Cyclophotocoagulation

A Report by the American Academy of Ophthalmology

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Objective: This document describes cyclophotocoagulation procedures for glaucoma and examines the evidence to answer key questions about patient selection, and efficacy of transscleral and endoscopic techniques.

Methods: A literature search conducted for the years 1968 to 2000 retrieved 130 citations. The author reviewed 34 of these articles and selected 19 for the panel methodologist to review and rate according to the strength of evidence. A Level I rating is assigned to properly conducted, well-designed, randomized clinical trials; a Level II rating is assigned to well-designed cohort and case-control studies; and a Level III rating is assigned to case series and poorly designed prospective and retrospective studies, including case-control studies.

Results: The predominant problem with all studies on cyclophotocoagulation is the lack of a uniform definition of success, which makes comparisons difficult. One randomized controlled trial (Level I evidence) compared the efficacy of transscleral cyclophotocoagulation with noncontact Nd:YAG and semiconductor diode laser. It found no significant difference between the two, although a significant problem was the variability allowed with laser parameters. Most of the literature consists of noncomparative case series that provide evidence that is limited and often not convincing.

Conclusion: Cyclophotocoagulation is indicated for patients with refractory glaucoma who have failed trabeculectomy or tube shunt procedures, patients with minimal useful vision and elevated intraocular pressure, and patients who have no visual potential and need pain relief (based on Level III evidence). It may be useful for patients whose general medical condition precludes invasive surgery or who refuse more aggressive surgery (i.e., filter or tube). It is also useful in emergent situations, such as the acute onset of neovascular glaucoma. There is insufficient evidence to definitively compare the relative efficacy of the cyclophotocoagulation procedures for glaucoma. It is the panel's opinion, however, that semiconductor diode systems appear to possess the best combination of effectiveness (based on Level III evidence), portability, expense, and ease of use at this time.
Ophthalmology 2001;108:2130–2138

Introduction

The American Academy of Ophthalmology (AAO) prepares Ophthalmic Technology Assessments (OTAs) to evaluate new and existing procedures, drugs, and diagnostic and screening tests. The goal of an OTA is to evaluate the peer-reviewed and published scientific literature, to distill what is well established about the technology, and to help refine the important questions to be answered by future investigations. After appropriate review by all contributors, including legal counsel, assessments are submitted to the Academy's Board of Trustees for consideration as official Academy statements.

Originally received and accepted: August 9, 2001.
Manuscript no. 210700.

Prepared by the Ophthalmic Technology Assessment Committee Glaucoma Panel and approved by the American Academy of Ophthalmology's Board of Trustees August 1, 2001.

Background

Coagulation or destruction of the ciliary body to reduce the rate of aqueous production has been advocated in the treatment of glaucoma since the 1930s,[1] when penetrating cyclodiathermy was introduced. In initial trials in the 1950s[2] cyclocryotherapy was shown to be a reasonably safe and effective treatment that was less destructive and more predictable than cyclodiathermy. Problems still existed, however, including intense postoperative pain, intraocular pressure (IOP) rise, marked inflammation, hemorrhage, and a significant incidence of hypotony and visual loss. Ultrasound for ciliary ablation was briefly utilized, but it was abandoned because of marked scleral thinning and ectasia at the treatment site.[3,4] In 1972, Beckman et al[5] first reported a laser method for transscleral cyclophotocoagulation (CPC) using a ruby laser (693 nm), and since then a wide range of wavelengths have been used. Laser cyclodestructive procedures that are used currently are as follows:

- Transpupillary CPC

ISSN 0161-6420/01/$–see front matter
PII S0161-6420(01)00889-2

- Transvitreal endophotocoagulation
- Transscleral CPC
  - Noncontact and contact neodymium: yttrium-aluminum-garnet (Nd:YAG) laser
  - Semiconductor diode laser
- Endoscopic CPC

In the United States, CPC is used predominantly for refractory glaucomas, such as neovascular glaucoma, traumatic glaucoma, glaucoma in aphakic eyes, advanced developmental glaucoma, inflammatory glaucoma, glaucoma associated with corneal transplantation, silicone oil-induced glaucoma, and glaucoma in eyes with conjunctival scarring from previous surgery. These conditions are some of the most difficult to control with conventional glaucoma filtration. Cyclophotocoagulation is also used in eyes with limited visual potential, in urgent situations with dangerously elevated IOP, or for pain relief in eyes with no visual potential. It has uncommonly been used in patients who are not candidates for conventional glaucoma therapy due to poor compliance with care or poor postoperative follow-up.

