Endolaser Cyclophotocoagulation in Glaucoma Management

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ABSTRACT

Endolaser cyclophotocoagulation is a safe and effective method to lower intraocular pressure. This is confirmed by several new, large, long-term studies summarized by the author. Because the ciliary processes are visualized directly and treated precisely with diode laser energy, the problems of pain, inflammation, hypotony, and visual loss associated with transcleral forms of cycloablation do not occur. The endolaser probe has an 18-gauge diameter and can be used through the limbus or pars plana to treat virtually any type of glaucoma, regardless of etiology. Endolaser cyclophotocoagulation is particularly easy and well suited to lower intraocular pressure and reduce the need for glaucoma medications by combining it with phacoemulsification in cases of cataract and medically controlled glaucoma. Surgical techniques and clinical “pearls” are provided by the author.

Keywords: endolaser cyclophotocoagulation, intraocular pressure, phacoemulsification

HISTORICAL PERSPECTIVE

Transcleral cycloablation has been performed for many years by penetrating diathermy and cryotherapy and, more recently, by Nd:YAG and diode. Traditionally, cycloablation procedures have been relegated as a last resort for eyes that have failed multiple glaucoma procedures such as trabeculectomies and glaucoma drainage devices or to eyes that are blind and painful or have very poor visual potential. This was appropriate because transcleral cycloablation procedures are unpredictable. They are “blind” procedures because the tissue being treated is not visualized, which means that overtreatment or undertreatment is likely. They are associated with many postoperative complications such as pain, inflammation, visual loss, and phthisis.

In contrast, endoscopic cyclophotocoagulation (ECP) is a much kinder and gentler procedure than transcleral cycloablation because the tips of the ciliary processes are visualized directly and treated precisely to achieve the desired tissue effect. Endolaser cyclophotocoagulation does not cause undesirable collateral tissue damage and therefore does not cause the complications associated with transcleral cycloablation described above. Endolaser cyclophotocoagulation can be done in eyes with excellent visual potential; the 2 procedures should not be “lumped” together.

Because ECP can be performed with topical/intracameral anesthesia, it is well suited for patients who are monocular or are anticoagulated. Transcleral diode cyclophotocoagulation must be done with retrobulbar or peribulbar anesthesia.

Ocular endoscopy was first suggested by Thorpe in 1934. However, there were no other reports until Norris and Cleasby described an endoscope for ophthalmology in 1978. In 1986, Patel et al were the first to report endolaser treatment of the ciliary body for uncontrolled glaucoma, but this was done with scleral depression through an operating microscope, not with an endoscope. Uram developed an intraocular laser endoscope with vitreoretinal and anterior segment
applications and reported his results treating neovascular glaucoma (NVG) using this technique in 1992.

**TECHNIQUES**

To benefit from minimally invasive endoscopic surgery, the practitioner must have an understanding of the components that are used. There are 2 basic sets of instrumentation: the laser endoscope itself and the equipment console.

The laser endoscope has 3 fiber groupings: the image guide, the light guide, and the laser guide. There is an 18-gauge endoprobe (Figs. 1A and B) with a 110-degree field of view and a depth of focus from 1 to 30 mm. The advantages of this larger diameter laser endoscope are the greater clarity provided by the image bundle and the panoramic field of view that it creates. This feature is especially helpful for the novice endoscopist in that the wide field of view permits simpler orientation to the anatomy.

The laser endoscope is connected to the console (Fig. 1C) that contains all of the instrumentation used for endoscopy, such as a video camera, light source, video monitor, and video recorder. A semiconductor diode laser tuned to the 810-nm wavelength is used. The surgeon places the console next to the surgical table and controls the progress of surgery by viewing the video monitor, rather than imaging through the operating microscope.

The ciliary processes may be accessed from either a limbal or pars plana approach. The status of the lens and vitreous is a primary consideration when planning ECP. Mechanism of glaucoma, level of intraocular pressure (IOP), previous surgical interventions, visual acuity, or visual field status are less important.

