, choroidal detachment, hypotonic maculopathy, and optic disc swelling [1, 2].

Before the advent of trabeculectomy, cyclodialysis was an accepted treatment strategy for glaucoma [3]. Nowadays, the deliberate creation of a cyclodialysis cleft is no longer performed, and the majority of cases occur inadvertently as a surgical complication or, more frequently, after blunt ocular trauma [1, 4]. Men are more frequently affected than women [1].

The presence of a cyclodialysis cleft should always be suspected in the setting of persistent hypotony after surgery or severe ocular contusion, especially when accompanied by other signs of anterior segment damage, such as hyphema and iris injuries, in the absence of an open globe injury [4].

Gonioscopy has traditionally been regarded as the gold-standard method for the diagnosis of cyclodialysis. Intracameral injection of a viscoelastic agent may be necessary to increase its effectiveness, since media opacity and globe hypotony can hamper the accurate identification of a cleft. Other noninvasive diagnostic techniques such as ultrasound biomicroscopy (UBM) are now an extremely valuable tool, as they not only increase the odds of cleft identification but also localize and measure the extent of the lesion, thus helping to delineate the best management plan [5].

Sealing a cyclodialysis cleft can be truly challenging. More than 20 different methods have been described in the literature, but no consensual standardized approach has been established [1, 2, 6]. Conservative medical treatment is usually used as a first-line option, but its success is limited to cases with small clefts. Therefore, more invasive techniques (ranging from laser-based to surgical interventions) are almost always necessary to restore normal ocular tonus [1, 2, 4, 5]. Here, we describe the case of a traumatic cataract and cyclodialysis cleft that were successfully treated with gas endotamponade, cyclocryotherapy, and phacoemulsification with intraocular lens (IOL) implantation. To the best of our knowledge, this “triple” procedure is the first of its kind reported in the literature.

Case Report

A 44-year-old Caucasian man presented to our emergency department with painful vision loss after blunt left eye trauma with an elastic band. On ophthalmic examination, the best-corrected visual acuity (BCVA) was 20/20 in his right eye (OD) and counting fingers at 30 cm in his left eye (OS). Left eye slit-lamp exam revealed exuberant eyelid ecchymosis, multiple conjunctival and corneal erosions, and significant corneal edema. A shallow anterior chamber, with a half-chamber hyphema and severe cellular and fibrinous reaction, was present. Fundoscopy was hampered by media opacity. Right eye biomicroscopy and fundoscopy were unremarkable. Intraocular pressure (IOP) was 12 mmHg OD and 5 mmHg OS. Pupillary evaluation and eye movements were normal. B-scan ultrasonography disclosed a small, flat peripheral choroidal detachment (Fig. 1). Orbital computed tomography (CT) was irrelevant.

The patient was prescribed cycloplegic drops, prednisolone/chloramphenicol ointment, topical hypotensive medication, and oral aminocaproic acid.

During subsequent follow-up visits, the hyphema and anterior chamber inflammatory reaction gradually resolved. Visual acuity improved to 20/50 and IOP remained consistently at 5 mmHg, even after discontinuation of hypotensive drops. Fundoscopy revealed radial star-shaped chorioretinal folds around the macula (Fig. 2a), as well as optic disc swelling (Fig. 2b). The choroidal detachment maintained its original extent and localization. Anterior displacement of the iris–lens diaphragm, with consequent shallowing of the anterior chamber, precluded accurate gonioscopy, but UBM showed a temporal cyclodialysis cleft and fluid in the suprachoroidal space (Fig. 3a–c). Topical steroids were tapered and the patient was maintained under conservative treatment with topical atropine 1% twice daily. However, after 7 weeks under cycloplegia, there was no improvement in IOP or fundoscopic findings. Also, the patient developed a subcapsular lens opacification, further reducing his visual acuity. At this stage, a triple surgical procedure, combining phacoemulsification and IOL implantation with gas endotamponade and subsequent cyclocryotherapy, was attempted under general anesthesia. Phacoemulsification was performed using a standard phaco-chop technique. Inferior-temporal zonular dehiscence was noted during

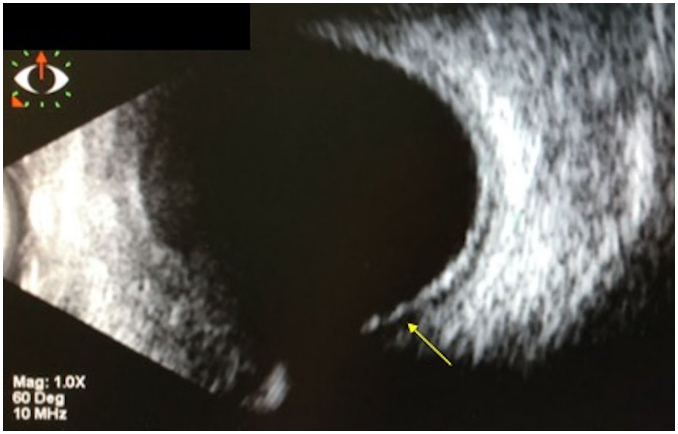

Fig. 1: B-scan ultrasonography of the patient's left eye at presentation, revealing a small, flat, peripherical choroidal detachment (arrow).