Cyclophotocoagulation has also been evaluated for use as primary surgical treatment in developing countries where conventional glaucoma therapy is not available, with inconclusive results.[6]

This assessment describes the four procedures and examines the published literature for transscleral and endoscopic CPC, which are the most commonly used.

Description of the Procedures

Transpupillary Cyclophotocoagulation

Direct transpupillary treatment of the ciliary processes with the argon laser (488 nm) is rarely used, because a clear visual axis and a well-dilated pupil are required to enable photocoagulation of the entire length of the ciliary processes. Clinical results have been poor when treatment was limited to the anterior most portion of the ciliary processes.[7,8]

Transpupillary CPC of the ciliary processes, exposed through peripheral iridectomy or a widely dilated pupil, can be effective in the treatment of ciliary block glaucoma.[9] The mechanism may relate to a laser-induced retraction of the ciliary body.

Transvitreal Endophotocoagulation

Transvitreal endophotocoagulation using an argon or diode laser probe has been used with some success but must be done in conjunction with a vitrectomy. It requires clear media and aphakia or pseudophakia to directly visualize and treat the ciliary processes, which are scleral depressed into the view of the operating microscope. The argon laser parameters used were continuous duration at 300 to 600 mW of energy. The diode uses up to 1 second duration and 300 to 800 mW of energy.[10–12]

Transscleral Cyclophotocoagulation

Transscleral CPC is performed with the Nd:YAG laser, either noncontact or contact, or the semiconductor diode laser.

Noncontact Nd:YAG Laser. Transscleral ciliary body ablation utilizing the Nd:YAG laser at 1064 nm wavelength has the theoretical advantage of better scleral penetration (60% to 75%) with less back scatter than shorter wavelengths, such as argon and diode.

Noncontact Nd:YAG laser CPC is used in the non-Q-switched free-running thermal mode of the Lasag Microruptor III (Thun, Switzerland, no longer commercially available) for a duration of 20 msec, and the laser is defocused to number 9, which offsets the focal point 3.6 mm into the eye when the He-neon aiming beam is focused on conjunctiva. The power is adjusted from 5 to 8 Joules (J) per application. Retrobulbar or peribulbar anesthesia is given, and the patient is seated at the laser slit lamp. The treatment is directed parallel to the visual axis, encountering the sclera 1.5 mm posterior to the limbus superiorly and inferiorly, and 1.0 mm posterior to the limbus nasally and temporally. A contact lens with 1.0 mm markings parallel to the limbus can be used,[13] which holds the lids open and blanches the conjunctiva, or a lid speculum can be used to open the lids, with the aiming beam in the center of a 3 mm slit beam. Approximately eight to ten applications per quadrant are placed from 270 to 360 degrees. Treatment may be reduced to 180 degrees in patients judged to be clinically at risk for hypotony.

Contact Nd:YAG Laser. Retrobulbar or peribulbar anesthesia is given, the patient lies supine, and a lid speculum is placed. The anterior edge of the 2.2 mm sapphire tip of the delivery fiberoptic handpiece (Surgical Laser Technologies, Inc., Malvern, PA) is placed 0.5 to 1.0 mm from the limbus (the probe is centered 1.5 to 2.0 mm posterior to the limbus). Gentle pressure is applied with the probe, which is oriented perpendicular to the sclera. The power setting is 5 to 9 watts, for a duration of 0.7 seconds, with approximately eight spots per quadrant placed from 270 to 360 degrees. Treatment may be reduced to 180 degrees in patients judged to be clinically at risk for hypotony.

