Veterinary Ophthalmology (2017) **20**, 5, 427–434 DOI:10.1111/vop.12443

Use of a 350-mm^2 Baerveldt glaucoma drainage device to maintain vision and control intraocular pressure in dogs with glaucoma: a retrospective study (2013–2016)

Kathleen L. Graham,* David Donaldson,† Francis A. Billson‡ and F. Mark Billson§

**Department of Ophthalmology and Eye Health, Sydney Medical School, University of Sydney, Sydney, NSW, Australia; †Ophthalmology Department, Dick White Referrals, Cambridgeshire, UK; ‡Sydney Eye Hospital, University of Sydney, Sydney, NSW, Australia; and §Ophthalmology Department, Small Animal Specialist Hospital, North Ryde, NSW, Australia*

Address communications to:

K. L. Graham

Tel.: +61 2 86273647
e-mail:
kgraham@mail2world.com

Abstract

Objective To evaluate the 350-mm^2 Baerveldt glaucoma drainage device (GDD) in dogs with refractory glaucoma when modifications to address postoperative hypotony (extraluminal ligature; intraluminal stent) and the fibroproliferative response (intraoperative Mitomycin-C; postoperative oral colchicine and prednisolone) are implemented as reported in human ophthalmology.

Design Retrospective case series.

Animals Twenty-eight client-owned dogs (32 eyes) including seven dogs (nine eyes) with primary glaucoma and 21 dogs (23 eyes) with secondary glaucoma.

Methods The medical records of all dogs undergoing placement of a 350-mm^2 Baerveldt GDD at a veterinary ophthalmology referral service between 2013 and 2016 were reviewed. Signalment, diagnosis, duration and previous treatment of glaucoma, previous intraocular surgery, IOP, visual, and surgical outcomes were recorded.

Results IOP was maintained <20mmHg in 24 of 32 (75.0%) eyes. Fourteen eyes (43.8%) required no adjunctive treatments to maintain this IOP control. Fewer doses of glaucoma medication were required following surgery. Vision was retained in 18 of 27 (66.7%) eyes with vision at the time of surgery. No eyes that were blind at the time of surgery (n = 5) had restoration of functional vision. Complications following surgery included hypotony (26/32; 81.3%), intraocular hypertension (24/32; 75.0%), and fibrin formation within the anterior chamber (20/32; 62.5%). The average follow-up after placement of the GDD was 361.1 days (median 395.6 days).

Conclusion Efforts to minimize postoperative hypotony and address the fibroproliferative response following placement of a 350-mm^2 Baerveldt GDD showed an increased success rate to other reports of this device in dogs and offers an alternative surgical treatment for controlling intraocular pressure in dogs with glaucoma.

Key Words: Baerveldt, canine, dog, glaucoma drainage device, glaucoma surgery, gonioimplant

INTRODUCTION

Glaucoma is a neurodegenerative disease characterized by progressive retinal ganglion cell death and optic nerve degeneration and is one of the leading causes of blindness in humans and dogs worldwide.[1–4] Glaucoma in dogs is consistently associated with an elevated IOP with both primary and secondary causes recognized.[3] Therapeutic interventions used to manage glaucoma are aimed at reducing IOP to a level which is compatible with comfort and halts progressive vision loss.[2] Initial glaucoma therapy uses ocular hypotensive medications which lower IOP either by reducing production or by increasing the rate of aqueous humor outflow from the eye.[2] Unfortunately, failure to control IOP often occurs over time at which stage surgical techniques are implemented. Surgical

management is aimed at either facilitating aqueous humor outflow or decreasing aqueous humor production through ciliary body destruction.

Historically, ciliary body cyclodestructive procedures (cyclophotocoagulation or cyclocryotherapy) have been used to manage IOP inadequately controlled with medication in dogs. Limitations associated with ciliary body destruction include the inability to directly assess treatment targets (with trans-scleral techniques) and the susceptibility of adjacent tissues to damage. Decreasing aqueous humor production can have ramifications for eye health as aqueous humor is required for intraocular nutrition, metabolism, and the removal of retinal by-products.[5,6] These techniques are therefore associated with relatively high ocular morbidity (pain, decreased vision, inflammation, hypotony, and phthisis bulbi) as well as cataract formation and corneal decompensation which can affect visual outcome.[5–7] While many cyclodestructive procedures may result in IOP within the reference range in the short term, long-term control is more variable with a normal IOP, retinal, and optic nerve function often not retained for >6 months after surgery.[8] Reports in dogs following trans-scleral cyclophotocoagulation (TSCP) with varying periods of follow-up show control of IOP in up to 92% of cases;[9] however, retention of vision in potentially visual eyes was only 22[8]–50%.[9] Based on these results, increasing outflow of aqueous humor should be a more physiologically appropriate treatment of elevated IOP.[10]

Glaucoma drainage devices (GDDs), or aqueous shunts, allow for aqueous humor to bypass the iridocorneal angle facilitating outflow and are becoming the primary surgical option for management of raised IOP in human glaucoma patients.[11] The most commonly used GDDs in human glaucoma surgery include the Ahmed, Baerveldt, Krupin, and Molteno devices. These devices differ in their endplate surface area, shape, plate thickness, material, and the presence or absence of a valve.[12,13]

