Primary Congenital Glaucoma

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ABSTRACT

Glaucomas of the childhood are devastatingly deceptive in their presentations because of an insidious onset and late recognition. Primary congenital glaucomas (PCG) which serve as a prototype for glaucomas in the young Subtleties of diagnosis may lie in simple symptoms of watering and photophobia. This article is aimed to summarize all common manifestations and basics of surgical treatment, conventional and contemporary. Parameters of diagnosis and success have been undergoing modifications from time to time, hence the need to take stalk. How we look at childhood glaucomas in the light of conclusions drawn from glaucoma clinical trials in adults, evolving concepts of risk factors like central corneal thickness at the first and subsequent visits are of practical concern.

Keywords: Childhood glaucoma, Pediatric glaucoma, Trabeculotomy, AGV.

INTRODUCTION

With the availability of medical literature on the click of a mouse, it is important that specific queries be answered.

What are the Common causes and Age of Onset?

Childhood glaucomas are of three etiological types (Table 1) and the commonest age of onset is under the first year of life, with 80% of patients present in the first year of life, out of which, 20% present as ‘newborn glaucoma’ while the remaining 80% report as infantile glaucoma. Conventionally, the term infantile glaucoma is extended up to 3 years, after which it is termed ‘juvenile’ glaucoma. This ambiguity in the nomenclature is due to the typical clinical features attributed to the distensible eye up to three years. Some study groups are less rigid and prefer to club all these together as ‘Primary infantile and Congenital glaucomas’ or ‘Infantile glaucomas.’ In any case, ‘New born glaucoma’ as a separate entity is important to recognize as this is the most severe form with worst outcome.

How Frequently do We see PCG?

There have been some additions to the older figures quoting an incidence of 1 in 5 years in general ophthalmic practice and 1/10,000 live births (LB). Results of a survey of newly diagnosed cases by the ‘British infantile and congenital glaucoma study Group’ (BIG study) in three population groups were published in 2007:

- 1/18,500 LB in British caucasians
- 9 times higher in British-Pakistani population
- 1/30,200 LB in irish population.

Other Study Groups have Reported as Under

- 1/30,000 LB among Australians
- Hungary: Higher incidence among gypsies
- 1/1,250 LB in Slovak nomads
- ½,500 LB in Saudi Arabia
- 1 in 3300 LB in Andhra Pradesh
- Brazil: 10.8% of 3,210 visually handicapped children
- 6.3% in China.

Higher incidence in inbred communities has got the molecular biologists striving to find some correlations between genetic mutations and phenotypes in the hope of predicting the onset or the severity of disease. Hyderabad group is leading in this global research.

What is the Gender Distribution and How often does it affect both Eyes?

An interesting fact—a pseudoautosomal dominant pattern may emerge in families with consanguinity at multiple levels with seemingly equal predilection for either sex.

What is the Social Impact, if any of this Rare Disease?

It is true that this is a rare disease but we also know that glaucoma causes progressive and complete blindness. With a long anticipated life span, these children suffer economic blindness and social discrimination and end up becoming a burden to the society. There is also a higher chance of more than one just one member of a family suffering. Hence, the importance of catching
them young for treatment as well as parental counseling cannot be over emphasized. Statistical estimations reveal that there are 1.5 to 2 million glaucoma blind children globally, of which 2/3rd are in the developing nations. They constitute 15% of blind school entries and 4.2% of all cases of pediatric blindness.\textsuperscript{10}

**Which cases have the Worst Prognosis?**

Patients presenting with severe corneal clouding in the first year have the worst outcome (Figs 1A and B).\textsuperscript{6,11,12}

**What is the Role of Medical Therapy?**

Glaucoma medications have a limited and palliative value in PCG because of poor response and compliance. Child should be started on medical treatment only as a stopgap and surgery should be performed without further delay.\textsuperscript{12,13}

**Which Drugs are not to be used in Children?**

Alpha 2 agonist group of drugs like brimonidine are contraindicated in children \textless; 2 years of age because of the risk of apnea.\textsuperscript{12,13} In general, prostaglandin analogues too are to be avoided in unilateral glaucomas and prior to surgery. Pilocarpine may paradoxically raise the intraocular pressure (IOP) due to its action on the scleral spur, which may cause further collapse of the trabecular meshwork due to the abnormally high insertion of uveal tissue.\textsuperscript{14} Short-term use of a topical carbonic anhydrase inhibitor (CAI) and beta-blocker (0.25% or 0.50%) either alone or in combination is a safer choice in these cases. Betaxolol may be used in children with asthma. Additional benefit with oral acetazolamide may be obtained in very high levels of IOP as it seems to have an additive effect with topical CAI drops in pediatric patients unlike in adults.\textsuperscript{15} Timolol instillation should be followed by mechanical punctual occlusion for at least 3 to 4 minutes, to minimize systemic absorption. In case, the surgical response is incomplete postoperatively or late failure occurs, qualified control with minimum medication may be achieved.\textsuperscript{16,17}

**What is the Best Surgical Option for these Patients?**

An ideal surgical procedure aims to achieve the following:\textsuperscript{11,17-19}

- Ensure short-term and long-term control of IOP
- Should have no vision threatening complications.