Semiconductor Diode Laser. A semiconductor solid state diode laser system (IRIS Oculight SLx, IRIS Medical Inc., Mountain View, CA) with an 810 nm wavelength exhibits less scleral transmission (~35%) but considerably greater absorption by melanin than the 1064 nm Nd:YAG wavelength. The laser energy is transmitted by a 600-micron-diameter quartz fiber with a spherical polished tip oriented by a handpiece called the "G-Probe". This centers the fiberoptic tip 1.2 mm from the corneoscleral limbus. The tip protrudes 0.7 mm beyond the contact surface, which indents the conjunctiva and sclera to enhance transmission. The probe footplate is curved spherically to match the scleral curvature. Maximum power from the system is 3.0 watts for 9.9 seconds duration.

Retrobulbar or peribulbar anesthesia is given and a lid speculum is placed. Duration is set at 2000 ms (2 seconds), and the initial power setting is 1750 mW. The power is increased in 250 mW increments to a maximum of 2500

mW until an audible "pop" (caused by tissue explosion of the ciliary process, the iris root anteriorly or the retina posteriorly) is heard, then the power is backed off 250 mW and treatment is completed at this power. Some surgeons prefer lower power and longer duration burns, for example 1250 mW at 4 seconds in heavily pigmented eyes and 1500 mW at 3.5 seconds in lightly pigmented eyes.

The number of spots used is typically six per quadrant for 270 degrees of treatment. This is based on burns spaced apart half the width of the G-Probe (~2 mm), but various reports have used from 18 to 40 spots, with 180 to 360 degrees of initial treatment. Generally, the incidence of retreatment increases when lower energy is applied and when the number of spots is smaller.

With noncontact or contact Nd:YAG and semiconductor diode lasers, predictability is limited by the inability to visualize target tissue. In lieu of direct visualization, transillumination may be used to identify the location of the ciliary body, especially in eyes with abnormal anatomy or enlarged eyes (congenital glaucoma). An ocular transilluminator is placed against the posterior globe and directed towards the ciliary sulcus. In a darkened room, the diffuse illumination will demarcate the ciliary body, which can be marked externally.[14]

Endoscopic Cyclophotocoagulation

Endoscopic CPC (Endo Optiks Inc, Little Silver, NJ) is accomplished with an ophthalmic laser system that provides simultaneous microendoscopic viewing and diode laser delivery. The triple-function handpiece (20 g) incorporates fiberoptic elements for a pulsed continuous-wave 810 nm diode laser, a 175-watt xenon light source, and a 4.5-lux video camera. The fiberoptics are connected to a self-contained portable main unit, which includes a high-resolution monitor (horizontal resolution, 470 lines/inch), a control panel, and a VHS recorder. The diode laser has 1.2 watts of available power output and is focused visually by means of a 670 nm (2.0 mW) diode laser-aiming beam. Optimal focal distance for the laser is 0.75 mm from the end of the probe. Depth of focus while viewing is from 0 to 20 mm, and the camera lens has a 110-degree field of view.

A footpedal controls firing of the laser, the duration of the laser pulse up to 9.99 seconds, and the intensity of illumination. The laser can be used in the pulsed or continuous mode. A self-sealing 3.2 mm cataract incision is placed through peripheral cornea or at the limbus in phakic, pseudophakic, or aphakic eyes. A pars plana approach is preferred in the presence of an anterior chamber lens. Viscoelastic (sodium hyaluronate) is used to balloon the iris away from the crystalline lens or posterior chamber implant. Once the probe has entered the eye and is positioned in the posterior chamber, attention is diverted from the microscope to the monitor. It is important to rotate the handpiece so that images on the video monitor are upright in order to maintain orientation. Since 7 to 8 clock hours is the largest area treatable through a single corneal incision, two incisions are necessary. Power is about 300 mW, using visible whitening and shrinkage of the ciliary processes without tissue explosion as an endpoint. It is important to remove the sodium hyaluronate from the eye after the procedure to prevent postoperative IOP spikes.