Efforts to control postoperative hypotony have always been considered important to success of a GDD. While valved GDDs are reported to have a lower incidence of early postoperative hypotony compared to nonvalved devices, hypotony was still reported indicating that the valves often do not function as anticipated (with a theoretical closing at 8–9 mmHg).[14] Reports in the medical literature describing restrictions to aqueous flow through nonvalved devices in the early postoperative period demonstrate improved results and decreased hypotony-related complications.[14] There has been some success described using valved Ahmed devices in dogs (with[15,16] and without[17,18] adjunctive TSCP), but there are few reports on the use of nonvalved devices.[10,19,20]

The Baerveldt GDD consists of a nonvalved silicone tube and endplate which, when encapsulated, creates a potential space into which aqueous humor drains.[12,21] The primary resistance to flow is via passive diffusion through the capsule that forms around the endplate.[13] Clearance of aqueous from the periocular tissues is presumed to be primarily via venous capillaries. Use of Baerveldt GDDs in human glaucoma patients has been associated with lower adjunctive medications and rates of additional surgery compared to Ahmed devices.[11,21–24] The relatively larger size of the scleral endplate has been shown clinically and experimentally in humans to correlate with better drainage capacity compared to smaller devices.[12,13,25]

Investigations into the pathogenesis of implant failure in humans have focused on managing the postoperative inflammatory response, minimizing the risk and duration of hypotony, as well as managing the fibroproliferative response to help maintain a functional 'draining bleb' around the implant.[22] Pro-inflammatory factors present in glaucomatous aqueous accelerate fibrosis associated with the scleral endplate.[22] Therefore, in addition to controlling postoperative inflammation with anti-inflammatory medication, recommendations to minimize exposure of the developing bleb to glaucomatous aqueous by delaying aqueous flow through the shunt have been proposed.[22] Using this information, we revisited the use of nonvalved implants in dogs with the aim of minimizing hypotony by obstructing aqueous flow through the implant tubing and using oral medications postoperatively to minimize the fibrous response associated with the implant. Placement of the GDD in this study was undertaken in dogs diagnosed with naturally occurring glaucoma inadequately controlled with medical management.

MATERIALS AND METHODS

Selection criteria

Medical records of all dogs (28 dogs; 32 eyes) treated with surgical placement of a 350-mm^2 Baerveldt GDD between September 2013 and February 2016 at the Small Animal Specialist Hospital were reviewed. Nine eyes (seven dogs) with primary glaucoma and 23 eyes (21 dogs) diagnosed with glaucoma following phacoemulsification were included. Diagnosis of primary glaucoma was made if goniodysgenesis, a narrow or closed iridocorneal angle, was identified on gonioscopy (in the affected or contralateral eye), and when physical and ophthalmic examinations revealed no evidence of disease that might result in secondary glaucoma. Signalment, eye(s) affected, IOP, previous intraocular surgery, medical and surgical interventions, complications, visual status, IOP control, and postoperative medication were recorded.

Surgical procedure

Surgery on each eye was performed by a veterinary ophthalmologist with one surgeon treating 29 eyes and the other surgeon treating three eyes. Dogs were premedicated with methadone (0.1–0.5 mg/kg IM; Physeptone, Aspen Pharma Pty Ltd, St Leonards, NSW, Australia) with or without acepromazine (0.005–0.03 mg/kg IM; ACP-2, Ceva Animal Health Pty Ltd, Glenorie, NSW, Australia). Anesthesia was induced using propofol (4–

6 mg/kg IV; Propofol, Sandoz Pty Ltd, Pyrmont, NSW, Australia) and/or thiopentone (4 mg/kg IV; Pentothal, Link Medical Products Pty Ltd, Warriewood, NSW, Australia) to effect. Each patient was intubated and anesthesia maintained with inhalational isoflurane and oxygen. Atracurium besylate (0.2 mg/kg IV; Hospira Australia Pty Ltd, Mulgrave, Vic., Australia) was administered to achieve neuromuscular blockade with additional doses (0.1 mg/kg increments) administered to allow appropriate globe positioning as required. A fornix-based conjunctival flap was made in the dorsolateral conjunctiva and the Baerveldt device (Abbott Medical Optics Pty Ltd, Pymble NSW, Australia) (Fig. 1) placed beneath the dorsal and lateral rectus muscles (Fig. 2). A scleral site was prepared, and in 23 cases, 0.4 mg/mL Mitomycin-C (MMC; Baxter Healthcare, Old Toongabbie NSW, Australia) soaked swabs were applied to the site for 2–4 min. The implant was secured to the sclera using 9/0 nylon (Vicryl; Johnson & Johnson Medical Pty Ltd, North Ryde NSW, Australia). An intraluminal suture (partial stent) was placed within the tube using 4/0, 5/0 or 6/0 nylon with one or two extraluminal ligatures tied around the tubing using 6/0 or 8/0 polyglactin 910 {Vicryl; Johnson & Johnson Medical Pty Ltd, North Ryde NSW, Australia}. In addition, up to three through-and-through stab incisions were made in the tubing anterior to the ligature (using either 8/0 or 9/0 gauge suture needles) (Fig.3). The anterior chamber was entered either via a scleral tunnel using a 21-gauge needle (five cases) or by creation of a scleral flap and a 23-gauge needle (27 cases) (Fig.4). Viscoelastic (sodium hyaluronate 10 mg/mL [Provisc, Alcon Laboratories, Inc, or Acrivet Biovisc 1.2%, Bausch & Lomb Inc., Warszawa, Poland]) and/or air were used to maintain the anterior chamber and facilitate placement of the tube into the anterior chamber (Fig.5). The scleral flap and conjunctiva were closed with 9/0 polyglycolic acid suture (Safil; B.Braun Pty Ltd, Bella Vista NSW, Australia). Triamcinolone 4 mg (Kenacort 40 mg/mL; Aspen Pharmacare, St Leonards NSW, Australia, {all cases}) and dexamethasone (0.1 mg, Dexafort; Intervet, Bendigo East Victoria, Australia {three cases}) were injected subconjunctivally. Intracameral injections of tissue plasminogen activator (tPA; Actilyse, Boehringer Ingelheim Pty Ltd, Macquarie Park NSW, Australia) were used postoperatively to manage fibrinous reactions and intraocular hypertension.

