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Diagnostic and surgical techniques

Endoscopic ophthalmic surgery of the anterior segment

Brian A. Francis, MD, MS[a,*], Julie Kwon, MD[b], Ronald Fellman, MD[c], Robert Noecker, MD[d], Thomas Samuelson, MD[e], Martin Uram, MD[f], Henry Jampel, MD[g]

[a] Doheny Eye Institute, Department of Ophthalmology, Keck School of Medicine, University of Southern California, Los Angeles, California
[b] University of Medicine and Dentistry New Jersey—Robert Wood Johnson Medical School, Piscataway, New Jersey
[c] Glaucoma Associates of Texas, Dallas, Texas
[d] Ophthalmic Consultants of Connecticut, Fairfield, Connecticut
[e] Minnesota Eye Consultants, Minneapolis, Minnesota
[f] Retina Consultants of New Jersey, Attending Surgeon, Manhattan Eye, Ear and Throat Hospital, New York, New York
[g] Wilmer Eye Institute, Department of Ophthalmology, Johns Hopkins School of Medicine, Baltimore, Maryland

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ABSTRACT

We summarize the uses of anterior segment endoscopic techniques and the basic science and technology of endoscopic cyclophotocoagulation (ECP) as compared with transscleral cyclophotocoagulation. This is followed by an analysis of patient selection for ECP, a description of surgical techniques, and clinical results. In addition, the ophthalmic endoscope has other uses in anterior segment surgeries. We discuss the techniques for these endoscope-assisted surgeries.

1. Introduction

The endoscopic ophthalmic surgical system gives a unique view of the interior structures of the eye and can be used for a wide variety of anterior and posterior segment surgeries. The system allows for visualization of structures that are not routinely accessible through standard viewing, such as the anterior chamber angle, the ciliary body and its processes, the ciliary sulcus space, and the anterior retina. It may also be useful in eyes with opaque media. Fibertech Co., Ltd. (Tokyo, Japan) produces two viewing only ophthalmic endoscope systems, the AS-611 and the MS-611, the latter having a higher resolution. Another viewing system is the Endognost Vitroptik Flex (Polydiagnost, Pfaffenhofen, Germany), which also has an endoscope and light source, but no laser. The only systems currently approved by the U.S. Food and Drug Administration for use in the United States are the E2 and E4 by Endooptiks, Inc. (Little Silver, NJ), first made available in

* Corresponding author: Brian A. Francis, MD, MS, DEI 4804, 1450 San Pablo Street, Los Angeles, CA, 90033.
E-mail address: bfrancis@usc.edu (B.A. Francis).
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1991. The E4 is an endoscope only. The E2 combines a diode laser with a light source, aiming beam, and fiberoptic camera. The most frequent indication for its use is the treatment of glaucoma with endoscopic cyclophotocoagulation (ECP).

Glaucoma is the most common cause of irreversible blindness worldwide.[36] Although the pathophysiology of glaucoma is multifactorial, the treatment strategy remains essentially one-dimensional: lowering of intraocular pressure (IOP). Medical management involves agents that either improve aqueous outflow or suppress inflow. When surgical intervention is required, the traditional treatment focuses on improving outflow. Procedures that reduce aqueous production have previously been reserved for refractory glaucoma. Recent technological advancements challenge this treatment paradigm, however.

The traditional gold standard for the surgical management of glaucoma has been trabeculectomy or guarded filtration surgery.[47] Such surgery is associated with postoperative complications, however, including over-filtering blebs, hypotony, and cataract.[8,16,18,19,47] Late complications such as bleb infection or endophthalmitis may occur years or even decades later. Aqueous drainage devices are a reasonable alternative to trabeculectomy, with less risk of infection or conjunctiva related complications, but tube shunts also subject patients to significant risks including diplopia, hypotony, corneal decompensation, and tube exposure.[11,18,39,47] More recently, angle-based glaucoma procedures have been introduced such as Schlemm canal stenting or trabecular meshwork ablation by internal approach in attempts to avoid some of these complications; ECP remains the only approach to reducing aqueous production, however.

