ABSTRACT

Objective: To describe and present results of an original technique for nonvalved glaucoma implants.

Patients and methods: Thirty-five eyes of 34 patients with aggressive and/or advanced glaucomas of different causes were included. A Baerveldt implant was used in all cases, using an absorbable ligature that had been titrated to allow flow from day 1, but avoiding hypotony. Intraocular pressure (IOP) during the first 8 weeks, final IOP, visual acuity and complications were analyzed.

Results: Mean preoperative IOP was 42.8 mm Hg (range: 24-64 mm Hg), IOP was 14.4, 17.2, 18.6, 19 and 16.4 mm Hg during the 1, 2, 4, 6 and 8 postoperative weeks. Mean final IOP was 13.8 ± 4.25 mm Hg, a 67.8% reduction, after a mean follow-up time of 13 months (range: 8-29 months). Twenty-nine eyes (82.9%) had complete success, two had qualified success (5.7%) and four were failures (11.4%). Choroidal detachments and transient tube obstructions were the most frequent complications.

Conclusion: Titrated ligature of Baerveldt tubes was effective for controlling IOP during both the early and late postoperative phases in eyes with severe glaucomas.

Keywords: Glaucoma surgery, Glaucoma implants, Titrated ligature.

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INTRODUCTION

Glaucoma implants are a valuable alternative for controlling intraocular pressure (IOP) in difficult to treat glaucomas that have been in use for the past 30 years. All implants share some common features, although design, materials and size differ. In all a tube is inserted into the anterior chamber that is connected to a main body or plate, located at or behind the equator, around which a fibrous capsule that regulates aqueous outflow is formed. Implants may have restrictive flow (e.g. Ahmed or Krupin) or unrestrictive (e.g. Molteno and Baerveldt).¹

Implants with restrictive flow are designed to permit a more controlled flow from the beginning, while the tube must be occluded fully or partially during the first postoperative days in unrestricted implants to avoid severe hypotony. Occluding the tube will raise IOP until the ligature is removed or reabsorbed, an event that is usually planned for a time when sufficient fibrosis is formed around the implant, usually after 3 to 6 weeks. During this hypertensive period, eyes with advanced glaucomas or those with very high initial IOP might suffer additional devastating damage. Making venting slits anterior to the ligature, or using a suture inside the tube to permit some limited flow are established techniques that tend to have unpredictable results.²,³

After years of using Baerveldt implants we have devised the ‘Ortiz’ partial titrated ligature’ technique to lower IOP from the first postoperative day with limited flow that lasts until the implant begins functioning fully.
The tube of the implant was connected through a 26G cannula to a BSS bag placed 50 cm above the head of the patient. Every 15 cm of height above the eye represents about 10 mm Hg, so any flow that occurred at this level would mean that pressure would be less than 30 mm Hg (Fig. 1). Once the tube was tested for permeability the tube was ligated with an absorbable suture (7-0 or 8-0 polyglactin, Vicryl® Ethicon Inc.) titrating for a slow, continuous flow of BSS, similar to checking the flow of a trabeculectomy (Fig. 2). Once the desired flow was obtained the suture was locked in place with 5 knots. Then the implant was fixed in place in the conventional manner, in the superotemporal quadrant, using a long-needle tract with a 23G needle bent as a Z without a patch (Dr Felix Gil’s Technique).4

**SURGICAL PROCEDURE**

The tube of the implant was connected through a 26G cannula to a BSS bag placed 50 cm above the head of the patient. Every 15 cm of height above the eye represents about 10 mm Hg, so any flow that occurred at this level would mean that pressure would be less than 30 mm Hg (Fig. 1). Once the tube was tested for permeability the tube was ligated with an absorbable suture (7-0 or 8-0 polyglactin, Vicryl® Ethicon Inc.) titrating for a slow, continuous flow of BSS, similar to checking the flow of a trabeculectomy (Fig. 2). Once the desired flow was obtained the suture was locked in place with 5 knots. Then the implant was fixed in place in the conventional manner, in the superotemporal quadrant, using a long-needle tract with a 23G needle bent as a Z without a patch (Dr Felix Gil’s Technique).4

**Postoperative Regimen**

Every patient was examined on the first or second day, and at the end of weeks 1, 2, 4, 6 and 8 as per protocol, then every 2 to 3 months depending on IOP behavior or complications behavior. A topical antibiotic was used during the first week and prednisolone 1% every 2 to 4 hours during 8 to 10 weeks. Whenever, hypotony was present prednisolone was replaced with a nonsteroidal anti-inflammatory to promote a greater and faster scarring around the implant.