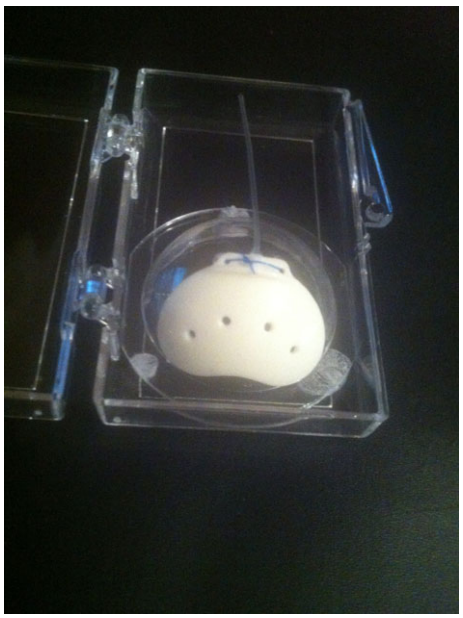

Figure 1. 350-mm^2 Baerveldt drainage device.

Postoperative management consisted of oral amoxicillin/clavulanic acid (15–25 mg/kg PO q12 h; Clavulox, Pfizer Australia Pty Ltd, West Ryde, NSW, Australia), oral prednisolone (0.25–1 mg/kg PO q12 h; Apex Laboratories Pty Ltd, Somersby NSW, Australia), and colchicine (0.02–0.03 mg/kg PO q24 h; Aspen Pharmacare Australia Pty Ltd, St Leonards NSW, Australia). Topical medications included prednisolone 1% drops (Prednefrin Forte; Allergan Australia Pty Ltd, Gordon, NSW, Australia), ketorolac trometamol 5 mg/mL [Acular; Allergan Australia Pty Ltd], and a topical antibiotic preparation (chloramphenicol drop 5 mg/mL [Chlorsig; Aspen Pharmacare Pty Ltd] or ointment 10 mg/g [Opticin; Troy Laboratories Australia Pty Ltd, Glendenning, NSW, Australia]). In addition, a topical carbonic anhydrase inhibitor (dorzolamide hydrochloride 2%/timolol maleate 0.5% [Cosopt; Merck Sharp & Dohme Pty Ltd, Macquarie Park, NSW, Australia] or brinzolamide 1% [Azopt; Alcon Laboratories Pty Ltd]) and/or a prostaglandin analog (travoprost 0.004% [Travatan; Alcon Laboratories Pty Ltd], latanoprost 50 μg/mL [Xalatan; Pfizer Australia Pty Ltd], or bimatoprost 0.03% [Lumigan; Allergan Australia Pty Ltd]) were used to help control IOP in the postoperative period. Medications for concurrent diseases were continued as necessary.

Follow-up

IOP was measured via rebound tonometry (Icare® Tonovet, Icare, Finland) postoperatively at intervals (q1-6 h) for the duration of hospitalization with frequency determined by the postoperative IOP. Clinical examination by a veterinary ophthalmologist was performed daily until discharge, and then weekly for the first month before decreasing the frequency dependent on progress.

Outcomes evaluated

Successful control of IOP was defined as IOP < 20 mmHg. Vision was considered present if there was an intact menace response on clinical examination with the ability to navigate an unfamiliar environment (veterinary clinic) under photopic conditions.

RESULTS

Clinical findings

Breeds represented included two Miniature Poodles; one case in a Basset Hound, Bichon Frise, Cavalier King