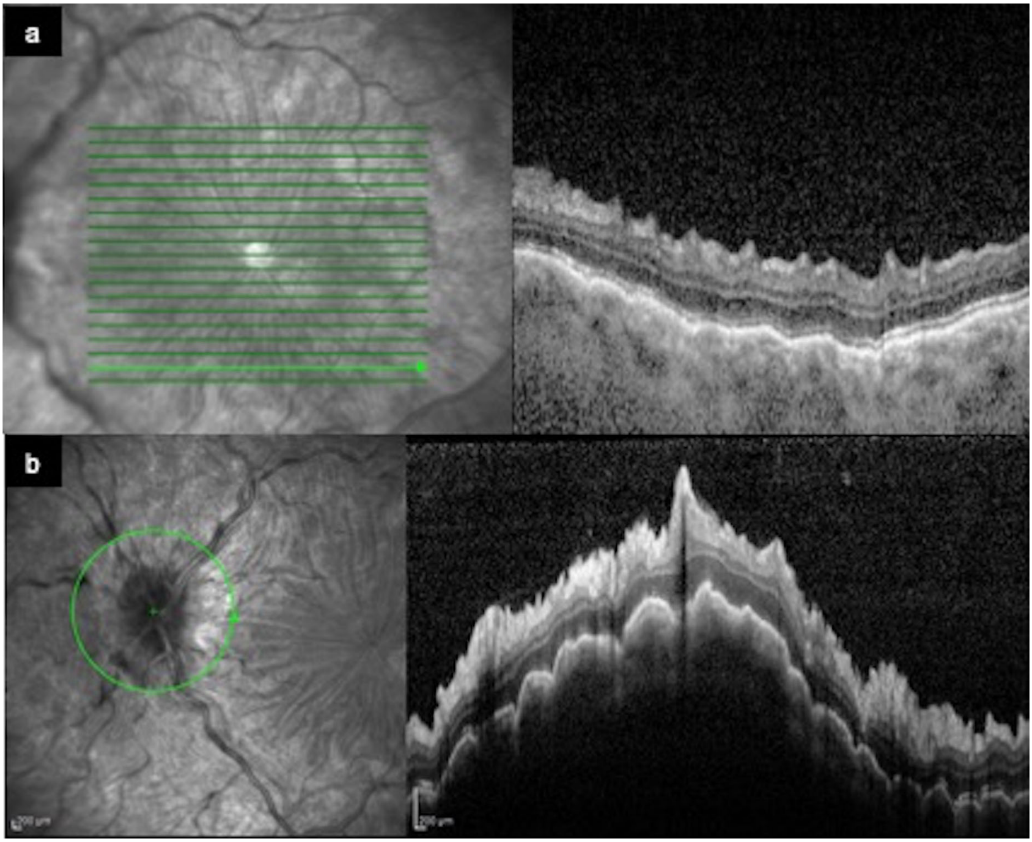

Fig. 2: a, b Infrared images (left panel) and spectral-domain optical coherence tomography (OCT) scans (right panel) showing evident hypotonic maculopathy and optic disc swelling.

cortical aspiration, which required a 13 mm capsular tension ring (CTR) implantation. In-the-bag IOL implantation was then successfully achieved. Afterward, the anterior chamber was filled with a viscoelastic agent, and direct gonioscopy revealed a cyclodialysis cleft, extending from the 12 to 4 o'clock positions. A single bubble (0.5 ml) of 20% sulfur hexafluoride–air mixture (SF_6) was injected via pars plana, in the inferonasal quadrant, 3.5 mm behind the limbus. At this point of the surgery, the patient reacted to eye stimulation, and an unquantifiable part of the introduced gas was expelled. Transconjunctival cryotherapy was then performed using a 3 mm metal tip glaucoma probe (Fig. 4a), placed 1.5 mm behind the limbus. The cryoprobe was connected to a freezing console using nitrous oxide as a cryogen. Six contiguous applications, at a temperature of −80 °C, with a duration of 20 s each, were applied to the sclera, covering the entire extension of the cleft (Fig. 4b).

After the procedure, the patient was advised to rest on his right side for 1 week to guarantee a successful endotamponade. Topical levofloxacin, flurbiprofen, and dexamethasone were prescribed. Atropine 1% twice daily was re-introduced on the second postoperative day and maintained for 2.5 months.