**RESULTS**

During the study period (January 2000 to December 2003) 53 eyes (19 were left eyes) of 51 patients received a Baerveldt implant, but 18 had to be excluded due to a short follow-up period.

We included 35 eyes of 34 patients, of which 22 were women; mean age was 59.9 years (range 22-73), including 30 mestizos, 3 Caucasian and 1 black. Demographic and surgical data for each case are included in Table 1. Most cases (25) received a Baerveldt 350 mm$^2$ implant and the rest (10) a 425 mm$^2$ implant. The tube was inserted into the anterior chamber in most eyes, 6 eyes additionally required an anterior or pars plana vitrectomy to avoid tube blockage.

Visual acuity improved in at least 1 line in 9 eyes, remained the same in 19 and worsened in 7. Initial visual acuity ranged from LP to 20/60 and final visual acuity from NLP to 20/40 (Table 2).

During follow-up the tube got blocked with vitreous in five cases, one could be treated with YAG laser vitreolysis, another also required medications and the other three additional surgical vitrectomy; one of these ultimately failed. One tube retracted out of the anterior chamber and needed to be relocated without loss of IOP control. Seven cases had transient hypotony with no choroidal detachments; only one of them had a mild shallow anterior chamber. Four additional cases had choroidal detachments, three of which were solved spontaneously; the other had to be drained. A patient who initially had light perception only had repeated tube extrusions and after finding calcified material inside the lumen, the tube was trimmed and removed from the anterior chamber. It was considered a failure and eventually needed cyclocryotherapy to further control IOP. In total 13 eyes needed additional procedures to either free the tube or relocate it in a better position (Table 3).

Mean initial IOP was 42.8 mm Hg (range: 24-64), and it was 14.4, 17.2, 18.6, 19 and 16.4 mm Hg during the 1, 2, 4, 6 and 8th postoperative weeks. Mean final IOP was 13.8 ± 4.25 mm Hg, a 67.8% reduction, after a mean follow-up time of 13 months (range: 8-29 months, Table 2, Graph 1).

Mean IOP for 425 mm$^2$ implants was 14.7 mm Hg and it was 13.5 mm Hg for the 350 mm$^2$ implant, a nonsignificant difference. Twenty-nine eyes (82.9%) had complete success, two had qualified success (5.7%) and four were failures.
Table 1: Patients, diagnosis and procedures