**Should the Small Infant undergo such Major Surgery? Does an Ideal Procedure Exist?**

Undoubtedly, on the basis of documented clinical evidence, the one fact we do know is that delay is disastrous for vision. Concerns about general anesthesia (GA) and surgical outcome in babies have been put to rest in recent years with advances in safe anesthesia for newborns with significant reduction in morbidity and mortality associated with GA than yesteryears. A calculated risk needs to be taken because complications like hypothermia, apnea spells and hemorrhage have been reported in newborns making a case for minimizing the use and abuse of GA in newborns.\textsuperscript{20,21} By far and large, modern anesthesia and resuscitation methods have made surgical intervention quite safe in newborns. No major complication were reported by Mandal in 2003 in a study of 47 eyes of 25 patients of congenital glaucoma operated under one month of age except one case of hypothermia and one of uncontrolled bleeding from the trachea, both resuscitated successfully. The above author prefers to operate both eyes simultaneously as his way of maximizing the care with the underlying need for urgency required to manage such cases. Complete clearance of cornea was noted in the same study in 66% of cases, IOP control at the end of 12 months of follow-up with the Kaplan-Meier survival rate of 89.4% and the mean glaucoma medication rate fell from 68.1\% to 14.9\%. Excellent visual outcomes and reversal of cupping with early intervention in these cases is known to occur universally.\textsuperscript{16,22}

There are several surgical options depending on the severity. Let us first briefly summarize the relevant anatomy and embryology of the anterior chamber (AC) angle for better orientation and approach to the case at hand.

**Anatomy and Embryology of the AC Angle**

The limbal transition zone between the cornea and sclera measuring 1 to 1.5 mm is bounded anteriorly by the end of the Descemet’s membrane (Schwalbe’s line) and posteriorly by the scleral spur, which is the outer landmark for the trabecular meshwork (TM). The TM fills up an indentation or depression...
known as the scleral sulcus on the under surface of the sclera in front of the scleral spur and stretches anteriorly upto the Schwalbe’s line (Fig. 2). Schlemm’s canal courses circumferentially beneath the TM tissue. The ciliary muscle, on the other hand, takes attachment to the scleral spur, rendering it taut so that the intertrabecular spaces do not collapse. The same structures when viewed on gonioscopy are seen as lines or bands peeping into the angle recess in the posteroanterior order, i.e. iris, ciliary body, scleral spur, TM and Schwalbe’s line.

**Embryology of the AC Angle**[^13]  

In general, ocular development goes through three stages:

- **Stage of embryogenesis** (up to 3rd week): In the initial stages after fertilization, sequential formation of three cell masses—morula, blastula and lastly gastrula occurs. Cells within the gastrula differentiate into three primary germ layers: ectoderm, mesoderm and endoderm.

- **Stage of organogenesis** (3rd to 7th week): Is the period of organization of the segregated cells into rudimentary organs. The lens separates from the surface ectoderm (6 weeks) and the fetal fissure closes. The hitherto undifferentiated mass of cells from the neural crest migrate to appear in the vicinity of the anterior equator of the lens (Fig. 3) and give origin to the corneal endothelium, stroma, iris, ciliary body, trabecular meshwork and sclera. The limbus makes its appearance and the AC appears as a potential space. The three waves of neural migration now proceed as follows:
  - First wave forms the corneal and trabecular endothelium
  - Second wave forms corneal stroma
  - Third wave forms the iris stroma.

  The anterior chamber boundaries are formed by the cornea and tunica vasculosa lentis during the 7th week of gestation.

- **Stage of differentiation** (8th week onwards): With the appearance of limbus, the rudimentary TM also appears. The TM undergoes a process of internal reorganization so that the highly specialized task of aqueous secretion and excretion can begin. Following theories of meshwork development have been proposed:
  - Atrophy and Absorption
  - Rarefaction
  - Cleavage
  - **Theory of growth and differentiation**: This new and the most accepted process was demonstrated by McMenamin in his study of 432 human fetal eyes. Trabecular tissue undergoes a process of differentiation in which there appear gaps in the matrix with reorganization of the cells so that the TM attains its porous character with the creation of intertrabecular spaces. The nonpigmented secretory epithelium of the ciliary body gets thrown into folds by 12 weeks and the longitudinal ciliary muscle development takes place in the 4th month. Finally the primitive TM establishes communication with the anterior chamber by 20 to 22 weeks of gestation. This is about the time the ciliary body starts to function but the complete maturation of the angle with regression of the hyaloid system occurs by the 8th month. Further posterior movement of the AC angle is a continuous process with full angle recess formation achieved up to 6 to 12 months in the postnatal period. Histopathology support was provided by Anderson DR (1981) with demonstration of the high insertion of the anterior uvea across the posterior TM in the third trimester, persistence of which could be the cause for compression of the trabecular beams leading to congenital glaucoma. However, the possibility of primary defects at various levels within the TM and

[Fig. 2: Normal anterior chamber angle structures](Image)

[Fig. 3: Origin of neural crest cells](Image)
Suggested Sequence for EUA
- Tonometry (as early as possible after induction and before intubation)
- External examination
- Anterior segment examination
- Corneal diameter measurement
- Fundus examination
- Gonioscopy
- Refraction, pachymetry, axial length measurement.