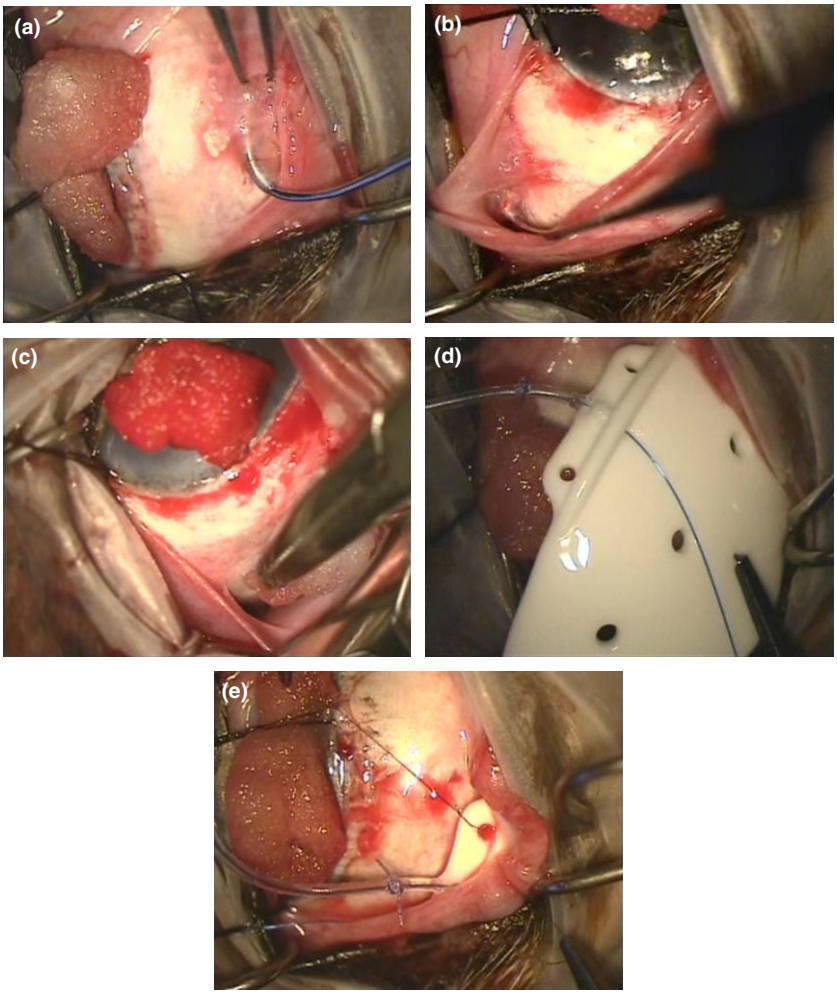

Figure 2. The dorsal (a) and lateral (b) rectus muscles are identified and isolated (c) a MMC-soaked sponge is used to soak the scleral bed at the surgeon's discretion; (d) the implant is prepared with an intraluminal suture and extraluminal ligature before being placed beneath the rectus muscles; (e) the implant is secured to the sclera.

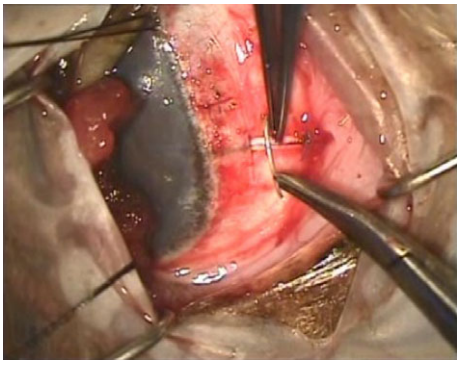

Figure 3. Stab incisions are made through the tubing anterior to the extraluminal ligature.

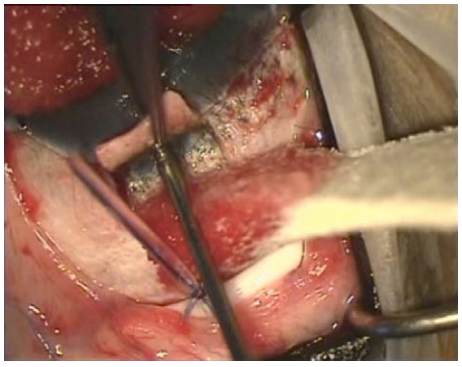

Figure 4. Entry into the anterior chamber using a 23-gauge needle under a scleral flap.

Charles Spaniel, Cocker Spaniel, Miniature Daschund, Miniature Pinscher, Shar Pei, Tenterfield Terrier, West Highland White Terrier; and 17 mixed breed dogs. There were 19 female and nine male dogs. The age range of dogs at the time of surgery was 4.1–14.1 years (average 9.1; median 9.9 years). The left eye only was operated on in nine cases and the right in 15 cases. Four dogs had a Baerveldt implant placed in both eyes within the study period.

Seven dogs (nine eyes) had been diagnosed with primary glaucoma while remaining dogs were diagnosed with secondary glaucoma following phacoemulsification. Glaucoma surgery was performed on average 58.5 days (median 21; range 4–264) after onset of glaucoma and

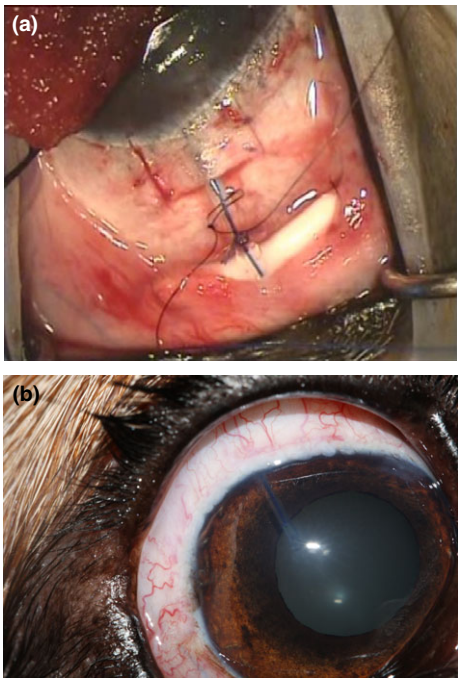

Figure 5. a) Mattress sutures may be used to anchor the tubing to the sclera with caution not to direct the tip of the tubing toward the corneal endothelium; b) tubing positioned within the anterior chamber without contacting corneal endothelium or iris.