| No. | Age | Sex | Glaucoma diagnosis | Race | Tube location | Implant | Ligature material |
|-----|-----|-----|-------------------|------|---------------|---------|------------------|
| 1   | 54  | M   | Pseudophakic AC IOL | MES  | PC            | Baerveldt 425 | 7-0 Vicryl       |
| 2   | 62  | M   | Pseudophakic        | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 3   | 75  | F   | PK                 | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 4   | 76  | F   | CACG               | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 5   | 50  | M   | PK                 | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 6   | 72  | F   | PK                 | MES  | PC            | Baerveldt 425 | 7-0 Vicryl       |
| 7   | 65  | F   | Uveitic            | CAU  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 8   | 65  | F   | Uveitic            | CAU  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 9   | 61  | F   | Pseudophakic       | MES  | VC            | Baerveldt 350 | 7-0 Vicryl       |
| 10  | 70  | F   | Uveitic            | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 11  | 69  | F   | PK                 | BLA  | VC            | Baerveldt 350 | 7-0 Vicryl       |
| 12  | 65  | F   | Aphakic            | MES  | VC            | Baerveldt 350 | 8-0 Vicryl       |
| 13  | 49  | M   | Pseudophakic       | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 14  | 43  | F   | Pseudophakic       | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 15  | 49  | M   | Pseudophakic       | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 16  | 38  | M   | Uveitic            | CAU  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 17  | 69  | F   | PK                 | MES  | PC            | Baerveldt 350 | 7-0 Vicryl       |
| 18  | 35  | M   | NVG                | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 19  | 65  | M   | Pseudophakic       | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 20  | 60  | F   | GPAA               | BLA  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 21  | 60  | M   | PK                 | MES  | AC            | Baerveldt 425 | 7-0 Vicryl       |
| 22  | 72  | F   | PK                 | MES  | AC            | Baerveldt 425 | 8-0 Vicryl       |
| 23  | 64  | F   | Pseudophakic       | MES  | PC            | Baerveldt 425 | 7-0 Vicryl       |
| 24  | 72  | F   | Pseudophakic       | MES  | VC            | Baerveldt 350 | 7-0 Vicryl       |
| 25  | 37  | F   | PK                 | MES  | PC            | Baerveldt 350 | 7-0 Vicryl       |
| 26  | 67  | F   | PK                 | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 27  | 22  | F   | PK                 | MES  | AC            | Baerveldt 425 | 7-0 Vicryl       |
| 28  | 65  | F   | PK                 | MES  | PC            | Baerveldt 425 | 7-0 Vicryl       |
| 29  | 38  | M   | Post-traumatic     | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 30  | 62  | M   | PK                 | MES  | AC            | Baerveldt 425 | 7-0 Vicryl       |
| 31  | 67  | F   | Pseudophakic       | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 32  | 73  | F   | PK                 | MES  | AC            | Baerveldt 425 | 7-0 Vicryl       |
| 33  | 64  | M   | PK                 | MES  | AC            | Baerveldt 350 | 7-0 Vicryl       |
| 34  | 70  | F   | PK                 | MES  | PC            | Baerveldt 350 | 7-0 Vicryl       |
| 35  | 73  | F   | Pseudophakic       | MES  | AC            | Baerveldt 425 | 7-0 Vicryl       |

AC: Anterior chamber; PC: Posterior chamber; VC: Vitreous cavity; MES: Mestizo; BLA: Black; CAU: Caucasian; IOL: Intraocular lens; PK: Penetrating keratoplasty; M: Male; F: Female; CACG: Chronic angle closure glaucoma; POAG: Primary open angle glaucoma; NVG: Neovascular glaucoma

(11.4%, Table 2, Graph 2). Two failures were due to tube obstruction with vitreous, one to repeated tube extrusion and one neovascular glaucoma that went from hand movements to no light perception.

**DISCUSSION**

We found that modifying Baerveldt implant technique by using ‘Ortiz’ partial titrated ligature’ was useful in our group of patients to lower IOP significantly during the immediate postoperative period, although not all eyes to normal levels.

Long-term results are also encouraging, since our success rate was 88.6% (84.9% cumulative success rate at 30 months by Kaplan-Meier), while maintaining a low complications rate, many transient and not needing many reinterventions.

In fact, the seven cases of transient hypotony and the three cases of transient choroidal detachments are comparable to
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Table 2: IOP, visual acuity and final result

