Core Concepts

- Because filtering surgery with adjunctive anti-fibrosis agents which filters aqueous to the anterior subconjunctival space and tube-shunts from anterior chamber to equatorial sub conjunctival space have potentially devastating complications, the search has begun for safer, effective choices.
- Newer surgeries have been introduced that seek to bypass the trabecular meshwork and/or dilate Schlemm's canal either ab interno or ab externo. Other approaches have shunted aqueous from anterior chamber to the supraciliary (suprachoroidal) space. Generally these newer shunting procedures are safer than trabeculectomy or glaucoma drainage devices (to the equatorial subconjunctival space).
- As these newer approaches can lower intraocular pressure to the mid-teens but not much lower they may be a alternatives for patients with early to moderate glaucoma seeking to reduce or eliminate topical medications.
- Often these newer procedures are coupled with cataract surgery. Some are technically easier than others. No comparative data is available to suggest which of these is safest and/or most effective.
- Time and more extensive studies will tell which ones will become a part of the standard glaucoma armamentarium.
- The advent of these new procedures may allow surgical procedure for glaucoma to be tailored to the specific needs of individual patients.

1. Introduction

Lowering intraocular pressure consistently to levels in the low teens has been shown to slow or halt progression of glaucoma. Anti-glaucoma medicines, laser techniques and incisional surgeries all seek to lower intraocular pressure (IOP). Incisional surgery is indicated when medical treatment and/or laser surgery have failed, are likely to fail or are not available, likely to be followed or practical. In the past, the most likely surgical procedure to be attempted first was trabeculectomy (or some variation thereof e.g. ExPRESS shunt): aqueous is shunted from the anterior chamber under Tenon’s capsule and conjunctiva anteriorly. Antimetabolites markedly improved the success rate of anterior filtration but increased the potential for short and long term problems e.g hypotony, late bleb leakage and bleb-related infections. When anterior filtering surgery fails or is likely to fail such as in some secondary glaucomas, tube and plate shunts drain aqueous humor to the equatorial region of the eye under Tenon’s capsule and conjunctiva. These procedures are time-tested and generally succeed in experienced hands. Increasingly a tube-shunt operation may be the first one attempted after laser trabeculectomy. Hypotony, anterior chamber bleeding, supra-choroidal hemorrhage, serous choroidal detachments, late bleb leaks, endophthalmitis, corneal decompen-sation and bleb scarring occasionally (but too often) bedevil efforts to prevent vision loss with these operations. Efforts are ongoing to provide effective and safer alternatives. Holmium laser sclerostomy, viscosanalostomy and deep sclerectomy achieved success but were limited by relative ineffectiveness, challenging surgery or unanticipated problems.

Several new approaches to improve aqueous drainage can be classified either by the approach, ab interno vs. ab externo, by the tissue compartment into which the shunted aqueous flows or by the location of the actual surgical site. I describe some of the more popular of these as well as a few that are still in their infancy, classified by the approach and the principles, as well as published results.

2. Recent approaches

Three new ab interno procedures bypass trabecular meshwork by shunting fluid from the anterior chamber either directly into Schlemm’s canal or into the supra-choroidal space.

- Trabectome trabeculotomy

At its distal end, the Trabectome® has a ceramic probe that is inserted into Schlemm’s canal under gonioscopic control after being passed across the anterior chamber through a small, clear corneal limbal incision. Proximal to the ceramic tip, the trabecular mesh is ablated by a radiofrequency current across a spacer (Figure 1). About one quarter to one-third of the meshwork can be ablated through one corneal wound. Presumably this permits aqueous more easily and directly to enter Schlemm’s canal and from there directly into the scleral collector channels.