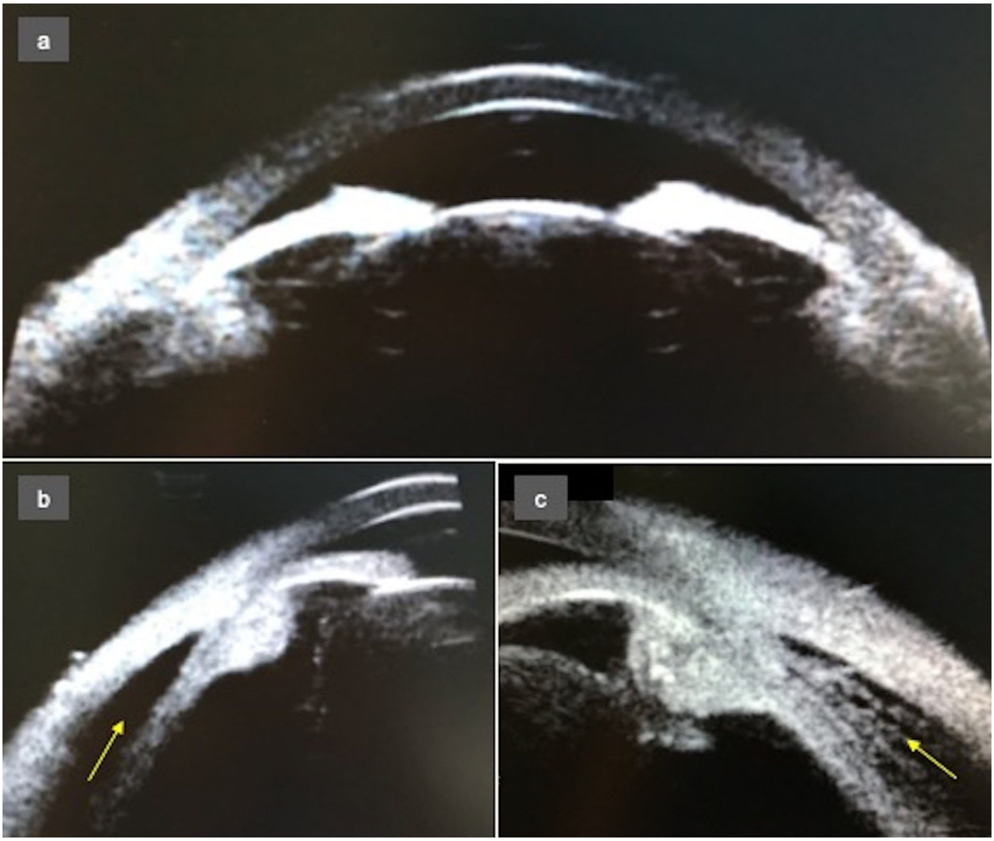

Fig. 3: a High-resolution ultrasound biomicroscopy (UBM) of the left eye, showing anterior displacement of the iris–lens diaphragm and shallowing of the anterior chamber. **b, c** UBM radial section of the cyclodialysis cleft displaying the disinsertion of the longitudinal ciliary muscle fibers from the scleral spur, with fluid in the suprachoroidal space (arrows).

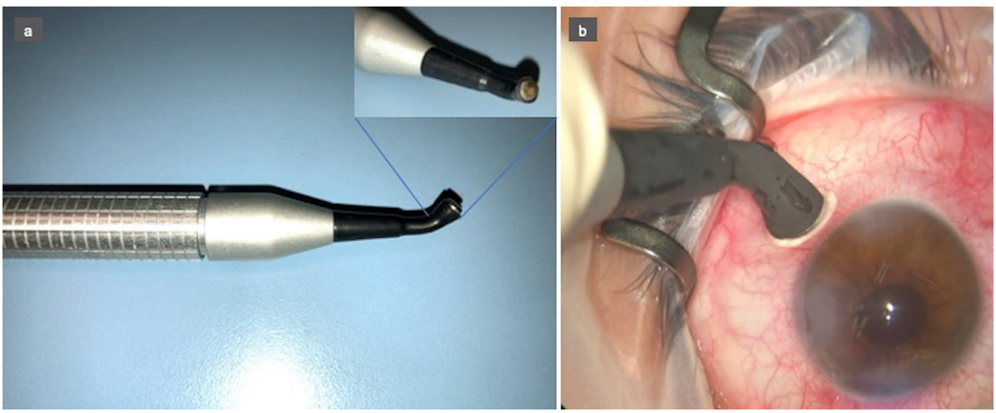

Fig. 4: a Photograph of the glaucoma cryoprobe used in the procedure, and an inset of its 3-mm-diameter round metal tip. **b** Transconjunctival cryotherapy application, 1.5 mm behind the limbus, over the cyclodialysis cleft. A temperature of −80 °C is reached and an "ice ball" is formed at the tip of the probe, ensuring successful freezing. Each application was limited to 20 s duration.

During the early postoperative period, there was a severe anterior chamber inflammatory response (Fig. 5a), with considerable flare and cellular reaction, and a thin hypopyon layer. A small bubble of gas was present in the vitreous cavity for only 5 days (Fig. 5b) and, during that time, IOP increased to 7 mmHg. The inflammation gradually resolved with topical treatment, and 2 weeks after the procedure, the IOP increased to 12 mmHg. By the second postoperative month, successful closure of the cyclodialysis cleft was achieved, as proved by gonioscopy and UBM (Fig. 6a). Fundus examination no longer showed signs of hypotonic maculopathy (Fig. 6b) or choroidal detachment. Three months after the procedure, Nd:YAG laser capsulotomy was performed due to posterior capsular opacification, and the BCVA improved to 20/25. The IOP remained constant (12 mmHg) during the next 14 months of follow-up.

This case report complies with the guidelines for human studies and was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The patient gave his consent to publish this report and all accompanying images.

Discussion

Treating a cyclodialysis cleft is a daunting task for any ophthalmologist. Due to the rarity of this disorder, and the consequent lack of strong scientific evidence, there are no established treatment guidelines [1, 6].

