

PERSPECTIVE

Endoscopic cyclophotocoagulation

S Lin

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Glaucoma surgery can be classified as either cyclodestructive (reducing inflow) or filtering (increasing outflow). Filtration has traditionally been the procedure of first resort because of its efficacy and relative predictability, whereas ciliary destruction has been reserved for more refractory cases of glaucoma and in eyes which have little or no visual potential. Refractory glaucomas include neovascular glaucoma, post-traumatic glaucoma, glaucoma associated with aphakia, severe congenital/developmental glaucoma, post-retinal surgery glaucoma, glaucoma associated with penetrating keratoplasties, and glaucoma in eyes with scarred conjunctiva from surgery or disease processes.

In the past, cyclodestruction has been carried out by various methods including surgical excision,^{1,2} diathermy,^{3–6} cryotherapy,^{7–11} and laser.^{12–25} Laser cyclophotocoagulation has now become the principal method for “turning down the tap.” Beckman and Sugar popularised the use of trans-scleral cyclophotocoagulation (TCP) in the early 1970s.^{12,13} Initially, they used the ruby laser¹² but soon discovered that the neodymium:yttrium-aluminium-garnet (Nd:YAG) laser was more effective in penetrating the sclera and optimising energy absorption by the ciliary epithelium.¹³ The delivery of laser energy through the sclera may be performed by either the non-contact or contact method. (Transpupillary cyclophotocoagulation with the argon laser has also been utilised; however, it is only applicable in certain aphakic eyes.) In the non-contact approach, a slit lamp is employed to apply laser energy through the conjunctival/scleral surface.^{12–19} A contact lens may be used to keep the eyelids open and blanch the conjunctiva. The focus of energy delivery is 1–1.5 mm behind the limbus and is offset from the aiming beam so that maximal therapeutic effect is at the level of the ciliary body. The total number of laser applications is usually about 32 (eight per quadrant), avoiding the 3 and 9 o’clock positions in order to preserve the long posterior ciliary arteries.

More recently, contact cyclophotocoagulation has gained favour as a preferred method for treating refractory cases of glaucoma.^{20–22} Using the Nd:YAG laser (Surgical Laser Technologies (SLT), Inc, Malvern, PA, USA), a hand held sapphire tipped probe is placed on the conjunctiva and sclera, centred 1–2 mm behind the limbus, for the transmission of laser energy. Sixteen to 28 spots are applied, also avoiding the 3 and 9 o’clock positions. Energy levels are titrated to avoid an

audible “pop” which indicates overtreatment and explosion of the ciliary body tissue.

The development of compact, portable diode lasers for ophthalmic use has made it more convenient to perform contact TCP.^{23–25} The semiconductor diode laser (Iris Oculight SLx, Iris Medical Inc, Mountain View, CA, USA) emits at 810 nm wavelength and is better absorbed by melanin than the Nd:YAG, although scleral transmission is reduced at this wavelength.^{23–25} The flat tip of the hand piece (known as the “G-Probe”) protrudes 0.7 mm deeper than the contact surface, indenting the conjunctiva and sclera to allow better laser penetration. Principles of treatment are similar to the Nd:YAG laser.

Both contact and non-contact TCP have been shown to be effective surgeries for treating end stage and/or severe glaucoma in which other surgeries have failed or potential vision is very limited.^{12–25} Although definitions of success vary among reports, success rates for intraocular pressure (IOP) control have been between 34% and 81%, with mean follow ups of up to 30 months.^{12–25} Even though TCP has been used effectively for managing refractory and severe glaucoma, it is a procedure that has a significant incidence of complications^{12–29} and postoperative discomfort, and should be reserved for eyes with very limited visual potential.