The advantage of endoscopic CPC is the ability to selectively treat the ciliary body epithelium with relative sparing of underlying and adjacent tissues [Trevisani MG, Allingham RR, Shields MB. Invest Ophthalmol Vis Sci 36 (Suppl):331. 1995]. Currently, the endoscopic laser procedure may be most appropriate for patients who have failed other surgical and/or cyclodestructive procedures. The disadvantages of this procedure include the initial learning curve, the risk of damage to the crystalline lens in a phakic eye, and the risks that are inherent in any ocular procedure.

Complications of Cyclophotocoagulation

Potential complications seen with all modes of cyclodestruction include intraocular hemorrhage, prolonged ocular inflammation, hypotony, phthisis bulbi, visual loss, postoperative pain, and the need for retreatment.

An additional, although extremely rare, complication of the Nd:YAG cyclophotocoagulation is sympathetic ophthalmia.[15–18]

Potential complications of transscleral diode CPC include conjunctival surface burns that may occur if tissue debris becomes coagulated on the tip and chars. In addition, increased perilimbal conjunctival pigmentation[19] has been correlated with conjunctival burns, which heal quickly.

Another potential complication is intraocular disruption ("pop"), which is characterized as an intraocular uveal micro-explosion[20] and represents boiling of tissue water. Postoperative iridocyclitis is more severe with an increased number of pops observed.[21] Pops are less likely with burns over 2 seconds in duration and at a power setting of less than 2 watts.[22] Gaasterland and Pollack[23] and Kosoko et al[19]reported that patients with dark brown iris color were more likely to have audible pops during cyclodiode than patients with less pigmented iris colors. However, Rebolleda et al[21] found no difference in the number of pops between green, blue, light brown, or dark brown irides. Endoscopic evaluation of the ciliary body shows no visible difference between ciliary body pigmentation in patients with blue-green and brown irides.[24]

Malignant glaucoma has been reported in one case series following diode CPC.[25]

The potential complications of endoscopic CPC include all risks listed except for conjunctival surface burns. In addition, endoscopic CPC carries the risk of damage to the crystalline lens, zonular rupture, and the inherent risks of an intraocular procedure, which include retinal detachment and endophthalmitis. There have been no reported cases of these potential complications in the literature.

FDA Status

The following devices have been given FDA 510(k) clearance for marketing for CPC in the United States. This may not be an all-inclusive listing.

- Lasag Microruptor III Nd:YAG Laser

- Surgical Laser Technologies, Inc. Nd:YAG Laser
- IRIS Oculight SLx Diode Laser with G-Probe, Iris Medical Inc.
- Surgical Laser Video Endoscope and Laser Endoscopy Console, Endo Optiks, Inc.
- Instruments for Medicine and Diagnostics, Inc. TSX Probe for contact transscleral CPC

No viscoelastic substance currently approved for marketing in the United States has FDA-approved labeling indications for use in CPC. The use of viscoelastics in CPC is considered an off-label use of an FDA-approved product.

Resource Requirements

Transscleral procedures require local (peribulbar or retrobulbar) anesthesia and can usually be performed in an office setting. Endoscopic CPC requires local (peribulbar or retrobulbar) or general anesthesia and is performed in an outpatient surgical or hospital setting.

Questions for Assessment

The key questions that are the focus of this assessment are as follows:

- For which patients is this procedure indicated?
- How do various instruments compare?

Description of Evidence

The literature search was conducted in MEDLINE for the years 1968 to 2000. The terms glaucoma and laser coagulation were used and results were limited to articles in English. Approximately 130 articles were found. The author reviewed 34 articles and selected 19 for the panel methodologist to review and rate according to the strength of evidence. A Level I rating is assigned to properly conducted, well-designed, randomized clinical trials; a Level II rating is assigned to well-designed cohort and case-control studies; and a Level III rating is assigned to case series and poorly designed prospective and retrospective studies, including case-control studies. Members of the Ophthalmic Technology Assessment Committee (OTAC), other AAO committees, and relevant subspecialty societies (American Glaucoma Society) reviewed drafts of this document prior to formal approval by the Board of Trustees.

