Surgical Treatment of Strabismus Secondary to Glaucoma Drainage Device

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Objective: To describe surgical strategies in a series of patients with diplopia following implantation of a glaucoma drainage device.

Methods: Retrospective review of 9 consecutive patients who underwent strabismus surgery because of strabismus and diplopia after implantation of a glaucoma drainage device.

Results: Seven patients with marked limitation to ocular rotations and incomitant strabismus underwent surgery on the eye with the implant. Two patients with mild limitation to ocular rotations of the involved eye underwent surgery on the contralateral eye. All patients had a large fibrous capsule surrounding the implant plate, adjacent muscles, and sclera. Intraocular pressure was not elevated postoperatively. Postoperative diplopia in the primary position was eliminated in 5 patients and markedly improved in 3 patients.

Conclusions: Strabismus following implantation of a glaucoma drainage device is an uncommon but serious complication. Restoration of ocular alignment is a complex undertaking requiring strabismus and glaucoma surgical expertise. Multiple surgical complications may occur. Surgical intervention may require complete removal of the fibrous capsule surrounding the implant and involved adjacent structures. Size reduction of the implant plate is helpful and did not interfere with postoperative intraocular pressure control in this study. Surgery on the contralateral eye is an option in patients with mild restriction.
METHODS

We conducted a retrospective review of 9 patients with strabismus and diplopia after implantation of a glaucoma drainage device. All patients had extraocular muscle surgery performed by the same surgeon (A.L.R.) between January 1, 1997, and December 31, 2005. Appropriate internal review board approval was obtained.

All patients underwent an ocular examination that included the measurement of distance acuity, near visual acuity, and cycloplegic refraction (with the use of cyclopentolate hydrochloride 1%); a slitlamp examination; and a dilated fundus examination. The visual acuity was measured for distance with best correction using a binocular testing system (Mentor Binocular Visual Acuity Testing; Medtronics Solan, Jacksonville, Florida) with Snellen optotypes at 20 feet. Intraocular pressure was measured with the Goldman applanation tonometer preoperatively and postoperatively on the first day after surgery, 2 months later, and then periodically as recommended by the glaucoma specialist. All patients' ductions and versions were assessed preoperatively and postoperatively in the 9 gaze positions (Figure 1).11

Motor alignment was determined by prism cover testing while the subject was fixing at a 20/70 target at 6 meters and at 35.6 cm. A prism bar was held in front of the affected eye while an optical occluder covered the prism over the nonfixing eye. The patient was asked to fix with the unaffected eye. The optical occluder was then moved away from the affected eye to cover the unaffected eye. The angle of deviation was determined by measuring the amount of prism required to neutralize the movement of the nonfixing eye. In cases where the visual acuity in either eye was 1.3 or more logarithm of the minimum angle of resolution lines, the Krimsky test was performed to assess ocular alignment.13 Sensory response was evaluated with the Titmus stereo test (Stereo Optical Co, Inc, Chicago, Illinois).

Subjective torsion was measured with the double Maddox rod test. Two Maddox rod cylinders, one red and one green, were placed in a trial frame. The patient was asked to rotate each knob on the frame until the red and green lines were both parallel to the floor. The amount of cyclotorsional deviation (in degrees) was determined directly from the axis scale on the trial frame after the patient made the proper adjustment. Objective torsion was determined by the position of the macula relative to the optic nerve during examination of the posterior pole with the use of an indirect ophthalmoscope and a 20-diopter lens, as described elsewhere.14

A forced-duction test was performed at the beginning of the surgical procedure and then intraoperatively to determine the area of mechanical restriction and to confirm release of the restriction, respectively. This was performed by carefully grabbing the limbus with a toothed forceps on the opposite side of the gaze limitation, causing slight protrusion of the eye, and then rotating the eye in the direction of the limited duction.15 In all cases, the origin of restriction was determined to be in the area of the valve.

