Techniques of Endoscopic Cyclophotocoagulation

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# ABSTRACT
Endoscopic cyclophotocoagulation is an exciting and novel approach to the management of glaucoma. The basic principal is quite simple. Aqueous production (inflow) is diminished by photocoagulating the epithelium of the ciliary processes. The technology, the various technical iterations, the results, and the complications will be discussed.

# HISTORICAL PERSPECTIVE
Inflow reducing surgical procedures have had a sordid history mostly characterized by poor outcomes and substantial complications. Difficulties were mainly due to the lack of direct visualization of the target tissue and by poor control of the destructive force. Collateral damage to healthy tissue from external cyclodestruction leads to significant inflammation and complications. The transvitreal approach to cyclophotocoagulation was first described by Charles, wherein the eye first underwent vitrectomy and lensectomy. The ciliary processes were then scleral depressed into the view of the operating microscope and photocoagulated under direct visualization. The first study of this approach was by Patel and Thompson in a cohort of intractable glaucoma patients treated by this transvitreal method. A high degree of intraocular pressure (IOP) control was obtained with few complications. Unfortunately, this approach to glaucoma treatment is beyond the scope of most ophthalmologists and involves extensive intraocular surgery. Uram devised the notion of combining endophotocoagulation with endoscopic imaging and demonstrated the ability to access the ciliary processes and photocoagulate them from both a limbal or a pars plana approach and depending on the lens status of the patient. The third skill is learning how to properly and adequately inflate the ciliary sulcus. Finally, the surgeon must learn how to use an “invisible” wavelength laser with long duration applications. All of these will be discussed.

# TECHNOLOGY
To benefit from this approach to glaucoma surgery, the practitioner must have an understanding of the basic technology involved. There are 2 sets of components, the first are the laser endoscopes themselves, and the second is the laser and endoscopy console.

Currently, the laser endoscope is a 20-gauge instrument that incorporates a 10,000-pixel image guide with a wide view, a plurality of light fibers, and a single laser fiber. The endoscope may be in a straight or a curved configuration (Fig. 1). This instrument permits delivery of image, illumination, and laser to the target tissue.

The console (Fig. 2) contains a videocamera, light source, and semiconductor diode laser tuned to the 810-nm wavelength.

# TECHNIQUE
The surgeon must acquire 4 skills that are used during ECP. The first of these is that the surgeon views the course of surgery on the video monitor of the endoscopy system (Fig. 3) rather than looking through the operating microscope. This is a foreign experience to most ophthalmologists and requires some adaptation. The second skill is to learn how to access the ciliary processes given an anterior or a pars plana approach and depending on the lens status of the patient. The third skill is learning how to properly and adequately inflate the ciliary sulcus. Finally, the surgeon must learn how to use an “invisible” wavelength laser with long duration applications. All of these will be discussed.

# VIDEO MONITOR VIEWING
The surgeon must place the video monitor adjacent to the operating table in a convenient location so that the image may be viewed from not too great a distance. Typically, the surgeon places the laser and endoscopy system adjacent to the operating room stretcher on the opposite side of where one would place the unit for phaco and/or vitrectomy.

# ACCESSING THE CILIARY PROCESSES
The surgeon must decide whether a limbal or a pars plana approach would be most useful. Most ECPs are performed from a limbal approach; however, a pars plana approach...
can be quite helpful when there is marked disruption of the anterior segment architecture complicating a limbal entry.

**LIMBAL APPROACH**

The ciliary processes may be accessed from an anterior segment incision in the phakic, pseudophakic, or aphakic eye (Figs. 4A, B, 5A, B, and 6A, B) and may be combined with cataract surgery as well.

A basic concept is that if there is a lens posterior to the iris, then one must inflate the sulcus with a sodium hyaluronate viscoelastic. The maneuver opens the potential space that exists between the iris and the anterior portion of the lens permitting access to the processes. One must inject sufficient viscoelastic so as to view the entirety of each ciliary process and view the zonules emanating from the more posterior aspect of the processes. This technique works well to create a wide approach to the processes and protects the posterior aspect of the iris and anterior portion of the lens from contact with the endoscope.

