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Diode laser transscleral cyclophotocoagulation for the treatment of primary glaucoma in 18 dogs: a retrospective study

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Abstract

Objective To evaluate a higher total energy protocol for diode laser transscleral cyclophotocoagulation (TSCP) for the treatment of primary glaucoma in dogs.
Procedures Diode laser TSCP was performed on 24 eyes of 18 dogs (six dogs were treated bilaterally). A glaucoma probe with a spot size of 600 microns was applied in 25 sites 3–4 mm posterior to the limbus for dogs. A power of 1000 milliwatts (mW) for a duration of 5000 milliseconds (ms) to deliver an average 125 J of energy per eye, which is higher energy delivery than previously reported for the diode laser for the treatment of canine glaucoma. Anterior chamber needle paracentesis was performed using a 30-gauge needle until intraocular pressure (IOP) was measured to be less than 15 mmHg by applanation tonometry. Subconjunctival corticosteroids were administered in all cases and a temporary tarsorrhaphy was applied in 13 of the 24 treated eyes. Postoperative topical and systemic corticosteroids, and carbonic anhydrase inhibitors were administered as required to maintain an IOP of less than 25 mmHg. Intraocular pressure was measured at approximately 3 h postoperatively then at 1, 2, 3, 7, 14, 28, 60, 120, and 180 days. Adequate control of IOP was considered to be less than 25 mmHg on re-examination.
Results Intraocular pressure was successfully maintained within the normal range in 22/24 eyes (92%). Three eyes required a second diode laser treatment within the first week postoperatively. Two eyes developed recurrence of glaucoma at 8 and 32 weeks postoperatively. Follow-up ranged from 8 to 21 months. Fourteen eyes were assessed by clinical examination and history to be potentially visual. Of these, seven eyes (50%) regained useful visual function. Mean IOP at 6 months was 11.0 ± 7.6 mmHg and at 12 months was 11.0 ± 8 mmHg. Postoperative complications included cataracts (six cases), corneal ulceration (three cases), and keratitis (three cases). Of 13 cases that were treated postoperatively with a temporary tarsorrhaphy, only one case (8%) developed corneal disease. Of the remaining 11 cases that were not treated with a temporary tarsorrhaphy, there were three cases of corneal ulceration and two cases of vascular keratitis (45% incidence of corneal disease). This was found to be statistically significant ($P < 0.05$). Postoperative complications of hyphema and phthisis bulbi were not seen in this series.
Conclusion Low energy, higher power laser cyclophotocoagulation was effective in the treatment of canine primary glaucoma, with 50% of potentially visual eyes regaining vision, but may cause an increased incidence of secondary cataracts.

Key Words: cyclophotocoagulation, diode laser, dog, glaucoma, transscleral

INTRODUCTION

Many surgical techniques have been described for the treatment of glaucoma in dogs. There are two basic methods of treating glaucoma: filtering procedures and cyclodestructive techniques. Techniques such as drainage implants, gonioimplants and filtering procedures work by increasing the outflow of aqueous.[1–7] It is generally considered that these techniques are invasive, technically difficult to maintain, and are associated with high complication rates. Cyclocryotherapy, intravitreal gentamicin, intraocular cidofovir, and cyclophotocoagulation have been used to destroy part of the ciliary body in an attempt to control canine glaucoma.[8–14] Neodymium:YAG lasers and diode lasers have been described as methods of cyclophotocoagulation.[15–19] Recently, Bentley *et al*. reported results of the use of combined cycloablation and gonioimplantation.[20]

Diode laser transscleral cyclophotocoagulation (TSCP) is a noninvasive procedure with a low complication rate. It has a high success rate for control of normal intraocular pressure, thus preserving a comfortable and cosmetic eye in most cases.[15] Diode laser TSCP has the ability to preserve vision in approximately 50% of cases treated.[15]

The purpose of this study was to analyse the effectiveness of a lower energy setting (1000 mW) for a longer duration (5000 ms) for 25 sites. This protocol delivered a higher total quantity of laser energy to the canine glaucomatous eye than has been previously reported for the diode laser.