206.6 days (median 46; range 15–2135) after phacoemulsification surgery.

Cyclodestructive procedures had been used without success to treat four eyes prior to implantation of the Baerveldt device with one dog receiving two treatments with trans-scleral cyclophotocoagulation (TSCP) and one dog receiving two treatments with TSCP and one cryosurgery treatment. One eye had undergone surgical placement of an Ex-PRESS glaucoma shunt (Alcon Laboratories [Australia] Pty, Macquarie Park NSW, Australia) 2 days prior to placement of the Baerveldt device, and IOP remained uncontrolled.

The average time until discharge was 8.3 days (median 6; range 1–45 days). The average duration of follow-up was 361.1 days (median 395.6; range 8–890 days).

Implant and technique modifications

An intraluminal suture was placed in all cases. The first 24 eyes had 6/0 nylon placed within the lumen of the tube extending from the anterior chamber to the scleral endplate. After initial results and due to ongoing concerns for hypotony, 5/0 nylon was used in six eyes. The use of 4/0 nylon in two eyes resulted in intraocular hypertension and was no longer used.

Extraluminal ligatures placed around the implant tubing were placed in all cases. Initially 6/0 absorbable suture was used, but with difficulties controlling IOP in the first 2–3 weeks postoperatively, 8/0 absorbable suture was used in latter cases. The number of venting holes placed through the tubing anterior to this ligature at the time of surgery varied at the surgeon's discretion depending on how refractory each eye was to medication, as well as the degree of IOP elevation.

MMC was applied intraoperatively in 23 cases. Cases where MMC was not used included the initial cases in this series (n = 7), and those where surgery was performed on an emergency basis, precluding waiting the period of time for ordering of the compounded medication (n = 2).

Postoperative courses of oral colchicine and prednisolone were started in all cases. Colchicine was continued for a minimum of 6 weeks postoperatively unless adverse side effects were reported (n = 6). Prednisolone was tapered according to individual cases, with more rapid tapering and lower doses used in diabetic dogs due to the implications on diabetic control.

Surgical outcome

Following GDD implantation, IOP was maintained <20 mmHg in 24/32 eyes (75.0%) (Table 1). Five eyes (15.6%) required an additional surgical procedure to maintain adequate IOP control. Surgeries required to help control IOP included surgical breakdown of iris adhesions (n = 4) and phacoemulsification to deepen the anterior chamber to facilitate appropriate tube positioning (n = 1).

At the time of surgery, 27 eyes had vision (positive menace response) and five eyes were functionally blind (no menace response). Of eyes that had vision at the time of surgery, 18 of 27 (66.7%) retained functional vision at the time of censor (or at the time of death when death was not related to implant failure). Of the five eyes that were blind prior to surgery, two regained some vision for a short period (up to 48 h) in the immediate postoperative period but this was not maintained.

Eleven of 32 (34.4%) eyes were enucleated following placement of a Baerveldt device either due to inadequate IOP control (8/32) or endophthalmitis (3/32). Endophthalmitis was suspected when there was rapidly progressive corneal edema, blepharospasm, and hypopyon, and was confirmed on histopathology. This loss of IOP control and/or endophthalmitis occurred on average 82.7 days after surgery (median 65, range 3–242 days).

An average of 6.3 (median 6) doses of glaucoma medication were administered on a daily basis prior to glaucoma surgery. At all time points measured through the postoperative period, there were fewer daily doses of glaucoma medication administered in all eyes that were not censored (mean 1.2 doses/day at 1 month {n = 29}; 0.3 doses/day at 3 months {n = 24}; 0.6 doses/day at 12 months {n = 10}).

Additional surgery was performed on ten eyes (31.3%) following Baerveldt implantation. Four eyes required surgery to separate iris adhesions to the tube (n = 3) and to the anterior lens capsule (n = 1). One eye underwent irrigation/aspiration for management of suspected endophthalmitis and one eye for treatment of hyphema. Other

Table 1. Outcome following 350-mm^2 Baerveldt implantation

Outcome	Definition	Eyes affected (%)
IOP control	IOP < 20 mmHg	24/32 (75.0%)
	IOP < 20 mmHg without medication	14/32 (43.8%)
	IOP < 20 mmHg with medication	5/32 (15.6%)
	IOP < 20 mmHg with additional surgery	5/32 (15.6%)
	No control (IOP > 20 mmHg)	8/32 (25.0%)
Visual outcome	Vision retained	18/27 (66.7%)
	Loss of vision	9/27 (33.3%)
	Return of vision in eyes blind before surgery	0/5 (0%)
Complications	Hypotony (IOP < 5 mmHg)	26/32 (81.3%)
	Intraocular hypertension (IOP > 25 mmHg)	24/32 (75.0%)
	Fibrin formation in anterior chamber	20/32 (62.5%)
	Corneal ulceration	14/32 (43.8%)
	Corneal degeneration, dystrophy, pigment	12/32 (37.5%)
	Vision loss	8/32 (25%)
	Hyphema	6/30 (18.75%)
	Cataract formation	4/32 (12.5%)
	Endophthalmitis	3/32 (9.4%)
	Tube protrusion through conjunctiva	1/32 (3.1%)
	Exophthalmos	1/32 (3.1%)
	Absolute keratoconjunctivitis sicca	1/32 (3.1%)
	Gastrointestinal signs (vomit, diarrhea)	6/32 (18.8%)

surgeries performed on one eye included placement of a buccal mucosal graft over an extruded tube; phacoemulsification to create a deeper anterior chamber and allow breakdown of tube–iris adhesions; placement of an ExPRESS shunt and adjunctive TSCP; and placement of a corneoconjunctival transposition for treatment of progressive stromal corneal mineralization. Of these cases, both the eye diagnosed with presumed endophthalmitis and the eye undergoing placement of an additional shunt with adjunctive TSCP were considered surgical failures as IOP was not controlled in either case with the use of a Baerveldt GDD.