A new method to directly photocoagulate the ciliary body under endoscopic guidance—known as endoscopic cyclophotocoagulation (ECP)—has become an increasingly important weapon in the glaucoma surgeon’s armamentarium for the treatment of refractory glaucomas^{30–34} and may have distinct advantages over the trans-scleral approach in eyes with visual potential. Furthermore, ECP may have advantages in the management of glaucoma associated with penetrating keratoplasty.^{32,35}

DESCRIPTION OF DEVICE

The laser unit for ECP (Endo Optiks, Little Silver, NJ, USA) incorporates a diode laser that emits pulsed continuous wave energy at 810 nm, a 175 W xenon light source, a helium-neon laser aiming beam, and video camera imaging which can be recorded (Fig 1). All four elements are transmitted via fibreoptics to a 18 or 20 gauge probe that is inserted intraocularly. The optimum focus for the laser is 0.75 mm from the probe tip, and the endoscope provides a 70 degree field of view. The main unit is compact and portable, with a maximum power output of 1.2 W. Controls for laser power and duration (up to 9.99 seconds) are adjustable on the console. The foot pedal controls laser firing with the actual duration of each treatment determined by how long the pedal is depressed.

Correspondence to:
S Lin, Department of
Ophthalmology, UCSF, 10
Kirkham Street, San
Francisco, CA 94143,
USA; shanl@itsa.ucsf.edu

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Figure 1 Endoscopic cyclophotocoagulation laser unit. The laser console is compact and the high resolution monitor is used to guide the laser probe for direct, selective treatment of ciliary processes.

METHODS FOR ECP

The results of ECP surgery in refractory glaucoma cases at UCSF have shown that treatment of at least 180 degrees of ciliary processes is required to achieve significant reductions in IOP.³² We prefer to treat close to 360 degrees in order to more likely achieve target IOPs in adults.³² In the paediatric population, IOP response to cyclophotocoagulation may be less predictable.^{32,34} Treatment is usually between 180 and 270 degrees at the first surgery and additional clock hours if it is later required. There have been no cases of persistent hypotony or choroidals in our group of patients using these parameters.

The two main approaches to reach the ciliary processes are via a limbal or a pars plana entry. The limbal approach is preferred because anterior vitrectomy and associated risks for choroidal and retinal detachment are avoided. However, there are some cases which are more safely treated through the pars plana—for example, in aphakic eyes with posterior synechiae limiting access to the ciliary sulcus.

In the limbal approach, after dilatation of the pupil with cyclopentolate 1% and phenylephrine 2.5%, a paracentesis is created and the anterior chamber is filled with viscoelastic agent which is further used to expand the nasal posterior sulcus. This viscoelastic expansion of the posterior chamber allows for easier approach to the pars plicata with the ECP probe. A 2.2 mm keratome is then used to enter into the anterior chamber at the temporal limbus. After orientation of the probe image outside of the eye, the 20 gauge probe is inserted through the incision and into the posterior sulcus. At this time, the ciliary processes are viewed on the monitor and treatment can begin. The laser is set at continuous wave and energy settings are 60–90 mW. Approximately 180 degree span of ciliary processes is photocoagulated. Laser energy is applied to each process until shrinkage and whitening occur (Fig 2). Only the raised processes are treated, without affecting the “valleys” between processes. If excessive energy is used, the process explodes (or “pops”) with bubble formation, leading to excessive inflammation and breakdown of the blood-aqueous barrier. After the nasal 180 degrees of ciliary processes are treated, a separate incision is created at the nasal limbus in a similar fashion as above. The temporal processes are then photocoagulated for a total of 360 degrees, if so

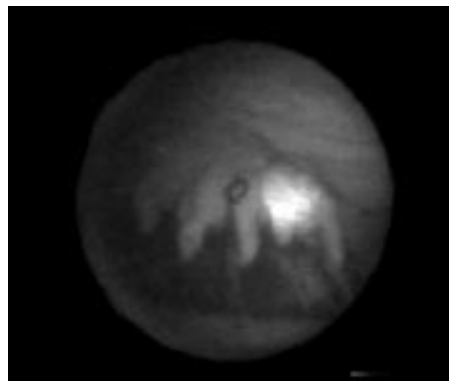


Figure 2 Endoscopic view of ciliary processes in a patient with refractory glaucoma. The white ciliary process has been treated and shows evidence of shrinkage.

desired. Before closure of the wounds, viscoelastic is flushed out using balanced salt solution irrigation of the anterior chamber.

