

“Cyclodiode”: results of a standard protocol

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Abstract

Aims—To analyse the results of intraocular pressure (IOP) reduction in refractory glaucoma following diode laser cyclophotocoagulation with a repeatable standard protocol.

Methods—58 eyes of 53 patients were followed for 6–37 months (mean 19 months) after initial cyclodiode treatment.

Results—Mean (SD) pretreatment IOP for the 58 eyes was 33.0 mm Hg (10.7) reducing at final index visit to 16.7 mm Hg (7.8) ($p < 0.0001$). The mean antiglaucoma medication score per eye was significantly reduced from 2.4 (0.8) to 1.4 (1.0) at last index visit ($p < 0.0001$) with 91% of patients able to stop oral acetazolamide. 45% of eyes required more than one treatment and the overall mean per eye was 1.6 (range 1–5). Of eyes with visual acuity 6/60 or better pretreatment, 12 (32%) lost more than two lines of Snellen acuity and two eyes with poorer acuity initially dropped to NPL. Poor visual outcome was associated with the presence of diabetic retinopathy. Hypotony (IOP < 5 mm Hg) was noted in two eyes at the last index visit although neither had specific signs of the same. No phthisis was seen.

Conclusion—The simple treatment protocol, repeated if necessary, appears relatively safe and effective at lowering IOP in eyes with refractory glaucoma.

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Ciliary body ablation has been used effectively in the treatment of refractory glaucoma for many years. A number of methods have been described including cyclocryotherapy and laser photocoagulation using energy of different wavelengths.^{1–6} Until recently, most experience of cyclophotocoagulation has been with the neodymium:YAG (Nd:YAG) laser utilising either contact or non-contact methods.^{4–7–10}

The advent of the 810 nm semiconductor diode laser appears to offer a better method of cycloablation with potentially fewer complications as there is better absorption of this wavelength by the pigmented tissues of the ciliary body than the 1064 nm Nd:YAG laser.^{11–12} Initial reports suggest a lower incidence of the complications seen with other cyclodestructive techniques—namely, phthisis, hypotony, uveitis, pain, and loss of visual acuity.^{13–15} These advantages, combined with the compact and portable nature of the diode, make it an attractive treatment modality. To date, published studies have either not used a standard protocol throughout or have not addressed the

results of repeated treatments should the first treatment fail to lower intraocular pressure (IOP) effectively.^{15–18} We therefore report the results of the diode laser for cyclophotocoagulation (“cyclodiode”) for all eyes treated in our unit using a standard protocol.

Methods

All eyes treated between April 1994 and May 1997 (and therefore with a minimum follow up of 6 months) were entered into the study. Cyclophotocoagulation (“cyclodiode”) was performed using the Oculight Sx semiconductor diode 810 nm laser (Iris Medical Instruments) and the contact G-probe (Iris Medical Instruments).

Patients received cyclodiode treatment because either (a) they had medically uncontrollable glaucoma and had had previous failed filtering surgery and/or were unlikely to respond to or declined filtering surgery, or (b) we were attempting to discontinue medications to which they were intolerant, usually systemic carbonic anhydrase inhibitors (all but one of the patients were taking these before cyclodiode). All patients had given informed consent for cyclodiode treatment.

Each treatment session was performed either under local anaesthesia, using a peribulbar or retrobulbar injection, or under general anaesthesia at the patient’s request (including the only “child” treated). The laser energy was delivered through a 600 μ m diameter quartz fibre oriented within the G-probe handpiece to centre treatment 1.2 mm behind the limbus. Transillumination was used to identify the ciliary body position in eyes with congenital glaucoma or where the limbal anatomy was distorted by previous surgery. The fibreoptic tip protrudes 0.7 mm from the G-probe contact surface in order to indent the conjunctiva and sclera thereby improving the laser transmission to the ciliary body. Care was taken to apply the G-probe to the limbus indenting as above as this ensured that the G-probe surface contour matched the scleral curvature and the posterior angulation was correctly oriented to protect the lens of phakic eyes from laser damage. Each laser application was spaced by half the width of the G-probe surface, easily guided by the visible indentations of the previous application and ensuring an equal separation of about 2 mm.