The predominant problem with all studies on CPC is the lack of a uniform definition of success. Two randomized controlled trials were identified. In a prospective, randomized, unmasked controlled trial, Youn et al[26] compared the efficacy of transscleral CPC with noncontact Nd:YAG and a semiconductor diode laser, and they found no significant difference between the two. Compliance to protocol and follow-up was good. The study had sufficient power to detect a difference between the two groups if it existed and was thus rated Level I evidence.

Hampton and Shields[29] compared two energy levels for noncontact transscleral Nd:YAG CPC in a prospective, randomized unmasked trial. Compliance to protocol was good. Although the difference between the groups approached significance, the results were undermined by incomplete follow-up and lack of sufficient power to detect significant differences in success between the two groups. For these reasons the study was rated as Level II evidence.

Most of the literature consists of noncomparative case series (rated as Level III) that provide evidence that is limited and often not convincing. Information about the effect of an intervention should be obtained by comparing a treated group and untreated group that are similar in all important respects. Because case series have no control group and do not use randomization, there is no way to estimate how an intervention might have changed the outcome. Properly documented case series can provide important insights into the potential utility of a new treatment and serve as pilot studies for appropriate controlled clinical trials. Necessary documentation includes details about patient selection criteria, the number of patients who declined surgery, and how the enrolled patients compared to the patients who refused treatment.

Published Results

Success of cyclophotocoagulation procedures has been defined as achieving IOPs that range from 5 to 20 mmHg, or 7 to 21 mmHg, that are less than 21 or 22 mmHg, and/or a reduction in IOP of from 20% to 30%. Most studies allow the postoperative use of medications to achieve this definition of success. It is difficult to compare studies that have such different definitions of success.

Transscleral Cyclophotocoagulation

Noncontact Nd:YAG Laser. Early studies did not utilize a contact lens, and they focused 1 to 3 mm posterior to the limbus with the assistance of a lid speculum. When a contact lens was utilized, the markings were used to focus 1.5 mm posterior to the limbus at the 12 and 6 o'clock positions, and 1 mm posterior to the limbus at the 3 and 9 o'clock positions. Histologic reports confirmed that this positioning caused maximal damage to the ciliary processes.[28,29] Retrospective studies such as that performed by Youn et al[30] reviewed 479 patients for a 3- to-75-month follow-up (mean 22 ± 18.2 months). Eight J of power were utilized on the first 200 patients and 4 to 8 J on the next 100, with 30 spots placed over 360 degrees. The remaining patients had 4 to 6 J per spot if the IOP was less than 30 mmHg and visual acuity was better than 20/100. Between 6 and 8 J per shot were used if the pressure was over 30 and vision was poor. Postoperative IOPs were between 5 and 20 mmHg in 52% of the patients (247/479). Forty percent of the patients lost two or more lines of Snellen visual acuity. Visual deterioration was significantly associated with the diagnosis of neovascular glaucoma, African descent, post-treatment hypotony, and more than 6 months of follow-up.

Phthisis was seen in 14% of treated patients. As the criteria for success varied in the different studies, it is not surprising that the rate of success ranged from 48% to

90%.[8,24,27,30–40] Laser settings varied from 1.8 to 8.7 J, with the number of applications ranging from 10 to 40, distance from limbus 1 to 3 mm, and range of follow-up from 4 to 36 months. There is little uniformity between the components of treatment, making any real comparisons difficult. In addition to altering laser parameters, the use of a contact lens to facilitate placement of the laser lesions may also introduce a variability in results. In a study of human autopsy eyes, Simmons and co-workers[41] found no difference in lesions produced with similar laser treatments both with and without the lens. The most common complications included inflammation, loss of two or more lines of Snellen visual acuity or one low vision line in 3% to 56% of patients, hypotony in 0% to 12%, phthisis in 0% to 7%, choroidal detachment, hyphema, cystoid macular edema, and sympathetic ophthalmia.[8,24,27,30–40]