In the pars plana approach, an infusion port is inserted through the inferior pars plana and two superior entries are created for vitrectomy and illumination. Only a limited anterior vitrectomy is performed to allow adequate and safe access to all of the ciliary processes. The ECP probe is inserted through each superior entry for treatment of the opposite 180 degrees of processes. There may be a few superior processes that cannot be accessed since the entry ports are not exactly 180 degrees opposite each other. Laser cyclophotocoagulation is carried out with the same parameters and end points as described for the limbal approach.

If the anterior segment surgeon has not had extensive experience in posterior segment surgery, assistance from a retinal surgeon should be sought for the establishment of the pars plana entry ports and the limited anterior vitrectomy. Risk of inadvertent choroidal and/or retinal detachment is a serious concern and should be minimised.

In all patients, whether under local or general anaesthesia, retrobulbar bupivacaine is administered before or at the end of surgery to minimise postoperative pain. Sub-Tenon’s injection of 1 ml of triamcinolone (40 mg/ml) is also given for inflammation. On postoperative day 1, patients are placed on a regimen of topical antibiotics, steroids, non-steroidal anti-inflammatory agents (NSAIDs), cycloplegics, and their preoperative glaucoma medications except for miotics and prostaglandin analogues since these may exacerbate intraocular inflammation or its sequelae. Antibiotics are discontinued after 1 week, and the steroids, NSAIDs, and cycloplegics are tapered as inflammation subsides. Glaucoma medications are removed according to the IOP requirements. Administration of acetazolamide during the evening of surgery may be used to prevent a spike in IOP from underlying glaucoma, inflammation, or possible retained viscoelastic.

CLINICAL STUDIES ON ECP

The largest series on ECP was reported by our group at UCSF and included 68 eyes from 68 patients with refractory glaucoma of various diagnoses including primary open angle (16), congenital (12), chronic angle closure (11), aphakic/pseudophakic (10), uveitic (10), pseudoexfoliation/pigmentary (five), neovascular (two), and traumatic (two) (Table 1).³² Fifty two patients were white, 14 were African-American, and two were Asian-American. With the exception of those undergoing combined cataract extraction and ECP, all of these patients had failed maximal medical therapy and most had undergone one or more previous glaucoma surgeries. Affected eyes were judged to be poor candidates for filtering surgery, either because of the underlying diagnosis

Table 1 Intraocular pressure response to endoscopic photocoagulation treatment as a function of underlying glaucoma diagnosis

Glaucoma	Mean intraocular pressure (mm Hg)		
	Preoperative	Postoperative	p Value
Primary open angle (n=16)	21.3	15.6	0.0001
Congenital (n=12)	30.1	20.3	<0.0001
Chronic angle closure (n=11)	34.4	18.6	0.006
Aphakic/pseudophakic (n=10)	24.7	16.2	0.004
Uveitic (n=10)	24.7	15.2	0.001
Pseudoexfoliation/pigmentary (n=5)	29.2	15.2	0.058
Neovascular (n=2)	47	22	0.459
Traumatic (n=2)	26.5	13	0.286
Total (n=68)	27.7	17.0	<0.0001

(uveitis, neovascular glaucoma) or previous glaucoma surgery. Eyes received between 180–360 degrees of ciliary body treatment. The majority (56 eyes, 12 had concurrent cataract extraction) were treated through the limbal approach, while the others (12 eyes) were treated via pars plana incision; 7% had retreatment. The mean follow up period was 12.9 (SD 5.1) months and the mean preoperative IOP was 27.7 (10.3) mm Hg. The mean IOP at last follow up was 17.0 (6.7) mm Hg, yielding a mean reduction of 10.7 mm Hg (34% mean reduction). Table 1 provides the preoperative and postoperative IOPs among the various subgroups. Glaucoma medication was reduced from an average of 3.0 (1.3) preoperatively to 2.0 (1.3) postoperatively. Success in controlling IOP <22 was 90% at last follow up. Using Kaplan-Meier life table analysis, the cumulative success at 1 year is 94% and 2 years is 82%.