A standard treatment protocol was used at each “session” to treat three quarters of the circumference of the ciliary body. This usually resulted in 14 applications (four eyes had 13 applications and one eye 12 applications), in order not to treat more than 270 degrees. An energy of 2.0 W was used for 2.0 seconds, resulting in a power delivery of 4.0 J per appli-

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Table 1 The diagnostic groups of glaucomatous eyes which had cyclodiode

	POAG	Aphakic	Pseudo phakic	Uveitis	Corneal/PK	Rubeotic	Silicone oil	Trauma	CCAG	All eyes
No of patients	10	11	5	9	7	6	4	5	1	58
Percentage of total	17.3	19	8.6	15.5	12.1	10.3	6.9	8.6	1.7	100
Mean IOP pretreatment	29.9	28.1	26.2	31.2	44.0	35.8	31.2	32.8	50.0	33.0
SD of IOP pretreatment	6.7	8.4	8.2	7.1	7.8	12.4	6.3	11.2	—	10.7
Mean IOP last index visit	20.0	17.8	12.8	18.8	16.0	12.3	11.2	14.2	42.0	16.9
SD of IOP last index visit	10.1	4.8	7.2	6.9	7.6	3.4	4.3	7.8	—	7.8
Percentage IOP reduction	33.1	36.7	51.1	39.7	63.6	65.6	64.1	56.7	16	48.8
Mean No treatment sessions	1.5	2.0	1.6	1.2	1.7	1.7	1.7	1.4	3.0	1.6
Mean follow up (months)	20.3	21.2	20.0	19.1	17.7	16.8	12.8	21.4	10	18.7

POAG = primary open angle glaucoma, CCAG = chronic closed angle glaucoma, IOP = intraocular pressure, SD = standard deviation.

cation (56 J per session for 14 applications). This was not altered even if “pops” were heard during treatment. In the first treatment session the temporal 90 degrees was left untreated. A different 90 degrees was left untreated if further treatment sessions proved necessary. On subsequent treatments the 90 degrees untreated varied depending on the appearance of the sclera and conjunctiva at the limbus—that is, if an area of scleromalacia from previous surgery was present this area could be avoided. If one eye underwent more than two treatments, a different 90 degrees was left untreated on each subsequent occasion.

Oral acetazolamide, if prescribed before laser treatment, was continued for a period of 1 week after laser treatment. Topical antiglaucoma medications were discontinued if the IOP was <22 mm Hg on day 1 post-laser treatment. At 1 week post-laser treatment oral acetazolamide was discontinued if the IOP was <22 mm Hg, with reintroduction of topical IOP lowering medications at the discretion of the clinician. Topical steroids, usually dexamethasone 0.1% eye drops, were prescribed four times a day for 2–4 weeks after treatment. At further follow up, topical IOP lowering medications were reintroduced if IOP control required this. If an adequate response was not achieved, cyclodiode was repeated up to a maximum of five treatment sessions. IOP assessment was made using the Goldmann applantation tonometer in most cases with occasional use of the Tonopen where the corneal condition dictated.

Age, sex, diagnosis, length of follow up, IOP pretreatment, and post-treatment at 6, 12, 18, 24, 30, and 36 months, and at the last index visit was noted. Visual acuity, topical and oral medications pretreatment and at last index visit were noted as were the number of laser treatment sessions performed.

Treatment was defined as a success with respect to (a) IOP <22 mm Hg; (b) IOP <17 mm Hg; and (c) for a drop in IOP of greater than 30% (as used by Bloom *et al*¹⁸), despite the use of topical and/or oral medications. A further definition of success was used to identify the number of patients not requiring oral acetazolamide post-treatment as this is a practical consideration for many ophthalmologists using this treatment modality.

Statistical analysis was performed using a two tailed paired Student's *t* test where data approximated to normal distribution, and the Mann-Whitney U test when it did not.

