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Contact Transscleral Neodymium: Yttrium–Aluminum–Garnet Laser Cyclophotocoagulation: Long-term Outcome

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Abstract

Purpose— Contact transscleral neodymium:yttrium–aluminum–garnet (Nd:YAG) laser cyclophotocoagulation (CYC) is a treatment option for advanced glaucoma refractory to alternative treatments. This study determined the long-term efficacy and risks of contact transscleral Nd:YAG laser CYC.

Design— A prospective study was performed with patients with advanced, uncontrolled glaucoma who received CYC from 1988 through 1989.

Participants— Records for 68 eyes of 64 patients were obtained and reviewed for the 10-year follow-up.

Methods— A transscleral continuous-wave Nd:YAG laser was used for photocoagulation of the ciliary body.

Main Outcome Measures— Intraocular pressure (IOP), visual acuity, and second intervention. Failure was defined as the need for second intervention, IOP of more than 25 mmHg, or IOP of less than 3 mmHg.

Results— The mean follow-up period was 5.85 ± 4.0 years (range, 0.1–10 years). The mean preoperative IOP of 36.3 ± 10.1 mmHg decreased to 22.6 ± 11.3 mmHg at 1 year of follow-up ($P < 0.001$). The mean postoperative IOP at 5 years was 21.8 ± 13.3 mmHg ($P < 0.001$) and was 18.9 ± 12.2 mmHg at 10 years of follow-up ($P < 0.001$). A second intervention after CYC was required in 30 eyes (44.1%). Six eyes (8.8%) with initial visual acuity of counting fingers or worse progressed to no light perception, and 5 of 8 eyes (62.5%) with visual acuity better than 20/200 lost 2 or more Snellen lines. Hypotony developed in 3 eyes (4.4%). Overall, the failure rate by 10 years of follow-up was 51.5% (35/68 eyes).

Conclusions— Cyclophotocoagulation resulted in a significant reduction of IOP after surgery at 1, 5, and 10 years of follow-up; however, 51.5% of eyes failed by the end of 10 years, with most failures occurring within the first year (40%). Although CYC provides a useful method to lower IOP significantly, this study suggests that its success in controlling IOP is tempered by its failure rate and risk of complications, including visual loss, phthisis, and loss of light perception.

Transscleral neodymium:yttrium–aluminum–garnet (Nd: YAG) cyclophotocoagulation (CYC) is effective in treating glaucoma refractory to medical or surgical treatment.^{1–3} Because

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of its lower rate of complications compared with cyclocryotherapy (CCT), use of Nd:YAG laser transscleral CYC has become more widespread in the past decades. Several studies have shown the efficacy of Nd:YAG CYC in treating glaucoma, with intraocular pressure (IOP) reduction in 59% to 73% of cases.^{1–4} Complications, including hypotony, malignant glaucoma, inflammation, hemorrhage, phthisis, and visual loss, have been reported in patients after both CYC and noncontact Nd:YAG laser CYC (NCYC).^{5–7} In previous papers, we reported our early and midterm results of CYC where a higher incidence of hypotony and visual loss and a greater need for retreatment were more apparent with longer follow-up.^{1,2} Dickens et al³ and Wright et al⁸ also showed successful IOP lowering, with a significant incidence of visual loss after long-term follow-up of patients treated by NCYC. The purpose of this study was to assess the results and complications associated with contact transscleral Nd:YAG CYC 10 years after the initial intervention.

Materials and Methods

Patient Selection

Contact Nd:YAG laser CYC was performed on 140 eyes of 136 patients from 1988 through 1989. The records of 68 eyes of 64 patients, beginning after initial treatment was administered, were obtained and reviewed for this 10-year follow-up study. Seventy-two eyes (51%) of the original study group were lost to long-term follow-up. Of these patients, 23 died; 17 patients changed their physicians because either the patient or physician relocated to another area, and their data were unavailable for review. Data could not be retrieved for 7 patients because of a change in the medical record system. Twenty-one additional patients were lost to follow-up for reasons including inaccurate contact information, incomplete patient data, or unavailable records. Four patients requested withdrawal from the study and therefore were excluded from analysis. Baseline characteristics of the participants in the initial group were compared with the characteristics of the participants in the current study to examine possible selection bias.

