

Suprachoroidal Devices in Glaucoma

The past, present, and future of surgery for suprachoroidal drainage.

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Targeting the suprachoroidal space with surgery is not a new idea. All ophthalmologists are aware of the effect on intraocular pressure (IOP) of a cyclodialysis cleft following trauma. A small gap between the iris root and the scleral spur can cause devastating hypotony and be difficult to manage.

In 1900, Ernst Fuchs, MD,¹ and Leopold Heine, MD,² both described the inadvertent and deliberate formation of a cyclodialysis cleft, which enabled seemingly endless fluid to escape the anterior chamber. The effect was often hypotony, but this did not deter Dr. Heine from inventing the cyclodialysis spatula to refine the operation and attempt to use it as a therapeutic approach to IOP lowering.² With no control over flow and tendency of the clefts to suddenly close, however, IOP was too unpredictable and uncontrollable, and the technique never gained popularity.

In 1967, James Gills, MD, reexamined the suprachoroidal space for glaucoma surgery and devised a Teflon implant in an attempt to both control the rate of flow and prevent sudden cleft closure; however, the device was hampered by its size and the difficulty of insertion.³

The suprachoroidal space as a surgical target lost favor until the early 2000s, when the effort to improve upon the gold standard of trabeculectomy began. In 2005, Yablonski³ described a revision to trabeculectomy whereby deep sclerectomy was performed beneath a trabeculectomy flap, into which a small silicone tube was placed between the intrascleral lake and the suprachoroidal space. His retrospective series included 23 eyes, in which preoperative mean IOP of 25.4 mm Hg was reduced to 13.8 mm Hg at 324 days follow-up (mean values). Mean medication use was 3.0 drops preoperatively compared with 1.1 drops at 1 year postoperative. In keeping with the route of drainage, suprachoroidal trabeculectomy resulted in barely detectable bleb formation, suggesting that most aqueous is absorbed in the suprachoroidal space, facilitated by the high colloid osmotic pressure environment of the uveal system in preference to the higher resistance route by which subconjunctival fluid drains.

Driven by evidence that, despite antimetabolite use, the subconjunctival space is prone to fibrosis and hence

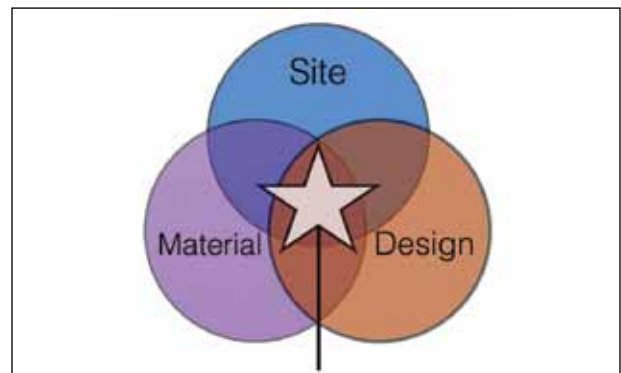


Figure 1. The triad of site, material, and design is essential for glaucoma devices.

reduction in efficacy or late failure, emphasis began to focus on how to divert drainage to a site of perceived lower resistance and scarring. In the early 2000s, two groups investigated how existing silicone tube implants could be adapted to divert flow from the equatorial subconjunctival space to the suprachoroidal space. A Turkish group modified a Krupin implant to drain from the anterior chamber directly to the suprachoroidal space.⁴ This technique was closely echoed by work in Germany.⁵ Both attempts were made in refractory eyes with high starting pressures (more than 40 mm Hg) and showed encouraging results (postoperative IOP in the mid 10s mm Hg). One of four patients in the Turkish series developed transient self-limiting hypotony,⁴ and two of 31 patients in the German series required tube removal due to endothelial decompensation.⁵

SITE, MATERIAL, DESIGN

The essential triad for glaucoma devices to work successfully is site, material, and design (Figure 1). As a target site, the suprachoroidal space offers the opportunity for large reduction in IOP. Evidence suggests that a negative pressure gradient exists between the anterior chamber and the suprachoroidal space, promoting aqueous outflow through a vacuum-like effect.⁶

Optical coherence tomography (OCT) allows the placement of devices to be checked postoperatively, and,

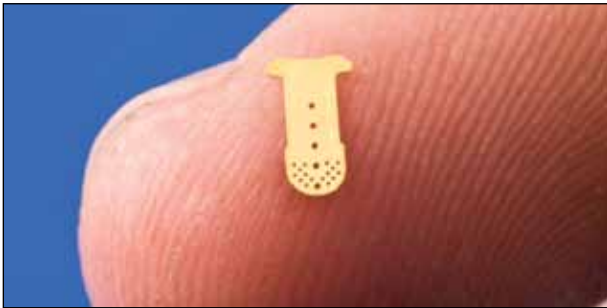


Figure 2. The Gold Shunt is composed of a pure gold plate.

in the near future, intraoperative real-time OCT will allow devices to be placed more accurately and more safely. The two early studies mentioned previously also highlight that device material and design are vital in allowing the suprachoroidal site to deliver on its potential.