Results

Fifty nine eyes of 54 patients were treated in the study period. Six month results are available for 58 eyes of 53 patients as one eye was eviscerated for bacterial endophthalmitis within 1 month. This rubeotic eye with bullous keratopathy had an IOP of 44 mm Hg before treatment, no reduction in IOP after treatment, and subsequently developed bacterial keratitis and endophthalmitis. The vision fell from bare hand movements to no perception of light, so the eye was eviscerated. Two eyes had further IOP lowering surgery for failure of a single cyclodiode treatment after 2–3 months. These eyes had been thought more likely to respond to the diode laser, before treatment, than to an enhanced trabeculectomy. As IOP was not controlled after cyclodiode, enhanced drainage surgery was performed at 2–3 months. In one of the two eyes, cataract surgery had been planned so a combined enhanced phacotrabeculectomy and intraocular lens implant was performed. These eyes were treated early on in our experience with the cyclodiode and had they occurred later in the series, they may have had further cyclodiode treatments in preference to filtration surgery.

Only one eye in the series had undergone previous cyclodestructive surgery—that is, cyclocryotherapy.

The mean (SD) number of applications per treatment session was 13.9 (0.36) and the total amount of energy delivered per treatment

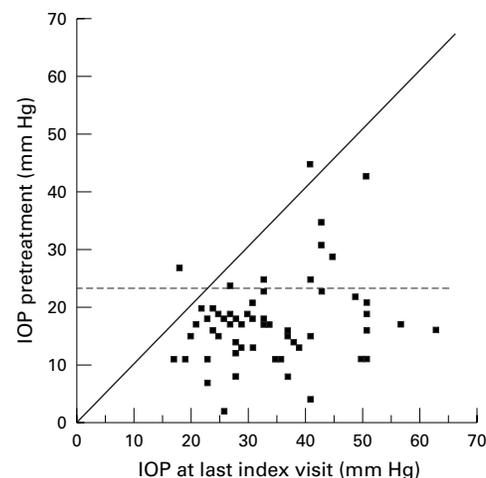


Figure 1 Pretreatment IOP is plotted against IOP at last index visit (mm Hg). The oblique line is the line of equivalence. The horizontal broken line is at 22 mm Hg.

Table 3 The 12 patients with visual acuity (VA) of at least 6/60 whose acuity fell more than one Snellen line on follow up

Pre-treatment VA	VA at last index visit	Diagnosis	Cause of visual loss
6/5	6/9	Pseudophakia	Mild ARMD
6/9	6/18	Uveitis (sympathetic)	Corneal oedema
6/9	6/36	Aphakia	Cystoid macular oedema
6/9	2/60	POAG	Glaucoma progression
6/9	2/60	POAG (in diabetic patient)	Ischaemic maculopathy (diabetic)
6/18	6/60	POAG	ARMD
6/18	1/60	Cornea (penetrating keratoplasty)	Corneal oedema
6/18	1/60	Rubeotic (diabetic)	Ischaemic maculopathy (diabetic)
6/24	6/60	Pseudophakia	Glaucoma progression
6/24	6/60	Pseudophakia (in diabetic patient)	Maculopathy (diabetic)
6/36	CF	Pseudophakia (in diabetic patient)	Diabetic traction detachment
6/36	PL	Cornea	Microbial keratitis

POAG = primary open angle glaucoma, ARMD = age related macular degeneration.

were used at the last index visit in 35 eyes, dorzolamide in 15 eyes, pilocarpine in nine eyes, latanoprost in six eyes, and brimonidine in two eyes.

Changes in visual acuity are demonstrated in Figure 2. Visual acuity before treatment was 6/60 or better in 37 out of 58 eyes (64%). Considering these 37 eyes, acuity fell more than one Snellen line in 12 eyes (32%), improved by more than one line in one eye (3%), and stayed within one line of initial acuity in 24 eyes (65%). The causes of visual loss and diagnostic category are listed in Table 3.

For the eyes with an initial acuity of less than 6/60, we defined one grade of acuity to be the difference between 6/60 and counting fingers (CF), between CF and hand movements (HM), between HM and perception of light (PL), and between PL and NPL. The visual acuity grade fell in three eyes by one grade and in two eyes by two grades (24%). In two eyes (9%) acuity improved; one improved one grade and the other two grades. The same acuity grade was retained in the remaining 14 eyes (67%). Two eyes had no perception of light at the last index visit; one eye was rubeotic following a central retinal vein occlusion, with PL vision pretreatment, and the other eye had chronic angle closure glaucoma with pretreatment acuity of HM (that is, a drop of two grades of acuity). The other eye that dropped by two acuity grades was also a rubeotic eye after a central retinal vein occlusion. Both of the rubeotic eyes had had their IOP controlled by the cyclodiode, after two and one treatments respectively. The eye with chronic angle closure failed to respond after three treatments.