The ultimate goal was to free all restrictions. To achieve this, we removed (as much as technically possible) the fibrous capsule surrounding the valve and its extensions (Figure 2 and Figure 3). A limbal incision was performed to isolate the superior rectus and lateral rectus muscles. In dissecting these

![Figure 1. Patient 9. A, After Ahmed valve implantation, exotropia and hypertropia are evident in the left eye. B, The limitation to adduction and downward rotation in the left eye markedly improved postoperatively.](https://archopht.jamanetwork.com/)
muscles, we encountered the fibrous capsule adjacent to or ex-
tending along the bellies of the superior rectus or lateral rec-
tus muscles. It then was necessary to excise the fibrous cap-
sule to reveal the muscle and free the restriction.

RESULTS

The preoperative and operative patient characteristics are summarized in Table 1. The mean age at the time of strabismus surgery was 71.2 years (age range, 49-86 years). Eight of the 9 patients reported diplopia. Six of those 8 patients (75%) had vertical and horizontal diplopia, 1 (12%) had vertical diplopia, and 1 (12%) had vertical, horizontal, and torsional diplopia. The mean interval between implantation of the glaucoma drainage device and the onset of diplopia was 23.5 days (range, 1-90 days). No patient had diplopia before the glaucoma drainage device was implanted.

Six of 9 patients (67%) had exotropia and vertical deviation in the primary position. Four of those 6 patients (67%) had hypotropia of the affected eye and 2 of the 6 patients (33%) had hypertropia of the affected eye. Two of the 9 patients (22%) had esotropia and vertical deviation in the primary position.

The mean preoperative intraocular pressure was 12.7 mm Hg preoperatively (range, 6-16 mm Hg). Eight pa-

Figure 2. Patient 2. A, The scissors point to the thick fibrotic capsule (FC) covering the implant; the FC extends from the superior rectus muscle (SR) (arrow) to the lateral rectus muscle. B, The implant with part of the FC (arrow) dissected. C, The valve plate is almost fully exposed. D, Note the implant’s size relative to the eye. The scissors are cutting a fibrous band that goes through the valve’s pore.
Table 1. Preoperative and Operative Patient Characteristics

<table>
<thead>
<tr>
<th>Patient No./Age, y</th>
<th>Implant/Location</th>
<th>Diplopic Field</th>
<th>Alignment in PP, PD</th>
<th>Torsion, Degrees</th>
<th>IOP, mm Hg</th>
<th>Stereopsis, Seconds of Arca</th>
<th>EDM Operation</th>
<th>Glaucoma Implant Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/74</td>
<td>Baerveldt/OS SN</td>
<td>LG</td>
<td>RHT, 1; RG XT, 4; LG ET, 10</td>
<td>5 Ex</td>
<td>10</td>
<td>RLR: rec 12 mm, res 7.5 mm; RMR: Faden procedure</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>2/70</td>
<td>Baerveldt/OS ST</td>
<td>All gazes</td>
<td>XT, 20; LHoT, 14</td>
<td>13 Ex</td>
<td>16</td>
<td>LSR: rec 6 mm; LLR: rec 6 mm; LSO: reatt</td>
<td>Capsule excision, Baerveldt removal, Ahmed valve implantation</td>
<td></td>
</tr>
<tr>
<td>3/58</td>
<td>Ahmed/OD SN</td>
<td>None (poor VA)</td>
<td>XT, 25; RHoT, 15</td>
<td>5 Ex</td>
<td>16</td>
<td>Fly</td>
<td>Capsule excision</td>
<td></td>
</tr>
<tr>
<td>4/86</td>
<td>Ahmed/OD ST</td>
<td>All gazes</td>
<td>XT, 20; RHT, 18</td>
<td>3 Ex</td>
<td>NA</td>
<td>RLR: rec 6 mm; RSR: rec 6 mm</td>
<td>Capsule excision, adhesion release; RSR, valve insertion SN, valve trimming</td>
<td></td>
</tr>
<tr>
<td>5/49</td>
<td>Ahmed/OS ST</td>
<td>All gazes</td>
<td>ET, 15; LHoT, 3</td>
<td>NA</td>
<td>12</td>
<td>LMR: rec 3 mm</td>
<td>Scar tissue removal</td>
<td></td>
</tr>
<tr>
<td>6/65</td>
<td>Ahmed/OD SN and STb</td>
<td>All gazes</td>
<td>XT, 15; RHoT, 20</td>
<td>NA</td>
<td>12</td>
<td>Fly</td>
<td>Capsule excision, adhesion release; RSR, valve insertion SN, valve trimming</td>
<td></td>
</tr>
<tr>
<td>7/81</td>
<td>Ahmed/OD ST</td>
<td>PP, LG</td>
<td>ET, 8; RHoT, 14</td>
<td>5 Ex</td>
<td>12</td>
<td>RIR: rec 4 mm</td>
<td>Scar tissue excision</td>
<td></td>
</tr>
<tr>
<td>8/80</td>
<td>Ahmed/OS ST</td>
<td>All gazes</td>
<td>XT, 10; LHoT, 8</td>
<td>5 Ex</td>
<td>6</td>
<td>RLR: rec 7.5 mm; RSR: rec 4.5 mm</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>9/78</td>
<td>Ahmed/OS ST</td>
<td>All gazes</td>
<td>XT, 35; LHT, 20</td>
<td>5 In</td>
<td>14</td>
<td>LSR: rec 7 mm; LLR: rec 7 mm; LSO: rep</td>
<td>Capsule excision, revision valve</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: EDM, extraocular muscle; ET, esotropia; Ex, excyclotorsion; In, incyclotorsion; IN, inferonasal; IOP, intraocular pressure; LG, left gaze; LHoT, left hypotropia; LHT, left hypertropia; LLR, left lateral rectus muscle; LMR, left medial rectus muscle; LSO, left superior oblique tendon; LSR, left superior rectus muscle; NA, not available; OD, right eye; OS, left eye; PD, prism diopters; PP, primary position; rec, recession; rep, repositioning; res, resection; RG, right gaze; RHoT, right hypotropia; RHT, right hypertropia; RIR, right inferior rectus muscle; RLR, right lateral rectus muscle; RMR, right medial rectus muscle; RSO, right superior oblique tendon; RSR, right superior rectus muscle; SN, superonasal; ST, superotemporal; VA, visual acuity; XT, exotropia.