CURRENT DEVICES

Gold Shunt. The Gold Shunt (Solx; Figure 2) is composed of a pure gold plate 60 μm thick. The material was chosen for its perceived bioinert characteristics. It contains tiny channels that can be opened by a laser to titrate flow. The 6.0-mm long plate is inserted via a trans-scleral route utilizing the supplied injector.

Although gold is bioinert, claims of biocompatibility have been refuted.⁷ In both in vitro and in vivo studies in rabbits, the shunt, while showing no foreign body reaction, exhibited fibrosis and vascularization in nearly all cases, although antimetabolite and steroid use transiently limited these. In a recent paper, approximately 40% of eyes showed fibrinous membranes of the anterior channels, and membranous blockage was observed in 67% of patients in a treatment failure group. However, care should be taken in extrapolating these results, as these were refractory eyes and not the intended population for suprachoroidal devices as first-line therapy.^{8,9}

IOP data from the same paper were more reassuring. Mean baseline IOP was 30.8 ± 8.8 mm Hg despite maximal medical treatment. After 2 years of follow-up, qualified success was achieved in 37 eyes (67.3%), and complete success was achieved in three eyes (5.5%). In patients in the success group, mean IOP decreased from 27.6 ± 6.9 mm Hg at baseline to 13.7 ± 2.98 mm Hg at 2 years. The mean number of medications decreased from 2.5 ± 0.9 at baseline to 1.4 ± 0.7 at 2 years.⁸

CyPass. Implanted in the suprachoroidal space, the CyPass (Transcend Medical; Figure 3) provides a conduit for aqueous to the uveoscleral system. The device is a flexible miniature stent with an external diameter of 510 μm and tiny fenestrations along the suprachoroidal portion of its 6.35 mm total length. The CyPass is injected across



Figure 3. Implanted in the suprachoroidal space, the CyPass provides a conduit for aqueous to the uveoscleral system.

the anterior chamber using gonioscopic visualization. It is packaged in a preloaded injector with a curved guidewire that mimics the plane between the ciliary body and sclera. This guidewire is noncutting and promises to create a controlled dialysis cleft, which the device then stents open and hopefully maintains.

Long-term data are lacking, but published series of 6- and 12-month results are available. A series of 81 eyes showed IOP reduction from 22 mm Hg⁹ preoperatively to 16.2 mm Hg at 6 months.¹⁰ Other papers illustrate IOP decreases of more than 33% and reduction of medications by more than 50%, but results are difficult to interpret as CyPass implantation was combined with phacoemulsification without a control group. As with all of these studies, the IOP-lowering effect of cataract surgery alone is large and unquantified and itself lasts longer than the 12-month follow-up of this study.¹¹

What this study does demonstrate, however, is the safety profile of the device; 265 eyes experienced no endophthalmitis, erosion, hypotony maculopathy, choroidal effusion, suprachoroidal hemorrhages, or acute IOP spikes. Mild hyphemas have been infrequent and typically resolve within 48 hours.^{10,11} The much-needed data comparing phacoemulsification alone versus phacoemulsification plus CyPass with 2-year follow-up and medication washout is ongoing but has finished recruiting; the results of this prospective study of 500 eyes will be interesting.

iStent Supra. The iStent Supra (Glaukos; Figure 4) is a polyethersulfone stent designed to create and maintain a patent lumen. It is the only device to have a heparin coating (proprietary DuraFlo) in addition to the usual claims of biocompatibility and sterility. The device has a slight curve designed to match the suprachoroidal space and has retention rings/ribs to provide stability in the wound tract and prevent extrusion. Like the CyPass, the iStent is inserted via an internal approach facilitated by a gonio-lens, either as a standalone procedure or combined with cataract surgery. The device is packaged with an injector consisting of a trocar, which is first passed into the



Figure 4. The iStent Supra is designed to create and maintain a patent lumen and is the only device with a heparin coating.

suprachoroidal space before the device is delivered via a trigger mechanism on the injector.

Prospective data on 25 eyes with no prior glaucoma surgery showed a baseline IOP of 20.7 ± 2.5 mm Hg prior to washout on two medications and 24.7 ± 1.9 mm Hg after washout. The iStent Supra was inserted without concurrent cataract extraction, and one medication was started (travoprost). At 1 year, mean IOP decrease was 43%, and, as per the protocol, medication use decreased from 2.0 to 1.0 agents. Ninety-six percent of eyes achieved a reduction of greater than 20% in IOP, 100% eyes achieved 18 mm Hg or less, and 80% reached 15 mm Hg or less.¹² Two-year results and full safety profile data are awaited.