Preanesthesia
Each clinical parameter is important in a unique way, either in diagnosis, prognosis or management of these children. With a view to maximizing the advantages of EUA in these small children, it is imperative that the surgeon/assistant be familiar with all possible variables associated with GA. The need to make a team with the anesthesiologist cannot be overemphasized in PCG patients.11 Informed consent for surgical intervention must be taken prior to GA, prognosis and risk, if any should always be explained beforehand. Parents must be educated about (a) the type of glaucoma and (b) high demands of care even after the operation and (c) the likely need for GA in future.20

Do Anesthetic Agents alter IOP Levels?26,27
Anesthetic agents and dosage are known to alter the IOP (Table 3). For this reason, high IOP in isolation should never be the basis for diagnosis. Despite the inconvenience associated with a GA event in terms of cost and time. A casual and inconsistent reporting in EUA is not uncommon. This can lead to an aimless venture towards controlling a pressure, which was erroneously recorded high.

Are these IOP readings Comparable to Adult Values?
IOP is also known to increase with age, hyperopia and corneal thickness. Adult values are normally reached only after the early teens (Table 4).27 In a study of 405 Indian children up to the age of 12 years Sihota et al found a mean overall value of IOP as 12.02 ± .74 mmHg and 8 ± 2.55 mmHg < 1 year of age. Adult values were achieved at 12 years of age.28

Photophobia, Watering, Redness, Pain
Severe photophobia causes the infant to bury the head into a pillow. This symptom complex should be differentiated from other causes of watering at this age. Symptoms of ocular

Schlemm’s canal has not been ruled out. Absence of the Schlemm’s canal, whenever found has been thought to be a secondary change. No true membrane exists as believed earlier.

Gonioscopic Anatomy of a Normal Infant Eye (Fig. 4)22,24
- Iris inserts posterior to the scleral spur
- Flat iris insertion due to poor development of the angle recess till the age of 6 to 12 months
- Ciliary body band is distinct in most cases
- TM appears thicker and more translucent than in adults.

When should Glaucoma be Suspected in an Infant?
Whenever the classical triad of watering eye, photophobia and cloudy cornea is seen, glaucoma should be suspected and an initial examination followed by examination under anesthesia (EUA) with prior consent for surgical intervention should be done.

Initial Examination
General systemic and ophthalmic examination is done to screen for possible systemic associations; adnexal sources of irritation in infants like epiblepharon, entropion and foreign body. Visual responses are judged and preliminary digital tonometry may be done whenever possible.12 After the initial history and office examination, EUA /surgery are planned (Fig. 5).

Table 3: Effect of anesthetic agents on intraocular pressure26

<table>
<thead>
<tr>
<th>IOP increases</th>
<th>IOP decreases</th>
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<tbody>
<tr>
<td>Succinyl choline</td>
<td>Halothane</td>
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<tr>
<td>Ketamine</td>
<td>Oxygen</td>
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<tr>
<td>Nitrous oxide</td>
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<tr>
<td>Endotracheal intubation</td>
<td>Sevoflurane</td>
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<tr>
<td>Midazolam</td>
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<td>Methohexitol</td>
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No change in IOP with oral chloral hydrate sedation. Tonometry with ≤ 1% halothane under the mask anesthesia is considered optimum.
irritation are also common in buphthalmic eyes due to steep corneas and poor tear film stability, appearing sometimes like dry eye.

**What are the Corneal Findings?**

Under the effect of high IOP, the ocular globe distends resulting in buphthalmos meaning ‘Ox Eye’. This expansion leads to typical ‘stretch marks’ in the cornea called ‘Haab’s Striae’ (Figs 6A and B, Fig. 7) due to ruptures in the elastic Descemet’s membrane typically in the circumferential direction. With passage of time the overlying edematous cornea undergoes opacification. 80% of PCG eyes in India have severe corneal clouding secondary to increased IOP during intrauterine life or later in infancy (Fig. 8). Posterior embryotoxon can also be noted in some cases (Fig. 9).

![Fig. 7: Severe stretching of the limbus](image)

**Table 4: Normal intraocular pressure by age**

<table>
<thead>
<tr>
<th>Age in years</th>
<th>IOP in mmHg</th>
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<tbody>
<tr>
<td>Birth</td>
<td>9-6</td>
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<tr>
<td>0-1</td>
<td>10.6</td>
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<tr>
<td>1-2</td>
<td>12.0</td>
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<td>2-3</td>
<td>12.6</td>
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<td>3-5</td>
<td>13.8</td>
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<td>5-7</td>
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<td>7-9</td>
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<td>9-12</td>
<td>14.3</td>
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<tr>
<td>12-16</td>
<td>14.5</td>
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*These values were obtained using a hand held noncontact tonometer Pulsair, Keeler.