Complications

Complications noted throughout the postoperative period are outlined in Table 1. Adverse gastrointestinal side effects were noted in six cases in the immediate postoperative period. Oral colchicine was discontinued when adverse side effects were noted (within 7 days of surgery) in these cases.

DISCUSSION

This series demonstrates control of IOP and preservation of vision following placement of a 350-mm^2 Baerveldt glaucoma drainage device in dogs. An important difference between this series and previous reports in dogs using the Baerveldt device was a consistent attempt to control postoperative hypotony and the fibroproliferative response by modifying previous protocols. Postoperative hypotony was minimized with placement of an extraluminal ligature and an intraluminal suture in all cases. Efforts to minimize the fibroproliferative response were made with the use of intraoperative MMC and a prolonged oral course of colchicine and prednisolone. The small number of cases, and the number of variables with which each eye was treated in this retrospective study mean definitive conclusions as to the significance of factors such as the type of glaucoma, use of MMC, the size of the intraluminal suture, adjunctive TSCP, and postoperative medications, cannot be determined. A randomized prospective study evaluating surgical techniques would allow evaluation of the significance of these factors.

The definition of success following glaucoma surgery varies between reports in both human and veterinary literature making direct comparisons between studies difficult. For this reason, in this series, a successful surgical outcome was defined as control of IOP (<20 mmHg) with the outcome of vision reported as no change in vision status following surgery. Control of IOP (75.0%) and maintenance of functional vision (66.7%) in this series is comparable with other studies using GDDs in dogs where IOP control is reported 22–80% and maintenance of vision in 41–88.0%.[10,15–17,19] Functional vision was not restored in any eyes which were blind at the time of implant placement. Based on these results, and on intensive postoperative management requirements of these patients, it is suggested that eyes that are blind prior to surgery have a grave prognosis for return of vision, and these cases should be considered poor surgical candidates.

The authors suggest the improved results reported in this series are potentially a result of modifications to previous protocols. In humans, most early complications following placement of a GDD occur as a result of postoperative hypotony and include choroidal effusions and/or hemorrhages, shallow anterior chambers with or without aqueous misdirection or maculopathy.[26] Placement of an intraluminal suture and ligation of the tubing of nonvalved GDDs are used to manage hypotony in the immediate postoperative period for nonvalved implants in humans, and therefore, a similar approach was used in this series. Oral colchicine and prednisone were used postoperatively in all cases in this series to minimize the fibroproliferative response. The anti-inflammatory effects of prednisone are well established. Colchicine binds to the subunits of fibroblast microtubules, thereby obstructing their assembly.[27] Colchicine has been reported to reduce subconjunctival fibrosis by reducing the number of fibroblasts and collagen fibers in the filtering wound.[28,29] Molteno *et al.*[29] showed this anti-inflammatory combination resulted in blebs with thinner walls and improved results.

In addition to postoperative medications, MMC was used in 23 eyes in this series. MMC has been shown to be helpful in promoting bleb formation and duration[30] and to decrease bleb capsule thickness in dogs.[31–33] Further investigation and modifications to minimize postoperative hypotony are considered essential due to the degree of fibrin production that accompanies hypotony in dogs and given that problems with hypotony were still the most common complication encountered in the current report.

Endophthalmitis was documented (confirmed on histopathology) in three cases with one case considered a result of a conjunctival rent. The other two dogs were diabetic, and this may have predisposed these cases to infection compared to nondiabetic patients.[34] No adverse effects were directly attributable to MMC; however, the influence of MMC and other antifibrotic agents on conjunctival wound healing should be considered and these agents should be used with caution.

In some cases where an elevated IOP was documented despite maximum tolerated medical management, additional doses of medication (typically a prostaglandin analog) administered on an emergency basis resulted in a reduction in IOP. We suggest it is these cases (rather than those where aqueous centesis is the only intervention that would lower IOP) that may require less intervention with potentially better outcomes, although case numbers are too low to draw definitive observations. A possible reason for this is exposure of the bleb to glaucomatous aqueous at an early stage if the extraluminal ligature was removed early. Compared to the aqueous of normal eyes, the aqueous of glaucomatous eyes has an irritant action (lasting for up to 9 weeks) on the episcleral tissues overlying the implants.[35] We therefore suggest that selecting cases for surgery while the IOP still responds to glaucoma medication would allow for better restriction of aqueous flow by occluding the implant tube with an absorbable suture, thereby protecting the filtration bleb during its formation. The requirement for aqueocentesis and/or intracameral tPA injections to manage fibrin and IOP typically resulted in hypotony and further fibrin production and should be avoided if possible.

