PRINCIPLES AND TYPES OF GLAUCOMA SURGERIES

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INTRODUCTION

AQUEOUS HUMOR

Production = Aqueous outflow
**Principle**

### Inflow
- Non-incisional:
  - Cyclocryotherapy
  - TCPC
- Incisional:
  - ECP

### Outflow
- Restores physiologic pathway
- Internal approach:
  - I-stent
  - Trabectome
- External approach:
  - Canaloplasty
  - Viscocanalostomy
- Non-physiologic pathway (subconjunctival space)
  - Trabeculectomy
  - Deep sclerectomy
  - GDD
CHOICE OF SURGERY

- Degree of ONH and VF damage (Target IOP)
- Mechanism of glaucoma
- Visual potential
- Risk of intraoperative and postoperative complications
- Cataract
- Discussion with the patient
**Antimetabolites**

**MMC**
- Antineoplastic, antibiotic
- Isolated from *Streptomyces caespitosus*
- Mechanism:
  - Intercalates with DNA and prevent replication
  - Suppress fibrosis and vascular ingrowth
  - Toxic to fibroblasts
- Toxicity:
  - Corneal decompensation
  - AC reaction
  - Scleral, CB and iris necrosis
  - Retinal toxicity

**5FU**
- Mechanism:
  - Affect S-phase of cell cycle
- Toxicity:
  - Corneal epithelium
  - Requires postoperative injections
  - MMC is more potent than 5-FU
Trabeculectomy

- First described in 1967
- Based on the principle: guarded filtration under guarded flap: aqueous flow from fistula to subconjunctival space under scleral flap
- The initial success rates were 37-85%
- MMC was introduced in 1983, but it’s application was not popular until 1991
- MMC increased the success rate to about 67-100% but also the rate of vision threatening complications increased.
*Trabeculectomy*

- **Indications:**
  - Failed medical therapy
  - Need low IOP
- **Risk factors for failure:**
  - Dark skin pigmentation
  - Prior surgery
  - Conjunctival scarring, tendency to keloid formation
  - Aphakia
  - Ocular surface disease
  - Uveitis
  - NVG
  - Prolonged use of antiglaucoma medications
Trabeculectomy

Steps:
- LA Vs. Subtenon
- Traction suture (remove at end of surgery)
- Conjunctival periotomy: fornix Vs. limbal
- Tenon’s capsule dissection, wet-field cautery
- Sclearl flap dissection
- Antimetabolites then irrigation
- Paracentesis
- Sclerotomy then PI
- Close flap and assess filtration and AC
- Close conjunctiva
- Subconjunctival injection
Trabeculectomy

Postoperative care:
- Postoperative ophthalmic evaluation: VA, IOP, Leak and bleb configuration, AC depth, PP exam
- Topical antibiotics
- Topical steroids
- Atropine (Not in combined surgery)

Complications:
- Preoperative
- Intraoperative
- Postoperative:
  I. Early
  II. Late
Trabeculectomy

• Preoperative:
  ➢ Retrobulbar hemorrhage
• Intraoperative:
  ➢ Conjunctival buttonholes
  ➢ Flap tears and holes
  ➢ Vitreous loss
  ➢ Suprachoroidal hemorrhage
  ➢ Bleeding
**Early Postoperative Complications**

**IOP OK**
- Hyphema
- Uveitis
- Dellen

**Low IOP**
- Formed bleb
  - Overfiltration
  - Flat bleb
    - Wound leak
    - Choroidal effusion
    - CB shutdown
    - Cyclodialysis cleft
  - RD

**High IOP**
- Deep AC
  - Internal block
  - Tight flap
  - External block
    - Shallow/flat AC
      - Pupillary block
  - Suprachoroidal Hge
  - Aqueous misdirection
# Late Postoperative Complications