Advantages are relatively short operating time (about 10–15 minutes), IOP drop to the 15–17 mm Hg range in about 65% of eyes with Trabectome alone and 87% in eyes combined with cataract extraction, and a low rate of serious complications.3,4 Good results have been reported out to 4 years.5 The operation can be combined with cataract extraction especially clear corneal, temporal phacoemulsification. Early post-operative complications include an IOP spike, back bleeding from Schlemm’s canal with hyphema, Descemer’s detachment or damage, and failure to find Schlemm’s canal. In the absence of a leaking wound, hypotony is rare. There are no published long-term, prospective, controlled studies comparing Trabectome trabeculecto-
my with other techniques or comparing combined Trabectome/cataract surgery with cataract surgery alone. However, the results from long-term observational studies suggest that the combined cataract extraction/Trabectome procedure does provide longer term pressure control than cataract surgery alone. This is a relatively simple operation that can fit into the glaucoma surgical spectrum between laser trabeculoplasty and trabeculectomy or other filtration procedure.

- **IStent and Hydrus Implants**

  The IStent is an L-shaped titanium tube that fits into Schlemm’s canal via an ab interno insertion; it shunts fluid from the anterior chamber to the collector channels by-passing the mesh and the juxtacanalicular tissue wherein lies much of the outflow resistance. It is inserted under gonioscopic control via a 2 mm clear corneal, temporal limbal incision (Figure 2). The device increases outflow facility above baseline and even more than cataract surgery alone. IOP control is improved compared with cataract surgery alone. In a multicenter, randomized controlled trial comparing cataract surgery alone with combined IStent and cataract surgery, at one year, the IStent plus cataract group achieved IOP below 21mmHg without medication more often than the cataract alone group (72% vs. 50%) and, while both groups achieved approximately the same IOP, the IStent plus cataract group accomplished that IOP level with fewer medications. In both randomized trials, the complications were few and not significantly more frequent than cataract surgery alone. Implantation of two devices some degrees apart might improve outflow and IOP control over one device with excellent safety although the procedure is technically demanding and the catheter relatively expensive.

  The Trab360 and the ViscoTrab have been approved by the US FDA on the basis of substantial equivalence to existing devices. The Trab360 allows performance of a 180 degree or 360 degree trabeculotomy ab interno. The needle-like tip of the device is inserted through a small clear corneal incision. Under gonioscopic control, the tip is inserted into Schlemm’s canal and an enclosed nylon-like suture is advanced over 180 degrees of Schlemm’s canal (Figure 3). The device is then pulled out of the eye and the suture tears 180 degrees of trabecular meshwork. The suture can be rewound into the device and inserted in the opposite direction if desired to perform 360 degrees of trabeculotomy. No published data is available but this procedure is expected to provide similar efficacy to the Trabectome without the capital investment and with a less expensive hand piece.

  The ViscoTrab device is similar to the Trab360 except that the canula threaded into Schlemm’s canal is hollow. Once 180 degrees of Schlemm’s canal has been cannulated, a slow retrieval deposits a precise, metered amount of viscoelastic into Schlemm’s canal dilating it. The effect is similar to canaloplasty (see below) but the approach is ab interno through a small corneal incision. No results have been published yet.

  An excimer laser has been developed that performs multiple puncture trabeculotomies under gonioscopic control via an ab interno incision. Preliminary results with this very expensive but easy to use system have been promising.
3. Drainage to the Suprachoroidal Space

Some aqueous normally drains into the suprachoroidal space whose pressure is negative compared with the anterior chamber. A device that shunts aqueous fluid from the anterior chamber to the suprachoroidal space using an ab interno approach (CyPass) has been reported to lower IOP when used alone or in combination with cataract extraction. The Cypass is a tiny tube-like device made of polymide - a bio-compatible material that is inserted into the suprachoroidal space just above the ciliary face across the anterior chamber under gonioscopic control (Figure 4).

The clear corneal, temporal corneal incision is less than 2 mm. The operation is quick; its ease depends on angle landmark identification. A large multicenter study from Europe demonstrated good efficacy with excellent safety. A large multicenter randomized, control trial in the USA has met its primary endpoints of better IOP control than cataract surgery alone but the data have not yet been published.