Differential Diagnosis of Corneal Clouding (‘STUMPED’)

- Sclerocornea
- Traumatic rupture
- Metabolic
- Peter’s anomaly
- Posterior polymorphous dystrophy of cornea
- Endothelial dystrophy
- Dermoid.
Corneal Diameter

What about corneal diameter? What is the correct way to measure cornea in a stretched limbus (Fig. 7)?

Corneal diameter is measured by using callipers to measure the horizontal and vertical diameters (Fig. 10). Under good ambient illumination, callipers are held at the point of the first appearance of the white scleral fibers on one side to the same point on the other. This allows a measurement accuracy of approximately 0.5 mm. Normally, horizontal diameter measures marginally more than vertical. Considering 9 to 10.5 mm as normal at birth, taking ≥ 12 mm in either meridian as abnormal at 1 year, one should look for other evidence of glaucoma.\(^{23,29}\) A value of 13 mm or more is definitely abnormal for all age groups. The following formula has been worked out by Sherwin Isenberg for interpretation in preterm babies:\(^{30}\)

\[
0.0014 \times \text{Weight (in grams)} + 6.3 = \text{Corneal diameter}
\]

Developmental glaucoma may have anomalies like Microspherophakia with or without aniridia (Fig. 11), persistent hyperplastic primary vitreous and congenital ectropion uvea syndrome (Table 5).

<table>
<thead>
<tr>
<th>Table 5: Other developmental glaucomas with associated anomalies</th>
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<tbody>
<tr>
<td>1 Iridocorneal endothelial syndrome</td>
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<td></td>
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<tr>
<td>2 Posterior polymorphous dystrophy</td>
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<td>3 Peter’s anomaly</td>
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<td>4 Aniridia</td>
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<td>5 Iridogoniodysgenesis</td>
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<td>6 Oculodentodigital dysplasia</td>
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<td>7 Ectopia lentis et pupillae</td>
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<tr>
<td>8 Congenital ectropion uveae</td>
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<tr>
<td></td>
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<tr>
<td>9 Congenital microcoria and Myopia</td>
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Differential Diagnosis of Buphthalmos\(^{23,29,31}\)

- Congenital myopia
- Megalocornea
- Anterior megalophthalmos
- Keratoglobus
- Secondary glaucomas.

Gonioscopy

Why is Gonioscopy done and which Gonioscope is Preferable?

Gonioscopy is done with Koeppe’s type direct goniolens available in a set of different sizes for use in supine position.\(^{31}\) Direct goniolens gives an erect and panoramic view of the angle of the AC at a lower magnification than the commonly used indirect gonioprism of the Goldman type in adults. It is also
possible to see the fundus with this 50 diopter concave lens despite significant corneal edema through an undilated pupil. This is a nongonioscopic use of Koeppe’s lens.

Gonioscopic Features of PCG\textsuperscript{23,31}
Morning mist appearance.

Disc and Fundus Evaluation
Central, concentric steep walled cup (Fig. 12).

What Type of Refractive Errors are Common in PCG Patients?
• Induced myopia
• Astigmatism due to irregular scarring.

Pachymetry
• IOP in children shows an increasing trend with age, hyperopia and central corneal thickness (CCT), reaching adult IOP values by 12 years in a study of the Indian pediatric population by Sihota.\textsuperscript{28} PCG patients have revealed a trend towards thinner corneas on ultrasound pachymetry.\textsuperscript{31} Studies on CCT in PCG however are of preliminary nature and have not been confirmed.
• Determining accuracy of measurement of CCT in edematous corneas anyhow remains a challenge.

Axial Length (AL)
As a guide to the severity of glaucoma and for follow-up.

Severity Index
A severity assessment on first presentation has been proposed by Mandal et al in their review of cases (Table 6).\textsuperscript{32}

\subsection*{Surgical Treatment of PCG}
For all the practical reasons, buphthalmic eyes are a special surgical challenge:\textsuperscript{33-36}
• Opaque cornea
• Distended globe with high IOP
• Posterior shift of limbus
• Thin sclera and limbus
• Thick and active Tenon’s capsule, rapid wound healing
• Lower scleral rigidity
• Friable iris
• Life long lasting results anticipated
• Visual rehabilitation is difficult.

\subsection*{Choice of Surgery}
Due to aggressive fibrosis and rapid healing in younger age groups, conventional filtering surgery enjoys limited long-term success. Best surgical results are obtained, when surgery is done as early as possible before the onset of irreversible glaucoma and secondary changes in the angle and cornea occur.\textsuperscript{21,33-38} The following procedures are listed for their application in childhood glaucoma.\textsuperscript{39,40-46}
• Trabeculectomy with antimetabolites\textsuperscript{46}
• Trabeculotomy ab externo\textsuperscript{47}
• Combined trabeculotomy with trabeculectomy (CTT) with or without antimetabolites
• Nonpenetrating Schlemm’s canal resection\textsuperscript{44,45}
• Goniotomy\textsuperscript{50}
• Goniosomal drainage devices (GDD)
• Cyclodestructive procedures.

\textbf{Trabeculotomy with Trabeculectomy (CTT)}
This is the most commonly performed surgery in India. It has the following clear advantages over goniotomy.\textsuperscript{39,47}
• Can be performed in opaque cornea
• Familiarity with ab externo approach
• Can be combined with trabeculectomy
• Satisfactory IOP control.