Noncontact Nd:YAG cyclophotocoagulation in patients with previous penetrating keratoplasty represents a further risk of graft failure. Two studies that had a relatively small number of patients[32,33] reported between 38% and 44%. If laser CPC was unsuccessful initially, most patients were retreated after 4 weeks, and failure of the graft ranged from 11% to 57%.[27,32–34,42] In a prospective, unmasked randomized trial, Shields et al[27] had two groups of 89 patients divided into 4 J (range 3.7 to 4.5 J) and 8 J (range 7 to 8.5 J) power settings, with 30 applications utilizing a contact lens 1.5 mm posterior to the limbus at 6 o'clock and 12 o'clock and 1 mm posterior to the limbus at 3 o'clock and 9 o'clock. The two groups were comparable with respect to age, race, gender, and glaucoma diagnosis. Among the patients who did not require repeat surgery, better success (75% versus 60%) and fewer retreatments (25% versus 40%) were observed in the higher energy group. Among those patients who received no further surgery, vision loss was 56% in Group A (4 J) versus 42% in group B (8 J). There was no significant difference between the two groups. Mean follow-up was 12.6 months, ranging from 5 to 20 months. Follow-up was somewhat incomplete, with 2-hour results recorded for 73 of 89 eyes, and 1-day results for only 44 of 89 eyes. There was no phthisis or hypotony recorded and one enucleation occurred in each group.

Contact Nd:YAG Laser. There are fewer studies utilizing contact transscleral Nd:YAG laser CPC than there are using noncontact. Schuman et al[43] reported retrospectively on a series of 116 eyes of 114 patients followed for a minimum of 1 year (19.0 ± 0.6 mo). Treatment consisted of 32 to 40 applications with the probe placed 0.5 to 1.5 mm from the limbus, for a total of 7 to 9 watts of power delivered for 0.7 seconds. Intraocular pressure control of 3 to 22 mmHg was achieved in 65% of eyes, while pressure of less than 19 mmHg was achieved in 56%. Twenty-seven percent were retreated. Hypotony less than 3 mmHg was seen in nine eyes, six of which were phthisical. Nineteen eyes (16%) lost light perception, and 47% of patients with vision of 20/200 or better lost two or more Snellen visual acuity lines (17 of 36 eyes).

Diode Laser. There are relatively more studies in the literature that evaluate contact diode CPC than other CPC modalities. Histopathologic studies comparing Nd:YAG laser to diode found that treatment with diode CPC required less energy, and tended to cause less blanching, and deeper ciliary body contraction and coagulation.[41,44,45] Retrospective studies[21,31,42,44,46–51] evaluated 26 to 68 patients with varied diagnoses and laser parameters. Laser power ranged from 1.5 to 2.5 watts over 180 to 360 degrees of limbus, from four to seven applications per quadrant, sometimes adjusting the power for pops and sometimes not. Follow-up ranged from 1 month to 37 months, and the definition of success was varied, from 38% for IOP less than 21 on maximal medications[48] to 81%[46] for an IOP less than 22 with or without medications. Bloom et al[44] reported a large retrospective study of 210 eyes, of which 18% had previous cyclodestructive procedures. The diagnoses included neovascular glaucoma, post-traumatic glaucoma, aphakia, and silicone-oil induced glaucoma. The probe was placed at the limbus by transillumination rather than by using the footplate. The protocol varied widely, with no documentation of the mean energy delivered, and follow-up varied from 3 to 30 months. Twenty-eight percent of the patients experienced vision decrease, more commonly seen in patients with neovascular and silicone-induced glaucoma. Of patients with pre-existing corneal transplants, 9.5% had graft failure.

Brancato et al[42] reported a prospective, nonrandomized case series with 68 Caucasian patients, of which 48 had light perception or better vision and 20 had blind, painful eyes. Fifteen percent had a diagnosis of neovascular glaucoma. Follow-up was 20.7 ± 8.14 months and all patients were followed for more than 8 months. Power was 2.6 watts at 1.5 to 2.5 seconds duration with 16 to 20 applications over 360 degrees. The success rate was 70.8%, and success was defined as an IOP, with medication, over 2 mmHg and less than 21 mmHg in seeing eyes. Fifty-three percent had vision loss, with 2 of 68 eyes experiencing phthisis.

