Picosecond Neodymium:Yttrium Lithium Fluoride (Nd:YLF) Laser Peripheral Iridotomy

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PURPOSE: We evaluated the picosecond neodymium:yttrium lithium fluoride (Nd:YLF) laser for performing peripheral iridotomy of predetermined size and shape in various types of irides.

METHODS: In the first part of the study, we determined operating parameters from performing 60 iridotomies in human cadaver eyes. Subsequently, using the parameters obtained in cadaver eyes, iridotomies were created in eyes of patients with primary angle-closure glaucoma.

RESULTS: In the cadaver eyes, the optimal parameters were a nanosecond cutting power of 0.3 ± 0.3 mJ, 500-μm cutting depth, 50-μm spot separation, 200 to 400 μJ of energy per pulse, 200 to 400 pulses per second, and an focal offset distance. In 15 eyes of 11 patients, iridotomies with well-defined margins and iris were created. Minimal hemorrhage occurred intraoperatively in two of 15 eyes (13.3%), which did not affect the outcome of the procedure. Increases of postoperative intraocular pressure of one hour averaged 3.5 ± 3.1 mm Hg, with an increase of more than 10 mm Hg in these eyes (16.7%), and a maximum of 12 mm Hg. We observed no corneal or vitreal damage.

CONCLUSION: The picosecond Nd:YLF laser seems to be an effective instrument for reliably performing peripheral iridotomies of predictable size and shape using low energy per pulse levels. This laser, unlike the argon laser, is successful independent of iris thickness or color and can easily make a larger iridotomy than is often possible with the Nd:YAG laser.

LASER IRIDOTOMY IS THE INITIAL SURGICAL TREATMENT OF CHOICE IN PRIMARY ANGLE-CLOSURE GLAUCOMA. Since the introduction of laser iridotomy in the 1970s, argon [1] and then the Nd:YAG lasers [2] have been the preferred laser systems for peripheral iridotomies. Complications, including transient increase in intraocular pressure, hemorrhage, inflammation, iridotomy closure, cataract formation, and corneal or vitreal damage, have been reported to occur with both laser systems [3]. Currently, Nd:YAG lasers are often preferred because of the ease of performance, increased success rate, and increased long-term success. However, these are concerns associated with perforating an Nd:YAG iridotomy. Damage to the adjacent anterior segment structures induced by shock waves and cavitation bubbles from high power Nd:YAG laser pulses have been reported [4]. Another disadvantage of the Nd:YAG laser is the unpredictability of the iridotomy size and penetration depth. Iridotomies may be smaller than desirable, which has been reported to result in an acute angle-closure attack despite a patent iridotomy [5].

The neodymium:yttrium lithium fluoride (Nd:YLF) laser can create these situations with minimal thermal damage to surrounding tissues, which is possible because of the low energy per pulse levels.
with short pulse duration time, in the picosecond range, and the high repetition rate. The computer-controlled laser settings allow for controlled tissue removal of a precise size and shape. Additionally, the low energy per pulse levels produce low-amplitude shock waves and smaller cavitation bubbles, possibly resulting in less damage to the adjacent structures. We sought to determine the operating parameters and efficacy of the picosecond Nd:YLF laser for performing peripheral iridotomies.

MATERIAL AND METHODS

A two-part study was performed. The first part involved adult human cadaver eyes, the second, patient eyes. All iridotomies were performed with a Nd:YLF laser, which operates at the near-infrared wavelength of 1,053 nm, emitting pulses of less than 60 picoseconds duration with an energy per pulse level of 25 mJ at an energy per pulse level of 20% in 40% of the repetition rate of up to 1,000 pulses per second. The spot size of the laser beam was 20 μm. A 665-nm iridotomy laser lens (Ocular Instruments, Inc., Bellevue, Washington) was used with the Nd:YLF laser while performing iridotomies both in cadaver and patient eyes.

In the first part of the study, a cadaver eye model that closely simulated in vivo conditions was used before peripheral iridotomies were performed on human cadaver eyes. This model consisted of a reusable container, an artificial cornea (infrared absorption rate, 0.6%) with refractive power and anterior corneal radius of curvature similar to the human cornea, and a fresh cadaver eye (less than 48 hours from donation), which was prepared by removing the cornea and adjusting biomechanical parameters to normal values. An artificial anterior chamber was formed with balanced saline solution. A rand of 15 fresh human cadaver eyes were used in the study. Four iridotomies, 90 degrees apart, at the 11, 2, 5, and 6 clock positions, were performed in each cadaver eye. The main focus and scanning beams of the laser were sharply focused on a point in the peripheral one third of the iris through the Abbe-Abbe iridotomy lens. A 0.3 × 0.3-mm rectangular cutting pattern with 500-μm cutting depth and a focal laser diameter was used for all iridotomies. With 200-mJ energy and 200 pulses per second as a scanning point, we determined the optimal energy per pulse and pulse repetition rate per second to create iridotomies in a controlled fashion. If a full-thickness perforation could not be produced, energy per pulse or pulse repetition rate was increased and the procedure was repeated at an adjacent site. Required number of pulses and total energy level for each iridotomy were recorded. Slit-lamp biomicroscopy was performed on each cadaver eye in utero, postmortem of the iridotomy and to examine the increased crystalline lens for any capsular damage beneath the laser-created area.