\textbf{Principle}
To cannulate Schlemm’s canal from external approach and then tear through the TM into the anterior chamber, creating a direct communication between the AC and Schlemm’s canal. Additional trabeculotomy is done to enhance long-term success.

\textbf{History}
Burian and Smith independently reported it in 1960 as an alternative to goniotomy. Harms and Dannhiem modified the

\begin{table}[h]
\centering
\caption{Severity index in PCG\textsuperscript{18}}
\begin{tabular}{|l|l|l|l|l|}
\hline
Clinical parameter & Normal & Mild & Moderate & Severe/Very severe \\
\hline
• Cornea diameter in mm & Up to 10.5 & > 10.5-12 & > 12-13 & > 13 \\
• IOP mmHg & 11.5 & > 11-70 & > 10-30 & > 30 \\
• C:D ratio & 0.3-0.4 & > 0.4-0.6 & > 0.6-0.8 & > 0.8 \\
• Last BCVA & 20/20 & < 20/60-20/60 & < 20/60-20/200 & < 20/400-no PL \\
\hline
\end{tabular}
\end{table}

\textsuperscript{1}This comprehensive chart may help to provide a realistic approach in management of PCG.
procedure. Reported success rates vary from 73 to 100%. Indian studies reported a cumulative success rate of 60% over a long-term follow-up.

Steps of Combined Trabeculotomy with Trabeculectomy using Intraoperative MMC

Conjunctiva is sutured appropriately, fornix based flap with two wing sutures (purse string type) and multiple (usually 2-3) bleb forming sutures with 10-0 nylon. Limbus based flap requires double layer suturing of the Tenon’s layer and conjunctiva. Care is taken to hydrate the side port and titrate the bleb to ensure water tight closure (Figs 13 to 16).

Intraoperative Complications

- Perforation of sclera/false passage
- Descemet’s stripping
- Nonlocalization of TM’s canal
- Severe hypotony after first canulation, so noncanulation on second side
- Loss of anterior chamber and lens injury
- Wrap around iris
- Iridodialysis
- Cyclodialysis
- Hyphema.

Intraoperative Complications

- Chronic hypotony
- Shallow anterior chamber
- Hyphema
- Choroidal detachment
- Cataract
- Retinal detachment
- Inadequate IOP control
- Blebitis
- Endophthalmitis
- Long-term effects of antifibrotic agents is not known.
- Enhanced astigmatism.

Postoperative Complications

- Chronic hypotony
- Shallow anterior chamber
- Hyphema
- Choroidal detachment
- Cataract
- Retinal detachment
- Inadequate IOP control
- Blebitis
- Endophthalmitis
- Long-term effects of antifibrotic agents is not known.
- Enhanced astigmatism.

Postoperative Protocol

Topical steroid and cycloplegic drugs are given for a maximum of six weeks. Cushing’s syndrome has been reported with unsupervised topical use of glucocorticoids in infants.

Regular Follow-up

- To assess control of IOP
- Refraction
- Amblyopia therapy
- Success may be complete or qualified (on one topical drug) on the basis of IOP lowering effect
- Optical keratoplasty.

Fig. 13: Globe fixation with two bridle sutures through the episclera on either side of superotemporal quadrant

Fig. 14: Fornix based conjunctival flap dissection
Alternate Procedures

360° suture trabeculotomy.
6-0 Prolene suture is used to thread the entire Schlemm’s canal and rupture it to communicate with the anterior chamber.

Nonpenetrating Schlemm’s Canal Resection

In this procedure, a block of tissue is excised beneath the scleral flap to ‘exteriorize’ the Schlemm’s canal without penetrating the AC. It has been reported to be fairly successful.

Goniotomy

Aim is to transect the Schlemm’s canal by ab-interno approach.

Prerequisites

• Clear cornea
• Age 3 to 12 months preferably
• Good visibility of angle structures with clear identification of meshwork, which is difficult
• Technical expertise required
• Corneal diameter not >15 mm.

Procedure

A round, dome shaped direct gonioscope is placed on the cornea with suturing or with a handle (Swan Jacob type). A nontapered knife or needle enters the AC just inside the limbus and is withdrawn. Injection of viscoelastic is done to maintain the AC during the procedure. Re-entry is done with the knife, which courses in the same plane as the iris. The TM is engaged just below the Schwalbe’s line in the opposite quadrant and a circumferential incision is made across the visible meshwork. It should be a superficial incision with no grating or scraping sensation. Prior treatment with pilocarpine eye drops is recommended. An immediate widening of the angle under view and posterior movement of the iris, if visible is a definite indication of success. The knife is withdrawn in a similar fashion without collapsing the AC. An AC maintainer has also been used for the same.

Advantages

• Good success rate up to 90% between 3 to 12 month
• Special role in aniridia to prevent glaucoma.

Fig. 15: Gentle sponge application of MMC 0.02% on the surface for 1-2 minutes and washed copiously

Fig. 16: A 5 x 5 mm rectangular partial thickness scleral flap in the superotemporal quadrant dissected up to the clear cornea
Disadvantages

- Not possible in opaque cornea
- Minimal opacity like Haab’s striae can jeopardize visualization of the angle
- Expertise development required
- Peripheral anterior synechiae form easily leading to failure.