All treatments were performed according to the protocol outlined below, and the patients were followed up prospectively. The patients undergoing CYC had glaucoma refractory to conventional treatment and were receiving the maximum-tolerated medical therapy. No entry criteria regarding absolute IOP or visual acuity (VA) were used. The treatment protocol was reviewed and approved by the Human Studies Committee of the Institutional Review Board of the Massachusetts Eye and Ear Infirmary. All patients consented to participate in the study after the nature of the treatment and the study was explained fully. This study was performed in keeping with the principles of the Declaration of Helsinki.

Laser and Delivery System

All laser treatments were carried out using a continuous-wave Nd:YAG laser with a 600- μ m quartz fiberoptic contact probe (Surgical Laser Technologies, Inc., Malvern, PA). The probe tip was 2.2 mm in diameter and was made of synthetic sapphire.

Study Protocol

The treatment technique was described in detail previously.¹ The treatment consisted of delivering 32 to 40 applications of 7 to 9 W of energy for 0.7 seconds each, with the anterior edge of the probe positioned 0.5 to 1.5 mm posterior to the limbus. The 3-o'clock and 9-o'clock meridians were not treated to avoid damage to the long posterior ciliary arteries. The surgeons performing the treatments were permitted to vary the treatment power, number of applications, or the probe distance from the limbus at their discretion. Patients then were examined several times within the first postsurgical year and annually, or as clinically indicated thereafter. Hypotony was defined as an IOP of less than 3 mmHg, and failure of the treatment was defined

as the need for second intervention, IOP of more than 25 mmHg, or IOP of less than 3 mmHg at the end of follow-up.

Retreatment

Fourteen patients (21.9%) received more than 1 treatment each (mean, 1.4 ± 0.8 ; range, 1–5). Of these, 12 patients had 1 eye retreated with CYC once each, 1 patient had 1 eye retreated twice, and 1 patient had 1 eye retreated 4 times. Five patients had 2 eyes treated. Retreated eyes were considered to be continuations of the first treatment for statistical analysis purposes and were analyzed with the rest of the study population.

Race

Fifty-four patients were white (84.4%) and 10 patients were of ethnicities including African American, Hispanic, and Asian.

Additional Interventions

Additional surgical intervention, other than repeat CYC, was required in 30 patients (Table 1). Data collection was terminated for these patients at the date of such intervention.

Statistical Analysis

The data were analyzed using a commercial statistical software package.⁹ A 2-tailed Student's *t* test and Pearson's correlation analysis were used for comparison between pretreatment and post-treatment measurements. A chi-squared test was used to compare baseline characteristics of the current study group with those of the original study group. A significant value was taken to be one at which $P \leq 0.05$.

Kaplan-Meier survival analysis was used to determine the outcome of the surgical intervention. Retreatments were classified as continuations of the initial treatment. Thus, each eye was considered to be a single case even if it had received more than 1 treatment.

Results

The characteristics of the study population at the baseline visit are presented in Table 2. Five types of glaucoma were present in this population (Table 3).

Twenty of 68 eyes (29.4%) had previous glaucoma laser treatment before CYC. Altogether, 60 eyes (88.2%) had a history of previous eye surgery. These prior surgical treatments included filtering surgery in 27 eyes, CCT in 10 eyes, diode laser CYC in 4 eyes, scleral buckling in 7 eyes, vitrectomy in 7 eyes, and penetrating keratoplasty in 9 eyes. There were 31 phakic eyes, 24 pseudophakic eyes, and 12 aphakic eyes.

Baseline characteristics of the current study group were compared with the original study group. No significant differences were found between groups for age ($P = 0.053$), race ($P = 0.58$), pretreatment IOP ($P = 0.66$), number of pretreatment medications ($P = 0.87$), and previous glaucoma laser treatments ($P = 0.59$). The glaucoma subtypes and lens characteristics were similar between groups as well.