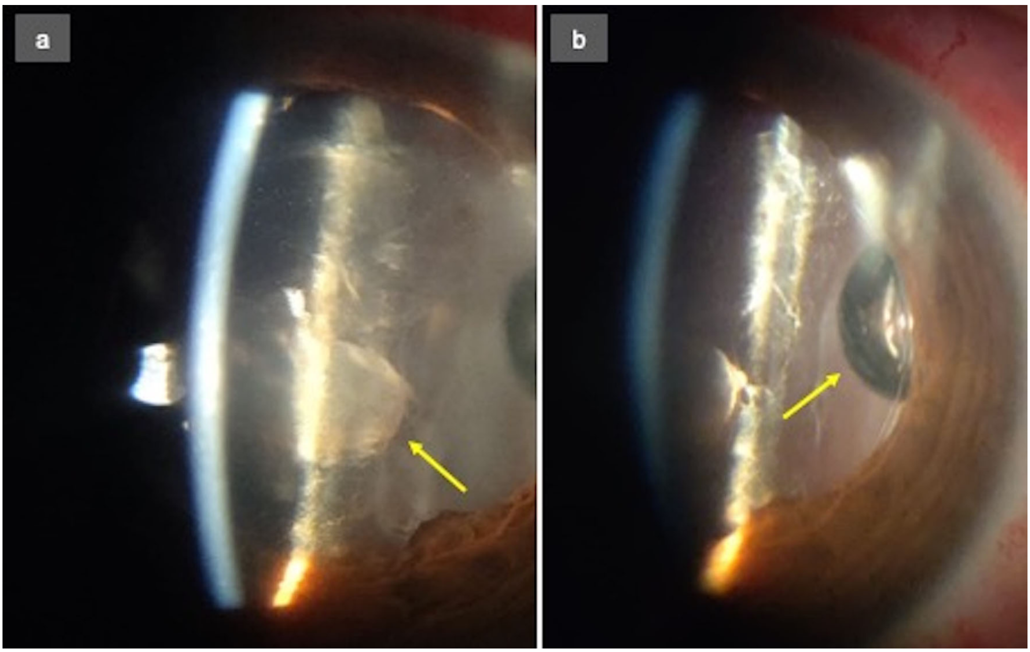

Fig. 5: a Slit-lamp photograph of patient's left eye by the second postoperative day. There is a marked anterior chamber inflammatory reaction, with cells and flare and a fibrinoid pupillary membrane (arrow). The hypopyon layer is not visible in this image. **b** The same image showing the small gas bubble present in the vitreous cavity (arrow).

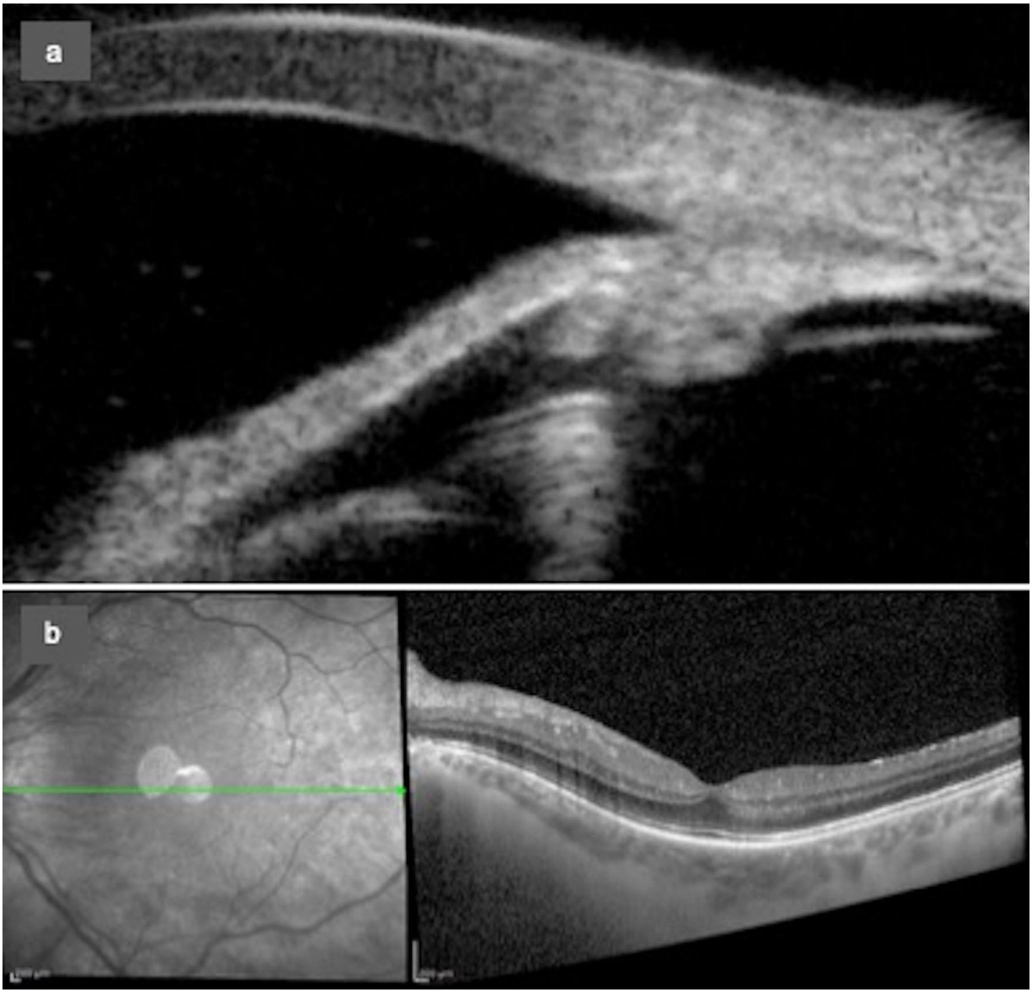

Fig. 6: a UBM radial scan 2 months after the procedure, demonstrating closure of the cyclodialysis cleft. **b** Infrared image (left panel) and OCT scan (right panel) showing resolution of the hypotonic maculopathy.

Medical treatment is consensually accepted as an adequate starting point for all patients. Theoretically, long-acting cycloplegics can close the clefts by relaxation of the ciliary muscle, thus facilitating its apposition to the sclera. However, the success rate of this conservative approach is disappointingly low, frequently creating the need to resort to more interventionist modalities [1, 4].

Laser-based treatments, such as ab interno argon laser photocoagulation and ab externo transscleral YAG or diode laser cyclophotocoagulation, act by generating a localized inflammatory reaction that stimulates cleft closure. However, the outcomes of these approaches can be unpredictable, and they are usually reserved for small clefts [1, 5].

Surgical modalities, namely direct cyclopexy, scleral buckling, vitrectomy (either alone or in combination with cryotherapy or endotamponade), and implantation of a CTR or IOL in the ciliary sulcus, are required for larger clefts, but they have all the inherent risks of invasive intraocular procedures [1, 4, 5].

Herein, we present the successful resolution of a traumatic cyclodialysis by gas endotamponade combined with cyclocryotherapy. This minimally invasive procedure takes advantage of the ability of gas to induce mechanical apposition between the ciliary body and the sclera, along with the inflammatory cicatricial reaction produced by cryotherapy.