All the above listed procedures have been modified from time to time. Some important ones are mentioned here:
- Goniotomy with goniopuncture—aim is to raise a bleb
- Trabeculopuncture—aim is direct laser opening of the Schlemm’s canal under gonioscopic visualization
- Trabeculodialysis—aim is surgical scraping of the TM from the scleral spur.

How is the Surgical Success determined after Any of these Operations?

The following parameters are to be assessed: \(21,35-38,41-58\)
- Corneal clarity
- A shallow AC is not common in PCG. Transient shallowing may occur in the first 3 to 4 days after the surgery
- Relief of photophobia
- Lowering of IOP: An IOP in the low teens is preferable
- Bleb: diffuse, pale blebs are seen after using MMC
- Reversal or nonprogression of disk cupping
- Reversal or nonprogression of myopia
- Visual outcome: Good visual recovery, which may be difficult to document in children.
  * Tonometry may be possible under topical anesthesia while the infant is being fed with the bottle.
  * Use of topical or systemic steroids must not be prolonged beyond 6 weeks.

What is the Status of these Surgeries?

Comparison of CTT with goniotomy—CTT is the first choice because of:
- Easy adaptability \(57,58\)
- Safe and successful
- Suitable even in compromised corneas
- More predictable than goniotomy
- Goniotomy not suitable for > 15 mm cornea
- Higher success rates of primary trabeculotomy than goniotomy, 83% vs 33% in a comparative study. \(57\)

Results of Primary CTT \(53-58\)

Surgical success has been defined as IOP < 16 mm under GA or < 21 mm without GA with no progression of cupping or corneal diameter. Qualified success is defined as maintenance of this pressure with a single drug (timolol). Extreme hypotony (< 5 mm) leading to maculopathy has been defined as failure. Macular hole has been reported following severe hypotony. \(56\)
- CTT is the preferred choice in Indian patients as 80% present with severe corneal clouding and are anyway not suited for goniotomy. Encouraging reports from Indian authors in large series of PCG cases add to the credibility of the procedure. Mandal AK et al have published several reports on the high success and safety profile of combined trabeculotomy and trabeculectomy in PCG even in very small infants. The authors were confident to perform this procedure simultaneously in newborn patients with bilateral glaucoma under one month of age with no complication, reporting a success rate of 94.4% by Kaplein Mayor analysis in 182 eyes of patients. \(59\)
  Bilateral simultaneous surgery is, however not a universally accepted practice. Good visual recovery was reported in another study on advanced glaucoma children with corneal diameter of 14 mm or more. \(18\)
  No sight threatening intra- or postoperative complications were noted in any of the patients.
- In a series of 61 eyes with PCG, Dietlein \(36\) however reported the need for resurgery in 1/3rd of their cases in 36 months of median follow-up with no decrease in the number of glaucoma medications.
- British infantile glaucoma (BIG) I study in a prospective analysis of 99 recently diagnosed cases of pediatric glaucoma patients reported \(\leq 21 \text{ mm IOP in 94% with medication, 60% without any glaucoma medication in the primary congenital group as compared to 86% with and 28% without glaucoma medication in the secondary glaucoma group.} \(5\)
- The success criteria chosen by different authors do not match, variable IOP levels at 21 mm, 18 mm and 16 mm have been taken as indicators of successful control. \(54,55\)

Results of Re-surgery

Trabeculectomy with mitomycin C (MMCT) has a moderate probability of success ranging from 36 to 95%, with lower success seen in younger children. Though this pharmacologic modulation does control IOP in refractory pediatric glaucoma, the procedure seems to have a higher risk profile with no additional IOP lowering effect in a retrospective study of 61 patients in 19 years of follow-up by Rodrigues. \(67\) Mandal in 1997 reported complete success in 94.74% of complicated glaucoma inclusive of failed secondary glaucomas. One patient had qualified success and one patient had retinal detachment which is a rare association for which cause could not be ascertained. \(20\)
  Fluorouracil (5FU) as a single intraoperative application has shown uniformly poor efficacy in children for controlling glaucoma. \(41\)

Management of Failures, Residual and Refractory Glaucoma

Medical Therapy

It is an established fact that best outcome is after first successful surgery. \(54\) Each time surgery is repeated, success rate is likely to drop. Following guidelines are recommended:
- Stop steroids: oral/topical
- Start on topical beta-blockers and CAI
• Prostaglandin analogues have to be avoided in unilateral cases due to hyperpigmentation and hypertrichosis of lashes.
• Alpha 2 agonists are not recommended in children below two years of age.
• Oral CAI have been reported to produce additive effect with topical drugs same in children but still long-term use is not advisable.