**APHAKIA AND ANTERIOR CHAMBER PSEUDOPHAKIA**

In this scenario, there is no lens to displace behind the iris, and so viscoelastic for this purpose is not required. On the other hand, many of these eyes comprise a “single chamber”; that is, the aqueous flows freely from the anterior to the posterior segment without a separating barrier, and often these eyes have had a least a partial vitrectomy as well. They are prone, therefore, to intraoperative hypotony, which is always undesirable but especially in glaucomatous eyes. It is important therefore to maintain some measure of perfusion by inserting an anterior chamber maintainer at the initiation of surgery with free-flowing balance salt solution into the eye. Once this has been established, then the endoscope may be inserted through a limbal incision through the pupillary space and often will easily and directly view the ciliary processes. Photocoagulation may then be applied.

**COMBINED ECP AND CATARACT SURGERY**

There are several approaches to the ciliary processes via the cataract surgery incision site. One approach is to empty the capsular bag of its contents then inject the viscoelastic “over the bag.” This maneuver collapses the capsular bag and directs it posteriorly while creating a bombe’ effect of the iris. The ciliary processes are then easily seen and photocoagulated. The capsular bag is then reinflated for lens implantation. A variation of the over the bag approach is for the surgeon to perform the
entire phaco-IOL insertion and remove all viscoelastic, as if the surgery were complete. Then a sodium hyaluronate viscoelastic may be injected over the capsular bag containing the lens implant and posterior to the iris, once again opening the potential space that exists in the region of the sulcus and permitting observation and coagulating of the processes. This is the most commonly used method. A third approach is “through the bag.” In this scenario, the capsular bag is emptied of its contents then viscoelastic is injected into the bag. The laser endoscope is then inserted through the pupil into the capsular bag and directed toward the ciliary processes. Although the view is slightly blurred because viewing takes place through the capsular bag, the access to the ciliary processes and pars plana region is quite good. Photocoagulating through the bag has not been reported to create any postoperative difficulties.

**METHOD OF CILIARY PROCESS PHOTOCOAGULATION**

The goal of the surgery is to completely whiten the entirety of each process in the treatment zone and to avoid photocoagulating the posterior aspect of the iris, intraocular prosthetic devices, and other nonaqueous producing tissue. “Popping” the ciliary process represents a

**FIGURE 4.** A, Limbal approach, phakic eye. B, View of ciliary processes from a limbal approach in a phakic eye.

**FIGURE 5.** A, Limbal approach, pseudophakic eye. B, View of ciliary processes from limbal approach in a pseudophakic eye.
tissue explosion with rapid gas bubble formation and pigment dispersion. This is undesirable and should be avoided. Because ECP is performed with a near infrared laser wavelength, there is no visible laser “flash” when it is fired. One uses very long duration applications lasting for many seconds while “painting” the ciliary ring. Because the progress of photocoagulation can be directly monitored and well controlled using relatively low power (200-300 mW) with long duration applications, it is relatively simple to create the desired tissue effect while avoiding the problems previously mentioned.

Most patients require 270 to 360 degrees of treatment to have a reliable, consistent, and long-lasting effect. Less treatment results in variable outcomes. The only exception to this is ischemic eyes, typically those with neovascular glaucoma. In that situation, the surgeon cannot know how much of the ciliary body is nonfunctional before surgery. If there is essentially normal aqueous production in such an eye, then the patient would require the typical extensive treatment, but on the other hand, if, for example, 50% of the ciliary body was nonfunctional and then 360 degrees were to be treated, hypotony might evolve.