Ceruti *et al*. reported a similar technique with a comparable good outcome [7], but in our case, simultaneous traumatic cataract surgery by phacoemulsification was performed. To the best of our knowledge, this "triple" procedure is the first of its kind to be described in the literature.

Our group previously published an analogous case, using a different type of gas (16% hexafluoroethane–air mixture–C2F6) [8]. This time, we elected the 20% sulfur hexafluoride–air mixture (SF6), hoping to lessen the potential effect of an excessive inflammatory reaction of both phacoemulsification and cryotherapy, on a rebound postoperative hypertensive spike.

There was no hypertensive spike, but the loss of a considerable amount of SF6 during eye injection due to accidental patient reaction might have contributed to that.

Additionally, considering the small amount of gas and the short period of time it remained in the vitreous cavity, it seems reasonable to admit that the inflammation induced by cryotherapy might have had a dominant effect in cleft closure and that eventually it might have sufficed. A review of the available literature suggests, however, that cryotherapy alone, without combined gas endotamponade or vitrectomy, has a minimal success rate [1].

The implantation of a CTR and/or IOL in the ciliary sulcus is another proposed option for cleft repair when a cataract is present [9, 10]. In our case, zonular damage and bag disinsertion precluded such a possibility.

Conclusion

Gas endotamponade followed by cyclocryotherapy is an advantageous alternative method for treating a cyclodialysis cleft. First of all, this is a minimally invasive technique free of the dangers associated with more invasive intraocular procedures. Secondly, it is technically simple and can therefore be executed without the need for a highly experienced surgeon. Lastly, our case demonstrated that it can be safely combined with other ocular procedures such as cataract surgery. Although further studies are necessary to validate the outcomes and safety profile of such a technique, this is a promising option in the treatment of cyclodialysis clefts unresponsive to medical therapy.

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Compliance with Ethics Guidelines: This case report complies with the guidelines for human studies and was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The patient gave his consent to publish this report and all accompanying images.

Data Availability: Data sharing is not applicable to this article as no datasets were generated or analyzed for this article.

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Source: Leuzinger-Dias, M., Lima-Fontes, M., Oliveira-Ferreira, C. *et al*. Traumatic Cyclodialysis Cleft Treatment Combined with Cataract Surgery: An Original Triple Procedure. *Ophthalmol Ther* 10, 1171–1179 (2021). https://doi.org/10.1007/s40123-021-00382-x. © The Author(s) 2021.

Association Between Endoscopic Cyclophotocoagulation and Vitreous Prolapse in Trabeculectomy: A Case Report

Vikki W. K. Ng, Jeffrey C. W. Chan* and Kenneth K. W. Li

Abstract

Background: To propose that possible alteration or damage to the ciliary zonules during uncomplicated endoscopic cyclophotocoagulation (ECP) can cause complications in subsequent filtration surgery.

Case Presentation: We present two cases with uncomplicated primary combined phacoemulsification and ECP that underwent subsequent trabeculectomy. Both cases were complicated with vitreous prolapse during the trabeculectomy procedure. We review the anatomy of the ciliary zonules and their spatial relationship with the ciliary processes targeted during ECP and propose an association between ECP, zonular damage and complications in subsequent trabeculectomy such as vitreous prolapse.

Conclusions: Damage to ciliary zonules during ECP may not manifest until subsequent glaucoma filtration surgery. In patients who received prior ECP, we may consider taking preventative measures to avoid associated complications such as vitreous prolapse. Patients with known risk factors for weak zonules may consider choosing alternative intraocular pressure-lowering means.

Keywords: Endoscopic cyclophotocoagulation, Zonular damage, Trabeculectomy, Vitreous prolapse, Case report

Background

Vitreous prolapse is an uncommon complication seen in less than 0.5% of glaucoma filtration surgery [1]. Possible risk factors include aphakia, a subluxed or dislocated lens or eyes with underlying zonular weakness. Zonular weakness can be secondary to ocular trauma, prior ocular

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surgery, high myopia, ocular diseases such as uveitis and pseudoexfoliation syndrome, as well as systemic connective tissue diseases such as Marfan syndrome.

We observed two eyes over a period of 10 years with the complication of vitreous prolapse during glaucoma filtration surgery, both of which received prior endoscopic cyclophotocoagulation (ECP). During ECP, the ciliary processes are targeted for treatment with a diode laser. The zonules are in close proximity to the ciliary processes and some even originate from its lateral walls. Yet clinically significant damage to zonules during uncomplicated ECP leading to subsequent complications is seldom suggested.

We propose that ECP could potentially weaken or damage the zonular integrity which may be a precipitating factor for vitreous prolapse in glaucoma filtration surgery. This knowledge may alter our future management. Procedures other than ECP can be considered in patients with underlying risk factors to prevent further exacerbation of zonular weakness. In eyes with prior ECP, preventative measures against vitreous prolapse should be taken if glaucoma filtration surgery is required.

Case Presentation

Case 1

A 75-year-old man with bilateral advanced primary open angle glaucoma (POAG) received a combined phacoemulsification and ECP surgery in his left eye in 2014. The eye had + 2.5 dioptres (D) of hyperopia (axial length 22.15 mm) and he had no other ocular or systemic diseases or trauma which would predispose him to zonulopathy. There was also no pre-existing phacodonesis or vitreous noted in the anterior chamber.

The surgery was uneventful: phacoemulsification was completed via a temporal 2.2 mm clear-corneal incision. Viscoelastic was then injected to open up the sulcus space and three-hundred degrees of ECP was performed from 4 to 2 o'clock. The power was set at 0.3 W and 94 shots were fired at approximately 0.5 to 2 s per shot. Post-operatively, the IOP was reduced without hypotony and well controlled until 2-years post-ECP.

