**Microinvasive Glaucoma Surgery:**
Glaucoma Surgical Innovations

Agnes S. Huang, MD
Seattle Ophthalmology, PLLC

---

**Traditional Glaucoma Surgery**

- All filtration surgeries rely on the creation of a fistula which shunts aqueous into the subconjunctival space, hence circumventing resistance in Schlemm's canal.

---

**Glaucoma Filtration Surgery**

- **Trabeculectomy**
  - Placement of fistula in the sclera, relying on fluid movement to keep fistula and subconjunctival space patent

- **Seton Devices**
  - Placement of a tube into the fistula to keep it and subconjunctival space patent
Trabeculectomy

Routes of Aqueous Drainage

- Aqueous usually filters through the conjunctiva and mixes with the tear film or absorbed by vascular or perivascular conjunctival tissue
- Possible flow through lymphatic vessels or aqueous veins
- Blebs tend to be proximal to limbus and thin walled

Trabeculectomy

Filtering bleb

- Drainage of aqueous fluid through sclerostomy maintains potential space between sclera and Tenon/conjunctival tissue
- Wound healing varies between individuals

Trabeculectomy

Variations in wound healing results in different shaped blebs

- Blebs with extension onto cornea
- Overly large blebs
- Blebs with poor filtration
- Over filtering bleb
Glaucoma Filtration Surgeries

The ultimate goal of glaucoma outflow surgery is maintenance of a patent fistula between the inside of the eye and the extra-ocular space. This is a non-physiologic condition.

Glaucoma Blebs

Glaucoma filtration surgeries work well to decrease intraocular pressure, but many complications are related to the non-physiologic bleb.

Complications of Glaucoma Filters

- Blebitis
Complications of Glaucoma Filters

- **Endophthalmitis**

- **Blebitis/Endophthalmitis**
  - Associated with red eyes, decreased vision, pain, possible purulent discharge

- **Large blebs**
Tube Shunts (Setons)

- Many types exist
  - Non-valved
    - Molteno
    - Baerveldt
  - Valved
    - Ahmed
    - Krupin

Setons

- Route of Aqueous Drainage
  - Filtration site is more posterior than a trabeculectomy
  - Blebs are thick walled with prominent vascularity
  - Fibrous capsule forms over the reservoir and tube
    - Aqueous passes through the fibrous capsule into orbital capillaries and lymphatics

Setons

- Tube related complications include
  - Conjunctival erosion
  - Corneal erosion
Seton Complications

- Tube retraction
- Tube-endothelial touch with corneal edema
- Tube with iris or vitreous
- Tube-lenticular touch causing cataract
- Strabismus

Complications of Glaucoma Filters

- Hypotony maculopathy

Hypotony maculopathy
- IOP typically less than 5 mmHg
- Decreased vision with retinal striae, choroidal folds, vascular tortuosity, possible papilledema due to scleral wall collapse
Complications of Glaucoma Filters

- Choroidal detachment
  - Serous
  - Hemorrhagic

Ideal glaucoma surgery

- Avoid filtration bleb (and its associated complications)
  - Especially true if there is no need for ultra-low intraocular pressures
- Provide a more physiologic method of controlling intraocular pressure
- Control intraocular pressure

Microinvasive Glaucoma Surgery (MIGS)

- Criteria for MIGS (Iqbal Ahmed)
  - Ab interno conjunctiva-sparing approach
  - Minimal trauma to the target tissue
  - Efficacy in controlling intraocular pressure
  - High safety profile
  - Rapid recovery period
Patient Profile: MIGS

MIGS-type Procedures
- Mild-moderate disease
- Hypertensive glaucoma
- Open angle
- Modest IOP target (15-16 mmHg)
- Able to tolerate some medications

Trab-type Procedure
- Moderate-advanced glaucoma
- Progressing normal pressure glaucoma
- Open, narrow, or closed angle
- Low IOP target (<13 mmHg)
- Intolerant to medications

Aqueous drainage anatomy

- Trabecular meshwork
  - Accounts for up to 85% of outflow
  - Most resistance at juxta-canalicular meshwork
  - Driven by IOP level

- Uveoscleral outflow
  - Accounts for 15-54% of outflow
  - Most resistance at ciliary body
  - Driven by hydrostatic pressure difference between anterior chamber and suprachoroidal space
Aqueous drainage anatomy

Microinvasive Glaucoma Surgeries

- Trabecular meshwork bypass devices
  - Improve trabecular flow to Schlemm’s canal
    - iStent and iStent inject (Glaukos)
    - Trabectome (Neomedix)
    - Gonioscopy-assisted transluminal trabeculotomy (GATT)
  - Improve flow within Schlemm’s canal
    - Hydrus (Transcend)
- Uveoscleral outflow facilitator
  - CyPass microstent (Transcend)
  - iStent Supra (Glaukos)