No phthisis was observed throughout the study although two eyes had chronic hypotony as defined by an IOP of <5 mm Hg for over 3 months. However, neither eye showed any clinical signs associated with hypotony (namely, choroidal folds, choroidal detachments, optic disc oedema) and both eyes retained their pretreatment acuity—one eye that had glaucoma secondary to trauma retaining an acuity of 6/6 and one eye with glaucoma secondary to penetrating keratoplasty retaining HM.

Discussion

Diode laser photocoagulation is developing an acceptable track record for the treatment of

complicated secondary glaucomas and primary open angle glaucoma refractory to treatment.¹³⁻¹⁸ The treatment is associated with only minor degrees of pain and inflammation in most eyes and, although not formally recorded in our study, our experience parallels that of other authors.¹⁵⁻¹⁸ The primary aim of therapy in these difficult eyes is to lower IOP to a level considered satisfactory for the eye in question while preserving visual function at pretreatment levels. For many patients discontinuation of oral acetazolamide is an important consideration and if IOP can be controlled on topical medications, this is acceptable.

In eyes with limited outflow facility, reducing aqueous production to a level that produces a “normal” IOP on no medication runs the risk of hypotony or phthisis. This has been well recognised in ciliary body ablation with cyclocryotherapy¹⁹ or Nd:YAG laser therapy.^{9, 20} We therefore chose a standard protocol, using information available at the commencement of the study, which we considered unlikely to result in phthisis after a single treatment in eyes that had not undergone previous cycloablative procedures. An internal audit of the results of the first 30 eyes with at least 6 months’ follow up provided encouraging data and resulted in a continuance of the protocol.

Direct comparisons are always difficult between studies with complex patients in view of referral practice, population demographics, and inclusion/exclusion criteria. As background information to our study, it is relevant that the glaucoma firm did not perform any seton procedures during the study period; all patients formerly considered for this treatment underwent cyclodiode. This may have resulted in a larger population of eyes with relatively good acuity being treated in comparison with other studies.¹⁵⁻¹⁸

The literature to date is difficult to interpret concerning the optimal treatment settings and number of applications per session for an eye with uncontrolled refractory glaucoma when utilising the Iris diode laser with the G-probe. Kosoko *et al*¹⁶ delivered between 17 and 19 applications to 270 degrees of the ciliary body for a 2.0 second period and commencing at 1.75 W increasing to 2.0 W if no “pops” or “snaps” were heard. However, their protocol allowed for a further reduction in energy delivered by reducing the power setting if consecutive “pops” were heard. This resulted in a mean energy delivery of 63.3 J (7.2) over 17.6 applications per session compared with our mean of 55.5 J (about 12% less). The theory behind reducing the energy so as not to hear “pops” at each application is that these are indicative of tissue disruption, and that a response of this nature to each application might induce more destruction in the ciliary body than desired and also result in more inflammation. It was not our experience that “pops” were heard continually with a consistent energy level, nor did we have any eyes with marked inflammation post-laser. We did not find a particular association between race and hearing “pops”. No eyes in Kosoko and others’ multicentre study¹⁶

of 27 eyes had had a previous cyclodestructive procedure and only two eyes had repeat treatment (after 9 and 13 months). About 60% of eyes were controlled (IOP <22 mm Hg) which is less than the figure of 81% from our study. The difference is likely to be due to the fact that the cyclodiode was not repeated in most of their study eyes, perhaps to avoid the risk of phthisis or hypotony. Follow up was nearly identical to ours but the mean number of glaucoma medications at the last index visit was greater than in our study (2.1 versus 1.4) and no mention was made of the use of systemic carbonic anhydrase inhibitors.