This eye then underwent a trabeculectomy. A fornix-based conjunctival flap was created in the superonasal quadrant, a partial-thickness scleral flap was raised and mitomycin-C (0.4 mg/ml) soaked pledgets were placed subconjunctivally for 3 min. After irrigation with 100 ml of balanced salt solution (BSS), a paracentesis at 9 o'clock was created. A sclerotomy was made with a Kelly punch and a peripheral iridectomy was created with Vannas scissors. While closing the scleral flap with 10/0 nylon sutures, vitreous prolapse through the sclerotomy was seen underneath the scleral flap. Scleral flap closure was completed, and thorough manual Weck-cel vitrectomy was performed with Westcott scissors. The conjunctiva was closed with interrupted 8/0 vicryl sutures. Post-operatively, there was no vitreous found in the anterior chamber or around the sclerotomy site and the intraocular pressure (IOP) was in the mid-teens. He remained drop-free for 4 months, and has now maintained a pressure of around mid-teens on anti-glaucomatous drops without the need for further glaucoma surgery thus far.

Case 2

An otherwise healthy 58-year-old man with bilateral POAG underwent combined phacoemulsification and ECP in his right eye in 2013. As above, he had no predisposing risk factors for or pre-existing zonulopathy. He was mildly myopic (-1.75D, axial length 24.65 mm). The surgery was uncomplicated with the same surgical steps as described in Case 1. 97 shots of ECP at 0.35 W was applied from 4 to 2 o'clock. Similarly, initial IOP control was good with no hypotony but gradually began to rise. In 2015, he underwent a non-penetrating trabecular surgery which was converted into a trabeculectomy due to macro-perforation.

The conjunctiva was opened with a fornix-based approach and subconjunctival Mitomycin-C (0.4 mg/ml) was applied in the same fashion after the partial-thickness superficial and deep scleral flaps were created. During the peeling of the inner wall of the Schlemm's canal and juxtacanalicular meshwork, a macro-perforation occurred (Fig. 1A). Viscoelastic and carbachol (Miostat) were used to maintain the anterior chamber depth and constrict the pupil respectively. A peripheral iridectomy was created through the perforation site (Fig. 1B) and the deep scleral flap was excised. The superficial scleral flap was then closed with 10/0 nylon sutures and vitreous prolapse was again noted at this stage (Fig. 1C). It was managed similarly as in the previous case by manual Weck-cel vitrectomy. Post-operatively, the IOP was well-controlled with no vitreous seen in the anterior chamber or blocking the drainage pathway. He remained drop-free for 4 months, and now has intraocular pressure controlled around mid-teens on anti-glaucomatous drops without further glaucoma surgery required thus far.

Discussion and Conclusions

ECP was first reported in literature for the treatment of uncontrolled neovascular glaucoma by Uram in 1992 [2]. It is a surgically non-demanding procedure shown to be both safe and effective and is commonly performed in early- to mid-stage POAG [3-5]. Even in cases with refractory glaucoma where filtration surgeries have failed, ECP is safe [6] and can reduce IOPs up to 34% at 1-year post-procedure follow up [7]. In one of our previous publications, we found that combined phacoemulsification and ECP when compared to combined phacoemulsification and

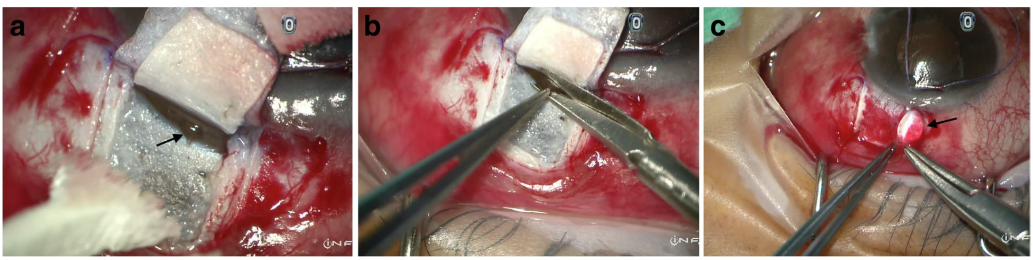

Fig. 1: a Macro-perforation with iris prolapse (black arrow) during peeling of the inner wall of Schlemm's canal and juxtacanalicular meshwork. **b** Surgical iridectomy performed over the prolapsed iris at the perforation site. **c** Vitreous prolapse (black arrow) during closure of the scleral flap.

trabeculectomy had lower complete success rates, but similar qualified success rates. (73.5% vs 74.4%) [8]. Complications of ECP that were reported by the ECP Collaborative Study Group included IOP spikes (14.5%), hyphema (3.8%), choroidal detachment (0.36%) and cystoid macular edema (0.7%). In their study, other severe complications such as retinal detachment (0.2%), choroidal haemorrhage (0.09%) and hypotony (0.12%) were only found in eyes with neovascular glaucoma [9].

This procedure is performed with an intraocular endoscope paired to a diode laser and the ciliary processes are approached ab-interno. The visible portions of the ciliary processes are then treated with continuous laser applied in a painting motion until whitening and shrinkage of the tissue is observed. As a result, IOP can be reduced by diminishing aqueous production [10]. Depending on the target IOP, it can be performed through a one-site corneal incision to cover 180 to 300 degrees of ciliary processes or two-site corneal incisions to treat all ciliary processes (360 degrees). It has been shown that 360-degree treatment resulted in significantly lower IOP without increased incidence of complications [11].