**Limbal Approach**

The ciliary processes may be accessed from an anterior segment incision in the phakic, pseudophakic, or aphakic eye and combined with cataract surgery and intraocular lens implantation. The incision should be 1.5 to 2.0 mm and may be in clear cornea or scleral tunnel.

**Phakic Eye**

Once the anterior chamber has been entered, an “over-the-capsule” approach may be used. Sodium hyaluronate is injected posterior to the iris but anterior to the capsule. This causes anterior displacement of the iris and posterior movement of the lens, creating a wide approach to the ciliary processes. Any adhesions between the lens capsule and the iris are severed by viscoelastic or mechanical dissection. Endolaser cyclophotocoagulation may then proceed.

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**FIGURE 1.** (A and B) Laser endoscope probe (straight). (C) E2 Laser and Endoscopy System, Endo Optiks, Little Silver, NJ.
Once completed, it is important to remove the sodium hyaluronate from the eye to prevent postoperative IOP rise (Fig. 2). Although there might be a concern that this technique would result in cataract formation, it should be noted that if enough of the viscoelastic is used, the laser endoscope should not come in contact with the lens. Furthermore, cataract formation would be much more likely if the lens capsule were to be gouged, so this type of contact is to be avoided.

**Posterior Chamber Pseudophakia.** The technique here is similar to that used in the phakic eye, with sodium hyaluronate being injected posterior to the iris but anterior to the lens capsule and lens implant, creating open access to the ciliary processes. Once ECP is completed, the viscoelastic is removed from the eye, and the incision is tested to determine that is water tight.

**Aphakia.** When the laser endoscope is inserted into the anterior chamber, the tip is directed posterior to the iris and advanced toward the ciliary processes. The anterior vitreous must be removed before any endoscope manipulation in this region. Usually, an anterior chamber maintainer is used, so viscoelastic is not necessary. Although the aphakic eye might seem to represent the simplest set of conditions under which ECP is performed, there are often many surprises awaiting the surgeon. Lens remnants, giotic capsule, and opacified vitreous may overlie the ciliary processes, preventing their visualization and treatment. Under these circumstances, the surgeon must be able to modify the therapeutic plan by either creating another anterior segment incision permitting access to a different region of the ciliary processes, switching to a pars plana approach to the ciliary processes, or by modifying the over-the-lens technique by injecting sodium hyaluronate over a large area of lens remnant and thereby gaining access to the ciliary processes. At times, a combination of all of these maneuvers is required to achieve a satisfactory tissue effect.

**Combined Endoscopic Cyclophotocoagulation and Cataract Surgery.** The same anterior segment techniques apply in this setting with one variation. Specifically, planned extracapsular surgery or phacoemulsification is executed in the surgeon’s typical fashion. Endolaser cyclophotocoagulation can be performed either before or after inserting the posterior chamber intraocular lens in the posterior capsular bag. The viscoelastic should be introduced over the capsular bag and posterior to the iris. This maneuver results in posterior displacement of the capsular bag and anterior movement of the iris, allowing a clear view of the ciliary processes (Fig. 3). This over-the-bag technique is identical to that used in the phakic eye and in posterior chamber pseudophakia. A clear corneal incision is preferable, leaving conjunctiva intact superiority, in case filtering surgery is needed in the future.

**ECP can lower IOP during Phaco/IOL**


**FIGURE 2.** All viscoelastic should be removed from the eye at the end of the procedure.

**FIGURE 3.** View from behind the iris of endolaser treatment to ciliary processes, with posterior chamber intraocular lens in place.
**Pars Plana Approach**

Although the anterior segment approach is generally the most useful, a pars plana entry can be advantageous and represents a simple method for accessing the ciliary processes. Pseudophakia or aphakia does not impede imaging or photocoagulation; however, presence of the crystalline lens precludes this surgical option. The human lens is typically spherical, and so the shaft of the endoscope would traumatize it while ECP is in progress. Cataract formation would ensue. After removal of anterior vitreous, the laser endoscope is inserted through the pars plana, 3.5 to 4.0 mm from the limbus. The tip is directed in an anterior direction, and the ciliary processes are easily viewed and photocoagulated.

