A Comparison of Neodymium:Yttrium Aluminum Garnet and Diode Laser Transscleral Cyclophotocoagulation and Cyclocryotherapy


Cyclodestructive procedures are done in selected patients in whom conventional filtering surgery either previously failed or was not indicated. Over the past several decades, cyclocryotherapy was the cyclodestructive procedure most commonly performed. However, several laser cyclodestructive techniques recently were described, using either the neodymium:yttrium aluminum garnet (Nd:YAG) or semiconductor diode laser energy.

In this study, we compared the gross and histologic changes in the ciliary body, crystalline lens, intraocular lens, and capsular bag of cadaver eyes, using various treatment parameters of these cyclodestructive techniques. Our results were evaluated using a modified Miyake posterior photographic technique and light microscopy.

Materials and Methods

Eight eyes, obtained within 36 hr of death, were prepared according to the Miyake posterior photographic technique by transecting the globe anterior to the equator and filling it with 1% hyaluronic acid. This technique was modified from the method used in previous reports to allow real-time posterior photographic imaging of transscleral cyclodestructive laser applications from a slit-lamp apparatus.

In four of the eyes evaluated in this study, the lens nucleus was removed by manual extraction, followed by aspiration of cortical material. A one-piece polymethylmethacrylate posterior chamber intraocular lens 12.5 mm in length with a 6-mm diameter optic was implanted in the capsular bag.

Cyclocryotherapy was applied to −80°C with nitrous oxide gas (Frigitronics, Coral Gables, Florida) and 2 mm posterior to the surgical limbus with slight pressure on a 2.5-mm diameter probe tip. Separate applications were done for 1, 2, 4, and 8 min.

A Microrupter 2 (Lasag, Eden Prairie, Minnesota) was used for the Nd:YAG transscleral cyclophotocoagulation. This laser has a wavelength of 1064 nm and was used in the thermal mode with a maximum defocus. Laser applications were evaluated that were aimed 0.5, 1, and 2 mm posterior to the surgical lim-
bus as measured by Castroviejo calipers. Also, energy levels of 2, 4, 6, and 8 J were studied. Applications were made with the eye perpendicular to the laser beam without a contact probe or contact lens.

The Microlase (Keeler, Broomall, Pennsylvania) was used for semiconductor diode laser transscleral cyclophotocoagulation. This is a portable photocoagulator with two infrared laser diodes with wavelengths of 780 to 830 nm. We applied laser burns 0.5, 1.0, and 2 mm from the surgical limbus as measured by Castroviejo calipers. In addition, we varied the depth of focus by first placing burns aimed at the scleral surface, then 1 and 2 mm posteriorly, by moving the slit-lamp apparatus toward the cadaver eye as measured with a millimeter rule. Spot sizes of 100, 200, and 500 μm were evaluated. Power settings of 1000 and 1200 mW were studied as were pulse durations of 0.2, 0.4, 0.5, 0.6, 0.7, and 1 sec. The laser was applied with the eye perpendicular to the laser light without using a contact lens or contact probe.

Cyclodestructive lesions were evaluated grossly by three independent observers (EIA, HLH, and UFCL) using 35-mm transparencies and videotape. For laser transscleral cyclophotocoagulation, ciliary process blanching and shrinking and pigment dispersion were believed to represent effective laser burns because they probably indicated destruction of the ciliary body epithelium and stroma. With cyclocryotherapy, ice-ball formation at the ciliary processes was considered to represent effective destruction of the ciliary body epithelium. For each cyclodestructive procedure, the effect on the crystalline lens, intraocular lens, and capsular bag also was noted.

Histologic evaluation was done by first fixing the cadaver eyes with 10% buffered neutral formalin.

Fig. 1. Gross photograph of a posterior view of an eye after the lens material was removed and a posterior chamber intraocular lens was implanted in the capsular bag. Ice-ball formation occurred after 3 min of cyclocryotherapy from a cryoprobe placed 2 mm from the limbus (left). The ciliary processes and the lens capsular equator are involved in the ice-ball.

Fig. 2. Photomicrograph shows the ciliary body after cyclocryotherapy treatment for 8 min. The stromal matrix appears looser with marked separation of cells compared with the untreated area of the same eye (periodic acid-Schiff, original magnification X40).

After processing and sectioning, the eyes were stained with hematoxylin and eosin and periodic acid-Schiff and examined for thermal or cryogenic destruction in the ciliary body stroma and epithelium. Tissue specimens for areas treated with different cyclodestructive techniques were examined by three independent observers (EIA, UFCL, and DJA) and compared with normal untreated areas of the same eye.

Results

Cyclocryotherapy

Ice-ball formation was observed grossly in the pars plana and ciliary processes 10–15 sec after freezing was begun. The ice ball reached 3–4 mm in diameter by 30 sec. Applications 2 mm from the surgical limbus caused ice-ball formation over the pars plana and posterior ciliary processes. Those 1 mm from the surgical limbus caused ice-ball formation in the anterior and posterior ciliary processes and the crystalline lens, intraocular lens haptic, and capsular bag (Fig. 1). After thawing no gross visible structural alterations were observed. Histologically, compared with untreated areas of the same eye, an increased separation of cells in the ciliary body stroma and epithelium was observed after 8 min of cyclocryotherapy but not after shorter times (Fig. 2).