After we received approval from the institutional review board, picosecond Nd:YLF laser peripheral iridotomy was performed on 18 consecutive phakic eyes of 11 patients with primary angle-closure glaucoma. Before the laser procedure, each patient underwent a complete ophthalmic examination, including Gonioscopy, visual acuity measurement, application of hemostats, slit-lamp biomicroscopy, and ophthalmoscopy. Central and peripheral anterior chamber depths were measured on the visual axis and 5 mm peripheral to the visual axis, respectively, on digitized Scheimplug images with the Bausch & Lomb Spectralis A-Scan system (Nidek, Fortuson, California). Fluorescein 2% was instilled 15 minutes before the procedure in eyes of patients who were not already on systemic therapy.

After proper informed consent was obtained, under topical anesthesia (proparacaine HCl 1%), one iridotomy was performed in each eye in the peripheral superior or suprasympathetic quadrants through the Abbe-Abbe iridotomy lens. We used a rectangular cutting pattern of 0.3 × 0.3 mm. 500-μm cutting depth, 50-μm spot separation, 300–400-mJ energy per pulse, and a repetition rate of 300 to 600 pulses per second with no focus offset. Intraoperative evidence of successful perforation was manifested by the flow of aqueous humor and pigment from the pupillary to the anterior chamber and nasopharynx was verified by direct slit-lamp visualization of the anterior lens capsule. The required number of pulses, total energy level, and laser application time were recorded. A complete ophthalmic examination, including central and peripheral anterior chamber depth measurements of each eye, was done one hour after the procedure. Postoperatively, patients were treated with prednisolone acetate 1% four times a day for one week and were asked to return for a follow-up visit at one week.
human cadaver eyes (nine blue, four brown, and two hazel irides) with laser settings of 200–400 μJ energy per pulse and 200 to 400 pulses per second (Fig. 1). Direct visualization of the tissue ablation with contact of the tip of delivery was harder with the lower separation rates. Iris thickness influenced the required pulse energy and pulse separation levels needed to create successful trichotomies. Thin, blue irides were easily penetrated with an iris of 200 μJ of energy per pulse and 200 pulses per second. However, in dark, thicker irides these settings were unsuccessful and 300 to 400 μJ of energy per pulse with 300 to 400 pulses per second, repetition rates were required.

Mean total energy levels needed to create successful trichotomies ranged between 131.6 and 987 μJ with a mean of 479.0 ± 190.1 μJ. Mean pulse repetition rate was 330.2 ± 35.8 Hz. No lens capsule damage was noted in any of the eyes.

Eighteen trichotomies were performed in 18 eyes of 11 consecutive patients with primary angle-closure glaucoma. Rectangular trichotomies approximately 0.3 × 0.3 mm in size were created in one session. Fourteen eyes were brown, two eyes were hazel, and two were blue. There were two men and nine women with a mean age of 63.6 years (range, 42 to 86 years). All eyes had previously had, or were judged to be in this state, an acute primary angle-closure attack. Pre- and postoperative intracocular pressure measurements, anterior chamber dimensions, and required mean energy levels are shown in the Table. The differences between the pre- and postoperative central anterior chamber depth (P = .03) and peripheral anterior chamber depths (P < .0001) were statistically significant.
The mean difference between preoperative and one-hour postoperative intraocular pressure was $3.5 \pm 2.1$ mm Hg (range, -5 to 12 mm Hg). A postoperative pressure increase greater than 5 mm Hg was measured in five of 16 eyes (31.2%). In three of 16 eyes (18.7%), no increase greater than 10 mm Hg was found. These eyes were treated with a simple drop of apraclonidine hydrochloride 1% and returned to preoperative levels within two hours.