## IOP OK
- Cataract
- Infection
  - Blebitis
  - Bleb-related endophthalmitis
- Corneal dissection/overhang

## Low IOP
- Hypotony maculopathy
- Leak

## High IOP
- Internal block
- Delayed LSL with subsequent scarring
- Encapsulation
  - Scarred, flat bleb
- Failure
In the 1980s, Fyodorov, Kozlov & Zimmerman took the next step in the evolution of glaucoma surgery by modifying the NPGD to have a scleral flap.
NPGS
TRABECULO-DESCEMET WINDOW

DEEP SCLERECTOMY

VISCOCANALOSTOMY

CANALOOPLASTY
**NPGS**

- **Indications:**
  - Primary and secondary OAG
  - High myopia
  - Aphakia and pseudophakia
  - Aniridia and AS dysgenesis

- **Relative contraindication:**
  - Narrow angle
  - PAS away from surgical site

- **Absolute contraindication:**
  - NVG
  - Extensive PAS
Steps:
- LA Vs. Subtenon
- Traction suture (remove at end of surgery)
- Conjunctival periotomy: fornix Vs. limbal
- Tenon’s capsule dissection, wet-field cautery
- Superficial scleral flap dissection 4-5mm X 4-5mm
- Antimetabolites then irrigation
- Paracentesis
- Deeper flap just above the choroid
- Expose Schlemm’s canal, TDW then de-roof the canal
- Excise deeper flap
Close the superficial scleral flap:

- Deep sclerectomy: loose
- Viscocanalostomy: tight

- Conjunctival closure
- Subconjunctival injection
Postoperative care:

- Postoperative ophthalmic evaluation: VA, IOP, Leak and bleb configuration, AC depth, PP exam
- Topical antibiotics
- Topical steroids
- Atropine ±
Complications:
- Moderate hypotony with deep AC
- Transient CME
- High IOP (LSL then goniopuncture)
- Blood at scleral lake with high IOP (need few days)
- Rupture TDW and iris prolapse blocking filtration site (revise to convert to penetrating surgery)
- PAS (laser iridoplasty Vs. laser synecholysis)
- Descemet membrane detachment (gas SF6)
- Scleral ectasia
Canaloplasty

Increase aqueous flow from the anterior chamber, through the trabecular meshwork & descemetic window, into & around the schlemm canal, & out through the collector channels, thereby reducing the intra-ocular pressure (IOP)

Restore the natural aqueous outflow system & avoid the presence of blebs & their complications
Canaloplasty

It involves catheterization & controlled viscodilation of the entire circumference of schlemm canal – unlike standard viscocanalostomy which involves only a section of it – in conjunction with placement of trabecular tensioning suture facilitated by a flexible microcatheter coupled to ophthalmic viscosurgical device source (OVD)
Canaloplasty

Indications:
• Patients with open angle glaucoma

Contraindications:
• Neovascular glaucoma
• Chronic angle closure (relative)
• Angle recession
• Narrow angle (relative)
• Narrow approach with plateau iris
• Previous surgery preventing 360 degree catheterization of Schlemm’s canal
Canaloplasty
Canaloplasty

Postoperative care:

• Postoperative ophthalmic evaluation
• Topical antibiotics
• Topical steroids
• Might have transient borderline to moderately high IOP
Canaloplasty
Canaloplasty

• Complications:
  ➢ Microhyphema-Hyphema
  ➢ Early elevated IOP (0 - 3 months postop) *(LSL then goniopuncture)*
  ➢ Blebs at 24 months
  ➢ Late elevated IOP (> 3 months postop) *(LSL then goniopuncture)*
  ➢ Wound Hemorrhage
  ➢ Descemet membrane detachment
  ➢ Suture extrusion through TM
  ➢ Hypotony
  ➢ Intracorneal hematoma
**i-Stent**

- Small titanium stent
- Implanted through TM to Schlemm’s canal
- Direct connection from AC to canal

**Patient selection**

- Target IOP in mid-teens
- Open angle
- Mild to moderate glaucoma
- Tolerant to glaucoma medications
- Conjunctival scarring and high risk for hypotony and infection: **NO PROBLEM**
Advantages:

• Restores physiologic pathway
• Spares conjunctiva
• Clear corneal approach (±Phaco)

Disadvantages:

• Opening is limited to size of stent
• Access to Schlemm’s canal is circumferentially limited
Trabeculotomy Ab Interno: Trabectome

• Internal approach
• Electocautery device ablates section of TM, un-roofing Schlemm’s canal and outflow collector channels

Patient selection
• Target IOP in mid-teens
• Open angle
• Mild to moderate glaucoma
• Tolerant to glaucoma medications
• Conjunctival scarring and high risk for hypotony and infection: NO PROBLEM
Trabeculotomy Ab Interno: Trabectome

Advantages:

• Restores physiologic pathway
• Opens a continuous pathway from AC to Schlemm’s canal
• Cautery removes tissue to prevent closure
• Spares conjunctiva
• Clear corneal approach (±Phaco)

Disadvantages:

• Cleft may close with PAS
• Access to Schlemm’s canal is circumferentially limited
• Cyclodialysis clefts (hypotony)
**Glaucoma Drainage Devices**

**Valved**
Contain internal mechanism to control the outflow of the aqueous humor. They drain once threshold IOP is reached thus preventing hypotony. Each device had different flow restriction method.

**Non Valved**
Do not contain a mechanism within the device to restrict the aqueous outflow. They relay of fibrous bleb formation on the end plate which will provide sufficient resistance to outflow & control of IOP is established.
Glaucoma Drainage Devices

- Indications:
  - Previously failed filtering surgery
  - High myopia
  - Aphakia and pseudophakia
  - Uveitic glaucoma
  - ICE syndrome
  - Congenital glaucoma with iridocorneal dysgenesis
  - Glaucoma post keratoplasty
  - NVG
  - Sever conjunctival scarring
<table>
<thead>
<tr>
<th>Product</th>
<th>Material</th>
<th>Model</th>
<th>Image</th>
<th>Surface area</th>
<th>Valve/no valve</th>
<th>Single Quadrant</th>
<th>Special feature</th>
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</thead>
<tbody>
<tr>
<td>Ahmed implant</td>
<td>Polypropylene</td>
<td>S1</td>
<td><img src="image1.png" alt="Image" /></td>
<td>364mm</td>
<td>Valved</td>
<td>Yes</td>
<td>Silicone elastomer membrane valve</td>
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<td></td>
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<td>S2</td>
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<td>Silicone</td>
<td>FP7</td>
<td><img src="image4.png" alt="Image" /></td>
<td>184mm</td>
<td></td>
<td></td>
<td>Slit-valve at tube distal end</td>
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<tr>
<td>Molteno</td>
<td>Polypropylene</td>
<td>Single plate</td>
<td><img src="image5.png" alt="Image" /></td>
<td>135mm</td>
<td>Non Valved</td>
<td>Yes</td>
<td>Single or double plate</td>
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<tr>
<td></td>
<td>Silicone</td>
<td>double plate</td>
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<td>270mm</td>
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<td>Baerveldt</td>
<td>Silicone</td>
<td>BG-103</td>
<td><img src="image7.png" alt="Image" /></td>
<td>250mm</td>
<td>Non Valved</td>
<td>Yes</td>
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<td></td>
<td>BG-101</td>
<td><img src="image8.png" alt="Image" /></td>
<td>350mm</td>
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<td></td>
</tr>
</tbody>
</table>
The Ahmed glaucoma valve implant was approved by the FDA in November 1993 & because of the potential advantages, it was used in children since 1992.
**Polypropylene plate**
- Rigid
- Less biocompatibility
- More inflammation
- Increase the thickness of the pseudocapsule
- ↑ IOP

**Silicone plate**
- Flexible
- More biocompatibility.
- Less inflammation
- Reduce the thickness of the pseudocapsule
- Lower long-term IOP
Ahmed Implant