MATERIALS AND METHODS

All dogs treated at the Animal Eye Care for primary glaucoma using the diode laser from May 1997 to June 1998 were included in the retrospective and prospective study. Follow-up on these dogs continued until March 1999. Dogs were excluded from the study if they had received any previous intraocular surgery or had secondary glaucoma of any kind. Eighteen dogs were included in this study for a total of 24 eyes, as six dogs were affected bilaterally.

Data analysed included breed, age, which eye was affected, IOP at presentation, duration of glaucoma, laser settings, number of treatments, control of IOP, potential for vision, whether vision was regained, postoperative medications, and complications.

All dogs were premedicated with carprofen (Rimadyl, Pfizer, West Ryde, NSW, Australia) and amlodipine (Norvasc, Pfizer) and all treatments were performed under general anesthetic using a 1 : 1 mix of intravenous diazepam (Pamlin, Parnell, Alexandra, NSW, Australia) and ketamine (Ketamine, Parnell) to effect. Topical local anesthetic drops were applied (Alcaine, Alcon, French's Forest, NSW, Australia). Globe exposure was enhanced using mosquito forceps attached to limbal conjunctiva. The cornea was kept moist during laser therapy by the application of topical artificial tear preparations (Tears Naturale, Alcon).

Diode laser transscleral cyclophotocoagulation (TSCP) was performed using a 810-nm diode laser (Diovet, Iris Medical, Mountain View, CA) with energy delivered via a fiber optic system through a 600-micron-diameter ball tip directly applied to the sclera with slight indentation. The probe was positioned perpendicular to the globe 3–4 mm posterior to the limbus, and 25 sites were lasered. There was no attempt to avoid the 3 o'clock and 9 o'clock sites (the long posterior ciliary arteries). Power settings of 1000 mW for a duration of 5000 ms were used. An audible 'pop' could usually be heard every 3–4 sites lasered using consistent pressure on the probe to indent the limbus. This parameter was used to adjust the power settings up or down (in 100 mW increments) to achieve the above frequency of 'pops' during the treatment.

Intraocular pressure (IOP) was measured immediately postoperatively. Anterior chamber paracentesis was performed on most cases immediately following laser treatment using a 30G needle inserted at the limbus until IOP was measured at 15 mmHg or less. In cases where sclerostomy had occurred with leakage of aqueous into the subconjunctival space resulting in an IOP less than 15 mmHg after laser treatment, no paracentesis was performed. A subconjunctival injection of 1.5 mg dexamethasone (Dexafort, Intervet, Castle Hill, NSW, Australia) was administered. A temporary tarsorrhaphy was placed in 13/24 cases.

Adjunctive therapy was used in some cases in the immediate (24–48 h) postoperative period when the IOP increased above 25 mmHg after initial laser and paracentesis. Topical dorzolamide (Trusopt, Merck, South Granville, NSW, Australia) and oral carbonic anhydrase inhibitors (dichlorphenamide, Daranide, Merck) were administered as required to normalize the IOP. In cases refractory to this medical management, repeat paracentesis was performed. In addition, an intracameral injection of 15–30 μg of tissue plasminogen activator (tPA) (Activase, Genentech, South San Francisco, CA) was administered when the aqueous humor removed by paracentesis was viscous in character. Animals were medicated with topical and systemic corticosteroids as required for between 2 and 8 weeks. Animals were hospitalized in most cases until IOP was maintained in the normal range, which was 2 days in most cases. No ocular lubricants were used in the postoperative period.

IOP was measured at approximately 3 h postoperatively, then at 1, 2, 3, 7, 14, 28, and 60 days in most cases and after this period 3–6 monthly. Postoperative medications consisting of topical prednisolone acetate (Prednefrin Forte, Allergan, French's Forest, NSW, Australia) and/or oral prednisolone (Solone, Fawns & McAllan, Clayton, VIC, Australia) were continued for the first 1 to 2 months after laser therapy in most cases. Temporary tarsorrhaphies were left in place for 2–6 weeks postoperatively. Duration of follow-up ranged from 8 to 21 months.

Successful control of IOP was defined as a value of less than or equal to 25 mmHg using applanation tonometry (Tonopen, Bio-Rad, Glendale, CA, USA) without the need for systemic medication or topical hypotensive agents.