Intraocular Pressure

Cyclophotocoagulation resulted in a significant reduction in IOP at 1, 5, and 10 years of follow-up (Table 4). The mean pretreatment IOP was 36.3 mmHg. Based on the IOP value recorded on the final visit for each eye, the overall mean IOP decreased to 22.0 mmHg. The IOP changes between the pretreatment measurements and the last visit measurements are presented in

Figures 1 and 2. A significant correlation was found between preoperative IOP and final IOP levels by Pearson correlation analysis ($r = 0.27$, $P = 0.039$). Of 58 eyes, the CYC procedure reduced IOP to 3 to 25 mmHg in 62.1% (36 eyes), to 3 to 22 mmHg in 56.9% (33 eyes), and to 3 to 19 mmHg in 50.0% (29 eyes) during the mean follow-up period of 5.85 years. This corresponded to an overall IOP decrease of 39.4% from the mean pretreatment IOP ($P < 0.0001$). Final visit IOP data could not be obtained for the remaining 10 eyes.

Among the 28 eyes that completed a 10-year follow-up, CYC reduced IOP to 3 to 25 mmHg in 78.6% (22 eyes), to 3 to 22 mmHg in 71.4% (20 eyes), and to 3 to 19 mmHg in 60.7% (17 eyes). The mean pretreatment IOP in this group was reduced from 32.0 ± 9.5 mmHg to 18.9 ± 12.2 mmHg, a decrease of 41.7% ($P < 0.001$) after 10 years (Table 4).

Neovascular glaucoma (NVG) patients had a higher mean pretreatment IOP than the non-NVG group, but there was no significant difference between the groups for IOP at the last follow-up visit (mean NVG pretreatment IOP, 42.2 mmHg; non-NVG IOP, 34.2 mmHg; $P = 0.03$; mean NVG final IOP, 23.9 mmHg; non-NVG final IOP, 20.9 mmHg; $P = 0.49$). Although the mean IOP reduction in the NVG patients was significantly greater than in the non-NVG patients (decrease in NVG IOP, 18.3 mmHg; non-NVG IOP, 13.3 mmHg; $P < 0.001$), the percent decrease in IOP was not different between the 2 groups (percent decrease in NVG IOP, 39.5%; non-NVG IOP, 34.9%; $P = 0.68$).

Nonprimary open-angle glaucoma patients had significantly greater pretreatment IOP than primary open-angle glaucoma (POAG) patients (pretreatment non-POAG IOP, 38.2 mmHg; POAG IOP, 32.9 mmHg; $P = 0.043$). The postoperative IOP difference between these 2 groups was not statistically significant (postoperative non-POAG IOP, 20.3 mmHg; POAG IOP, 24.4 mmHg; $P = 0.29$). Similar to the previous studies, nonprimary open-angle glaucoma patients had a significantly greater magnitude of reduction and percent decrease in IOP than POAG patients (mean decrease in non-POAG IOP, 16.0 mmHg; POAG IOP, 7.3 mmHg; $P = 0.022$; percent decrease in non-POAG IOP, 42.7%; POAG IOP, 23.5%; $P = 0.046$).

Patients who had a history of penetrating keratoplasty (PK) had a significantly greater reduction in IOP than those who had not undergone PK (decrease in IOP, 21.4 mmHg in PK and 13.4 mmHg in non-PK patients; $P = 0.027$).

Comparing phakic versus aphakic or pseudophakic patients, the differences in pretreatment IOP and IOP response to CYC were not statistically significant (pretreatment phakic IOP, 38.3 ± 10.6 mmHg; pseudophakic or aphakic IOP, 34.6 ± 9.6 mmHg; $P = 0.14$; postoperative phakic IOP, 20.2 ± 14.3 mmHg; pseudophakic or aphakic IOP, 23.6 ± 13.4 mmHg; $P = 0.35$). This corresponds to an IOP reduction of 43.6% in the phakic group and 30.4% in the pseudophakic and aphakic group (mean decrease in phakic IOP, 16.7 mmHg; pseudophakic and aphakic IOP, 10.5 mmHg; $P = 0.11$).