The leaves of the valves are relatively long and indicated by number 2. When the pressure in the anterior chamber is high, the valve leaves separate creating an open valve as depicted. When the pressure is low the leaves of the membrane have natural elasticity that keeps them together.
Ahmed Implant

- Steps:
  - LA Vs. Subtenon
  - Traction suture (remove at end of surgery)
  - Conjunctival periotomy: fornix Vs. limbal
  - Tenon’s capsule dissection, wet-field cautery
  - Antimetabolites then irrigation ??
  - Prime the tube using BSS
  - Fix to sclera using Prolene
  - Scleral tunnel to AC or PC using 23G needle
  - Patch graft after fixing tube
  - Conjunctival closure
  - Subconjunctival injection
Ahmed Implant

- Complications:
  - Early:
    - Hypotony (leak from tunnel)
    - Choroidal effusion (hemorrhagic! Pain)
    - Tube block with high IOP
    - Iritis
    - Hyphema
    - Shallow or flat AC
    - Vitreous hemorrhage
    - Instability
    - Corneal-lens contact
Ahmed Implant

• Complications:
• Late:
  > Plate encapsulation
  > High IOP
  > Diplopia
  > Plate migration to suprachoroidal space
  > Exposed tube
  > Corneal decompensation
  > Chronic iritis
Ahmed Implant

- Complications:
- Late:
  - Cataract
**Cycloablation**

- **Mechanism:**
  - 810 nm diode laser has lower scleral transmission than Nd:YAG (1064nm) but greater absorption by melanin in CB pigmented epithelium.

- **Treatment:**
  - 1.0-1.5 mm from limbus
  - Power 1500-3000 mW
  - Duration: 1000-1500 ms
  - Spare 3 and 9 o’clock positions

---

**TDCPC**

- **Mechanism:**
  - Damage epithelial, vascular and stromal elements of CB.
  - -60° to -80° produce -10° in CP necessary for cell necrosis.

- **Treatment:**
  - 1.0-1.5 mm from limbus
  - -80° for 45-75 seconds
  - 1 spot every 1 clock hour 180°
  - Unpredictable results

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**Cyclocryotherapy**

- **Mechanism:**
  - Damage epithelial, vascular and stromal elements of CB.
  - -60° to -80° produce -10° in CP necessary for cell necrosis.

- **Treatment:**
  - 1.0-1.5 mm from limbus
  - -80° for 45-75 seconds
  - 1 spot every 1 clock hour 180°
  - Unpredictable results
**External Cycloablation**

- **Indications:**
  - Poor visual potential
  - Failed previous surgery
  - Surgery at high risk of failure (extensive conjunctival scarring)
  - OCP
  - Patients unable to undergo filtration surgery (medical reasons)
External Cycloablation

- Complications:
  - Pain
  - Iritis
  - Loss of $\geq$ one line of VA
  - Persistent hypotony and phthysis
  - Transient flat AC with hypotony and choroidal
  - Scleral thinning
  - Malignant glaucoma
  - Hyphema
  - Vitreous hemorrhage
  - Sympathetic Ophthalmia
Endoscopic Cyclophotocoagulation

- First described in 1992 by Uram
- Direct visualization of CP
- More targeted tissue treatment with decreased energy level
- Fewer postoperative complications
Endoscopic Cyclophotocoagulation

• The laser unit for ECP (Endo Optics E2, LS, NJ, USA) incorporates:

  • An 810 nm diode laser pulsed continuous wave energy
  • A 175 W xenon light source
  • Helium-neon laser aiming beam
  • Recordable video camera imaging

• All four elements are transmitted via fibreoptics to an 18 or 20 G probe that is inserted intraocularly through the AC or pars plana.
Endoscopic Cyclophotocoagulation

• The optimum focus for the laser is 0.75 mm from the probe-tip, & the endoscope provides 70 degree field of view.
• The main unit is compact & portable
• The maximum power output is 1.2 W
BUT WHY DIODE & NOT Nd:YAG NOR ARGON?