Clinical examination and history were used to assess the potential for vision. Eyes with a history of glaucoma for less than 72 h and no sign of retinal or optic nerve degeneration on indirect ophthalmoscopy were considered to have the potential to regain useful vision. Vision after diode laser TSCP was assessed by the presence of an intact menace response, negotiation through an obstacle course, and observation by the owner.

RESULTS

There were 24 cases of primary glaucoma seen in 18 dogs (six dogs treated bilaterally). Ten dog breeds were represented, ranging in age from 3 to 14 years, with an average age of 9.7 years. The most common breeds affected included Maltese (*n* = 3), Golden Retriever (*n* = 3), America Cocker Spaniel (*n* = 2), Miniature Poodle (*n* = 2), Basset Hound (*n* = 2) and Springer Spaniel (*n* = 2). The right eye was treated in 13 cases, and the left eye in 11 cases.

Intraocular pressure at presentation ranged from 26 to 79 mmHg, with an average of 52 mmHg. The duration of the glaucoma ranged from 1 to 21 days, with an average of 5.3 days. In 13 cases the duration of the glaucoma was 72 h or less. In a further six cases the duration of glaucoma was between 3 and 7 days and in the remaining five cases the duration of glaucoma was over 10 days.

An average of 996 mW was delivered per site for 5000 ms for 25 sites. This resulted in an average of 121 ± 13 J. An average of 24 sites was treated per eye. Audible popping sounds were heard every 2–3 sites, i.e. 33–50% sites.

An immediate postoperative IOP rise was noted following cyclophotocoagulation in most cases (20/22 eyes; 92%). Although these measurements were not recorded, an elevation of between 10 and 40 mmHg was usually observed.

Mild aqueous flare occurred postoperatively in 19/24 (80%) cases, mild hyphema in 4/24 (17%) cases, and severe uveitis in one case (4%). There were variable degrees of conjunctival hyperemia and scleral injection. No significant postoperative discomfort was observed in any case. All dogs seemed more comfortable, and were more alert and active after cyclophotocoagulation with the reduction in IOP.

Intraocular pressure rose in the 24–48-h period postoperatively in 14/24 (58%) cases. In six (25%) of these cases, the rise in IOP was above 25 mmHg. During this period, topical and systemic corticosteroids and carbonic anhydrase inhibitors were administered. Four cases that failed to respond to these medications were treated by repeat paracentesis on the first day postoperatively. Intracameral injection of tPA was administered in two of these cases. A second laser treatment was performed on three cases in the first week. Animals were hospitalized for an average of 2 days (range of 1–5 days) in most cases until IOP was maintained in the normal range.

All cases were medicated with corticosteroids, either topical or systemic or both, as required for a duration of 2–8 weeks. The requirement for corticosteroids was based on the presence of perilimbal hyperemia and/or aqueous flare. Topical corticosteroids were used for an average of 35 days, and systemic corticosteroids were used for an average of 46 days at a reducing dose. Oral carbonic anhydrase inhibitors were used in four cases for the first 2 days postoperatively. Topical dorzolamide was administered in seven cases for between 2 and 14 days and topical timolol (Timoptol, Merck) was administered long-term in one case.

Successful control of IOP was maintained in 22/24 cases (92%), defined as maintenance of IOP less than 25 mmHg without hypotensive therapy. Follow-up periods ranged from 8 to 21 months. The mean pressure at 6 months was 11.0 ± 7.6 mmHg and the mean pressure at 12 months was 11.0 ± 8.0 mmHg. In this series, the number of cases less

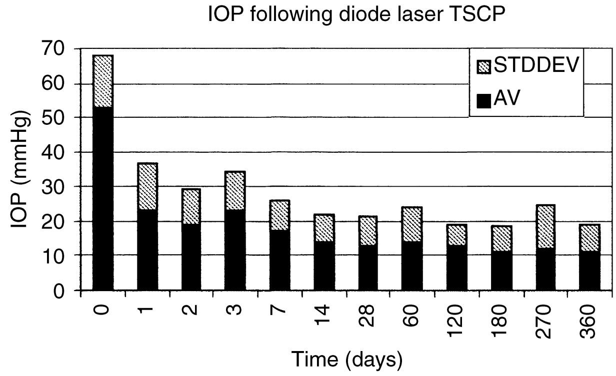

Figure 1. IOP following diode laser TSCP.

than 15 mmHg at 6 months follow-up was 19/23 (83%) with no follow-up on one case. At 12 months 14/17 (82%) had IOP less than 15 mmHg, with one case having IOP greater than 15 mmHg, two cases of failure, and seven cases with no follow-up (Fig. 1).