There was no significant difference in IOP effect (mmHg) for patients 40 years of age or younger or for patients more than 40 years of age ($P = 0.26$). In addition, there was no significant difference between the treatment results of the various surgeons.

Hypotony

Table 5 summarizes the cumulative results of complications that developed after Nd:YAG laser CYC treatment. Three eyes deteriorated to having an IOP of less than 3 mmHg and were classified as having hypotony. These eyes became hypotonic at 1, 2, and 7 years after the procedure. The pseudophakic eye with hypotony at year 1 had a primary diagnosis of NVG, with a pretreatment IOP of 40 mmHg and a post-treatment IOP of 0 mmHg. The pseudophakic eye that became hypotonic at year 2 had a diagnosis of POAG, with a pretreatment IOP of 26

mmHg and a post-treatment IOP of 0 mmHg. During year 7, a phakic eye with NVG became hypotonic. This eye had a pretreatment IOP of 42 mmHg and a post-treatment IOP of 1 mmHg. There was no significant difference between the mean pretreatment pressures of eyes that became hypotonic and those that did not (hypotony: preoperative IOP, 36 mmHg; nonhypotony: IOP, 35.2 mmHg; $P = 0.87$). However, there was a significantly greater change in IOP in eyes that became hypotonic (hypotony: change in IOP, 35.7 mmHg; nonhypotony: change in IOP, 11.9 mmHg; $P = 0.005$). Although all 3 eyes had pretreatment visual acuities of counting fingers or worse, none of the hypotonic eyes lost light perception.

Visual Acuity

Overall, 6 eyes (8.8%) had VA of no light perception (NLP) by the 10-year follow-up (Fig 3). One of these eyes had a pretreatment VA of NLP. Four eyes with final VA of NLP had an initial VA of counting fingers or worse. Loss of light perception occurred in 1 eye in year 4, with the remaining 4 eyes experiencing loss of light perception during years 5 through 10 (1 eye each year during years 5, 6, 9, and 10). The pretreatment IOP in the patients with NLP did not differ significantly from the pretreatment IOP of patients with VA better than NLP (pretreatment IOP, 36.6 mmHg in the NLP group; pretreatment IOP, 32.8 mmHg in eyes with VA better than NLP; $P = 0.47$). Three of these eyes had a history of POAG, 1 had NVG, and 2 had chronic angle-closure glaucoma (CACG) or mixed mechanism glaucoma (MMG).

Five of 8 eyes that had VA better than 20/200 before treatment lost 2 or more Snellen lines after treatment (62.5%). All 5 eyes experienced visual loss within the first 3 years after Nd:YAG treatment. Of the eyes with visual loss, 2 had POAG, 2 had CACG or MMG, and 1 had secondary open-angle glaucoma. One patient with CACG or MMG and initial VA better than 20/200 experienced visual loss after 1 year and deteriorated to NLP by year 9.

Second Intervention

Thirty of the 68 eyes (44.1%) required additional intervention by 10 years (Table 5). Table 6 summarizes the number of patients requiring second intervention subdivided into the initial clinical diagnosis. Patients with secondary open-angle glaucoma had the highest rate of second intervention, with 7 of 10 eyes (70%) requiring a second intervention within the 10 years of follow-up (Table 1).

Treatment Failure

Treatment failure was defined as cases in which a second intervention was performed, IOP was more than 25 mmHg, or IOP was less than 3 mmHg (Table 5). At the 1-year follow-up, 27 eyes (39.7%) failed treatment. Of these, 21 eyes received a second intervention, 5 eyes had IOP of more than 25 mmHg (with no second intervention), and 1 eye had IOP of less than 3 mmHg. The additional 4 eyes that failed by year 5 included 3 second interventions and 1 eye with IOP of less than 3 mmHg. By 10 years, 3 additional eyes had a second intervention and an additional eye had IOP of less than 3 mmHg. Thus, 51.5% (35 eyes) failed treatment overall, and 30 of them (44.1%) had received a second intervention. Intraocular pressure of more than 25 mmHg occurred in 1 eye, and IOP of less than 3 mmHg was noted in 4 eyes. Figure 4 demonstrates the Kaplan-Meier survival curve after CYC treatment.