Trabecular meshwork bypass

- Instead of rerouting aqueous, these techniques reestablish outflow through Schlemm’s canal to collector channels (physiologic mechanism).
  - Preventing collapse of Schlemm’s canal improves collector channel outflow.
TM bypass rationale

- Glaucoma eyes show collapse of collector channels due to inability of aqueous to enter the canal (Johnstone, et al)

Improving flow to Schlemm’s canal

- iStent and iStent inject (Glaukos)
- Trabectome (Neomedix)
- GATT (Goniotomy-assisted transluminal trabeculotomy)

iStent

- Heparin-coated, non-ferromagnetic surgical grade titanium stent
- 50-90% resistance to aqueous outflow in TM
  - Single patent TM bypass can increase outflow facility
iStent

- Titanium stent which inserts into Schlemm’s canal, allowing aqueous to drain directly into Schlemm’s canal from the anterior chamber, bypassing obstructed trabecular meshwork.
- Improves facility of outflow up to 84%.

**HOW THE STENT PREVENTS GLAUCOMA**

iStent

- iStent is placed into the trabecular meshwork at time of cataract surgery.

58 glaucoma patients in 24 month multi-center uncontrolled study had cataract surgery with iStent implantation.

- At 1 year, IOP dropped from 21.7 mmHg on meds to 17.4 mmHg with no meds.
- Decreased number of meds by 1.2 to keep IOP at 21 mmHg or less.

Prospective, multicenter study randomized 240 patients to cataract surgery with iStent vs cataract surgery only.

- 73% with iStent at IOP < 21 mmHg.
- 50% with cataract surgery only at IOP < 21 mmHg.
iStent
- IOP cannot drop below episcleral venous pressure
- (10 mmHg)

iStent
- European studies
  - Mean 22% decrease in IOP
  - May implant more than one iStent to get more effect

iStent Inject
- Allows 2 stents to be placed through a single incision
  - Bahler, et al. (AJO, 2012)
    - Outflow facility doubles with one stent and doubles again with second stent
    - Mean 14%-17% decrease in IOP
iStent Inject

Synergy Trial
- 99 patients in a pan-European, multicenter, prospective unmasked study
- Stand alone implantation of two iStents
- At 12 months, 66% achieved IOP<19mmHg without medications, 81% achieved with one or no meds
  - Mean IOP decreased from 26.3 mmHg to 15.7 mmHg (39.7%) at 12 months with one or no meds

Opening anterior wall of Schlemm’s canal
- Decrease aqueous inflow resistance into Schlemm’s canal
  - Improves aqueous outflow facility
    - Trabectome
      - GATT or ab interno trabeculotomy

Trabectome
- FDA approved 2004, first US use in 2006
- Bipolar 550 kHz electrode tip ablates trabecular meshwork and inner wall of Schlemm’s canal under direct observation
  - Ionization and disintegration, not cautery, to prevent thermal damage
Trabectome

- Allows aqueous direct access to Schlemm’s canal and collector channels
- Principle similar to goniotomy and trabeculotomy with less rupture of trabecular meshwork

Up to 180 degrees ablated to increase access to collector channels

Complications
- Transient hyphema in 79-100%
- No reports of choroidal effusion, infection or other causes of permanent visual impairment
- Rare hypotony due to inadvertent cyclodialysis
Trabectome

  - Retrospective study of 1127 Trabectome procedures (738 Trabectome only)
  - Mean decrease IOP by about 40% (25.7 mmHg to 16.6 mmHg) at 24 months
    - Failure in 8% lead to filtration surgery

Trabectome

- Vold SD (Int Ophthalmol Clin, 2011)
  - 1878 cases followed over 6 years
  - 38% IOP reduction maintained

Trabeculotomy ab Externo

- Goniotomy and Trabeculotomy ab Externo have long been used to successfully treat congenital glaucoma
Trabeculotomy ab Interno

- Saves conjunctiva for future surgery
- GATT
  - Uses iTrack (iScience)
  - Microcatheter is threaded through Schlemm's canal as in canaloplasty

---

Trabeculotomy ab Interno

- A 5-0 nylon suture can also be threaded into Schlemm's canal for 360 degree trabeculotomy

---

Trabeculotomy ab Interno

- Grover et al, Ophthalmology, 2014
  - 85 patients with GATT
    - After 12 months, 57 with OAG had 39.5% decrease IOP
    - 28 with secondary glaucoma had 56.8% decrease IOP