Nd:YAG Transscleral Cyclophotocoagulation

A thermal reaction in the ciliary body processes was observed with applications aimed 0.5–1 mm behind the surgical limbus using 4–6 J of energy (Fig. 3). Excessive damage (hole formation) was created with 8 J of energy; 2 J caused no thermal effect at the ciliary processes. Applications 2 mm behind the limbus...
showed a thermal effect in the pars plana and posterior ciliary processes only (Figs. 4–6). Histologically the ciliary body stroma showed coagulation necrosis and fragmentation along with separation of the epithelial layers (Figs. 5–7). No gross effects were observed on the crystalline lens, intraocular lens, or capsular bag for any parameter studied (Figs. 3, 4).

**Semiconductor Diode Transscleral Cyclophotocoagulation**

A thermal reaction at the ciliary body processes was observed with applications aimed 0.5–1.0 mm from the limbus using 0.84–1.20 J of energy (Fig. 8). Spot size had little effect on the quality of the lesion produced. Applications 2 mm behind the surgical limbus showed a thermal reaction in the pars plana only. Histologically, the ciliary body stroma showed coagulation necrosis and fragmentation along with separation of the epithelial layers (Fig. 9). No gross effects were observed on the crystalline lens, intraocular lens, or capsular bag for any parameter studied (Fig. 8).

**Discussion**

Cyclodestructive procedures are used in selected glaucoma patients who need a reduction in their intraocular pressure and in whom filtering surgery failed or was not indicated. In the past several decades, cyclo-
Cryotherapy was the most commonly used cyclodestructive procedure. It causes hemorrhagic infarction of the ciliary body, resulting in disorganized ciliary body epithelium, flattened ciliary processes, capillary obliteration, and epithelial fibrosis. Clinically, cyclocryotherapy controls the intraocular pressure in 60–90% of patients, but serious complications, such as phthisis, hypotony, or visual loss may occur postoperatively.

Recently, Nd:YAG transscleral cyclophotocoagulation was introduced. It has a potential advantage over cyclocryotherapy of being able to focus thermal destruction on the ciliary body. In cadaver eyes, blanching of the ciliary processes has been observed grossly, and epithelial disruption with separation from the underlying ciliary body stroma has been seen by light microscopy. Clinically, this procedure controls the intraocular pressure to less than 20–25 mm Hg in 65–86% of patients after one or more treatments; it has similar types of complications as does cyclocryotherapy. Semiconductor diode laser transscleral cyclophotocoagulation has been shown to produce a short-term decrease in intraocular pressure in rabbits comparable to that of the Nd:YAG laser.

We compared directly the effects on the ciliary body and lens structures in cadaver eyes of cyclocryotherapy with Nd:YAG and diode laser transscleral cyclophotocoagulation using a modified Miyake posterior photographic technique and light microscopy. Our study showed that blanching of the ciliary processes was observed with Nd:YAG transscleral cyclophotocoagulation at similar energy levels used in previous reports. A similar reaction also was observed with the diode laser at slightly lower energy levels; this may have resulted partially from the better melanin absorption associated with infrared wavelengths closer to the visible spectrum.

When viewed dynamically, both pigment dispersion and bubble formation were visualized using both types of lasers. The bubble formation we observed may account for the anterior chamber gas seen clinically after some cases of Nd:YAG transscleral cyclophotocoagulation. Both laser transscleral cyclodestructive procedures showed similar histologic features including coagulation necrosis and extensive shrinking of the ciliary processes, with fragmentation and detachment of the pigment epithelium. These effects were not observed grossly or histologically with cyclocryotherapy; this may be a result of the different cyclodestructive effects of this procedure compared with laser cyclophotocoagulation.
The cyclodestructive procedures studied did not affect the crystalline lens, intraocular lens haptic, or capsular bag grossly. A previous study using 8.8 J of energy focused transscerally in cadaver eyes caused thermal damage to the haptic. Our results with cyclocryotherapy and Nd:YAG cyclophotocoagulation also differed from clinical experience where cataract formation was reported postoperatively. This difference may have resulted because of the localized treatment we applied; more extensive treatment may have been done on patients evaluated in studies in which cataracts occurred. Also, clinically uveitis is produced after cyclodestructive procedures, which may promote cataract formation.

The potential usefulness of a modified Miyake technique in studying cyclodestructive procedures also was demonstrated by this study. The energy level required to create a thermal lesion at the ciliary processes with the Nd:YAG laser was similar to earlier studies where cadaver eyes were treated without the Miyake technique. This indicates that 1% hyaluronic acid probably has a minimum influence on the quality of ciliary body lesion produced, but it facilitates both real-time and still photographic imaging.

Our study suggests that diode and Nd:YAG transsceral cyclophotocoagulation produce similar thermal lesions in the ciliary body in cadaver eyes; therefore, they have the potential to produce comparable clinical results. Also, cyclocryotherapy and laser transsceral cyclophotocoagulation may have a minimum acute effect on lens structures when done clinically with the usual parameters. However, laser transsceral cyclophotocoagulation should be approached cautiously in the region of an intraocular lens haptic, especially when sulcus fixation is suspected. Thermal damage to the intraocular lens haptic was found previously in cadaver eyes.

Our results have only theoretic clinical value and do not specify the effects of these procedures when done in patients. This may be true especially for cyclocryotherapy because our study did not reproduce the insulating effects of ciliary body temperature or uveitic blood flow that may limit ice-ball formation. In addition, the procedures studied were not compared with therapeutic ultrasound, which may produce different effects on the ciliary body and lens structures. Further comparative clinical studies are needed to clarify which of these procedures is most useful in reducing the intraocular pressure in patients with glaucoma.

Key words: glaucoma, cyclodestructive procedure, cyclocryotherapy, neodymium:YAG transsceral cyclophotocoagulation, semiconductor diode laser

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References