The Diode Laser Ciliary Ablation Study Group[19] undertook a prospective, noncomparative case series study on 27 eyes of 27 patients with no previous ciliary ablation. Follow-up ranged from 6 weeks to 28 months (mean 17.9). Twenty-one of these patients had 11 to 28 months of follow-up. Laser settings were 1.75 watts titrated up by 0.25-watt intervals until a pop was heard, then lowered by 0.25 watts. Seventeen to 19 applications over 270 degrees were placed for a total energy of 63.3 ± 7.25 J. Failure was defined as 1) less than a 20% IOP reduction from the baseline or 2) either less than a 20% IOP reduction from the baseline or IOP greater than 22 mmHg. For failure defined by the latter criteria, the cumulative probability of success was 72% at 1 year and 52% at 2 years (41% of patients had IOP less than 22 mmHg). Thirty percent of patients lost vision, 33% had conjunctival surface burns, and 3.7% (1/27) had hypotony. Patients with dark-brown iris color were reported to be more likely to have audible pops during cyclodiode than those with less pigmented irides, supposedly because of increased ciliary body pigmentation. However, endoscopic evaluation of the ciliary body showed no visible difference in pigmentation of the ciliary body relative to iris color.[24]

Youn et al[26] compared transscleral noncontact CPC with Nd:YAG and semiconductor diode lasers in a prospective, randomized, unmasked trial. Of 91 patients, 39 were African American and 58 were Caucasian American; 31 of 95 eyes had a diagnosis of neovascular glaucoma. Follow-up

was only for 10.4 ± 3.16 months. A significant problem was the variability allowed with laser parameters. YAG parameters ranged from 5.21 to 7.75 J (mean 6.56 ± 0.61) with 24 to 42 applications (mean 31.98). Diode parameters ranged from 1.75 to 3 watts with 18 to 39 applications (mean 24.63). Success was defined as IOP between 5 and 20 mmHg, with 83% and 71% of the YAG and diode patients, respectively, meeting these criteria (no statistically significant difference). Retreatment in the YAG group was lower (8.7%; 4/46) than the diode group (18%; 6/49). Of those retreated, three of four in the YAG group were successful, and three of six in the diode group were successful. Medication use before and after laser was not specified. Since preoperative visual acuity was worse than 20/400 in 57% of the patients, the group was definitely skewed towards worse-seeing patients. Five patients (17%) in the YAG group and nine patients (26%) in the diode group lost either two lines of Snellen visual acuity or one low vision line (i.e., count fingers to hand motion vision). Four patients in the diode group progressed to no light perception vision, and three of them had neovascular glaucoma. Hypotony (IOP < 5) was seen in one YAG and two diode patients. Phthisis was seen in one diode patient after retreatment.

Several subgroups were singled out for analysis, but among those with a final IOP over 20 mmHg (group A), a final IOP between 5 mmHg and 20 mmHg (group B), a final visual acuity stable or better (group C), or a loss of two Snellen lines of vision (group D), there were no significant differences in results or complications between YAG and diode patients.

An interesting retrospective study[35] attempted to compare mitomycin C trabeculectomy, glaucoma drainage device (GDD) and Nd:YAG CPC to manage glaucoma after penetrating keratoplasty. This was a noncomparative case series with fewer than 20 patients in each group. Mean follow-up was 12.9 months. There were no statistically significant differences in successful IOP control between mitomycin C trabeculectomy (77% success), GDD (80% success), or CPC (63%), nor were there significant differences in failure rate of the corneal graft following trabeculectomy (15%), GDD (0%), or CPC (17%). In general, 11% to 65% failure of the corneal graft following glaucoma surgery has been stated in the literature.[32,36,52–59]