**Diode laser 810 nm:**
- More absorbed by the melanin-rich pigmented ciliary epithelium
- Diminish the required energy for tissue ablation
- Minimize stromal coagulative necrosis & subsequent inflammation
- Does not result in pigment dispersion or gas bubble formation
- The surgeon can observe the progress of tissue ablation & can terminate the laser application when the desired effect is obtained

**Nd:YAG 810 nm & Argon laser:**
- Less absorption by the melanin-rich pigmented ciliary epithelium
- Need more power with the risk of over treatment & coagulative necrosis. Subsequently, a trend to under treatment
HOW CAN WE DO IT?

Candidates:
- Patients going for cataract surgery
- Pseudophakic & aphakic eyes
- Pakic eyes? Reported but carry the risk of cataract formation
- Undesirable filtering surgery

Approach:

Anterior chamber approach: The most popular

Pars plana approach: A simple method to access the ciliary processes. ECP probe is inserted 3.5 mm away from the limbus after removing the anterior vitreous
**Treatment steps:**

- Temporal corneal incision
- visualize the ciliary processes:
  
  **OVER THE BAG:** inflate the sulcus using OVDs, an existing iris hooks

**THROUGH THE BAG**

- ? Second corneal incision

**Laser settings:**

- Start with 0.25 W, continuous mode, avoid POP
- Straight Vs curved probe
- Adjust illumination to visualize CP + aiming beam 100
- Currently the desirable treatment is 360 degrees
THE ENDPOINT TREATMENT IS WHITENING & SHRINKAGE OF THE CILIARY PROCESSES
The advantage of ECP over TCP includes:

- Direct visualization of the ciliary processes
- More targeted tissue treatment
- Decreased energy treatment levels
- Avoids collateral tissue damage
- Decrease postoperative inflammation
- Decrease the risk of complications
VASCULAR & HISTOLOGICAL CHANGES:

- Lin et al described the vascular effect of ECP versus TCP in rabbit eye model.
- They compared ECP & TCP groups with a control group where all groups underwent endoscopic fluorescein angiography immediately post treatment, 1 day, 1 week & 1 month.
• They found in the immediate & 1 day after laser that both TCP & ECP eyes demonstrated severely reduced or no perfusion.

• TCP treated processes remained non-perfused at 1 week & 1 month while ECP had some perfusion at 1 week & greater perfusion at 1 month.
**MORPHOLOGICAL CHANGES INDUCED BY ECP**

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<th>TCP</th>
<th>ECP</th>
</tr>
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<td><img src="ECP.png" alt="Image" /></td>
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<td>• Lacy contour</td>
<td>• Separation of pigment &amp; non pigment epithelium</td>
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<td>• Normal stroma</td>
<td>• Pigment clumping</td>
<td>• Loss of lacy appearance</td>
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<td>• Stromal coagulative necrosis</td>
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<tr>
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<td>• Architectural destruction</td>
<td>• Destruction of non-pigment epithelium</td>
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**NORMAL**
- Lacy contour
- Normal stroma
- Normal epithelium

**TCP**
- Separation of pigment & non-pigment epithelium
- Pigment clumping
- Stromal coagulative necrosis
- Architectural destruction

**ECP**
- Loss of lacy appearance
- Pigment clumping
- Destruction of non-pigment epithelium
### MORPHOLOGICAL CHANGES INDUCED BY ECP

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<td><img src="image2" alt="Extensive architectural destruction extending to the pars plana" /></td>
<td><img src="image3" alt="Shrinking of the processes with blunt tips" /></td>
</tr>
</tbody>
</table>

- **NORMAL**
  - Normal ciliary process with adjacent pars plana & iris stroma

- **TCP**
  - Extensive architectural destruction extending to the pars plana
  - Pigment clumping
  - Normal process visible adjacent to treated area

- **ECP**
  - Shrinking of the processes with blunt tips
  - Disruption of normal epithelial architecture
  - Unaffected pars plana & iris stroma