  - 12 patients with suture trabeculotomy ab interno
    - Mean IOP decreased from 19.4 mmHg to 13.8 mmHg after 6 months with decreased meds from 3.2 to 1.1
Sclemm’s canal scaffolding

- **Hydrus Microstent** (Ivantis Inc)
  - Bypasses the TM by circumferentially dilating Sclemm’s canal as an intracanalicular scaffold

**Sclemm’s canal scaffolding**

- **Hydrus**
  - **Sclemm’s canal collapses as IOP increases**
  - **Flexible nickel-titanium alloy with non-luminal open design extending 8 or 15 mm**
    - Increases circumferential flow by maximally dilating SC to 241 um (4-5 times normal SC)

**Hydrus**

- Provocative testing to place stent in area of unobstructed collector channels and aqueous veins
Hydrus

- In experimental eyes, outflow facility increased 92%
  - 28 eyes with phaco/hydru
    - After 6 months, IOP decreased from 29.9 mmHg (after med washout) to 14.3 mmHg
  - On going clinical trials

Uveoscleral outflow

- In 1900, Fuchs described cyclodialysis cleft following cataract surgery with IOP decrease
- Anders Bill has shown that 20-54% of aqueous outflow occurs via uveoscleral pathway

Uveoscleral outflow

- Driven by hydrostatic pressure differential between anterior chamber and suprachoroidal space
- Highest resistance to outflow is at ciliary body
CyPass Suprachoroidal Microstent

- Flexible fenestrated polyimide implant placed in the potential space between the sclera and ciliary body via trans-cameral approach through clear cornea

CyPass

- Creates and maintains a localized cyclodialysis cleft to facilitate uveoscleral outflow

CyCLET study (CyPass Clinical Experience)

- Prospective, open label, interventional multicenter clinical trial (European)
- 460 patients (222 with CyPass implantation alone, 238 with CyPass and cataract surgery)
- Divided into 2 groups:
  - Cohort 1 (mean IOP >20 mmHg) goal to decrease IOP
  - Cohort 2 (mean IOP <21 mmHg) goal to decrease medication burden
CyPass

CyCLE study (as of 2014)
- In combined cataract surgery/CyPass group:
  - After 24 months, Cohort 1 had mean IOP decreased of 37%, and meds dropped from 2.2 meds to 1 med. In Cohort 2, mean IOP dropped from 16.4 mmHg to 15.8 mmHg with decrease meds from 2.0 to 1.0.
  - Adverse events: transient hypotony (15.4%), stent obstruction (8.8%), postop IOP spike (4.4%)
- In CyPass only group:
  - After 12 months, Cohort 1 had mean IOP decrease of 26% with decrease medication from 2.1 to 1.1. In Cohort 2, decreased meds from 2.3 to 1.4 with no change in IOP

CyPass

DUETTE study (European)
- CyPass placement in 65 patients with IOP>20 on 1-4 glaucoma medications
  - Mean baseline medicated IOP was 24.5 mmHg on 2-4 drops
  - At 12 months, mean IOP dropped to 16.7 mmHg on 1.5 medications

COMPASS (USA)
- Has recruited 505 patients
- Results forthcoming

iStent Supra

- Ridged, heparin coated curved polyethersulfone stent
- Creates and maintains a lumen within suprachoroidal space
iStent Supra

Junemann, 2013 placed iStent Supra in 73 patients
- 98% met primary endpoint of 20% reduction in IOP with one med
- IOP decreased from treated 20.4 mmHg to 13.2 mmHg

Martinez 2014
- Implanted 2 iStents and 1 iStent Supra in 30 patients with elevated IOP after trabeculectomy
- Mean untreated IOP decreased from 26.4 mmHg to 13.2 mmHg
- Trabecular bypass MIGS and suprachoroidal shunts may have a synergistic effect

TM bypass rational

- Dilates Schlemm’s canal to open the outflow system
- Procedure
  - iScience 250 um microcatheter attached to Prolene suture intubates Schlemm’s canal circumferentially
  - Suture ends tied to provide tension to inner wall of canal, stretching the trabecular meshwork open

Newer physiologic glaucoma surgeries may be safer than traditional filtration surgeries which rely on blebs
Newer glaucoma surgeries

- Best for glaucomas where IOP in the mid teens is appropriate
  - No bleb = safer outcome
- Trabeculectomy is still the gold standard if low IOP is needed
  - Average IOP for canalopasty and Trabectome is 16 mmHg
  - Average IOP for trabeculectomy and setons is 12 mmHg

Mahalo!