Implant extrusion has been reported with the use of Baerveldt[19] and Ahmed[17] implants in dogs. In this series, there was no extrusion of scleral endplates which were positioned directly over the sclera, beneath Tenons capsule and conjunctiva, and under the extraocular muscles, as opposed to the subconjunctival space as previously reported.[10] In the first case in this series, there was conjunctival erosion over the implant tube which has been reported in humans.[36] A buccal mucosal graft prevented further problems in this case, and care was taken with placement of the tube in future cases.

A significant limitation of the findings reported here are the issues that arise from the retrospective nature of our study. All dogs undergoing glaucoma surgery were included rather than selecting only dogs with primary glaucoma. The impact of this aspect of case selection on the surgical outcomes reported here cannot be determined. Two dogs underwent placement of a Baerveldt device 15 days after phacoemulsification was performed (on the same day for both dogs). Both dogs had markedly inflamed, painful eyes with corneal edema and required daily aqueous centesis in an effort to control IOP prior to glaucoma surgery. With no infectious agents identified on culture of aqueous humor, toxic anterior segment syndrome was suspected. Were it possible to manage the intraocular inflammation successfully, control of IOP may have been obtained without glaucoma surgery; however, delaying intervention would have resulted in loss of vision. Surgery did not control IOP or maintain vision in either of these eyes.

In the authors' opinion, the ocular morbidity seen with the use of the Baerveldt GDD appears improved through the follow-up period to date compared to eyes treated with cycodestructive procedures. Eyes appeared generally comfortable with most complications in the early postoperative period. Further investigation is indicated to compare the use of the Baerveldt GDD to other reported surgical treatments of glaucoma in dogs, as well as whether there is any difference in surgical outcome dependent on glaucoma type (primary versus secondary).

The success of glaucoma filtering surgery is ultimately reliant on the presence of a functional, filtering bleb. Blebs in human glaucoma patients are often visualized, and ultrasound is used to assess for the presence of a bleb in cases of implant failure when direct visualization is not possible. Visualization and monitoring of a bleb was inadequate in this series. This is probably due to the posterior location of the implant as a result of the large corneal diameter in dogs in association with the posterior location of the scleral extraocular muscle insertions under which the implant was placed. However, there was a bleb noted in several cases. Further investigations are warranted to better understand the process of aqueous drainage when using Baerveldt implants in dogs.

CONCLUSION

The present series shows control of IOP and maintenance of vision in dogs with glaucoma following surgical placement of a Baerveldt glaucoma drainage device. The authors consider the additional techniques and medications to minimize postoperative hypotony and fibrosis essential in achieving this outcome. The success rate and follow-up reported is comparable to existing reports in the veterinary literature describing the surgical treatment of glaucoma in dogs. With the surgical outcomes described, the Baerveldt drainage device is proposed to be a more physiologically appropriate treatment for refractory canine glaucoma compared to cyclodestructive techniques. However, further studies to refine the techniques, evaluate the significance of modifications and variables, and minimize early postoperative hypotony as well as compare longer term follow-up with existing techniques are indicated.