**HUMAN HISTOPATHOLOGY**

Endoscopic cyclophotocoagulation can be differentiated from other inflow reducing procedures based on its histologic effect. It has been well documented in multiple studies that ECP is specifically ablative to the epithelium of the ciliary processes and spares underlying structures, especially the vasculature. Because it is applied under direct visualization, other intraocular structures are typically not included in the treatment zone. On the other hand, all of the transscleral modalities of cyclodestruction incorporate all tissue in the treatment region and especially the ciliary body vasculature. In addition, anatomic variation induced either by previous surgery or by development may result in incorporation of the iris or

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**FIGURE 6.** A, Limbal approach, aphakic eye. B, View of the ciliary processes from a limbal approach in an aphakic eye.

**FIGURE 7.** A, Pars plana approach, pseudophakic eye. B, View of the ciliary processes from a pars plana approach in a pseudophakic eye.
retina in the treatment zone with its associated untoward effects.

**DISCUSSION**

Endoscopic cyclophotocoagulation has been used in the treatment of an array of glaucoma mechanisms. These vary from treating ultrarefractory glaucomas that have failed multiple surgeries to combining it with phaco to manage medically controlled glaucoma.\(^5\)\(^-\)\(^23\)

Endoscopic cyclophotocoagulation was first reported by Uram,\(^24\) in the treatment of uncontrolled neovascular glaucoma. Other reports include patients with uncontrolled open-angle, chronic angle closure, postpenetrating keratoplasty, and pediatric mechanisms. In general, successful control of IOP was performed in approximately 90% of treated eyes. Complications that would typically be associated with the transscleral form of cyclodestruction have been reported rarely. In their safety study, the ECP collaborative group reported their findings at the ASCRS 2007. In this study, 5824 eyes were evaluated for complications arising from ECP and stratified according to mechanism of glaucoma. The mean follow-up in this group was 5.2 years. The most commonly observed problem was a postoperative IOP spike being seen in 14.5% of eyes. This was universally caused by retained viscoelastic. Transient intraocular hemorrhage was observed in 3.8% of eyes. Serous choroidal effusion was observed in 0.4% of eyes, and most of these occurred in patients with refractory forms of glaucoma. Intraocular lens displacement was seen in 0.4%, and all of these were seen in either refractory forms of glaucoma or neovascular glaucoma. Cystoid macular edema developed in 0.7%. This finding is in keeping with most series on intraocular surgery and is certainly vastly better than what is typically seen with transscleral forms of destruction where this problem is observed in the 40% to 50% range. Visual loss greater than 2 lines was seen in 1.03%. Retinal detachment occurred in 0.2%. Choroidal hemorrhage, hypotony, phthisis, and progression to no light perception vision were seen in 0.1% of eyes. All of these patients presented with refractory or neovascular forms of glaucoma. Interestingly, no patients with open-angle or pseudoexfoliative glaucoma, postpenetrating keratoplasty glaucoma, or medically controlled glaucoma combined with phaco developed these issues. In addition, no patients in any group developed chronic inflammation or endophthalmitis. Considering the extremely large study cohort with extensive follow-up, it is clear that ECP exhibits a high safety profile and perhaps may be the safest glaucoma surgical procedure.\(^25\)\(^-\)\(^30\) In the post-PK glaucoma group of 57 eyes, 3 patients experienced acute graft rejection with subsequent resolution, and none of the patients were found to have chronic graft rejection and failure. This is significant considering that tube implantation in the setting of post-PK glaucoma has high potential for engendering graft failure.\(^31\)\(^,\)\(^32\)

**COMBINED PHACO-ECP IN THE SETTING OF MEDICALLY CONTROLLED GLAUCOMA**

There is no historical precedent for combining an inflow reducing procedure with cataract surgery. Indeed, it would be inconceivable to perform a brutal transscleral cyclodestructive procedure with sophisticated phaco and intraocular lens implantation. Uram\(^7\) reported the first group of eyes where ECP was combined with phaco and posterior chamber intraocular lens implantation. This proved to be highly efficacious with no significant complications. The first suggestion to combine ECP with phaco in the setting of medically controlled glaucoma was made by Richard Mackool. The goal of this approach was not to lower IOP per se but rather to allow a lower IOP with fewer medications. In his unpublished study of 24 phaco-ECP patients and 22 phaco-alone eyes, 87% of the ECP group decreased their medications whereas only 9% of the phaco-alone eyes did. No significant complications were observed in either group.\(^33\)

