Evolution of Glaucoma Surgery

Sonal Dangda MS, DNB, Kirti Jaisingh MS, Yashpal Goel MS, Amrit MBBS, Shraddha Saraf MBBS
Guru Nanak Eye Centre, New Delhi

Surgical treatment for glaucoma has seen a paradigm shift since the later half of the 19th century, when Albrecht von Graefe first proposed surgical iridectomy way back in 1856. Research since then have evolved from creating a “filtration cicatrix” to surgical wound modulation and the more sophisticated shunts and stents.

Treatment for glaucoma can be broadly categorised on two fundamental basics.

1. Decreasing the inflow/production of aqueous humor and
2. Increasing the aqueous outflow – which can further be divided into
   a) creating an alternative outflow pathway or
   b) enhancing the pre-existent one

Medical therapy in glaucoma is mostly directed towards the inflow mechanism. Destruction of ciliary body either by surgical excision or use of techniques like irradiation, cryofreeze, and of late laser photocoagulation also aims at the same.

Glaucoma filtering surgery aims to provide an outflow of the aqueous through an alternative path from the anterior chamber to the sub-conjunctival space or the suprachoroidal space. There are two basic types of fistula in glaucoma filtering surgery –

1. Extending through the full thickness of limbal tissue.
2. Fistula guarded by a partial thickness scleral flap.

Surgical techniques for enhancement of the pre-existing filtration pathway aim at decreasing the resistance at the juxtacanalicular trabecular meshwork and inner wall of Schlemm’s canal.

Here we review the evolution of glaucoma surgeries which formed the basis of treatment in the early 20th century to the recent advancements in near future.

In 1856, von Graefe introduced peripheral surgical iridectomy, which worked well in patients with acute angle closure and those with pupillary block due to seclusio pupillae1. With time, these iridectomies became larger but spectrum of patients who could benefit remained the same. It was slowly realised that smaller iridectomies could also serve the purpose and the approach shifted from surgical to non-surgical with the advent of laser delivery systems. Even after being the mainstay for fifty years, the realisation that iridectomy alone does not result in drastic intraocular pressure lowering, the approach shifted towards creating a fistula for aqueous drainage. De Wecker in 1867 laid the foundation for future glaucoma filtration surgeries by describing anterior sclerotomy which he named as the “filtration cicatrix”1. Dianoux advocated ocular massage to keep this cicatrix permeable by preventing primary intention healing2. This anterior sclerotomy was described as a full thickness scleral incision 1 mm posterior to the limbus. Subsequently many modifications were suggested, a few popular ones being3,4 –

a. Lagrange- excised a piece of tissue from the anterior lip of the wound (Figure 1).

b. Herbert- made one or both the lips of incision jagged and uneven by sawing movements of knife and cut out a wedge which would shrink sufficiently to provide for filtration but not enough to cause an actual fistula formation.

c. Holst- used punch forceps to cut anterior lip of wound.

d. Iliff and Hass- introduced posterior lip sclerectomy in 1960s.
The next major advancement came in 1909 in the form of trephination introduced independently by Fergus and Elliot. The fistula was created using a Bowman’s trephine; while Fergus removed a scleral disc of 1-2mm from the apparent corneal margin with no iridectomy, Elliot removed a sclero-corneal disc anteriorly combined with an iridectomy.

A special instrument called sclerectome was introduced for trephination by Verhoeff which could cut 1mm disc from corneal margin with a small button hole in the iris. However these procedures produced extremely thin blebs, hence Sugar advocated a more posterior limbo scleral approach5 (Figure 2).

Introduced in 1924 by Preziosi, Thermal Sclerostomy was applied to the bare sclera until anterior chamber was entered however iridectomy was not done6. Scheie modified this procedure by using cautery to retract the wound edges. After doing peritomy, cautery is applied to the sclera 1mm behind the limbus. A 5mm incision is then made in the cauterized sclera and cautery applied to edges until a gape of 1mm remains between them followed by aniridectomy7. Blebs produced hereby were flatter and more diffuse than those with trephination or Preziosi’s procedure (Figure 3).

Another procedure which gained momentum was Holth’s operation/ Iridencleisis. In this, iris is grasped after making a sclerotomy short distance from the limbus and incised in a manner that one pillar can be incarcerated through the wound. The conjunctival flap is then used to cover the laid out iris and the wound is closed with a running suture8. The fear of sympathetic ophthalmia played a role in the abandonment of this once extremely popular operation for primary open-angle glaucoma (Figure 4).