REFERENCES

1. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. *British Journal of Ophthalmology* 2006; **90**: 262–267.
2. Marquis RE, Whitson JT. Management of glaucoma: focus on pharmacological therapy. *Drugs and Aging* 2005; **22**: 1–21.
3. Plummer CE, Regnier A, Gelatt KN. The canine glaucomas. In: *Veterinary Ophthalmology*, 5th edn. (ed. Gelatt KN) John Wiley & Sons, Inc, Iowa, 2013; 1050.
4. Ofri R, Narfstrom K. Light at the end of the tunnel? Advances in the understanding and treatment of glaucoma and inherited retinal degeneration. *The Veterinary Journal* 2007; **174**: 10–22.
5. Capriolo J. The ciliary epithelia and aqueous humor. In: *Adler's Physiology of the Eye*, 9th edn. (ed Hart W Jr) Mosby Year Book Inc, St Louis, 1992; 228–247.
6. Bito L. Glaucoma: a physiologic perspective with Darwinian overtones. *Journal of Glaucoma* 1992; **1**: 193–205.
7. Lima FE, Magacho L, Carvalho DM *et al.* A prospective, comparative study between endoscopic cyclophotocoagulation and the Ahmed drainage implant in refractory glaucoma. *Journal of Glaucoma* 2004; **13**: 233–237.
8. Cook C, Davidson M, Brinkman M *et al.* Diode laser transscleral cyclophotocoagulation for the treatment of glaucoma in dogs: results of six and twelve month follow-up. *Veterinary and Comparative Ophthalmology* 1997; **7**: 148–154.
9. Hardman C, Stanley RG. Diode laser transscleral cyclophotocoagulation for the treatment of primary glaucoma in 18 dogs: a retrospective study. *Veterinary Ophthalmology* 2001; **4**: 209–215.
10. Bentley E, Nasisse M, Glover T *et al.* Implantation of filtering devices in dogs with glaucoma: preliminary results in 13 eyes. *Veterinary and Comparative Ophthalmology* 1996; **6**: 243–246.
11. Shuchi P, Pasquale LR. Glaucoma drainage devices: a review of the past, present, and future. *Seminars in Ophthalmology* 2010; **25**: 265–270.
12. Minckler DS, Shammas A, Wilcox M *et al.* Experimental studies of aqueous filtration using the Molteno implant. *Transactions of the American Ophthalmological Society* 1987; **85**: 368–392.
13. Prata JA Jr, Mermoud A, LaBree L *et al.* In vitro and in vivo flow characteristics of glaucoma drainage implants. *Ophthalmology* 1995; **102**: 894–904.
14. Hong C-H, Arosemena A, Zurakowski D *et al.* Glaucoma drainage devices: a systematic literature review and current controversies. *Survey of Ophthalmology* 2005; **50**: 48–60.
15. Sapienza JS, van derWoerdt A. Combined transscleral diode laser cyclophotocoagulation and Ahmed gonioimplantation in dogs with primary glaucoma: 51 cases (1996–2004). *Veterinary Ophthalmology* 2005; **8**: 121–127.
16. Bentley E. Combined cycloablation and gonioimplantation for treatment of glaucoma in dogs: 18 cases (1992–1998). *Journal of the American Veterinary Medical Association* 1999; **215**: 1469–1472.
17. Westermeyer HD, Hendrix DVH, Ward DA. Long-term evaluation of the use of Ahmed gonioimplants in dogs with primary glaucoma: nine cases (2000–2008). *Journal of the American Veterinary Medical Association* 2011; **238**: 610–617.
18. Garcia-Sanchez GA, Whitley RD, Brooks DE *et al.* Ahmed valve implantation to control intractable glaucoma after phacoemulsification and intraocular lens implantation in a dog. *Veterinary Ophthalmology* 2005; **8**: 139–144.
19. Tinsley DM, Betts DM. Clinical experience with a glaucoma drainage device in dogs. *Veterinary and Comparative Opthalmology* 1994; **4**: 77–84.
20. Cullen CL. Cullen frontal sinus valved glaucoma shunt: preliminary findings in dogs with primary glaucoma. *Veterinary Ophthalmology* 2004; **7**: 311–318.
21. Minckler DS, Francis BA, Hodapp EA *et al.* Aqueous shunts in glaucoma. A report by the American Academy of Ophthalmology. *Ophthalmology* 2008; **115**: 1089–1098.
22. Molteno ACB, Suter AJ, Fenwick M *et al.* Otago glaucoma surgery outcome study: cytology and immunohistochemical staining of bleb capsules around Molteno implants. *Investigative Ophthalmology & Visual Science* 2006; **47**: 1975–1981.
23. Tsai JC, Johnson CC, Kammer JA *et al.* The Ahmed shunt versus the Baerveldt shunt for refractory glaucoma II: longer-term outcomes from a single surgeon. *Ophthalmology* 2006; **113**: 913–917.
24. Syed HM, Law SK, Nam SH *et al.* Baerveldt-350 implant versus Ahmed valve for refractory glaucoma: a case-controlled comparison. *Journal of Glaucoma* 2004; **13**: 38–45.
25. Heuer DK, Lloyd MA, Abrams DA *et al.* Which is better? One or two? A randomised clinical trial of single-plate versus double-plate Molteno implantation for glaucomas in aphakia and pseudophakia. *Ophthalmology* 1992; **99**: 1512–1519.
26. Sharkawi E, Artes PH, Oleszczuk JD *et al.* Systematic occlusion of shunts: control of early postoperative IOP and hypotony-related complications following glaucoma shunt surgery. *Journal of Glaucoma* 2016; **25**: 54–61.
27. Borisy GG, Taylor EW. The mechanism of action of colchicine, binding of colchicine-3H to cellular protein. *The Journal of Cell Biology* 1967; **34**: 525.
28. Yu YS, Youn DH. The effect of colchicine on fibroblast proliferation after glaucoma filtering surgery. *Korean Journal of Ophthalmology* 1987; **1**: 59–71.
29. Molteno ACB, Straughan JL, Ancker E. Control of bleb fibrosis after glaucoma surgery by anti-inflammatory agents. *South African Medical Journal* 1976; **50**: 881–885.
30. Duan X, Jiang Y, Qing G. Long-term follow-up study on Hunan aqueous drainage implantation combined with mitomycin C for refractory glaucoma [in Chinese]. *Yan Ke Xue Bao* 2003; **19**: 81–85.
31. Glover TL, Nasisse MP, Davidson MG. Effects of topically applied Mitomycin-C on intraocular pressure, facility of outflow, and fibrosis after glaucoma filtration surgery in clinically normal dogs. *American Journal of Veterinary Research* 1995; **56**: 936–940.
32. Palmberg P. The failing filtering bleb. *Ophthalmology Clinics of North America* 2000; **13**: 517–529.
33. Wilcox MJ, Barad JP, Wilcox CC *et al.* Performance of a new, low-volume, high-surface area aqueous shunt in normal rabbit eyes. *Journal of Glaucoma* 2000; **9**: 74–78.
34. Peleg AY, Weerarathna T, McCarthy JS *et al.* Common infections in diabetes: pathogenesis, management and relationship to glycaemic control. *Diabetes/Metabolism Research and Reviews* 2007; **23**: 3–13.
35. Teng CC, Chi HH, Katzin HM. Histology and mechanism of filtering operations. *American Journal of Ophthalmology.* 1959; **47**: 16–33.
36. Smith MF, Doyle FW, Tierney JW. A comparison of glaucoma drainage implant tube coverage. *Journal of Glaucoma.* 2002; **11**: 143–147.