When first introduced in the 1970s, cyclophotocoagulation was used as a last resort method to lower IOP. The procedure has evolved through much iteration, including both contact and non-contact transscleral delivery systems with various laser platforms. The transscleral approach to cyclophotocoagulation, although effective at lowering IOP, has an unacceptably high rate of chronic inflammation, hypotony, and phthisis, and therefore has limited use early in the disease process. More recently, a more targeted endoscopically guided technique has been introduced. ECP allows delivery of laser energy in a precise and efficient manner so that for many surgeons the indications for cyclophotocoagulation expand to include eyes with better visual potential. Moreover, given that the procedure may be performed through the same incision, many surgeons have used ECP as an adjunct to cataract surgery.[30] This inflow-reducing strategy may be more synergistic to the IOP lowering effect of phacoemulsification than procedures that completely bypass the trabecular meshwork such as trabeculectomy. Additionally, ECP spares the sclera and conjunctiva so that trabeculectomy or aqueous drainage procedure may be performed if needed in the future.[25,43]

ECP uses a diode laser with a wavelength of 810 nm, a 175 W xenon light source, a helium-neon aiming beam, and video imaging integrated into a fiberoptic system delivered through an 19–20 gauge probe. The laser delivery system allows the cilio-ablation to be performed under direct visualization, which helps to titrate the treatment better than the transscleral approach.[43]

2. Basic science and tissue effects of cyclophotocoagulation

Several modalities exist to reduce aqueous secretion, including the traditional method in which the ciliary body is frozen (cyclocryotherapy), transscleral cyclophotocoagulation, and endoscopic cyclophotocoagulation. Cyclocryotherapy sometimes induces severe pain and may be associated with the development of hypotony and phthisis. For this and other reasons, safer laser procedures have been developed for the ablation of ciliary body tissue in the treatment of recalcitrant glaucoma.

The Neodymium:Yttrium Aluminum Garnet (Nd:YAG) laser was originally developed to pass a beam of light ($\lambda = 1{,}120$ nm) from a slit lamp onto targeted ciliary body (CB) tissues by passing through the conjunctiva and sclera. The length of the beam's path was shortened subsequently by placing a fiber optic probe in contact with the conjunctiva and sclera and focusing the laser light onto the CB tissues. When used in ciliary body applications in continuous mode, the Nd:YAG laser causes a thermal disruption of structural molecules such as proteins that results in coagulation of the targeted tissues. The diode laser emits a beam of light ($\lambda = 810$ nm) that is well adsorbed by melanin chromophores in the CB tissues, generating sufficient thermal energy to coagulate them. The diode laser beam can be applied by either passing the laser light transsclerally (TCP) or directly onto the CB process by using the endoscopic delivery system (ECP).

The energy requirements for the laser procedures differ widely due to the distance and pathway from the light source to the targeted tissues (i.e., transscleral vs direct photocoagulation), and the wavelength of light applied (i.e., 1,120 vs 810 nm).[45] The lesions produced in the eyes of patients undergoing laser ablation may also mirror these differences in the energy levels applied. Histopathological analyses have been performed on the effects of these procedures in vivo and postmortem. The results range from contact and non-contact TCP to ECP diode in human and animal, living and enucleated eyes.

2.1. *Normal ciliary body architecture*

The ciliary body and processes form the pars plicata and consist of the non-pigmented (NPCE) and pigmented ciliary epithelium (PCE), which rest on a loose connective tissue, or stroma, that contains numerous capillaries and some fibrocytes and melanocytes. The NPCE is the monolayer of cuboidal cells located internally facing the posterior chamber, and the PCE is the monolayer of cells containing numerous melanin granules that is located more externally facing the ciliary body stroma. The two monolayers interact with each other along the apical surface and contain basement membranes along their basal surface. The NPCE and PCE work in concert in the aqueous formation process.

2.2. *Histopathology of transscleral cyclophotocoagulation*

McKelvie and Walland studied nine human eyes that had been treated with diode laser TCP in vivo and subsequently