| No. | Visual Acuity | Preoperative | Intraocular Pressure (mm Hg) | Final | Result |
|-----|---------------|--------------|-------------------------------|-------|--------|
|     |               |              | Pre | 1 day | 1 week | 2 weeks | 4 weeks | 6-8 weeks | Final |
| 1   | HM            | HM           | 48  | 24    | 30     | 34      | 38      | 26       | 16 Success |
| 2   | 20-60         | 20-40        | 41  | 18    | 19     | 17      | 18      | 12       | 17 Success |
| 3   | HM            | HM           | 32  | 7     | 17     | 23      | 22      | 13       | 13 Success |
| 4   | CF 1M         | CF 1M        | 38  | 9     | 17     | 24      | 3       | 8        | 8 Success |
| 5   | CF 50 cm      | HM           | 40  | 4     | 12     | 19      | 20      | 14       | 12 Success |
| 6   | HM            | HM           | 66  | 16    | 24     | 30      | 54      | 9        | 9 Success |
| 7   | 20/100        | 20/70        | 31  | 15    | 8      | 7       | 7       | 8        | 12 Success |
| 8   | CF            | CF           | 28  | 5     | 18     | 17      | 6       | 15       | 15 Success |
| 9   | HM            | HM           | 66  | 16    | 10     | 11      | 12      | 10       | 14 Success |
| 10  | CF 20 cm      | CF 20 cm     | 30  | 5     | 4      | 4       | 7       | 15       | 9 Success |
| 11  | LP            | LP           | 50  | 35    | 30     | 26      | 17      | 16       | 17 Success |
| 12  | HM            | HM           | 38  | 2     | 2      | 14      | 14      | 13       | 18 Success |
| 13  | CF A 1M       | CF 2M        | 28  | 19    | 21     | 20      | 25      | 24       | 23 Failure |
| 14  | HM            | HM           | 39  | 9     | 12     | 14      | —       | 8        | 13 Success |
| 15  | LPP           | HM           | 29  | 23    | 9      | 10      | 12      | 10       | 12 Success |
| 16  | 20/400        | 20/400       | 28  | 4     | 7      | 7       | 4       | 16       | 12 Success |
| 17  | HM            | CF 2.5M      | 52  | 28    | 24     | 28      | 29      | 22       | 20 Relative success |
| 18  | HM            | NLP          | 60  | 18    | 38     | 30      | 10      | 39       | 15 Failure |
| 19  | CF 50 cm      | CF 50 cm     | 44  | 22    | 23     | 20      | 22      | 15       | 17 Success |
| 20  | 20/60         | 20/200       | 24  | 22    | 24     | —       | 28      | 10       | 14 Success |
| 21  | HM            | CF 20 cm     | 46  | 10    | 9      | 11      | 13      | 14       | 16 Success |
| 22  | HM            | HM           | 41  | 5     | 6      | 15      | 10      | 31       | 17 Success |
| 23  | HM            | NLP          | 60  | 16    | 30     | 22      | 30      | 19       | 24 Failure |
| 24  | 20/400        | 20/400       | 32  | 2     | 9      | 9       | 6       | 6        | 10 Success |
| 25  | LP            | LP           | 59  | 17    | 16     | —       | 15      | 15       | 14 Success |
| 26  | HM            | HM           | 32  | 7     | 27     | 34      | 35      | 40       | 12 Success |
| 27  | CF 50 cm      | CF 50 cm     | 56  | 7     | 12     | 12      | 11      | 12       | 10 Success |
| 28  | HM            | CF 1M        | 46  | 20    | 26     | 22      | 46      | 22       | 8 Success |
| 29  | 20/100        | 20/300       | 40  | 21    | 25     | 24      | 11      | 12       | 11 Success |
| 30  | CF 3M         | CF 3M        | 39  | 17    | 16     | 14      | 18      | 12       | 16 Success |
| 31  | CF 2M         | CF 20/800    | 28  | 22    | 20     | 23      | 20      | 14       | 13 Success |
| 32  | CF 50 cm      | CF 2M        | 55  | 18    | 18     | 15      | 13      | 15       | 13 Success |
| 33  | HM            | LP           | 46  | 32    | 26     | 28      | 29      | 11       | 4 Failure |
| 34  | CF 20 cm      | CF 20 cm     | 42  | 8     | 7      | 16      | 59      | 29       | 12 Success |
| 35  | LPP           | LPP          | 64  | 2     | 16     | 15      | 12      | 20       | 18 Relative success |

NLP: No light perception; LP: Light perception; LPP: Light perception and projection; HM: Hand movements; CF: Counts fingers