A second laser treatment was performed on three cases during the first week postoperatively. Two of these cases maintained normal IOP throughout the postoperative period, and remain visual. The third case maintained normal IOP for over 6 months postoperatively before representing with buphthalmos.

Inadequate control of IOP occurred in two of 24 eyes (8%) over the follow-up period. The timing of the IOP elevation was at 8 and 32 weeks postoperatively. Both these cases were Golden Retrievers. One of these failures was treated with the diode laser a second time within 1 week after initial treatment. The IOP then remained in the normal range for 32 weeks postoperatively before recurring. The second case had marked uveitis postoperatively, which persisted despite medical therapy. The IOP was well controlled (less than 20 mmHg) until 8 weeks postoperatively, when the IOP suddenly increased and caused enlargement of the globe. Both these cases were treated with intrascleral prosthesis.

Fourteen eyes were considered to be potentially sighted by a combination of history and ophthalmic examination. Of these eyes, seven regained useful visual function (50%) and remain visual up to the present time. Ten eyes were judged to be already blind and did not regain vision.

Cataracts were observed in six eyes (25%), which were all already judged to be blind before cyclophotocoagulation. The onset of cataract was from 4 weeks to 9 months postoperatively. When noticed in the early stages, the lens opacities were not limited to the equatorial lens, but instead appeared to involve the cortical region of the lens. The cataracts occurred bilaterally in two dogs treated bilaterally, and unilaterally in two dogs treated bilaterally. The breeds affected were one Bull Terrier (unilateral cataract), two Maltese (one developing unilateral cataract), and one Miniature Poodle. The bull terrier developed an early cataract in the left eye 1 month after laser surgery. One Maltese developed cataracts in both eyes 9 months after bilateral laser surgery. The other Maltese developed immature cataract in the left eye 5 months after surgery, having had a hypermature cataract in the right eye at first presentation. The Poodle had an immature cortical cataract in the right eye at first presentation that became mature 7 months after laser surgery to this eye. The left eye developed an immature cataract in the left lens 4 months after surgery.

Corneal ulceration occurred in three cases, and vascular keratitis in three cases. Thinning of the sclera at the laser contact sites was occasionally observed, but this was not clinically significant in any case. Most eyes exhibited black burns at the sites of TSCP, which were in many cases permanently visible as pinpoint black spots, and bore no clinical significance.

Superficial corneal ulceration or vascular keratitis was noted in six eyes during the early postoperative period. The ulceration resolved within 7 days when a temporary tarsorrhaphy was placed. The incidence of corneal disease reduced dramatically after inclusion of a split-thickness partial temporary tarsorrhaphy (TT) in the glaucoma treatment protocol. Of 11 cases that received no TT, there were five cases of corneal disease (5/11; 45%). Three of these cases developed corneal ulceration, and two cases developed marked vascular keratitis. Of 13 cases that received a TT, there was one case of mild keratitis (1/13 cases; 8%). No ocular lubricants were used in the postoperative period.

DISCUSSION

This study supports the findings of Cook *et al.* that diode laser cyclophotocoagulation is an effective treatment modality for canine glaucoma.[15] Our study demonstrates that the diode laser can be used at higher energy levels than previously reported to successfully treat primary glaucoma in dogs with few postoperative complications. The use of a lower power setting for a longer duration may reduce the complications of dyscoria, significant hyphema, and phthisis bulbi, but may result in a higher incidence of secondary cataract formation. Adequate control of IOP was achieved in 22 of 24 cases (92%) in this series. This study has also shown that a larger total dose of laser energy can be delivered to glaucomatous eyes without risking the potential for vision. Vision was retained or regained in 50% of the potentially sighted eyes assessed.