The pretreatment IOP of patients who failed treatment was 38.0 ± 9.0 mmHg. This was not significantly different from the pretreatment IOP of patients who did not fail (IOP, 34.5 ± 11.2 mmHg; $P = 0.16$).

Between diagnostic groups, the failure rate was highest in patients with a diagnosis of secondary open-angle glaucoma (70%; 7 of 10 eyes). Patients with POAG experienced a failure rate of 54.2% (13 of 24 eyes). Neovascular glaucoma patients failed at a rate of 52.4% (11 of

21), and patients with CACG or MMG failed at a rate of 30.8% (4 of 13). Furthermore, patients with NVG seemed to experience failure earlier than those with POAG; 8 of the 9 NVG eyes that required a second intervention failed during the first 5 years of follow-up (Table 6).

Medications

The number of glaucoma medications used before surgery was 3.4 ± 1.0 medications per eye (Table 4). This number decreased to 2.8 ± 1.3 at 1 year ($P = 0.023$). At 5 years, the number of medications remained similar at 2.6 ± 1.3 ($P = 0.015$). The mean number of medications remained unchanged for up to 10 years of follow-up, with 2.6 ± 1.1 medications per eye. This was significantly lower than the number of medications used before treatment ($P = 0.047$).

Discussion

Over the past decades, various cyclodestructive procedures have been performed to treat glaucoma refractory to medical and surgical treatment. Until the mid-1980s, CCT was a standard method of ciliary body destruction because it was an effective means of lowering IOP and was less destructive than diathermy. However, transscleral CYC was demonstrated to be an effective treatment to lower IOP and slowly replaced CCT over time, because it resulted in fewer and less profound side effects than CCT. Both CYC and NCYC have been shown to be useful in treating the different types of glaucomas.^{3,4,10–13}

Currently, 2 laser delivery systems are commonly available: Nd:YAG laser and diode laser photocoagulation. Both lasers can penetrate tissues deeply to destroy the ciliary body, decreasing the amount of aqueous humor produced. The continuous-wave Nd:YAG laser with a wavelength of 1064 nm has a higher scleral transmission (approximately 75%) than the semiconductor diode laser (wavelength, 810 nm; scleral transmission, approximately 35%) with less backscatter than the shorter wavelengths. However, the near infrared light generated by the diode laser has greater absorption by melanin than the longer wavelengths.^{10,14,15} This advantage allows the diode laser to use less energy to produce comparable lesions.

Seventy-two of the 140 eyes (51%) from the original study were lost to follow-up over 10 years. Comparing the baseline characteristics of patients who completed the follow-up and those who did not, we found that both populations had similar baseline characteristics. Thus, it is possible but unlikely that the high dropout rate induced a prominent selection bias or affected the validity of our results. However, we cannot preclude the possibility that our results may be skewed toward patients who had more complications, because these patients required closer monitoring and additional medical intervention. Patients with fewer complications after CYC may not have sought further care and were lost to follow-up. Conversely, it is possible that the group who were lost to follow-up may have experienced worse results than this study group. Those lost to follow-up may have had complications that led them to seek other alternatives or physicians.

Our results suggest that CYC offers long-term success in lowering IOP, but that it is also associated with a significant rate of visual loss, hypotony, and treatment failure. Although the decrease in IOP was statistically significant (Table 4), more than half of all eyes failed treatment by the end of 10 years (Table 5). Complications were more apparent after a longer follow-up period than initial short-term results in this same population had indicated¹; there was a greater need for retreatment and an increased incidence of hypotony and visual loss as time progressed. In a previous paper, we reported midterm results showing that in 9 of 116 eyes, IOP of less than 3 mmHg developed.² Six of these eyes were not included in this long-term study because the patients were lost to follow-up.