**How to Photocoagulate a Ciliary Process.** Perhaps the most outstanding quality of ECP is the ability to deliver laser energy in a highly titratable fashion to the ciliary processes, in a given eye, despite numerous anatomic impediments, and on surgeon demand. The optimum tissue effect in glaucoma management is clear. The physical goals of treatment are to whiten the ciliary process and effect visible tissue shrinkage (Fig. 4). The entirety of each process should be incorporated into the treatment zone, and in general, 200 to 300 degrees of this tissue should be treated (Fig. 5). Gas bubble formation, pigment dispersion, audible “popping,” photocoagulation of nonciliary process tissue, and inclusion of prosthetic material in the treatment zone should be avoided.

**DISCUSSION**

Laser endoscopy permits visualization and photocoagulation of the ciliary processes in the phakic, pseudo-

![FIGURE 4. Treated ciliary process is shrunken and white.](image)

phakic, and aphakic eye from a limbal approach and in the pseudophakic and aphakic eye from a pars plana approach in essentially any patient, despite the presence of corneal opacification, miotic pupil, or previous glaucoma surgery. Laser endoscopy benefits from the advantages of directly viewed ciliary process photocoagulation yet avoids the complications associated with transscleral cyclodestruction. Furthermore, semiconductor diode laser tuned to the 810-nm wavelength is preferable to argon laser photocoagulation (the modality used in the transpupillary and transvitreal approaches) for several reasons. It is more deeply absorbed by the ciliary process tissue, reducing the energy required to achieve tissue ablation. It does not result in pigment dispersion or gas bubble formation, and most importantly, the surgeon can observe the progress of tissue ablation and, when the desired effect is obtained, terminate that laser application. This could not be done with a visible wavelength laser because the video camera of the endoscopy system is momentarily “blinded” by the laser flash.

Endoscopic cyclophotocoagulation should be considered in any eye requiring glaucoma surgery that is a poor candidate for filtration or drainage device surgery. This includes eyes that have scarred conjunctiva or cases where the contralateral eye developed trabeculectomy or bleb-related problems. These include flat anterior chamber, chronic choroidal detachment, hypotony, bleb leak, bleb dysesthesia (pain), blebitis, endophthalmitis, exsudative hemorrhage, suprachoroidal hemorrhage, excessive astigmatism, and so on.

Endoscopic cyclophotocoagulation is preferable to filtration surgery in eyes where an ocular fistula is problematic, such as cases of elevated episcleral venous pressure, intraocular tumor, contact lens wear, or blepharitis.
TABLE 1. Phaco-ECP vs Phaco Alone (mean F/U 3.2 yrs)

<table>
<thead>
<tr>
<th></th>
<th>Pre-op IOP mm Hg</th>
<th>Post-op IOP mm Hg</th>
<th>P</th>
<th>Pre-op Meds (#)</th>
<th>Post-op Meds (#)</th>
<th>P</th>
</tr>
</thead>
</table>
| Phaco-ECP (n = 626) | 19.08 ± 4.14     | 15.73* ± 3.00     | 4.48 × 10^-72 | 1.53 ± 0.89     | 0.65* ± 0.95     | 1.23 × 10^-85 |}
| Phaco Alone (n = 81) | 18.16 ± 3.38     | 18.93 ± 4.12      | .01    | 1.20 ± 0.83     | 1.20 ± 0.87      | 0.50   |

*Statistically significant by 2-tailed t-test.

Endolaser cyclophotocoagulation is also preferable in patients who are anticoagulated or monocular because it can be performed with topical/intracameral anesthesia.