Control of IOP

The success rate in this study was defined as the percentage of cases with IOP less than 25 mmHg. Our success rate of 92% compares favorably to previously reported success rates of 65%.[15] Cook *et al.* defined success as the percentage of cases with IOP less than 30 mmHg over a 6-month period.[15] Other success rates reported include 83% (20/24) success over 3–6 month follow-up when using the Nd:YAG laser[17], and 85% success over 6 months follow-up when using cyclocryotherapy.[9]

The IOP increased in the first 24 h postoperatively in 14/24 cases (58%). Cook *et al.* also noted that the IOP would variably rise during this period, and medical treatment controlled this increase in most cases,[15] as was found in our study. In potentially visual eyes this pressure increase should be treated aggressively to maximize the chance for recovery of vision. The authors found that topical and/or systemic hypotensive agents appeared to control this initial increase in IOP in most cases, and would currently recommend topical dorzolamide.

The target IOP of less than 25 mmHg after treatment is perhaps not ideal, and the IOP should remain less than 20 mmHg or even less than 15 mmHg. In this series, the number of cases less than 15 mmHg follow-up at 6 months was 19/23 (83%) with no follow-up on one case. At 12 months 14/17 (82%) had IOP less than 15 mmHg, with one case having IOP greater than 15 mmHg, two cases of failure, and seven cases with no follow-up.

Preservation of vision

The ability to preserve vision when still present is perhaps the most significant advantage of the diode laser over cyclocryotherapy in treating canine primary glaucoma. Cyclocryotherapy is used infrequently in visual eyes because prolonged periods of elevated IOP may follow the procedure.[21] Of the 14 cases that were judged to be potentially visual, seven animals had already lost vision in the fellow eye, making functional assessment of vision easier.

Of the 14 potentially visual cases, vision was regained in seven cases (50%). This vision was maintained over 6 and 12 month follow-up, and beyond in some cases when longer follow-up data was available. These results are similar to the 37% (11/30 cases) 6-month and 53% (10/19 cases) 12-month retention of vision observed at following diode laser treatment for glaucoma in dogs.[15] Of the 45 eyes that tested positive with the menace test before laser therapy, only 10 (22%) were still evaluated as being visual at 12 months.[15,21]

Difficulty with control of IOP during the early first 24 h may have resulted in failure to recover vision in one of seven cases (IOP 36 mmHg at 24 h). It is likely that these seven potentially visual eyes that failed to regain vision had suffered irreversible damage to the optic nerve. It has been suggested that postoperative IOP elevations are a likely reason for loss of vision in potentially sighted eyes.[15] To maximize the potential for vision, intensive postoperative monitoring and aggressive medical lowering of the IOP or repeat paracentesis is required. This perhaps suggests a possible role for drainage devices, e.g. shunts/drains at the time of laser TSCP as an option to attempt to control these IOP spikes. In a study using combined cycloablation and gonioimplantation, 58% (11/19 cases) retained vision for more than 12 months postoperatively.[20] It is the authors' experience that laser sclerostomy is ineffective in preventing these spikes due to rapid sealing of the holes with fibrin.

If vision has already been lost because of the glaucoma, this study has shown that diode laser can be used to control the glaucoma and normalize the IOP. Once the IOP is controlled, the animals are usually no longer painful, and there is no globe enlargement. Diode laser treatment in this study resulted in the preservation of a cosmetically acceptable globe that was pain free and without the need for continued medications in 22/24 cases (92%). Once the globe is enlarged, diode laser can be used to control the elevated IOP, but will not control the complications that accompany buphthalmos. Furthermore, accompanying globe enlargement is thinning of the sclera, and this can result in sclerostomy and hypotony during laser TSCP, making the procedure difficult, and less likely to achieve favorable outcomes. In these cases intraocular prosthesis insertion or enucleation are recommended.

Energy levels delivered

Various energy levels have been reported in cyclophotocoagulation. Nasisse *et al.* treated normal eyes either 100 J or 228 J by non contact Nd:YAG laser. The higher energy level resulted in more consistent and sustained reductions in IOP during the 1 month study period.[18] In a later study, Nasisse *et al.* used 222 J for glaucomatous eyes and 250 J for normotensive eyes.[17] In this study 40 applications of between 5 and 18 J were performed. It was noted that in clinically normal eyes, 5 J had only a temporary effect on ciliary epithelial function[18] and it was postulated that the ciliary epithelium of glaucomatous eyes may be more susceptible to laser damage due to already compromised blood supply.[17] Sapienza *et al.* used contact Nd:YAG on normal dogs, in three separate energy groups (126, 154 and 212 J), and found that lower energy levels were associated with a decreased incidence of vision threatening side-effects, and the IOP was significantly reduced in all three groups.[19] Cook *et al.* used contact diode laser at 30–40 sites to deliver a total of 85 J per eye, thus 2–3 J per site.[15] Our study used contact diode laser delivering 125 J over 25 sites, thus 5 J per site.