aFly indicates 3000 seconds of arc.
bThis patient had 2 implants in 1 eye.

The patients had 1 implant in 1 eye and 1 patient had 2 implants in 1 eye. Seven devices were implanted in the superotemporal quadrant and 3 were implanted in the superonasal quadrant.

Intraoperative forced-duction test results showed restriction to ocular rotations in all 9 patients. Four patients had restriction to ocular rotations in all fields. Two of the 3 patients with superonasally implanted devices had restriction to adduction and elevation in adduction.

One patient with a superotemporal implant had restriction to downgaze and adduction.

The surgical approach was individually tailored to each patient. All of the surgical procedures, except for 1 re-operation, were performed with the patient under general anesthesia. All patients underwent limbal conjunctival incision near the drainage device. The incision was extended with 2 radial incisions to the area of the adjacent rectus extraocular muscle for better exposure of the

Figure 3. Patient 2. A, The hook is under the lateral rectus muscle (LR). The fibrotic capsule (FC) covering the implant extends to the LR. B, The LR is disinserted and reflected from the sclera. The scissors are cutting the FC extensions between the sclera and the LR. C, The FC extensions (top arrow) continue to be removed from the LR (bottom arrow) and sclera far posteriorly.
The incidence of strabismus following implantation of glaucoma drainage devices is variable; it appears to be more common following placement of large-plate implants. Previous authors \(^1, 14, 16, 17\) have reported more than an 80% incidence of strabismus following implantation of the 350-mm\(^2\) Baerveldt implant or the Krupin valve with disc. In our study, 7 patients had had an Ahmed valve implanted. To our knowledge, the incidence of strabismus following Ahmed valve implantation is not reported in the literature, and there are only a few reports of strabismus after implantation of the device. \(^6, 18\) The Ahmed valve may induce fewer motility disturbances because its surface area (184 mm\(^2\)) is smaller than that of the double-plate Molteno (270 mm\(^2\)) or the Baerveldt (350 mm\(^2\)) implant. \(^1, 19\)

We found that limitation to ocular rotations in fields of gaze away from the implant and deviation toward the implant is most likely due to the presence of the fibrous capsule surrounding the implant, which causes marked restriction to ocular rotations. Superonasal implantation may create hypotropia with limitation to elevation in adduction. \(^2, 6, 9\) Two of our patients had limitation to elevation in adduction; both patients had implants in the superonasal quadrant.