Endoscopic cyclophotocoagulation is much faster and easier to perform intraoperatively than filtering surgery or drainage devices and involves far fewer postoperative visits and manipulations such as laser suture lysis, bleb needling, 5-FU injections, and so on. It is preferable for patients who are unable to make frequent postoperative visits or are unable to cooperate for laser suture lysis, suture removal, or other bleb manipulations.

Likewise, ECP is preferable to glaucoma drainage devices in patients who have already experienced problems associated with these devices such as extracorneal muscle dysfunction, tube erosion, plate erosion, or corneal decompensation.

Combined Phacoemulsification/ECP Versus Phacoemulsification Alone for Patients with Glaucoma Undergoing Cataract Surgery

More than 3 million cataract surgeries are performed in the United States each year. Many of these patients are also being treated for glaucoma. Every time we encounter one of these patients preoperatively, we, as surgeons, are faced with a decision: should we perform phacoemulsification alone or phacoemulsification combined with a glaucoma procedure, such as trabeculectomy or ECP?

Before 1998, my options in treating these patients were limited to phacoemulsification alone or combined phacoemulsification/trabeculectomy. In my glaucoma patients who underwent phacoemulsification alone, some experienced a modest decrease in IOP, but most remained on the same number of glaucoma medications. Some patients experienced no change in IOP or even an increase in IOP, necessitating subsequent surgical trabeculectomy. This is consistent with other reports in the literature.

Since 1998, my partners and I have performed more than 1000 cases of combined phacoemulsification/ECP, primarily in patients with medically controlled glaucoma. Analysis of our first 25 consecutive cases with 1 year follow-up was presented at the American Glaucoma Society Meeting in March 2000. Treating 180 degrees of ciliary processes resulted in a mean decrease in IOP of 15% (from 20.2 to 17.2 mm Hg) along with a 68% reduction in glaucoma medications (from 1.6 to 0.5). There was no visual loss postoperatively and no significant postoperative sequelae.

In other words, a typical patient with an IOP of 20 mm Hg on 3 medications preoperatively would end up with a 3-mm Hg drop in IOP on only one medication postoperatively. Both patients and surgeons appreciated this effect because fewer medications mean less cost, less inconvenience, less local and systemic side effects, and improved compliance.

More recently, we analyzed our long-term phacoemulsification/ECP results and presented our findings at the American Glaucoma Society Meeting in March 2006 (Table 1). In this study, 626 phacoemulsification/ECP

TABLE 2. ECP Collaborative Study Group: Complications in 5824 Eyes

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>IOP spike</th>
<th>Hemorrhage</th>
<th>Serous choroidal effusion</th>
<th>IOL displacement</th>
<th>Visual loss &gt;2 lines</th>
<th>RD</th>
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</thead>
<tbody>
<tr>
<td>Uncontrolled phakic OA or PEX GL</td>
<td>323</td>
<td>51</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Refractory GL</td>
<td>2641</td>
<td>344</td>
<td>87</td>
<td>18</td>
<td>9</td>
<td>34</td>
<td>7</td>
</tr>
<tr>
<td>NVG</td>
<td>605</td>
<td>77</td>
<td>99</td>
<td>0</td>
<td>12</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>Post-PK GL</td>
<td>57</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Medically controlled GL + Phaco</td>
<td>2193</td>
<td>368</td>
<td>24</td>
<td>0</td>
<td>15</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Total</td>
<td>5824</td>
<td>544</td>
<td>221</td>
<td>21</td>
<td>21</td>
<td>54</td>
<td>16</td>
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</table>

% 100 14.5 3.8 0.36 0.36 1.03 0.27

Follow-up range, 1–13 years. Mean follow-up, 5.2 years.

OA indicates open angle; PK, penetrating keratoplasty; PEX, pseudoexfoliation; GL, glaucoma; and NLP, no light perception.

