A Brief History of Surgical Innovation in Glaucoma

The roots of many of today's devices and procedures are clearly evident in the mid-1800s.

BY NATHAN M. RADCLIFFE, MD

A brief review of the history of surgical innovation in glaucoma illustrates that the pursuit of the ideal IOP-lowering operation, including the restoration of physiologic aqueous egress, has long been the target of glaucoma surgeons. Razeghinejad and Spaeth recently published a comprehensive review of the topic.[1] On the most fundamental level, IOP-lowering surgeries have decreased pressure either by inhibiting aqueous production or by enhancing its outflow. Because most glaucoma surgeries promote the latter goal, it is helpful to group them into extra-scleral drainage (ie, bleb-forming) procedures versus those that enhance physiologic outflow. Some surgeries are difficult to categorize, however, and may have more than one mechanism of action (eg, canaloplasty). Both the enhancement of physiologic outflow and the bleb-forming procedures were first attempted more than 150 years ago (Table), but great progress has been made since then.

THE FIRST IOP-LOWERING SURGERIES

The first described attempt to incise the eye to lower IOP occurred in 1856, when von Graefe performed an iridectomy for angle-closure glaucoma. In 1867, de Wecker described the first external filtration procedure, the anterior sclerectomy. In 1876, he also described the use of a gold wire to drain fluid outside the sclera.[1] Thus, the first 20 years of surgical innovation in glaucoma provided the basis for trabeculectomy, tube shunts, and procedures that revise internal ocular anatomy to restore physiologic outflow.

Early innovation in glaucoma surgery did not end there. Reported in 1906, cyclodialysis was the first internal or suprachoroidal filtration surgery. Destruction of the ciliary body was first performed in 1932 and represents ophthalmologists' initial attempt to reduce IOP through the surgically induced inhibition of aqueous production.[1]

ADVANCES IN DRAINAGE DEVICES

In 1967, Molteno developed the first aqueous shunt to an external reservoir, initially using a juxtalimbal implant that was removed after a capsule formed. He eventually developed the (permanent) long tube implant that is very similar to the Molteno device (IOP Ophthalmics) used today. Additional tube designs were to follow from Ahmed, Krupin, and Baerveldt, providing surgeons with a variety of options.[1]

In glaucoma drainage device surgery, it was initially thought that large tube plates produced better results.[2] It has since been sufficiently demonstrated that large devices are not necessarily more effective than small ones (although a plate size smaller than approximately 150 mm^2 may lower the IOP less).[3] Further study has suggested that valved devices may provide a more favorable safety profile, with a small sacrifice in IOP lowering, than nonvalved implants.[4]

ADVANCES IN OTHER FILTRATION SURGERIES

The peripheral iridectomy described by von Graefe in 1856 was the first surgery to attempt to enhance aqueous egress through normal physiologic channels, but it certainly was not the last. Ironically, the Cairns trabeculectomy (1968) was initially conceived as a method of restoring physiologic outflow by removing the juxtacanicular trabecular meshwork, but it ultimately became a sclerokeratectomy procedure that reduced IOP by permitting suprascleral fluid to escape and forming a bleb.[1]

Probably a more important advance in the surgical restoration of physiology came in 1891, when Taylor performed goniotomy to remove the inner wall of the Schlemm canal. Other advances were to follow, including sinusotomy, nonpenetrating deep sclerectomy, viscocanalostomy, and canaloplasty. The last attempts to enhance physiologic aqueous outflow through the trabeculocanalicular outflow pathway. The surgeon passes a 10–0 Prolene tension suture (Ethicon, Inc.) through the canal of Schlemm. This process ultimately allows aqueous to escape through the episcleral veins.