Endoscopic Cyclophotocoagulation

Relatively few studies have been reported with this modality, most of which have been retrospective case series with a small number of patients.[40,60–62] A retrospective review of 68 patients by Chen et al[63] evaluated patients with refractory glaucoma who had failed prior medical and surgical treatment. Success was defined as IOP less than or equal to 21 mmHg with or without medications. Kaplan–Meier life table analysis predicted a 94% probability of success at 1 year, and 82% at 2 years, with no significant difference based on age, type of glaucoma, or lens status. The failures had significantly higher preoperative pressures. The mean number of glaucoma medications was reduced from 3 ± 1.3 before laser to 2 ± 1.3 postoperatively. A large proportion of the patients had preoperative vision from count fingers to light perception (35%), yet only 6% of patients had a decrease in postoperative vision over two Snellen lines or one low vision line. There was no hypotony or phthisis noted, although 10% of patients had cystoid macular edema.

Plager and Neely[64] reported on a prospective group of ten eyes in eight children with pediatric glaucoma in a nonrandomized study with no control group. Minimum follow-up was 3 years. Fifty percent of patients maintained an IOP between 8 and 22 mmHg with or without adjunctive medications after initial treatment. Four of the five successfully treated eyes had a primary diagnosis of aphakic glaucoma, while only one of four eyes with refractory congenital glaucoma demonstrated an adequate response. No sight-threatening complications were observed. None of the five treatment failures had repeat endoscopic CPC.

Conclusions

Cyclophotocoagulation (based on Level III evidence) is indicated for patients with refractory glaucoma who have failed trabeculectomy or tube shunt procedures, patients with minimal useful vision and elevated IOP, patients who have no visual potential and need pain relief, and patients with complicated glaucoma and conjunctival scarring from previous surgery. It may be useful for patients whose general medical condition precludes invasive surgery or who refuse more aggressive surgery (i.e., filter or tube). It is also useful in emergent situations, such as the acute onset of neovascular glaucoma.

There is insufficient Level I evidence to definitively compare the relative efficacy of the cyclophotocoagulation procedures for glaucoma. It is the panel's opinion, however, that semiconductor diode systems appear to possess the best combination of effectiveness (based on Level III evidence), portability, expense, and ease of use at this time. Unlike endoscopic CPC, transscleral treatment can usually be performed in an office setting. However, visualizing the treatment target tissue directly is impossible with transscleral treatment and can potentially cause more collateral tissue damage.

Future Research

- How does CPC compare with other treatments for end-stage glaucoma?
- Will improved laser technology lead to better uveal absorption and less collateral damage?
- Will the use of photosensitizing agents to the ciliary epithelium allow lower energy and more focused application of laser, possibly reducing complications?
- What is the long-term risk of vision-threatening complications such as retinal detachment and phthisis bulbi?
- What is the risk of corneal failure/graft failure compared with control groups when treating glaucoma following penetrating keratoplasty?
- What is the risk of sympathetic ophthalmia following CPC?
- Will CPC become the treatment of choice in underserved areas and developing countries?

Preparation was coordinated by the Ophthalmic Technology Assessment Committee Glaucoma Panel.

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*Proprietary interests stated

Category	Abbrev	Specific Financial Interests
Product	P	Financial interest in equipment, process, or product presented.
	Pc	Such interest in potentially *competing* equipment, process, or product.
Investor	I	Financial interest in a company or companies supplying the equipment, process, or product presented.
	Ic	Such interest in a potentially *competing* company.
Consultant	C____	Compensation received within the past 3 years for consulting services regarding the equipment, process, or product presented.
	Cc____	Such compensation received for consulting services regarding potentially *competing* equipment, process, or product. Examples of compensation received include:
	C1 or Cc1	1. Retainer
	C2 or Cc2	2. Contract payments for research performed
	C3 or Cc3	3. Ad hoc consulting fees
	C4 or Cc4	4. Substantial nonmonetary perquisites
	C5 or Cc5	5. Contribution to research or research funds
	C6 or Cc6	6. Contribution to travel funds
	C7 or Cc7	7. Reimbursement of travel expenses for presentation at meetings or courses
	C8 or Cc8	8. Reimbursement of travel expenses for periods of direct consultation
None	N	No financial interest. May be stated when such interests might falsely be suspected.

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