Bloom *et al*¹⁸ allowed more than one treatment session but 18% of their eyes had had cyclodestructive procedures before cyclodiode and the mean follow up was only 10 months. In addition, the treatment protocol varied considerably between eyes, from 20 to 40 applications of 1.5 W and 1.5 seconds "titrated against risk of phthisis". The mean energy delivered is not stated and therefore their results may be difficult to reproduce in another setting. In Bloom and others' series systemic carbonic anhydrase inhibitors were "spared" in 93% of cases which is similar to the 90% in our series despite our longer mean follow up. The mean number of treatment sessions was 1.75 in Bloom and others' study which is similar to our 1.6, suggesting that by 1 year after the first treatment most patients will have been stabilised.

Brancato *et al*¹⁷ and Bock *et al*²¹ had a higher retreatment rate of 65% and 70% respectively than our 45%. This is probably due to patient group differences as Bock *et al* treated refractory paediatric glaucoma eyes and 10/48 patients in Brancato's series had "paediatric glaucoma". Although the numbers in each diagnostic category in our study are small, it appears that with our protocol, all of our groups respond well to the treatment (with the possible exception of the lone chronic angle closure eye). The rubeotic eyes, those with silicone oil glaucoma, those with glaucoma related to corneal disease (including post-keratoplasty glaucoma), and those with chronic post-traumatic glaucoma had the greatest percentage drop in IOP (56.7% to 65.6%). These groups, however, had the highest pretreatment IOPs and therefore would have required a larger drop to achieve the target pressure. It is interesting that the eyes with uveitis had an initial IOP similar to the aphakic eyes but required fewer treatment sessions (mean 1.2 compared with 2.0) to achieve a similar target pressure. Owing to the relatively small numbers of eyes, these figures just failed to reach significance but it suggests that these patients may be particularly sensitive to our cyclodiode protocol.

The results of this study indicate that with our protocol it is not necessary to change power/time settings as neither excessive uveitis or hypotony/phthisis is common. Our IOP results can be expected to be repeatable in a similar cohort of eyes provided our simple protocol is followed. We did not exclude uveitic eyes (compare Kosoko *et al*¹⁶) or eyes with

good acuity, or vary our treatment significantly from one eye to another, preferring to consider cyclodiode as a course of treatment in which multiple sessions were acceptable.

In view of this we consider Kaplan–Meier survival curves inappropriate for assessing the results of IOP control. Analysis is inevitably a "snapshot in time" with eyes at various stages in their "course". This is substantiated by the status of our eyes with IOP >22 mm Hg at the last index visit. The above does not, of course, apply to visual function as the results of our eyes with relatively good acuity (64%) provide useful data for counselling patients before this therapy (Fig 2), particularly when the causes of significant decrease in acuity are taken into account (Table 3). These results indicate that in the absence of diabetic retinopathy, the visual prognosis for most eyes with good acuity is acceptable over the course of the first 18 months of treatment. In particular, the incidence of cystoid macular oedema appears low with our protocol, even with repeated treatments. Visual loss was common when treatments were repeated in Bloom's series with 50% of those having three or more treatments losing vision. This may be related to each full treatment being a total of 90 J compared with 56 J in our protocol.

To date no study has compared cyclodiode with seton tube surgery. However, our "success" rate of 81% <21 mm Hg at a mean follow up of 19 months for cyclodiode compares favourably with 87% at a mean of 8 months in Nouredin and others' study²² for seton surgery, particularly as no seton procedures were performed by the glaucoma firm during the period of review. Cyclodiode has therefore rapidly become the treatment of preference in our unit for refractory glaucomas.