STARflo. STARflo (iSTAR Medical; Figure 5) is another device currently undergoing clinical evaluation, having received the Conformité Européenne (CE)-Mark in May 2012. The first version of the device measured 11 mm long and 5 mm wide, with a slightly smaller neck region to prevent extrusion. The second version of the device will be smaller. Both designs are made of a unique biomaterial, which is silicone with a precise pore structure. The material is thought to reduce fibrous response, and early in vitro and in vivo data are encouraging.¹³ This device is implanted externally, similar to the Gold Shunt approach.

CONCLUSION

The suprachoroidal space, as a target for aqueous drainage, has the potential to achieve significant reduction in IOP by harnessing a unique downstream negative resistance. Previous surgical attempts to exploit this failed due to poor device design. The triad of site, material, and design is beginning to be understood, manipulated, and mastered, and a new generation of suprachoroidal devices such as those

TAKE-HOME MESSAGE

- The suprachoroidal space has the potential to achieve significant reduction in IOP by harnessing a unique downstream negative resistance.
- Site, material, and design are important concepts to be considered in the design of devices for drainage to the suprachoroidal space.
- Suprachoroidal drainage offers an alternative paradigm that can theoretically provide superior IOP reduction to trabecular bypass or Schlemm canal procedures.



Figure 5. The STARflo device is made out of silicone with a precise pore structure.

described above shows promise. More data are needed, and studies must be prospective and controlled to measure the effect versus that of cataract surgery alone.

Currently, subconjunctival drainage remains the gold standard due to experience and a wealth of published studies; however, suprachoroidal drainage offers an alternative paradigm that can theoretically provide superior IOP reduction to trabecular bypass or Schlemm canal procedures due to the unique physiology of the suprachoroidal space. ■

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1. Fuchs E. Ablösung der aderhaut nach staaroperation. *Graefes Arch Clin Exp Ophthalmol.* 1900;51(2):199-224.
2. Heine L. Die Cyclodialyse, eine neue glaukomoperation. *Dtsch Med Wschr.* 1905;824-826.
3. Yablonski ME. Trabeculectomy with internal tube shunt: a novel glaucoma surgery. *J Glaucoma.* 2005;14(2):91-97.
4. Ozdamar A, Aras C, Karacorlu M. Suprachoroidal seton implantation in refractory glaucoma: a novel surgical technique. *J Glaucoma.* 2003;12(4):354-359.
5. Jordan JF, Engels BF, Dinslage S, et al. A novel approach to suprachoroidal drainage for the surgical treatment of intractable glaucoma. *J Glaucoma.* 2006;15(3):200-205.
6. Emi K, Pederson JE, Toris CB. Hydrostatic pressure of the suprachoroidal space. *Invest Ophthalmol Vis Sci.* 1989;30(2):233-238.
7. Oatts JT, Zhang Z, Tseng H, Shields MB, Sinar JH, Loewen NA. In vitro and in vivo comparison of two suprachoroidal shunts. *Invest Ophthalmol Vis Sci.* 2013;13;54(8):5416-5423.
8. Figus M, Lazzeri S, Fogagnolo P, Lester M, Martinelli P, Nardi M. Supraciliary shunt in refractory glaucoma. *Br J Ophthalmol.* 2011;95:1537-1541.
9. Mastropasqua L, Agnifili L, Ciancaglini M, et al. In vivo analysis of conjunctiva in gold micro shunt implantation for glaucoma. *Br J Ophthalmol.* 2010;94:1592-1596.
10. Ianchulev T. Minimally invasive ab externo suprachoroidal device (CyPass) for IOP control in open angle glaucoma. Poster presented at: the American Academy of Ophthalmology Annual Meeting; October 18, 2010; Chicago, IL.
11. Hoeh H, Rau M, Reitsamer H, et al. Clinical outcomes of combined cataract surgery and implantation of the CyPass Micro Stent for the treatment of open angle glaucoma. Paper presented at: the XXX European Society of Cataract & Refractive Surgeons Congress; September 9, 2012; Milan, Italy.
12. Donnenfeld ED. Open angle glaucoma treated with implantation of suprachoroidal stent and topical travoprost. Paper presented at: the American Society of Cataract and Refractive Surgery Annual Meeting; April 20-24, 2012; Chicago, IL.
13. JD Bryers, CM Giachelli, BD Ratner. Engineering biomaterials to integrate and heal: the biocompatibility paradigm shifts. *Biotechnology & Bioengineering.* 2012;109(8):1898-1911.