Although the results of ECP appear favourable, potential complications are not insignificant. Postoperative complications encountered in our study are as follows: fibrin exudate in 24%, hyphaema in 12%, cystoid macular oedema (CMO) in 10%, vision loss of two lines or more in 6%, and choroidal detachment in 4%. In all but one patient, the cases of fibrin exudate and hyphaema cleared spontaneously. The single patient who required intracameral injection of tissue plasminogen activator (TPA) and anterior chamber washout had a diagnosis of neovascular glaucoma and developed a large blood and fibrin clot. Among the four patients (6%) who lost significant vision, two lost vision due to poorly controlled IOP and the other two due to worsening of their pre-existing CMO. The remaining five patients with CMO returned to their baseline vision after one or more posterior sub-Tenon's injections of triamcinolone. There were no instances of phthisis, endophthalmitis, retinal detachment, or sympathetic ophthalmia.

One the patients who lost vision as a result of glaucoma progression had a diagnosis of neovascular glaucoma with a pre-ECP vision of 20/60. After multiple TCP procedures by the referring ophthalmologist, intraocular pressures ranged from 35–60 mm Hg in the period before ECP. The pressure ranged from 16–36 mm Hg after ECP; however, the vision fell to 20/200 without improvement. No ocular pathology could be detected and vision loss was attributed to glaucoma progression. The other patient had nanophthalmos, pseudophakia, and end stage chronic angle closure glaucoma. Visual acuity was 20/200. After an initially uncomplicated postoperative course, the patient developed malignant glaucoma with IOPs exceeding 40 mm Hg. After YAG capsulotomy and anterior hyaloidectomy, the IOP stabilised to 15 mm Hg, but the vision was at the counting fingers level.

Among the remaining two who lost vision, one had a diagnosis of pseudophakic glaucoma as well as a previous hemiretinal vein occlusion. There was previous macular oedema requiring macular grid photocoagulation, such that the pre-ECP vision was 20/80. After ECP, the vision became

20/400 and fluorescein angiography revealed worsening of the macular oedema. Sub-Tenon's injections of steroid did not improve the vision acuity. The final patient who lost vision had chronic angle closure glaucoma and vision of 20/200 secondary to an epiretinal membrane and chronic CMO. The ECP procedure in this patient was complicated by vitreous haemorrhage which resolved spontaneously in the postoperative period. Unfortunately, the vision decreased to counting fingers, without improvement even after the haemorrhage had cleared. Despite steroid injections, there was persistent, increased CMO, confirmed by fluorescein angiography.

Uram developed the technology for ECP and has also published papers on its clinical use in glaucoma. (Dr Martin Uram has a proprietary interest in EndoOptiks, Inc, the manufacturer of the laser unit for endoscopic cyclophotocoagulation.) In a series of 10 patients with intractable neovascular glaucoma, ECP was employed through a pars plana incision to treat between 90–180 degrees of ciliary processes.³⁰ With a mean follow up of 8.8 months, the IOP was reduced from a mean preoperative level of 43.6 mm Hg to a mean of 15.3 mm Hg postoperatively (mean reduction of 65%). Nine of the 10 eyes (90%) were able to achieve an IOP <21 mm Hg, with three of those eyes requiring glaucoma medication. The only major complication encountered was hypotony in two eyes, although both had chronic retinal detachments.

Uram also reported on 10 patients who had combined phacoemulsification, ECP, and intraocular lens (IOL) implantation.³¹ After phacoemulsification to remove the cataract, 180 degrees of ciliary processes were treated before insertion of the posterior chamber IOL. The mean preoperative IOP was 31.4 mm Hg in these patients with uncontrolled open angle glaucoma. After a mean follow up of 19.2 months, the mean IOP was reduced 57% to 13.5 mm Hg. In addition, all patients except one had a reduction in glaucoma medication. There were no significant complications except a transient vitreous haemorrhage that was noted on the second postoperative day.