Histopathologic observations on human eyes following Nd:YAG laser cyclophotocoagulation for glaucoma revealed that energy levels ranging from 4.4 to 5.6 J were effective in producing appropriate lesions.[22] Schuman *et al.* found the optimum energy for contact transscleral semiconductor diode laser cyclophotocoaulation in human cadaver eyes to be 3–4.5 J of energy per site, producing mild to moderate whitening of the ciliary processes.[23] Nadelstein *et al.* described the histopathologic effects of diode laser TSCP in the normal canine eye.[16] Lesions seen 28 days following delivery of 2.25 J per site for 35 sites included dissolution of the ciliary muscle, replacement with fibrous tissue, and complete atrophy of the ciliary processes that were in close proximity to the laser application site.

Degree of histopathologic injury is related to scleral transmission, a factor of duration, energy density and distance, and pigmentation.[15] Preferential absorption in melanin-containing tissues occurs, resulting in coagulation necrosis.[16] Laser cycloablation has been shown to be ineffective for inducing ciliary epithelial damage in eyes with nonpigmented uveal tissue.[17] Diode and Nd:YAG lasers produce cyclodestructive effects by their thermal effects on tissues causing coagulation necrosis. This occurs with less energy with the diode compared to the Nd:YAG.[16] This results in reduced collateral tissue effects and complications when the diode laser is used.[15]

As energy level increases, tissue temperature increases linearly. Histologically, this results in coagulation necrosis and epithelial cell destruction. The objective of effective laser treatment is to maximize the thermal effects while approaching the threshold of photodisruption.[15] This threshold is the point where an audible popping sound is heard, and a pop frequency of 20% is suggested.[15] This will depend on variation in pigmentation, and consistency with probe positioning and pressure.[16] This criteria was used to identify the threshold of photodisruption in the series reported by Cook *et al.* and in this series. The diode laser power was adjusted to ensure that these ‘pops’ were audible for at least 20% of the treatments. It is interesting to note that these ‘pops’ were heard frequently in this study and in the study by Cook *et al.* without regular adjustment of the power setting, suggesting adequate energy delivery to cause cyclophotocoagulation.[15] It may be noted that when a glaucoma laser treatment probe is not working effectively (for example due to fractures in the glass tip) these pops are not heard as regularly, suggesting lower than desired quantities of energy delivered. Another situation when reduced frequency of pops is encountered is when there is inaccurate positioning of the probe, suggesting incomplete delivery of energy to the target tissue.

All cases in this series were treated circumferentially, to attempt even distribution of laser energy and equivalent effects throughout the majority of the ciliary body. Treating eyes in quadrants has been suggested to cause less localized swelling of the trabecular meshwork and scleral venous plexus. Even though a spreading effect is seen histopathologically,[16] adjacent ciliary tissue may be spared when a quadrant treatment approach is used.[21]

Complications

Complication rates after diode laser TSCP appear to be much lower than for Nd:YAG TSCP[17] and cyclocryoablation.[8–11,24] After diode laser TSCP there is reduced inflammation compared to other cyclodestructive techniques. There is reduced anterior chamber flare, hyphema, and perilimbal hyperemia in most cases. Minimal conjunctival chemosis is seen following diode laser TSCP, which is in marked contrast to cyclocryotherapy, after which severe chemosis is commonly reported.[8–11,24] The lack of such swelling appears to be a major reason for better postoperative comfort with cyclophotoablation compared to cyclocryoablation.