Possible alteration to zonular anatomy secondary to ECP has been suggested in a previous study by Sheybani A *et al* [12]. It looked at the effect of ECP on refractive outcomes in cataract surgeries performed on open angle glaucoma patients. Their results showed a significantly larger difference between predicted and actual refractive outcomes in eyes that underwent combined phacoemulsification and ECP than those with phacoemulsification alone. Eyes that underwent the combined procedure demonstrated a myopic shift (-0.169D to -0.312D in combined phacoemulsification and ECP group vs + 0.029D to -0.110D in phacoemulsification alone group [$p < 0.05$]). The authors hypothesized that as the lens zonules are attached to the ciliary body, an alteration in the ciliary body position after ECP induces a change in the position of the capsular bag-intraocular lens complex and therefore the effective lens position and refractive outcome. Another study by Manoharan N *et al* [13] showed no significant difference in number of refractive surprises between combined phacoemulsification and ECP and phacoemulsification alone. However, they defined "significant" as a difference of greater than 1D. Therefore, their results do not directly contradict those of Sheybani A *et al*. and any statistically significant refractive surprise of less than 1D is unknown. In both of our cases, a myopic shift was noted—case 1 had a target refraction of spherical equivalent (SE) -0.51D but outcome at 1 month was -2D; case 2 had a target refraction of SE -0.53D and outcome at 1 month was -1.38D. These outcomes corroborate the findings of Sheybani A *et al*. but whether this shift directly translates to zonular damage would require further investigation.

The zonular apparatus of the lens consists of anterior and posterior radial fibres connecting the lens to the ciliary body. They insert into the anterior and posterior lens capsules respectively. Over the years there have been conflicting opinions on the origins and insertions of the zonular fibres. It is largely accepted that the primary origin of these fibres is the pars plana [14]. Electron microscopy performed by M. Canals *et al* [15] showed that the zonular fibres traverse through the ciliary valleys before inserting into the lens capsule—the anterior fibres in particular are in close proximity to the lateral walls of the ciliary processes during their journey. Furthermore, although most fibres originate from the pars plana, some of the anterior fibres originate from the ciliary valleys or the lateral walls of the ciliary processes themselves (Fig. 2A & 2B). Therefore, anatomically, alteration of or damage to the zonular fibres during ECP is certainly possible. The resultant weakening of zonular integrity—although may not cause immediate complications—may manifest when additional stress to the zonules is applied. An example of when this may occur is during glaucoma filtration surgery, then complications such as vitreous loss or zonulysis may arise.

A few other studies have also touched upon zonular damage during ECP. Lindfield D *et al* [16] noticed vitreous in the anterior chamber in one patient on postoperative day one after combined phacoemulsification and ECP. The authors postulated that it was caused by a small area of zonular dehiscence during surgery. This could have been induced by either the phacoemulsification or the ECP. Morales J *et al* [17] reported another case of combined phacoemulsification and ECP where intraoperative zonular dialysis was noted during the procedure. However, in these reports, the complications were noted during or immediately after the primary procedure and neither elaborated on the mechanism of zonular injury or reported any complications in subsequent procedures.

In our two cases reported above, the primary ECP procedure was seemingly uncomplicated intra- and post-operatively, with no signs of zonular damage such as vitreous loss, zonulysis or intraocular lens decentration. It was not until the second-stage glaucoma filtration surgeries that vitreous prolapse through the sclerotomy upon creation of a surgical iridectomy was noted. Incidence of vitreous prolapse as a complication of trabeculectomy is seldom cited in literature and is considered to be rare. In our center, 242 trabeculectomies were done from 2010–2020 and 44 had prior ECP. Only the 2 cases illustrated above were complicated with vitreous prolapse making the overall incidence of vitreous prolapse during trabeculectomy with or without prior ECP 0.8% (2/242) and in those with prior ECP 4.5% (2/44). The route of prolapse begins when

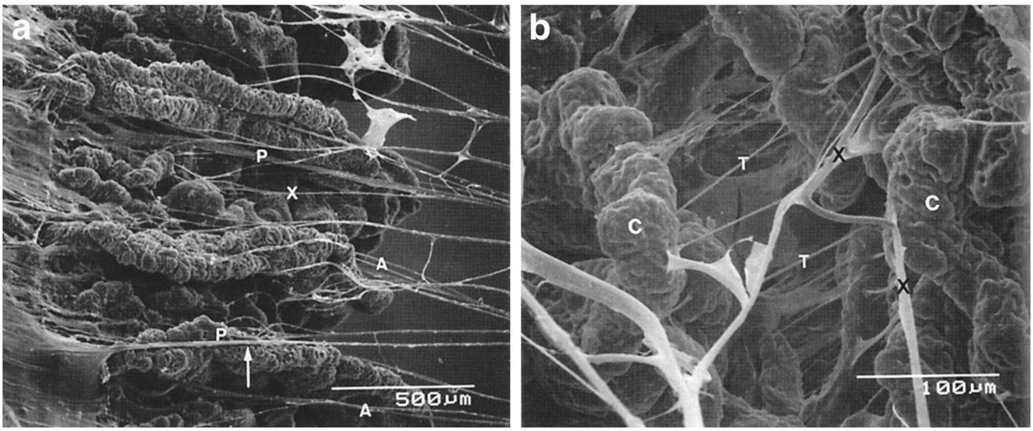

Fig. 2: a Scanning electron micrograph of pars plicata of the ciliary body. Anterior zonular fibres (A) are attached to the lateral walls of the ciliary processes and emerge at their anterior endings. Fibres originating at the ciliary valleys are observed (X). × 49. (Reused with permission from Canal M [15], Copyright Karger Publishers). **b** Scanning electron micrograph. At a higher magnification, transversal fibres (T) can be seen between adjacent ciliary processes (C). Fibres originating at the lateral walls of the ciliary processes belonging to the anterior zonular layer are seen (X). × 240. (Reused with permission from Canal M [15], Copyright Karger Publishers).

vitreous from the vitreous cavity enters the posterior chamber. Under normal anatomical circumstances, this communication is blocked by the zonules.