In a randomised prospective study of combined cataract and glaucoma surgery, Gayton *et al* compared the efficacy and safety profiles of concurrent trabeculectomy versus endoscopic laser cycloablation.³³ In the ECP group, 240–270 degrees were treated. With a mean follow up of 2 years, the success rate in controlling IOP <19 mm Hg without medication was 42% in the trabeculectomy group and 30% in the ECP group. Although probably not as effective as trabeculectomy, ECP appears to be a safe alternative in patients who require both cataract and glaucoma surgery.

Other studies on ECP have targeted specific glaucoma groups which are difficult to treat. Neely *et al* treated 36 eyes of 29 paediatric patients with various childhood glaucomas.³⁴ Between 180 and 270 degrees of ciliary processes were ablated. After 19 months of average follow up, 12 eyes (34%) remained successfully treated with IOP (21 mm Hg (with or

without medications) after the initial ECP and 15 eyes (43%) were successfully controlled with one or more ECP treatments (mean of 1.42 procedures). Significant complications occurred in four eyes and were composed of two retinal detachments, one case of chronic hypotony, and one patient who progressed from hand movement vision to no light perception (unclear aetiology). All four eyes were aphakic.

In eyes that have glaucoma associated with penetrating keratoplasty, ECP has also been shown to be an effective treatment that may have advantages over trans-scleral cyclophotocoagulation. In our study of keratoplasty associated glaucoma, 10 patients who had penetrating keratoplasties (PKPs) were treated by ECP to control their IOP.³⁵ The IOP control rate (IOP <22 mm Hg) was 80% at last follow up, which was 30 months from the time of PKP. The average reduction in number of medications was 1.4. There were no corneal graft failures in this group. In comparison, several studies evaluating TCP treatment of keratoplasty associated glaucoma have demonstrated a high rate of graft failure after laser.³⁶⁻³⁷

INDICATIONS FOR ECP AND TCP

TCP is an effective laser surgery for reducing IOP.¹²⁻²⁵ However, the outcome is less predictable than in other glaucoma surgeries and there is often a substantial risk for significant vision loss.¹²⁻²⁵ By the non-contact method of TCP, vision loss (greater than 2 Snellen lines or 1 low vision category) rates in large series with comparable follow up periods to our study were 35-47%.¹⁴⁻¹⁶ Progression to no light perception occurred in 6-8% of eyes, although the pretreatment vision was poor among those with this complication, ranging from counting fingers to light perception. The success rates for IOP control (IOP between 7 and 20 mm Hg) were 56-65% but IOPs less than 7 mm Hg occurred in 9-11% of eyes. Phthisis rates were 0-6% of eyes.

In their study of 116 eyes treated by contact Nd:YAG TCP, Schuman *et al* had 19 eyes (16%) that progressed to NLP and 17 of 36 eyes (47%) with vision of 20/200 or better that lost 2 or more Snellen lines.²² In addition, nine out of 116 eyes (8%) developed hypotony (IOP of 3 mm Hg or less) with six of these eyes having a pressure of 0 mm Hg. Many of these hypotonous eyes were also considered to be phthisical. The success (IOP between 3 and 22 mm Hg) rate was 65%, with an average follow up of 19 months. In their series, the Diode Laser Ciliary Ablation Study Group used the diode laser for contact TCP and had a success (IOP reduction <20%) from baseline and <22 mm Hg) rate of 72% and 52% at 1 and 2 years, respectively. Vision loss of 2 lines or more occurred in 30% of eyes treated. One eye out of 27 had dropped to no light perception, although the baseline vision was light perception and had decreased after IOP elevation because of discontinuation of medications. Hypotony (IOP <3 mm Hg) occurred in one eye but none of the patients developed phthisis.