One patient had 13° of excyclotorsion. Surgical exploration showed partial disinsertion of the anterior half of the superior oblique tendon, which was sitting directly under the implanted valve. As soon as the valve

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### Table 2: Postoperative Patient Characteristics

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>F/U, mo</th>
<th>IOP, mm Hg</th>
<th>Alignment in PP, PD</th>
<th>Torsion, Degrees</th>
<th>Stereopsis, Seconds of Arc</th>
<th>Diplopic Field</th>
<th>Patient Satisfaction</th>
<th>Strabismus Reoperation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>18</td>
<td>Ortho, LG</td>
<td>None</td>
<td>Fly–</td>
<td>Extreme RG</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>10</td>
<td>Ortho</td>
<td>3 Ex</td>
<td>50</td>
<td>No</td>
<td>Yes</td>
<td>RMR rec 6 mm, res 3 mm</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>15</td>
<td>XT, 4, RHOT, 10</td>
<td>None</td>
<td>Fly</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>NA</td>
<td>XT, 2, RHT, 2</td>
<td>None</td>
<td>NA</td>
<td>Vertical</td>
<td>Yes</td>
<td>No; required 2 PD</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>14</td>
<td>Ortho</td>
<td>None</td>
<td>Fly</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>12</td>
<td>XT, 5</td>
<td>None</td>
<td>3000</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>9</td>
<td>HT, 3</td>
<td>None</td>
<td>3000</td>
<td>No</td>
<td>Yes</td>
<td>RIR adv 2 mm</td>
</tr>
<tr>
<td>8</td>
<td>48</td>
<td>12</td>
<td>ET, 2, LHOt, 4</td>
<td>3 Ex</td>
<td>Fly</td>
<td>Intermittent in PP</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>14</td>
<td>XT, 6</td>
<td>None</td>
<td>Fly</td>
<td>Reading position</td>
<td>Yes</td>
<td>No; separate reading Rx</td>
</tr>
</tbody>
</table>

Abbreviations: adv, advancement; ET, esotropia; Ex, exocycloversion; F/U, follow-up; HT, hypertropia; IOP, intraocular pressure; LG, left gaze; LHoT, left hypotropia; NA, not available; ortho, orthotropia; PD, prism dioplers; PP, primary position; rec, recession; RG, right gaze; RHOT, right hypertropia; RIR, right inferior rectus muscle; RMR, right medial rectus muscle; Rx, prescription; XT, exotropia.

\(^4\)Fly indicates 3000 seconds of arc.

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A Fly indicates 3000 seconds of arc.

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COMMENT

The mean intraocular pressure was 13.0 mm Hg (range, 9-18 mm Hg). After surgery, no patient had uncontrolled intraocular pressure on any examination. Two patients with preoperative diplopia and 1 patient without preoperative diplopia owing to poor vision were diplopia free in all fields of gaze after the initial strabismus surgery. Two patients were diplopia free in the primary position after they underwent a second strabismus surgery because of an inferior rectus muscle slippage. Diplopia in the primary position improved but persisted in 3 patients: 2 patients had a smaller deviation and were diplopia free with prisms and 1 had intermittent diplopia.
was elevated, prior to any tissue dissection, it was apparent that the tendon was not in its normal location. The anterior portion of the superior oblique tendon most likely was accidentally detached from its insertion during implantation of the valve. The superior oblique tendon was reinserted in its normal position with a nonabsorbable suture, resulting in the absence of excyclotorsion postoperatively (Figure 4).