TABLE. HISTORY OF GLAUCOMA SURGICAL INNOVATION		
YEAR	SURGEON/COMPANY	PROCEDURE/DEVICE
1856	von Graefe	Peripheral iridectomy
1867	de Wecker	Anterior sclerectomy
1876	de Wecker	Gold wire "shunt"
1891	Taylor	Goniotomy
1906	Sugar	Iridencleisis
1906	Heine	Cyclodialysis
1906	Rollet	Horse hair shunt
1909	Elliot	Trephine
1962	Sugar	Guarded filtration (trabeculectomy)
1964	Krasnov	Sinusotomy (nonpenetrating deep sclerectomy)
1968	Cairns	Guarded filtration (trabeculectomy)
1969	Molteno	Modern tube shunt
1990	Chen	Trabeculectomy with mitomycin C
1997	Latina	Selective laser trabeculoplasty
2004	Stegmann	Canaloplasty
2005	Baerveldt	Trabectome (trabecular microelectrocautery; NeoMedix Corporation)
2005	Dahan	Ex-Press Glaucoma Filtration Device (under scleral flap; Alcon Laboratories, Inc.)
2007	Glaukos Corporation	iStent (trabecular microbypass; Glaukos Corporation)
2007	Solx, Inc.	Solx Gold Shunt (suprachoroidal; Solx, Inc.)

THE MODERN ERA

The modern era of glaucoma surgery has clearly placed improved safety for patients at the center of surgical innovation. Two recent examples of this trend include the Trabectome (NeoMedix Corporation) and the Ex-Press Glaucoma Filtration Device (Alcon Laboratories, Inc.). The former lowered IOP by 20% in 22% of patients at 2 years, but it has an excellent safety profile[5]; as a result, many surgeons have adopted the Trabectome. Many glaucoma surgeons also use the Ex-Press Glaucoma Filtration Device implanted underneath a scleral flap, not for superior IOP reduction (it reduces IOP to a similar level as trabeculectomy), but for a more favorable safety and postoperative recovery profile than standard trabeculectomy.[6]

Introduced in 2007 and approved by the FDA in 2012, the iStent Trabecular Micro-Bypass Stent (Glaukos Corporation) represents an extension of many ideas present in the history of surgical innovation. Perhaps based on the lesson of tube shunts that bigger is not necessarily better, the iStent is the smallest medical device ever made. Its tip is self-trephining and enters the trabecular meshwork ab interno. The metallic shunt builds on de Wecker's initial use of gold wire and removes resistance at the inner wall of the trabecular meshwork similarly to Taylor's goniotomy. It is possible that this microincisional surgical option will usher in a new era of surgical innovation. History will be the judge. ■

Nathan M. Radcliffe, MD, is an assistant professor of ophthalmology at Weill Cornell Medical College, New York- Presbyterian Hospital, New York. He has received honoraria from Alcon Laboratories, Inc. Dr. Radcliffe may be reached at (646) 962-2020; drradcliffe@gmail.com.

1. Razeghinejad MR, Spaeth GL. A history of the surgical management of glaucoma. *Optom Vis Sci*. 2011;88:E39-47.
2. Heuer DK, Lloyd MA, Abrams DA, et al. Which is better? One or two? A randomized clinical trial of single-plate versus double-plate Molteno implantation for glaucomas in aphakia and pseudophakia. *Ophthalmology*. 1992;99:1512-1519.
3. Britt MT, LaBree LD, Lloyd MA, et al. Randomized clinical trial of the 350-mm^2 versus the 500-mm^2 Baerveldt implant: longer term results: is bigger better? *Ophthalmology*. 1999;106:2312-2318.
4. Christakis PG, Kalenak JW, Zurakowski D, et al. The Ahmed Versus Baerveldt study: one-year treatment outcomes. *Ophthalmology*. 2011;118:2180-2189.
5. Jea SY, Francis BA, Vakili G, et al. Ab interno trabeculectomy versus trabeculectomy for open-angle glaucoma. *Ophthalmology*. 2012;119(1):36-42.
6. Maris PJ Jr, Ishida K, Netland PA. Comparison of trabeculectomy with Ex-Press miniature glaucoma device implanted under scleral flap. *J Glaucoma*. 2007;16:14-19.