**Glaucoma Drainage devices in Children**

- Glaucoma drainage devices (GDD) offer a promising alternative in such conditions. Quoting Albert W Biglan (Costenbader Lecture, 2006) ‘Success in treatment of primary infantile glaucoma will be determined by the age of onset and the ability to deliver a safe and effective procedure’. Several glaucoma procedures and devices have been attempted to fulfil this adage.
- In an initial clinical experience with Ahmed glaucoma valve (AGV) in 21 pediatric patients, Coleman has reported similar success as other GDD – up to 77.9% at 12 months and 60.6% at 24 month. In another comparative study, 38 eyes of complicated pediatric glaucoma were studied in two groups, 20 had MMCT and 18 had AGV implantation. Comparisons drawn in the complication rates between MMCT and AGV are given in Table 7.

**Glaucoma Drainage Devices**

These are broadly divided into two types:

- **Nonvalved/nonrestrictive**
  - Molteno
  - Baerveldt
  - Schocket.
  
  These rely on the formation of a fibrous bleb that is formed on the endplate. This fibrous capsulation provides resistance to outflow. Amount of outflow depends on the surface area of the implant encapsulation and the capsular thickness. The non-valved implants have a higher incidence of postoperative hypotony. Either two stage surgery to implant the plate first followed by 2nd stage tube implantation or a flow restrictive suture in the initial postoperative period is recommended to prevent hypotony.

- **Valved/flow restrictive**
  - Ahmed
  - Krupin
  - Joseph
  - Optimed.

Valved implants have an internal mechanism to control the outflow of the aqueous. Therefore, the fluid is not able to drain unless a minimum IOP is reached. Once the threshold IOP is reached, the device allows aqueous humor to flow. The valved devices prevent hypotony.

**Implants used in Pediatric Cases**

**Non-valved**

*Molteno:* This was the 1st aqueous shunt to gain widespread acceptance, with the initial model being released in 1976. It can be single or double plate.

*Baerveldt:* This flexible elliptically shaped silicone rubber device is available in three plate sizes 250/350/500 mm. The current version has been modified with the introduction of fenestrations to encourage tissue ingrowth.

*Valved implants:* Ahmed glaucoma valve (AGV) has been in use for adults and children. The newer all silicon models have shown more encouraging and improved results. The author’s experience in GDD is confined to AGV and the same will be presented here.

**Ahmed Glaucoma Valve (AGV)**

**Specifications of Pediatric Model of AGV**

- Surface area of plate—96 mm²
- Tube outer diameter—0.635 mm
- Tube inner diameter—0.305 mm

When the IOP rises (8-12 mmHg), the valve opens, thus letting fluid flow out of the eye through the drainage tube. The valve automatically closes when the pressure is normal again. Aqueous humor from AC of the eye flows through the tube into the trapezoidal chamber within the plate element. This chamber

<table>
<thead>
<tr>
<th>Table 7: Comparisons in complication rates between Ahmed glaucoma valve (AGV) and trabeculectomy with mitomycin C (MMCT)</th>
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<tbody>
<tr>
<td><strong>AGV (% eyes)</strong></td>
</tr>
<tr>
<td>Tube extrusion</td>
</tr>
<tr>
<td>Reposition of tube</td>
</tr>
<tr>
<td>Shallow AC</td>
</tr>
<tr>
<td>Choroidal hemorrhage</td>
</tr>
<tr>
<td>Corneal blood staining</td>
</tr>
<tr>
<td>Scleral graft thinning</td>
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<tr>
<td>Choroidal detachment: drainage</td>
</tr>
<tr>
<td>Aqueous misdirection</td>
</tr>
<tr>
<td>Corneal decompensation</td>
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<tr>
<td>Lenticular opacity</td>
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</tbody>
</table>

Total no. of patients = 38, MMCT = 20, AGV = 18.
is formed by a folded-over silicone elastomer membrane with its free edges forming a one way valve.

**Accessories**
- Tube extender and tube holding forceps.
  In the rare event of tube retraction with the growth of the eye, tube extension is possible using the extender. Adjunctive tissue may be needed for better tube stability and to prevent its exposure. Use of the following materials has been reported in literature: pericardium, sclera, fascia lata and amnion.

**Indications in Pediatric Glaucoma**
- Failed glaucoma surgery
- Failed medical control after surgery
- Pseudophakic/aphakic glaucoma
- Secondary glaucoma
- Complicated PCG
- Neovascular glaucoma.

**Steps of AGV Implantation**

**Postoperative Treatment**
Topical steroids and cycloplegia as in any other intraocular surgery.

**Advantages of GDD (Valved)**
- Avoids the risk of a thin avascular filtering bleb.
- Ciliary body function is preserved.
- Safer surgery in large buphthalmic eyes.

**How to Maximize Results of AGV**
- Conjunctiva should be adequate
- Two episcleral bridle sutures; on either side of proposed site
- Must prime the valve
- Subscleral tube insertion
- Use only 23G needle for entry into AC
- Do not hold implant at the trapezoid chamber
- Use atraumatic forceps for holding tube
- Introduce tube bevel up and in iris plane
- Water tight conjunctival closure
- Patch graft over the tube prevents late exposure.

**Complications**
- Tube migration/retraction with
- Diplopia
- Tube exposure/extrusion
- Posterior Tenon’s cyst
- Tube blockage
- Endothelial decompensation
- Hypotony
- Infection
- Failure to control IOP
- Corneal blood staining
- Shallow AC
- Scleral flap thinning
- Choroidal detachment
- Aqueous misdirection.