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TABLE 3. Ten Reasons To Do Combined Phacoemulsification/ECP

10. Easy to do—only adds a few minutes to the procedure (2-4 min)
9. Titratable—no reports of hypotony or phthisis as a primary procedure in our experience with >1000 cases during 5 years and >50,000 cases worldwide during 10 years
8. Repeatable—can treat full 360 degrees because the tips of the ciliary processes are treated, sparing the “valleys” in between
7. Value added for patients—cataract surgery “PLUS”; more likely to decrease IOP and number of glaucoma medications than phacoemulsification alone
6. No additional patient visits—patients can be seen postoperatively 1 day, 1 week, and 1 month, same as phacoemulsification alone
5. No long-term complications—no increased incidence of CME, hypotony, RD, etc
4. Conjunctiva is left undisturbed—in addition to selective laser trabeculectomy and repeat ECP, can do trabeculectomy or glaucoma drainage device, if necessary
3. No early or late complications—as opposed to trabeculectomies and glaucoma drainage devices (see text)
2. Reimbursable—codes for surgeon and facility to more than cover costs associated with the procedure
1. ECP is fun and interesting—the technology and the views are amazing; endoscopy can reveal pathological ciliary processes, pseudoexfoliation material, zonular and capsular defects, retained lens fragments, etc.

eyes were compared with a comparable cohort of 81 eyes with cataract and glaucoma that underwent phacoemulsification alone. Follow-up ranged from 6 months to 5 1/2 years, from January 2000 through December 2004, with a mean follow-up of 3.2 years. In the phacoemulsification/ECP group, IOP decreased 3.4 from 19.1 to 15.7 mm Hg, whereas in the control group, IOP increased 0.7 from 18.2 to 18.9 mm Hg. In addition, even more significantly, the number of preoperative glaucoma medications decreased from 1.53 to 0.65 at the end of the follow-up period in the phaco/ECP group, but remained unchanged from 1.20 in the phaco alone control group. There were no serious complications in either group, and the incidence of CME was equal in both groups (approximately 1%).

Another study involving more than 1000 eyes confirms our results and shows no difference in angiographic CME between eyes undergoing phacoemulsification/ECP as compared with phacoemulsification alone (approximately 2% in both groups).12

In 1997, Chen et al13 reported a 90% success rate for treating refractory glaucoma in 68 eyes with ECP, with a mean follow-up of 13 months. Success was defined as final IOP of 21 mm Hg or less. There was a mean decrease in IOP of 34% along with a mean decrease in glaucoma medications by 38%. The mean area of ablation was 300 degrees. Visual acuity was stable or improved in 94% of eyes, and there were no devastating complications. The 7 eyes that “failed” had a higher preoperative IOP. Four of the 7 had a 20% decrease in IOP. 2 had ECP for relief of pain only, and 1 with NVG declined a second procedure.

Since then, the ECP Collaborative Study Group14 performed an analysis of short- and long-term complications with a range of follow-up from 1 to 13 years and a mean of 5.2 years (Table 2). Five categories of glaucoma were studied with a total of 5824 eyes. Our analyses of the 626 eyes are included in the 2193 eyes that underwent phacoemulsification/ECP for medically controlled glaucoma and cataract. The incidence of serious long-term complications, as well as transient short-term complications, was very low and occurred primarily in the NVG and refractory glaucoma groups. This study shows the relative safety of ECP for all types

### TABLE 2 (continued). ECP Collaborative Study Group: Complications in 5824 Eyes

<table>
<thead>
<tr>
<th>Choroidal hemorrhage</th>
<th>Hypotony or phthisis</th>
<th>NLP vision</th>
<th>Cataract</th>
<th>Acute graft rejection</th>
<th>Chronic graft rejection</th>
<th>Chronic inflammation</th>
<th>Endophthalmitis</th>
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<td>32 (32/119)</td>
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<td>0</td>
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<td>3</td>
<td>0</td>
<td>0</td>
<td>151</td>
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</tr>
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<td>2</td>
<td>7</td>
<td>7</td>
<td>78</td>
<td>NA</td>
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</tr>
<tr>
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<td>0</td>
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<td>NA</td>
<td>3</td>
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<td>0</td>
<td>0</td>
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<td>NA</td>
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<td>5</td>
<td>7</td>
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<tr>
<td>0.09</td>
<td>0.12</td>
<td>0.12</td>
<td>24.5 (261/1066)</td>
<td>5.3 (3/57)</td>
<td>0 (0/57)</td>
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</tr>
</tbody>
</table>