Cook *et al.* report a low complication rate with diode laser TSCP. Complications in their study included corneal ulceration (5%), hyphema, dyscoria (over 30%), phthisis bulbi, and cataract formation (3%).[15] In comparison Nd:YAG cycloablation complications reported include cataracts (37%), hyphema (16%) (resolved without complication in all but two eyes), and phthisis bulbi in one eye (2%).[17]

Cataract formation
Complications in this series included cataracts (6/24 eyes, 25%). This protocol uses higher total laser energies delivered to the eye than has been previously reported. Cook *et al.* report cataracts in 6/176 (6%) cases over a 6–12 month follow-up.[15] In comparison contact Nd:YAG cycloablation utilizes much higher energy levels, and has been associated with a higher rate of cataract development: 37% in glaucomatous eyes and 75% in normal eyes.[19] It is possible that the higher laser energy delivered in this protocol accounted for the higher rate of cataract development. Theoretically, however, little primary absorption of laser energy of this wavelength should occur in the lens.[17] It is also possible that an increased level of uveitis occurred after diode laser TSCP using a higher energy protocol, and the uveitis resulted in cataract formation. Baseline production of aqueous humor is necessary for the maintenance of intraocular metabolism and nutrition.[25] Lens metabolism may be altered by the change in aqueous humor composition before or after TSCP. Cook *et al.* suggest that the lens opacities seen may be in part a sequela to the IOP elevation and/or its associated inflammation, rather than a direct laser effect.[15] This is also supported by the apparent lack of initial involvement of the equatorial cortex. However, this area of the lens would be difficult to examine accurately, as mydriasis is contra-indicated in these animals. Development of a cataract was not the cause for vision loss in any potentially visual eyes, as all eyes that developed cataracts were already blind.

Corneal ulceration
Corneal ulceration has been reported with low incidence (5%) in previous studies with diode laser TSCP.[15] In contrast, keratitis and corneal ulceration were seen with relatively high frequency early in our study. The corneal disease has been associated with lagophthalmia,[15] perhaps the result of reduced corneal sensitivity from transient damage to the trigeminal nerve as a result of increased intraocular pressure (causing denervation) or the position of the laser probe during treatment. The increased incidence of corneal disease in our study may be related to higher energy levels used; however, one would expect a high incidence of corneal ulceration with Nd:YAG cycloablation. It has been suggested (Greg Fava, Iris Medical, personal communication) that laser treatment in four quadrants can reduce the incidence of corneal disease; however, the likelihood of increased failure rate has been eluded to above with such a treatment protocol.

After the inclusion of a split-thickness partial temporary tarsorrhaphy (TT) in the protocol, the incidence of corneal disease dropped dramatically. The authors believe that there is a role for TT for 2–6 weeks after using this laser protocol. If the TT is placed laterally for example, 4–5 mm from the lateral canthus, measurement of IOP is still possible with ease. The TT was very well tolerated by the dogs in this series, and appears to be well tolerated by most animals. The use of ocular lubricants is an alternative to TT; however, a very high frequency of administration would be necessary.

Uveitis and hyphema
There was no significant hyphema or phthisis bulbi in this series. Mild hyphema occurred in 4/24 (17%) cases which cleared without complication 2–3 days postoperatively. Severe uveitis occurred in one case, which was one of two treatment failures in this series. In treatment there was no attempt to avoid the 3 o'clock and 9 o'clock positions to avoid coagulation of the long posterior ciliary arteries. No complications, such as phthisis bulbi, were observed in this study that could be related to damage to these arteries.

Aqueous flare is an anticipated postoperative result of all eyes treated with cyclophotoablation.[18] It is a result of blood–ocular barrier disruption due to the direct vascular effects of congestion and mural necrosis.[26] Cook *et al.* report the presence of aqueous flare in most cases.[15] Plasmoid aqueous humor is described by Nasisse *et al.*[17] This was seen during paracentesis on a few cases requiring repeat paracentesis in the initial postoperative period. The IOP was well controlled in such cases, following treatment with intracameral injection of tPA and intensive anti-inflammatory therapy.

CONCLUSION

This retrospective study has shown that larger quantities of diode laser energy than previously reported can be used to treat glaucoma in dogs with few postoperative complications. Adequate control of IOP was achieved in 92% of cases in this study, and 50% per cent of potentially sighted eyes regained vision, which is similar to previously reported results. It is possible that this protocol may result in a higher incidence of secondary cataracts. Placement of a temporary tarsorrhaphy following diode laser TSCP is well tolerated, and minimizes the risk of corneal disease when increased energy levels are used.

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