Subsequently, this approach to glaucoma treatment has become widespread.\(^3\) Berke et al\(^24\) reported the first cohort of ECP combined with phaco in the treatment of medically controlled open-angled glaucoma in a retrospective analysis. The group reported their findings in a randomized, controlled study of phaco combined with ECP versus phaco alone in the management of medically controlled glaucoma and cataract with follow-up of 3.2 years. They found that the natural history of glaucoma after phaco was a gradual decline in IOP over the course of approximately 18 months only to slowly rise over the following year to slightly higher than initial levels without experiencing a decrease in number of medications used. On the other hand, the phaco-ECP cohort experienced a significantly greater decline in IOP as well as a significant decrease in number of glaucoma medications used that persisted throughout the follow-up period. The treatment group experienced an average decrease of $1500 per year in glaucoma medication expenditure after combined treatment whereas the phaco-alone group did not. This work represented the largest glaucoma surgical study of any type, and the control group by itself represented the largest evaluation of IOP and glaucoma medications after phaco. These findings are supportive of the notion that confronted with the cataract surgery patient who also has medically controlled glaucoma, a better long-term outcome may be performed by adding ECP to phaco both in IOP control and
medication utilization than performing phaco alone and continuing the patient’s regimen of glaucoma treatment. This is especially significant considering that adding ECP to phaco did not increase the risk of complications.

■ CONCLUSIONS
Endoscopic cyclophotocoagulation is a versatile and straightforward technique with a long record of safety and efficacy. It is one that can be rapidly mastered by most ophthalmic surgeons. It is unlike other sophisticated glaucoma surgical procedures that are useful only in uncontrolled forms of glaucoma and with specific anatomic and pathophysiological limitations. Endoscopic cyclophotocoagulation may be incorporated into the practice of most ophthalmic surgeons and may be used on a frequent basis for the treatment of a wide range of glaucoma mechanisms and disease severity.

TIPS ON GETTING STARTED
Your certification course will prepare you for your first cases. A few ideas mentioned here may be helpful.
1. Turn down the room lights and the microscope light as well. This will make visualization of the monitor easier and avoid photo toxicity.
2. Your standard incision for lens insertion should be adequate for the endoprobe. You can lift the superior lip of the incision with any manipulator or start with the probe at 45 degrees to ease entry.
3. Practice viewing the ciliary sulcus on several cataract cases. Keep illumination low at first to avoid washing out anatomic details and the aiming beam. This will get you familiar manipulating the probe while viewing through the monitor. You may be surprised at how much residual cortex you see at the equator.
4. Try to keep 3 ciliary processes in view at all times as you progress. This will help you maintain a consistent working distance and avoid the need to constantly change laser energy. Too close and you have to lower energy to avoid getting excessive tissue reaction, too far and you have to raise power significantly.
5. The tendency at first is to torque the eye while getting at 270+ degrees of treatment. Look back through the microscope periodically to maintain a neutral position, pivoting the probe at the incision. Instruct your scrub to monitor this even when you’ve become familiar with the procedure.
6. I suggest beginning with the straight probe and 2 incisions until you are very comfortable with the procedure. This will facilitate getting a complete treatment.
7. In some surgeon’s hands, 270 degrees can be visualized and treated through a single incision with the curved endoprobe. Practice as above by maintaining a constant viewing distance by rotating the probe with the finger tips as you progress. This will require more active adjustment of the orientation of the image by your laser assistant, so it is all the more important to have someone trained and experienced working with you.
8. Always clean the probe immediately after removing it from the eye. It is critical to hold the probe near the tip, not at the hand piece, to avoid breakage.

■ REFERENCES