Our study showed long-term control of IOP with CYC to be encouraging. Controlled IOP of 3 to 25 mmHg was achieved in 61% of eyes and of 3 to 22 mmHg in 56% after a mean follow-up of 5.9 years (71 months). This success rate is lower than our previous results and is comparable with other CYC and NCYC studies.^{3,4,8,11–13,16,17} Brancato et al¹¹ reported a short-term success rate of 66.6% who achieved IOP of 25 mmHg or less with CYC (mean follow-up, 8.4 months). Other short-term success rates for Nd:YAG laser CYC in reducing IOP have ranged from 52% to 72%.³ Youn et al¹² reported IOP levels between 5 and 20 mmHg in 52% of patients (mean follow-up, 22 months). Trope and Ma¹³ reported IOP levels of 21 mmHg or less in 57% over a mean of 22 months, and Hampton et al¹⁶ had a success rate of 65% for IOP between 7 to 20 mmHg after NCYC. In a long-term study of NCYC, Dickens et al³ found that 65% of eyes (104/160) had IOP levels of 22 mmHg or less after a mean follow-up of 30.5 months.

The success of CYC to control IOP in refractory glaucoma patients is tempered by the significant complication rates. At 10 years, 6 eyes (8.8%), all with initial VA of counting fingers or worse, lost light perception, and 62.5% of eyes with pretreatment VA of 20/200 or better experienced visual loss of 2 or more Snellen lines. Hypotony occurred in 4.4% of eyes. These rates are consistent with other published work on laser CYC.^{3,4,8,10,13,16} Visual loss has been reported to be in the range of 3% to 56%, and hypotony and phthisis have occurred in 0% to 12% of eyes after NCYC.¹⁰ Dickens et al³ showed visual loss in 40% of eyes and phthisis in 6.9%. Trope et al¹³ found that 30% of eyes lost some vision and 10.7% became phthisical. Baez et al¹⁷ reported 19.5% (25) of eyes with a decrease of VA of more than 2 Snellen lines and phthisis in 0.8% (1 eye).

Our current results further suggest that treatment failure may occur in more than half of CYC procedures with a long enough time frame. Few studies report the long-term effects of CYC and NCYC. Dickens et al³ had the longest period of follow-up after NCYC treatment that we could find in the literature, with a mean follow-up period of 30.5 months compared with our mean follow-up of 71 months. Furthermore, the differences in criteria for success and treatment parameters used by different investigators make it difficult to compare study results. Using Kaplan-Meier survival curves, Dickens et al³ estimated that 73% of NCYC procedures were successful at 3 years and that 61% were successful at 4 years. At 5 years, 45% of procedures remained successful. Their criteria of treatment failure were IOP levels of more than 22 mmHg, development of phthisis, or need for trabeculectomy or enucleation. In our study, we defined treatment failure as a second intervention being performed, IOP levels of more than 25 mmHg, or IOP levels of less than 3 mmHg. Using these criteria, we found 54% of eyes successful after 5 years and 48% after 10 years (Table 5, Fig 4).

Several important findings should be noted regarding long-term results in patients after CYC treatment. Approximately 50% of all the treatment failures occur within the first year after treatment, and thereafter the rate of failure stabilizes along the entire period of follow-up (Fig 4). Accordingly, most of the second interventions are performed during the early period of follow-up, and the need for additional intervention is reduced thereafter (Table 5). The highest reduction in IOP occurs in the immediate period after treatment. After the first year, the rate of change stabilizes with a continuous small reduction in IOP along the entire course of follow-up. The number of glaucoma medications decreases during the first year after treatment and remains constant throughout the follow-up (Table 4).

Patients with NVG required a second intervention within the first 5 years of follow-up; this is more prevalent than the period between 5 to 10 years after surgery (Table 6). This finding is more pronounced when compared with the other subgroups, where the division between the first and second 5-year period is more evenly distributed. Although our studies did not show

a significant difference in IOP reduction between NVG versus non-NVG patients, the NVG patients had a higher mean pretreatment IOP than the non-NVG patients.