We found it necessary to eliminate the restriction caused by the fibrous capsule that surrounds the implant in 5 of our 9 patients. We also found it necessary to explore the extraocular muscles adjacent to the implant in all cases to ensure that they were intact and to excise the fibrous capsule. This was contrary to previous reports that recommended only recession of the adjacent or opposing muscles to avoid creating a persistent restriction.1

The fibrous capsule was almost impossible to dissect in its entirety. The scar tissue, which was extensive in all cases, was removed until the restriction on forced-duction testing was released or until it was no longer technically possible to continue. The fibrous capsule will probably recur once the implant begins to function because of the continuous aqueous flow. However, the smaller size of the drainage device (accomplished by trimming the valve or replacing it with a smaller device), extensive dissection, intraoperative corticosteroid injection under the Tenon capsule, and the fact that the implant was situated as far as possible from the adjacent extraocular muscles may prevent recurrence of the restriction.

The main concern when operating on the eye that has the drainage implant is the risk of damaging the implant’s ability to control intraocular pressure.1,2,19 These patients usually have advanced glaucoma and intraocular pressure that is difficult to control. It is advantageous to have a glaucoma surgeon available to help with managing changes in aqueous flow when the fibrous capsule is opened, trimming or replacing the glaucoma drainage implant, and reforming the anterior chamber. When the integrity of the fibrous capsule is violated, aqueous humor is immediately discharged and the anterior chamber flattens. This is the primary reason for including a glaucoma specialist, who can immediately reform the anterior chamber with sodium hyaluronate or balanced saline solution and maintain intraocular pressure. Once the anterior chamber is reformed and the pressure is normalized, strabismus surgery can continue, restrictions can be relieved, and the appropriate muscles can be recessed. Then, the glaucoma specialist can address the issues of valve reduction and removal of viscoelastic material. Extensive scar tissue dissection may result in damage to the conjunctiva. Careful conjunctival dissection is warranted to prevent complications during conjunctival closure and to decrease the potential risk of endophthalmitis in a patient who has a glaucoma drainage device.

Strabismus surgery secondary to a glaucoma drainage device is a complex procedure with potential complications such as cataract, decentored intraocular lens, hypotony, difficulties with conjunctival closure, postoperative infection, endophthalmitis, and intraocular pressure spikes owing to retained viscoelastic material. The postoperative intraocular pressures in our patients are shown in Table 2. Postoperative intraocular pressure follow-up ranged from 1 to 48 months. No patient required additional medication or glaucoma surgery. However, this study was limited by the small number of patients and short follow-up. Longer postoperative follow-up with a glaucoma specialist is required to monitor changes in intraocular pressure and in the optic nerve.

Treatment of strabismus following the implantation of a glaucoma drainage device is challenging. Nonsurgical treatment is limited. Prism usually do not help because the deviations are incomitant and sometimes large. To our knowledge, there are no reports of the use of chemodenervation in these patients.1 In cases of mild restriction of the ocular rotations and a comitant strabismus deviation, surgery on the contralateral eye has the advantage of being technically easier, more predictable, and associated with less risk of damaging the glaucoma drainage implant.

From this study, we cannot conclude which characteristics of the deviation predict the need for capsule excision. Almost every case required some degree of scar tissue removal, especially when the forced-duction test result was positive. Because the fibrous capsule is very
The location of the drainage device should be explored directly if the restriction needs to be released. In summary, strabismus after implantation of a glaucoma drainage device is an uncommon but serious complication. Removal of the fibrous capsule surrounding the implant is essential to release restrictions identified on forced-duction testing. However, appropriate rectus extraocular muscle recession with the use of adjustable sutures is required to achieve ocular alignment.

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REFERENCES


Correction

Error in “Report of a Case” Section. In the Case Report titled “Dorsal Midbrain Syndrome With Bilateral Superior Oblique Palsy Following Brainstem Hemorrhage,” published in the December 2006 issue of the Archives (2006;124(12):1786-1788), on page 1786, third column, line 9, the incorrect published statement reads “Right head tilt revealed 20 Δ esotropia with 12 Δ left hypertropia, and left head tilt showed 25 Δ esotropia with 4 Δ left hypertropia.” The statement should have said that on left head tilt the patient showed 25 Δ esotropia with 4 Δ right hypertropia.