Neither patient had pre-existing risk factors for zonulopathy. We propose that the ECP was the culprit behind the zonular damage precipitating vitreous prolapse. During filtration surgery, there is a sudden drop in pressure when the sclerotomy is created. This generates a large pressure gradient, inviting the vitreous to prolapse through the weakened zonules. The surgical iridectomy then creates a communication between the posterior and anterior chambers, allowing the vitreous to enter the anterior chamber and prolapse through the sclerotomy.

Another possible cause of vitreous prolapse in trabeculectomy is surgical damage to the zonules or ciliary body during sclerotomy or surgical iridectomy. A sclerotomy fashioned too posteriorly can cause direct damage to the zonules or ciliary body. We believe this to be an unlikely cause in the cases illustrated above as no direct damage was noted intra-operatively and post-operative gonioscopy assessment did not reveal abnormally posterior sclerotomies.

Given the low incidence of vitreous loss during glaucoma filtration surgery, there is no consensus on its management approach. In our cases, after vitreous prolapse was noted, we maintained the anterior chamber with a cohesive viscoelastic. We then simply removed only the prolapsed vitreous at the edges of the scleral flap by manual Weck-cel vitrectomy (Fig. 3A). No anterior vitrectomy was performed. We then closed the scleral flap with a few more stitches and at a higher tension than usual (Fig. 3B) in order to minimize the aqueous outflow to avoid too steep of a pressure gradient which may lead to vitreous blockage of the sclerotomy. In both cases—with a well formed anterior chamber and the IOP at mid-teens—the vitreous retracted back into the vitreous cavity. IOP was then well-maintained until their latest follow up more than 4 years later with no further glaucoma surgeries required. In our opinion, when vitreous prolapse does occur the extent is minimal and can be managed without anterior vitrectomy. Early fundal examination was performed and is recommended to look for possible complications of vitreous traction secondary to vitreous prolapse such as retinal breaks.

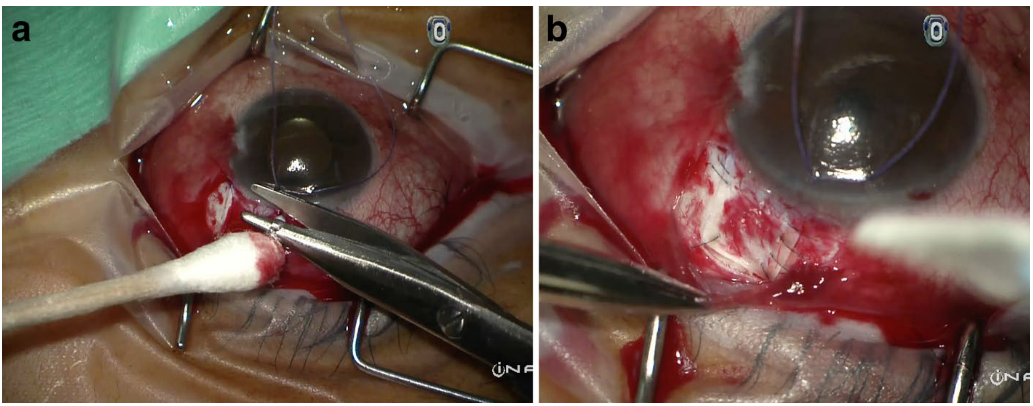

Fig. 3: a Manual vitrectomy by cotton tip applicator and Weck-cel to remove all vitreous at the edges of the scleral flap. **b** The scleral flap was tied down tight with multiple stitches to avoid postoperative hypotony and vitreous blockage of the sclerotomy.

Vitreous loss during surgery can potentially lead to multiple sight-threatening complications such as suprachoroidal haemorrhage, retinal detachment, cystoid macular edema and endophthalmitis. It also increases the risk of failure in glaucoma filtration surgery due to vitreous blockage of the sclerotomy. Therefore, methods to prevent this complication have a significant impact on the visual outcome of our patients. We have proposed that damage or weakening of the zonules can occur even in apparently uncomplicated ECP. Caution is advised when considering ECP for patients with high baseline IOP where the potential need for subsequent glaucoma filtration surgery is significant. In patients who have had prior ECP and require glaucoma filtration surgery, the anticipation of vitreous prolapse can prompt surgeons to adopt preventative measures so that sight-threatening complications can be avoided and surgical outcomes improved. For example, stabilising the anterior chamber with the use of an anterior chamber maintainer or injection of viscoelastic prior to sclerotomy can be considered. This can dampen the sudden drop in intraocular pressure and therefore minimize the pressure gradient that encourages the vitreous to prolapse. Alternatively, other surgical procedures such as glaucoma drainage device implantation rather than trabeculectomy can be considered in patients with prior ECP.

Abbreviations: ECP: Endoscopic Cyclophotocoagulation; POAG: Primary Open Angle Glaucoma; D: Dioptres; BSS: Balanced Salt Solution; IOP: Intraocular Pressure; SE: Spherical Equivalent.

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Authors' contributions: Conception of the case report – JCC, Data collection – VWN, Drafting the manuscript – VWN, JCC, Revising the manuscript – VWN, JCC, KKL. All authors read and approved the final version of the manuscript.

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Availability of data and materials: The datasets used and analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: Written informed consent for publication of identifying images or other personal or clinical details was obtained from both of the patients. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

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PHMB: Poly Hexamethylene Biguanide | BKC: Benzalkonium Chloride | DNA: Deoxyribo Nucleic Acid | ^: In vitro study | Brimolol contain PHMB 0.005%
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