**Brief Summary of Clinical Trials in Pediatric Glaucoma**

Earliest reported use of glaucoma drainage implants in pediatric glaucomas dates back to 1970 by Molteno in eyes with inadequately controlled IOP despite previous glaucoma surgery.66-71
- Dietlein et al performed different types of ab externo procedures in 61 eyes of 35 consecutive patients of PCG. 20 of 61 eyes (1/3) needed a resurgery at 36 months of median age.36
- In 149 eyes of 89 patients of development glaucoma, Ikeda et al reported complete success in 63.4% (71 eyes) and qualified success in 25.9% (29 eyes). Best corrected visual acuity of ≥ 20/40 was observed in 59.5% (78 eyes). Age < 2 years was found to be associated with poor prognosis and needed more interventions.78
- Englert et al found devastating complications in 20 eyes treated by MMCT as against 5% in the GDD treated group. Higher rate of complications like cataract and infections has prompted some surgeons to look to GDD as a favorable option especially in resurgery cases.70
- Beck and associates reported a success rate ranging from 87% in one year to 53% in six years of follow-up in children < 2 years of age. They also noted that drainage implantation provides a greater successful control as compared to MMCT. A relatively lower success rate of 36% was noted in the MMCT.69
- Armenian eye care project: 38 eyes of 34 patients underwent either MMCT (20) or Ahmed valve (18) with a mean age of 12.5 years for a variety of glaucomas, including secondary glaucomas. The AGV group was twice as likely to use postoperative antiglaucoma medication compared to MMCT—44% and 23% respectively. A remarkable drop of 3 lines in visual acuity mostly due to onset of cataract in the MMCT group was observed in 28% compared to 12% in the AGV group (p value < 0.05%). Total success rate was comparable in the two groups at 13.5 vs 14.8 mmHg (p value < 0.05%).67
- Overdam et al studied the role of Baerveldt implant in 55 eyes of 40 patients ≤ 16 years of age out of which 35 patients had congenital glaucoma. Baerveldt (350 mm²) implantation was performed. Surgical outcome was evaluated by Kaplan-Meier table analysis. The overall success rate was 80% at last follow-up, with a mean follow-up of 32 (range 2-78) months. Cumulative success was 94% in 12 months and 24 months, 85% in 36 months, 78% in 48 months, and 44% in 60 months. 11 eyes (20%) failed postoperatively because of an IOP >21 mmHg (eight eyes),
persistent hypotony (two eyes), and choroidal hemorrhage following cataract surgery (one eye). The most frequent complication needing surgery was tube related (20%). A new observation was mild to moderate dyscoria in 22% of the eyes, all buphthalmic, caused by entrapment of a tuft of peripheral iris in the tube track. The BGI is effective and safe in the management of primary and secondary glaucoma. When angle surgery has proved to be unsuccessful or inappropriate in pediatric patients, a BGI is a good treatment option. One must be prepared to deal with the tube related problems.68

- Another implant was introduced by Sussana in Brazil, which combined the features of both Molteno and Baerveldt implants. These implants were studied in 24 children of primary congenital glaucoma with uncontrolled IOP despite previous surgery. A success rate of 87.5% was noted at the end of 1 year.71

In summary, it appears that valves do have a place in pediatric glaucoma, though so far most reports are on patients with failure of prior surgery. It may be speculative to presume that results would be better in primary cases, where the tissues, especially conjunctiva, are well preserved. Preliminary evidence does support the need for a controlled trial of GDD as against the prevalent CTT in this subset of glaucoma.

Role of Cyclodestructive Procedures

- Trans-scleral cycloablation with Nd-YAG or diode has been used safely in children and seems to have a palliative and temporizing effect. Lower settings than adults are recommended as these children have thin sclera.
- Cyclocryotherapy has a significant risk of hypotony and recommended in eyes with low vision potential and cosmetically disfiguring eyes with high IOP only.

Role of Optical Keratoplasty

- Higher chances of graft failure
- Suture infections in pediatric age
- Arduous follow-up.

Prognosis of Childhood Glaucomas

These factors emerge decisive:
- The severity of the disease
- Age of onset and intervention
- Number of surgeries
- Timely and sustained control of IOP
- Residual corneal scarring, anisometropia and astigmatism
- Aggressive treatment of amblyopia.

Glaucoma in children presents a vexing problem. These, patients are often brought in late, firstly due to the ignorance of parents and secondly inadvertent delay caused by indecision on the part of the attending physician. To make matters worse, relative unfamiliarity with the condition extracts an arbitrary approach at the level of primary care, which further adds to the woes of the patients and soon all vision may be lost forever. Undoubtedly, the issues of timely diagnosis, techniques in children and parental motivation are some of the problems.

To sum up, it seems that surgical results are very case and surgeon specific depending on their experience in case selection and choosing the appropriate procedure. The time is now right to let go of the old dogmas and letting in the new. Let us join hands, organize newer multicentric control trials in childhood glaucomas as the disease is a special concern of the ethnic groups.

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