Required mean total energy level range was 928.5 ± 437.4 mJ (range, 165.2 to 1887.6 mJ) (Table) and mean total pulse number range was 1,357.4 ± 1,068.5 (range, 413 to 4,519). Laser application time ranged between 1.1 and 11.8 seconds with a mean of 4.1 ± 3.3 seconds. All eyes showed a trace of aqueous flare withacentric debris, which resolved within the first 24 hours. Minimal hemorrhage was seen during the procedure in ten of 16 eyes (62.5%), but stopped spontaneously with slight pressure on the contact lens and cleared within the first 24 hours. No corneal or lens capsule damage was noted. The mean follow-up period was 3.6 months (range, one to six months). All the iridectomies remained patent through the follow-up period and no change in the patient was noted in any of the iridectomies over time (Fig. 3).

**DISCUSSION**

**LASER IRIDOTOMY IS CURRENTLY THE METHOD OF choice for peripheral iridotomy in the treatment of pupillary block. Argon laser iridectomies may be difficult to perform in dark, thick irides, and can show because of proliferation of iris pigment epithelium.**

In one study, the picosecond Nd:YLF laser effectively performed laser iridectomies in all patients and patent eyes irrespective of iris color or thickness. Total energy required to perform a iridotomy varied with the thickness of the iris. Relatively high total pulse number and energy levels were required in patients eyes with thick, dark brown irides, while iridectomies

<table>
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<td><strong>ND:YLF IRIDOTOMY IN PATIENT EYES</strong></td>
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<th>TOTAL ENERGY (mJ)</th>
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* A plus (+) sign indicates iris hemorrhage during the iridotomy procedure; a minus sign (−), no hemorrhage.
lower-amplitude shock waves and cavitation bubbles and are expected to cause less damage to the adjacent intraocular structures. A current study suggests that the picosecond Nd:YLF laser pulse results in an approximately sevenfold reduction in the diameter of the shock wave radius, resulting in a reduction in the volume of the shock wave by approximately 390 times less than a nanosecond Nd:YAG laser. Additionally, cavitation bubble diameter is reduced from 1 to 4 mm with nanosecond pulses in 0.08 to 0.7 mm with picosecond Nd:YLF. Frangie, Park, and Aquavella successfully performed these iridotomies in patient eyes using 2-mm-long line patterns of the Nd:YLF laser with no complications. However, required total energy levels were relatively high with a mean of 1,925 J.

This laser allows preadjustment of the cutting depth in case the iris thickness (300 μm). Because recurrence of angle closure has been reported despite a mean 75-μm iridotomy, we performed a rectangular-shaped iridotomy of approximately 300 × 300-μm size with a minimum diameter of 150 to 200 μm in all eyes to prevent further attacks of angle-closure glaucoma. The rectangular pattern allowed selective clearance of micobubbles that nucleated in the defect.

The effectiveness of Nd:YLF iridotomy in patient eyes was confirmed with a significant increase in peripheral anterior chamber depth. Although this study's conclusions are limited by the relatively short follow-up and limited number of patients, no change in iridotomy size was observed through the follow-up period.

In general, required total energy to achieve iridotomies (165.2 to 1,887.6 mJ) in patient eyes with the picosecond Nd:YLF laser was higher than reported energy levels for Nd:YAG laser iridotomies (7 to 200 mJ). However, energy per pulse levels were significantly lower with the Nd:YLF laser (300 to 400 μJ) than Nd:YAG laser. Despite the possible clinical advantages between the treatment of angle in intraocular pressure and total energy level, postoperative intraocular pressure increase percentages were similar in these eyes with Nd:YAG laser.

The other kinds of complications seen in patients were similar to those found with the Nd:YAG laser. Intraoperative laser injuries occurred in one of 18 eyes.
(55.6%) possibly because of direct vessel ligation within the relatively large iridotomy area. However, bleeding was easily stopped with slight pressure on the contact lens and did not prevent the successful completion of the procedure. There was no evidence of damage to the lens capsule, which is consistent with the results of O'Connor. Rodriguez, and Thomas10 that suggest no energy per pulse threshold of 6 mJ with bursts of more than two pulses for lens damage. The major disadvantage of this laser compared to the ND:YAG laser was the relatively long laser application time to the range of a few seconds rather than milliseconds. This did not cause any difficulties for nor patients; however, patient movement not controlled with the contact lens could presumably be a problem. Should this be a concern, the duration of application could be reduced to one or two seconds and repeated applications could be performed to maximize the potential for movement.

In conclusion, using low energy per pulse levels, picosecond Nd:YLF laser seems to be an effective instrument for reliably performing controlled iridotomies of predetermined size and shape. The importance of its characteristics compared to the Nd:YAG and other lasers will need to be assessed in further clinical studies with long-term follow-up.

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REFERENCES