Around the same time, Heine described Cyclodialysis, which involved the separation of ciliary body from the scleral spur thus creating a direct communication into the suprachoroidal space. This worked by increasing the uveoscleral outflow and decreasing the aqueous production, both mechanisms causing a lowering the IOP. The surgery described was done by making a conjunctival incision 8mm from the superior limbus followed by a full thickness scleral incision 3-4mm from the limbus. A cyclodialysis spatula was then inserted through it into the supraciliary space till

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**Figure 1:** Sclerectomy: Lagrange’s procedure

**Figure 2**

**Figure 3:** Thermal Sclerostomy - Scheie
scar and Dianoux advocated a prevention of primary intention healing which was later popularized by use of pharmacological wound modulators in the form of antifibrotics like 5-flourouracil, mitomycin C, anti-VEGF etc.\textsuperscript{12} However, widespread cellular toxicity of these drugs has worked like a double edged sword and the use of these drugs is not free from serious sight threatening complications related to hypotony like shallow chambers, choroidal detachments and haemorrhage, bleb related infections and snuff out phenomenon. Suture modulations in the form of adjustable and releasable sutures and laser suture lysis help the glaucoma surgeon in somewhat negating the above side-effects in the early postoperative period caused due to overfiltration\textsuperscript{13}.

There still are situations were chances of success are minimal and other alternatives need to be looked for. The Glaucoma Drainage Devices (GDD) provides some respite in such high failure cases. Historically these shunts date back to late 19th century; deWeckers used ‘gold wire implants’ in patients with failed sclerotomies. Other notable ones include ‘Horse hair shunt’ by Rollet in 1906 and permanent silk thread implants independently in 1912 by Zorab and Mayou\textsuperscript{2}. Much before the modern tube shunt by Molteno in 1969, Qadeer devised a plastic plate for subconjunctival insertion with drainage channels engraved in it and its head was placed in the anterior chamber which through a hole drained the aqueous into those channels\textsuperscript{14}. The modern day implants consist of a silicon tube extending from anterior chamber or vitreous cavity to a plate, disc or encircling element around which the filtering bleb forms. Whereas Baerveldt, Molteno and Schocket implants are open tube devices, Ahmed and Krupin have a flow restricting valve mechanism that inherently provides them the property to function only at a specific range of IOP and preventing early hypotony.

Other popular surgical procedures include Trabeculotomy and goniotomy used primarily in congenital glaucoma. Trabeculotomy was introduced in 1960 by Burian and Smith and later modified by Harms and Dannheim\textsuperscript{15}. Smith used a nylon or prolene suture instead of a trabeculotome to thread the Schlemm canal 360\degree, and pull it taut thus rupturing the trabecular meshwork\textsuperscript{16}. Otto Barkan in 1938 introduced Goniotomy as the technique for incising the trabecular meshwork gonioscopically. It is one of the most successful techniques in vogue for childhood glaucoma\textsuperscript{17}.

**Non-Penetrating Glaucoma Surgery (NPGS)**

Although initially proposed by Krashnov in 1964, it emerged as a novel surgical alternative in 1990s only. Here, the filtration occurs across a semipermeable structure, maintaining some resistance to outflow and decreasing the rates of over filtration and hypotony. It enjoys a better safety profile since the anterior chamber is not entered. Mainly consisting of deep sclerectomy and viscocanalostomy,
these act by increasing the aqueous outflow through the micro perforations created in the trabeculo-descemet membrane by peeling of the inner wall of schlemm canal. Also micro ruptures occur in the wall of Schlemm canal on injecting viscoelastic. Numerous modifications have been introduced since the advent of NPGS to improve the success rates\(^{18,19}\).

**Other Recent Advances** - Recently developed technologies that are substantially less invasive than trabeculectomy and do not depend on external filtering bleb formation or adjunctive antifibrotic agents promise to herald a new era in glaucoma surgery. However, they are yet to demonstrate their long-term efficacy. These include Trabectome (Trabecular Microelectrocautery), Glaukos I Stent (Trabecular micro-bypass), SOLX Gold shunt and ExPress mini-glaucoma shunt\(^{20-23}\).

Being independent of the conjunctival status, these newer procedures hold good chances of success in difficult situations like aphakic, pseudophakic, post penetrating keratoplasty glaucoma etc. Besides they do not cause sufficient scarring to preclude subsequent conventional surgery.

Thus glaucoma surgery has come a long way from the formation of a mere filtrationicatrix to the use of sophisticated technologies for achieving a good success rate. The technological advancements have already given a new insight to the glaucoma scientists and the future is sure to witness many more such advances.

**References**