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TABLE 4. Tips for Performing ECP

- Treat at least 200 degrees for every case. Treating 270–300 degrees is preferable and can be accomplished with a second clear corneal incision or with a curved endolaser probe. Don’t worry about hypotony—it doesn’t happen.
- Treat the entire ciliary process from top to bottom, as well as the space between processes (the “valleys” between the “hills”).
- Treating eyes with pseudoxfoliation is more difficult because the ciliary processes are smaller, aberrant, and covered with white pseudoxfoliation material. It may be necessary to increase the power from 3.0 to 3.5 or 4.0 W, or to move the tip of the endolaser probe closer to the target tissue.
- Spend a few extra moments removing ALL viscoelastic from inside the eye, including in front of and behind the iris, as well as from behind the IOL.
- Monitor patients for postoperative pressure spike within the first 24 h postoperatively, and possibly even 3 h postoperatively. Treat all patients with a topical glaucoma medication and oral Diamox (acetazolamide) 500 mg sequl immediately postoperatively.
- If IOP is lower, taper off glaucoma medications. It may take 4–6 wk to see the full effect of the procedure.
- Some phacoemulsification/ECP patients appear exactly the same as phacoemulsification-alone patients and can be treated with the standard regimen of topical steroid and nonsteroidal anti-inflammatory agent QID for 2–3 wk. Other phacoemulsification/ECP patients may exhibit increased inflammation and are treated more intensively with anti-inflammatory agents for a longer period.

of glaucoma, particularly when compared with any other form of glaucoma surgery.

I do not perform phacoemulsification/ECP on every glaucoma patient undergoing cataract surgery. I still do phacoemulsification alone and combined phacoemulsification trabeculectomy on many glaucoma patients. In an average month, I will do 40 cataract surgeries, and approximately 10 eyes will have glaucoma. Of these 10 eyes per month, I will perform phacoemulsification alone on 25%, phacoemulsification/ECP on 50%, and phacoemulsification/trabeculectomy on 25%. Although every patient is evaluated on an individual basis, my general rule of thumb is as follows.15-17

If a patient has mild, well-controlled glaucoma on a single, well-tolerated glaucoma medication along with cataract, I will perform the phacoemulsification/IOL alone through a clear corneal temporal incision. This preserves the conjunctiva superiorly, in case trabeculectomy is needed in the future (Tables 3–5).

If the patient has moderate glaucoma on 2 or more medications, I would perform phacoemulsification/ECP through clear cornea, in an effort to lower IOP and reduce or eliminate glaucoma medications. Because a clear corneal incision is used with phacoemulsification/ECP, conjunctiva remains undisturbed superiorly, in case trabeculectomy is needed in the future.

Lastly, if a patient has far advanced glaucomatous cupping and visual field loss on maximum medical therapy (2 or more medications), I would perform a phacotrabeculectomy with intraoperative mitomycin C.

Other uses of the endolaser in ophthalmology may be limitless, including closure of a cyclodialysis cleft,18 goniotomy for congenital glaucoma,19 identifying lens remnants in the anterior or posterior segment, and so on.

In summary, ECP should not be considered the same as transscleral forms of cycloablation, which are “blind” procedures that can cause a lot of collateral tissue damage and which can result in overtreatment or undertreatment of the tips of the ciliary processes.

Endoscopic cyclophotocoagulation may not be indicated for some of our cataract patients with very mild or very advanced glaucoma. However, it is a simple and easy addition to our armamentarium to treat glaucoma patients with moderate disease on 2 or more medications.

■ REFERENCES


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