Mean: 42.8, 14.429, 17.235, 18.63, 19.6, 16.42, 13.82

Table 3: List of complications, some eyes had more than one

| Complications          | n    | Total (%) |
|------------------------|------|-----------|
| Choroidal detachment   | 4    | 11.4      |
| Tube occlusion         | 4    | 11.4      |
| Tube exposure          | 4    | 11.4      |
| Hyphema                | 2    | 5.7       |
| Hypotony               | 1    | 2.9       |
| Flat anterior chamber  | 1    | 2.9       |
| Tube migration         | 1    | 2.9       |
| Tube extrusion         | 1    | 2.9       |
| Vitreous hemorrhage    | 1    | 2.9       |
| Endothelial contact    | 1    | 2.9       |
| Uveitis                | 1    | 2.9       |

the rates of the same complications reported for restrictive implants or even for unrestricted implants with full ligature after it has dissolved.5-7

Studies comparing restrictive and unrestricted implants have shown variable results.8,9 A previous comparison of Ahmed vs Baerveldt 350 that used similar success criteria as our study, found similar results between them, with final IOP of 12.1 ± 5.3 mm Hg and 13.6 ± 5.6 mm Hg, but complete success rates of 15.6 and 18.7%, plus qualified success rates of 50 and 46.8% were not as good as in our series. The rates of hypotony were 34.4% for the Ahmed

Graph 1: IOP behavior (in mm Hg) from the preoperative IOP, during the first 8 postoperative weeks and at last visit
and 37.5% for the Baerveldt implants with venting slits in some eyes. We observed seven cases (20%) of early hypotony with spontaneous resolution during the first 2 weeks in 6, and at week 6 in the other.

Shallow anterior chamber was also present in one eye (2.8%), a better rate than the typical 5 to 44% reported with several other implants.

A hypertensive phase has been reported in up to 60% of Ahmed valves, beginning between weeks 2 and 6, requiring antiglaucoma medications and that will get better in a small percentage of cases after several months. A more recent study showed that the hypertensive phase lasted more than a year despite the use of mitomycin C, in 40% of cases if a partial removal of Tenon’s was performed and in 46% when it was not done. This prolonged hypertensive period was not present in our series, although a mild IOP elevation did occur in 4 eyes between months 2 and 3 that was spontaneously solved. Another 3 cases had early IOP elevation due to a too tight ligature or tube obstruction with either fibrin or vitreous.

Experimental studies in animals and humans have shown the formation of a fibrous capsule around the plate, which is responsible for primary resistance to aqueous outflow, and is made up of an inner acellular collagen band with spaces among its strands, an intermediate layer with greater organization and an external vascularized layer.

There are three different Baerveldt models, with surface areas ranging from 250, 350 and 425 mm². The surface area for the Ahmed valve is 185 mm² (and also of each additional plate), it is 184 mm² for the Krupin and each Molteno plate has an area of 134 mm². Several studies have found that a greater surface area is related with a better long-term aqueous outflow and a lower IOP, supporting a size of around 268 mm² for a Molteno-type implant and 350 mm² for Baerveldt. The role of aqueous in the bleb during the initial postoperative period might decrease fibrosis and be related to better IOP in the long run, so having some flow of aqueous initially might be desirable. This is an advantage of restricted implants and might explain why IOP reduction might be similar despite their smaller size and lower long-term outflow.

Among the disadvantages of restricted implants a higher risk of obstruction with detritus or inflammatory cells that might predispose them to a higher risk of a hypertensive phase. An implant that is closer to the ideal should have a larger area for long-term IOP control, a good aqueous outflow that will indefinably keep those IOP levels without peaks, but with a low risk of hypotony despite having an effective IOP lowering in the early postoperative period.

Our method is in line with all these postulations, but requires experience and is affected by the subjectivity of the surgeon during flow titration, which makes it less reproducible. A more exact and standardized method to restrict early flow during the first weeks that eventually frees full flow is needed.

**SUMMARY**

The modified surgical technique that we used in this group of patients, allowed us to obtain a success rate that compares favorably with most published studies on glaucoma implants. Further studies to ascertain the reproducibility of the technique, the results and even the design of new implants aiming to improve long-term results and reduce complications are needed.

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