The following new procedures are inserted via ab externo techniques:

• Solx

The Solx device is a thin, gold micro-wafer with internal channels that carry aqueous from the anterior chamber to the suprachoroidal space. The device is implanted ab externo from the scleral side after a conjunctival incision. The device was designed with many of the microchannels unopened. These unopened channels could be opened by a titanium-sapphire laser beam aimed at the device through a gonioprism in the postoperative period to increase aqueous drainage if needed. Results have been promising and the device is being evolved further.

• Canaloplasty

In canaloplasty, through a novel, flexible microcannula (ITrack) micro-amounts of viscoelastic are injected to enlarge Schlemm’s canal via an ab externo deep sclerectomy. Then an inserted circumferential 10/0 polypropylene suture is tied to apply traction on the trabecular mesh. The cannula contains a fiberoptic bundle whose tiny light emitting diode at the tip is visible through the sclera; this helps ensure the cannula stays in Schlemm’s canal as it is threaded around the limbus. First, a one-half thickness scleral flap is dissected. Then, an inner scleral block is excised. Then the cannula device can be used to perform an ab externo 360 degree trabeculotomy in eyes with congenital glaucoma and an ab interno trabeculotomy (see above).

4. Summary

How these procedures are best able to assist patient care has not been established. IOP results are summarized in Table 1 (note that the groups were probably not equivalent so drawing comparative inferences would be difficult). Several of these procedures have been adopted because of their reduced chances of profound vision loss. As more randomized, controlled studies

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**Table 1 Results of New Surgical Procedures.**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Approach</th>
<th>Alone or with Cataract surgery</th>
<th>Number</th>
<th>Initial IOP</th>
<th>Last F/u</th>
<th>IOP @ last F/U</th>
<th>% reduction</th>
<th># Meds @ last F/U</th>
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<tr>
<td>Trabecome</td>
<td>Internal</td>
<td>Alone</td>
<td>46</td>
<td>25.7</td>
<td>24Mos</td>
<td>16.6</td>
<td>40%</td>
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<td>iStent</td>
<td>Internal</td>
<td>With</td>
<td>117</td>
<td>18.4</td>
<td>12Mos</td>
<td>15.9</td>
<td>18%</td>
<td>0.2</td>
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<td>Cypass</td>
<td>Internal</td>
<td>With</td>
<td>94</td>
<td>20</td>
<td>12Mos</td>
<td>13</td>
<td>35%</td>
<td>0.8</td>
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<tr>
<td>Solx</td>
<td>External</td>
<td>Alone</td>
<td>77</td>
<td>27.6</td>
<td>12Mos</td>
<td>16.9</td>
<td>8%</td>
<td>0.2</td>
</tr>
<tr>
<td>Canaloplasty</td>
<td>External</td>
<td>With</td>
<td>85</td>
<td>23.6</td>
<td>36Mos</td>
<td>15.4</td>
<td>35%</td>
<td>0.9</td>
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<tr>
<td>Hydrus</td>
<td>Internal</td>
<td>With</td>
<td>50</td>
<td>24Mos</td>
<td></td>
<td>16.9</td>
<td></td>
<td></td>
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<tr>
<td>Excimer</td>
<td>Internal</td>
<td>With</td>
<td>64</td>
<td>19.8</td>
<td>12Mos</td>
<td>15.3</td>
<td>23%</td>
<td>0.9</td>
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<td>Laser Trab</td>
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</table>

**Note:** IOP results are summarized in Table 1 (note that the groups were probably not equivalent so drawing comparative inferences would be difficult). Several of these procedures have been adopted because of their reduced chances of profound vision loss. As more randomized, controlled studies.
are performed, the relative merits and disadvantages of these procedures will become known. Having more options in the surgical treatment of glaucoma raises the prospect of being able to tailor a procedure to the specific needs of each patient and to reduce some of the complications associated with the current standard operations.

References