In addition, there have been several published reports of sympathetic ophthalmia (SO) following TCP.²⁶⁻²⁸ Lam *et al* reported that the incidence of SO at their institution was 5.8% (four of 69) and 0.67% (one of 150) after non-contact and contact Nd:YAG cyclophotocoagulation, respectively.²⁷ Malignant glaucoma has also been reported after diode TCP.²⁹ No cases of SO have yet been identified in relation to ECP but malignant glaucoma was encountered in one case after an initially unremarkable post-ECP course.³²

In order to more definitively demonstrate the possible advantages of ECP over TCP, a prospective, randomised trial would need to be undertaken among patients with refractory glaucoma. However, results of our large series on ECP³² compare favourably with the results for TCP. Success (IOP <22 mm Hg) at 13 months of mean follow up was 90% and is predicted to be 82% at 2 years by Kaplan-Meier analysis. Vision loss of 2 Snellen lines or greater occurred in only 6%, and no

eyes progressed to no light perception. Also there were no cases of hypotony or phthisis.

It should be pointed out that the proportion of some subgroups in our population differed significantly from those in the TCP studies described above. For example, the number of eyes with a diagnosis of neovascular glaucoma was relatively small in our series (3%), compared to the 8-27% encountered in the TCP studies. Neovascular glaucoma eyes often have higher pretreatment IOPs and poorer success rates with TCP surgery.¹⁴⁻²² In addition, they comprise a disproportionate number of the eyes with hypotony and progression to NLP vision.¹⁴⁻²² Another difference in our population was the subgroup of 12 patients who had concurrent cataract extraction with ECP. However, the IOP responses of these patients were similar to the remainder of those undergoing ECP. They did have a lower incidence of serious complications than the rest of the group.

Furthermore, the mean preoperative IOP in our series (27 mm Hg) was significantly lower than in the TCP series (35-38 mm Hg). In part, this reflects the differences in proportions of glaucoma diagnoses, as noted above.

In conclusion, it is notable that the incidence of vision loss of 2 or more lines (or 1 low vision category) is significantly lower in the ECP study (6%) than in comparable TCP studies (30-47%). In addition, no eyes went to NLP vision or developed phthisis or hypotony with ECP in our study. These data suggest that ECP may be a more favourable treatment for eyes that have refractory glaucoma but relatively intact central visual acuity. Since the mean preoperative IOP was lower in our study, it may be that ECP is a more effective treatment for mild to moderate cases of refractory glaucoma, in which the IOP is not extremely high despite maximal tolerated medical treatment. TCP should probably be reserved for eyes with poor preoperative vision or visual potential, and severe refractory glaucoma.

SUMMARY

ECP is an efficacious tool for the treatment of refractory glaucoma and may have particular advantages over TCP in eyes with potentially useful vision. It has been used effectively for reducing IOP in POAG, congenital glaucoma, chronic angle closure glaucoma, aphakic/pseudophakic glaucoma, uveitic glaucoma, pseudoexfoliative/pigmentary glaucoma, neovascular glaucoma, and traumatic glaucoma.³⁰⁻³⁴ Also, in patients with penetrating keratoplasties, ECP may be preferred over TCP since it appears to be associated with a lower incidence of corneal graft rejection and failure.³²⁻³⁵⁻³⁷

In this technique, there is selective ablation of aqueous secreting ciliary body tissue, allowing sparing of adjacent tissues. This selectivity may be an important factor with regard to the relatively low incidence of vision threatening complications, compared to the trans-scleral approach.

The major disadvantage of ECP is that it is an intraocular procedure with the attendant risks of penetrating surgeries. Endophthalmitis, choroidal haemorrhage, and retinal detachment did not occur in our group of patients, but remain potential complications.³⁴ Therefore, although ECP may be a preferable surgery in cases of refractory glaucoma with relatively intact vision, it may not be recommended for eyes with very poor vision, since it would unnecessarily expose them to such potential complications.

The author does not have any proprietary interest in any of the products described in this article.

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