- 1 Bietti G. Surgical interventions on the ciliary body. New trends for the relief of glaucoma. *JAMA* 1950;142:889–97.
- 2 Weekers R, Lavergne G, Watillon M, *et al*. Effects of photocoagulation of ciliary body upon ocular tension. *Am J Ophthalmol* 1961;52:156–63.
- 3 Beckman H, Kinoshita A, Rota AN, *et al*. Transscleral ruby laser irradiation of the ciliary body in the treatment of intractable glaucoma. *Trans Am Acad Ophthalmol Otolaryngol* 1972;74:423–36.
- 4 Beckman H, Sugar HS. Neodymium laser cyclophotocoagulation. *Arch Ophthalmol* 1973;90:27–8.
- 5 Lee PF. Argon laser photocoagulation of the ciliary processes in cases of aphakic glaucoma. *Arch Ophthalmol* 1979;97:2135–8.
- 6 Finger PT, Smith PD, Paglione RW, *et al*. Transscleral microwave cyclodestruction. *Invest Ophthalmol Vis Sci* 1990;31:2151–5.
- 7 Fankhauser F, Van der Zypen E, Kwasniewska S, *et al*. Transscleral cyclophotocoagulation using a neodymium YAG laser. *Ophthalmic Surg* 1986;17:94–100.
- 8 Hampton C, Shields MB, Miller KN, *et al*. Evaluation of a protocol for trans-scleral neodymium:YAG cyclophotocoagulation in one hundred patients. *Ophthalmology* 1990;97:910–17.
- 9 Schuman JS, Bellows AR, Shingleton BJ, *et al*. Contact transscleral Nd:YAG laser cyclophotocoagulation. Mid-term results. *Ophthalmology* 1992;99:1089–95.
- 10 Dickens CJ, Nguyen N, Mora JS, *et al*. Long-term results of noncontact transscleral neodymium:YAG cyclophotocoagulation. *Ophthalmology* 1995;102:1777–81.
- 11 Assia EI, Hennis HL, Stewart WC, *et al*. A comparison of neodymium:yttrium aluminium garnet and diode laser trans-scleral cyclophotocoagulation and cyclocryotherapy. *Invest Ophthalmol Vis Sci* 1991;32:2774–8.
- 12 Brancato R, Leoni G, Trabucchi G, *et al*. Histopathology of continuous wave neodymium:yttrium aluminium garnet and diode laser contact laser trans-scleral lesions in rabbit ciliary body. A comparative study. *Invest Ophthalmol Vis Sci* 1991;32:1586–92.
- 13 Hennis HL, Stewart WC. Semiconductor diode laser trans-scleral cyclophotocoagulation in patients with glaucoma. *Am J Ophthalmol* 1992;113:81–5.

- 14 Hawkins TA, Stewart WC. One year results of semiconductor transscleral cyclophotocoagulation in patients with glaucoma. *Arch Ophthalmol* 1993;111:488-91.
- 15 Gaasterland DE, Pollack IP. Initial experience with a new method of transscleral cyclophotocoagulation for ciliary ablation in severe glaucoma. *Trans Am Ophthalmol Soc* 1992;90:225-46.
- 16 Kosoko O, Gaasterland DE, Pollack IP, et al. The Diode Laser Ciliary Ablation Study Group. Long-term outcome of initial ciliary ablation with contact diode laser transscleral cyclophotocoagulation for severe glaucoma. *Ophthalmology* 1996;103:1294-302.
- 17 Brancato R, Carassa RG, Bettin P, et al. Contact transscleral cyclophotocoagulation with diode laser in refractory glaucoma. *Eur J Ophthalmol* 1995;5:32-9.
- 18 Bloom PA, Tsai JC, Sharma K, et al. Cyclodiode: trans-scleral diode laser cyclophotocoagulation in the treatment of advanced refractory glaucoma. *Ophthalmology* 1997;104:1508-19.
- 19 Benson MT, Nelson ME. Cyclocryotherapy: a review of cases over a ten year period. *Br J Ophthalmol* 1990;74:103-5.
- 20 Al-Ghamdi S, Al-Obeidan S, Tomey KF, et al. Transscleral neodymium:YAG laser cyclophotocoagulation for end-stage glaucoma, refractory glaucoma and painful blind eyes. *Ophthalmic Surg* 1993;24:526-9.
- 21 Bock CJ, Freedman SF, Buckley EG, et al. Transscleral diode laser cyclophotocoagulation for refractory pediatric glaucomas. *J Pediatr Ophthalmol Strabismus* 1997;34:235-9.
- 22 Nouredin BN, Wilson-Holt N, Lavin M, et al. Advanced uncontrolled glaucoma. Nd:YAG cyclophotocoagulation or tube surgery. *Ophthalmology* 1992;99:430-6.