Patients with secondary OAG have the highest rates of secondary intervention and failure (70%) compared with other groups (31% to 54%), and therefore the decision of using this treatment method for these patients should be weighed accordingly. It is important to note that patients in this study were all treated with CYC when other interventions had failed or were expected to fail; patients in less extreme circumstances may respond differently than those with the severity of disease represented in this study group.

Our analysis did not reveal a significant difference in reduction of IOP among different racial or age groups. There also was no difference in CYC response between phakic and aphakic or pseudophakic patients. However, similar to our original study, patients who had a history of PK experienced a greater decrease in IOP than those who had not had PK. This finding may be explained by underlying or post-PK outflow obstruction that narrows the therapeutic window in these patients. Reducing the inflow by CYC restores the IOP equilibrium. As suggested in the short-term study,¹ CYC is attractive in this setting in light of the surgical difficulties in treating post-PK eyes.

In the study by Youn et al¹⁶ comparing NCYC with diode CYC, there was a statistically significant decrease in IOP after both Nd:YAG and diode laser CYC at 12 months after surgery. There were no significant differences in postoperative IOP or VA change between noncontact Nd:YAG and diode laser procedures, despite the lower energy used with the diode laser. Although the diode laser has technological advantages, including portability, ease of use, and versatility in clinical applications, the need for retreatment in some studies may be a disadvantage of the diode laser.^{10,18} Bloom et al¹⁸ had a retreatment rate of 49% within a mean period of 10 months with diode CYC, compared with a retreatment rate of 21.9% within 71 months in our study. The relative advantages of the diode laser, however, make it a desirable tool for CYC, and the high retreatment rate may be related to the power and duration settings chosen in the various studies reporting treatment outcomes. It is uncertain if our CYC results may be generalized to diode laser CYC, but because both technologies work in a similar fashion, this is likely to be the case. The diode laser is particularly useful for CYC not because it is superior to CYC, but because of its ability to perform multiple ophthalmic photocoagulation procedures. Its lower cost and portability add to its usefulness.

Our study illustrates the long-term effectiveness of CYC for lowering IOP in refractory glaucoma. At the same time, there is a significant risk of visual loss and hypotony associated with CYC, and more than half of our cases required a second intervention or had poor IOP control by the end of 10 years of follow-up. Although most failures occurred within the first year, the number of complications seemed to increase over time. Cyclophotocoagulation remains a viable and useful alternative for treating advanced glaucoma when other medical and surgical treatments fail.

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Figure 1. Scatterplot of pretreatment intraocular pressure (IOP) versus final visit IOP. Solid lines represent the linear regression for the mean and the 95% confidence intervals.

Figure 2. Mean (standard error) intraocular pressure (IOP) measurements after contact transscleral continuous wave neodymium:yttrium–aluminum–garnet laser cyclophotocoagulation over the 10-year follow-up period.

Figure 3. Scatterplot of pretreatment visual acuity (VA) versus final postoperative visit VA. Some points overlaid others and may represent more than one patient. CF = counting fingers; HM = hand movements; LP = light perception; NLP = no LP.

Figure 4. Kaplan-Meier survival curve for contact transscleral neodymium:yttrium-aluminum-garnet laser cyclophotocoagulation. Failure was defined as the need for a second intervention, intraocular pressure (IOP) > 25 mmHg or IOP < 3 mmHg.

Table 1
Number of Eyes Requiring Second Interventions during the Period of Study Follow-up

Procedure	No. of Eyes (%)
Tube shunt	6 (8.8%)
Diode laser cyclophotocoagulation	3 (4.4%)
Trabeculectomy	3 (4.4%)
Enucleation	5 (7.34%)
Cyclocryotherapy	11 (16.2%)
Laser sclerostomy	1 (1.5%)
Bleb revision	1 (1.5%)
Total	30

Table 2**Baseline Characteristics of the Study Population**

	No. of Eyes (%)	Mean $\pm$ Standard Deviation (Range)
Age (yrs)	64	54.5 $\pm$ 19.9 (9–82)
$\leq$ 40	18 (28.1%)	
>40	46 (71.9%)	
Follow-up (yrs)	68	5.9 $\pm$ 4.0 (0.1–10)
Gender		
Male	31 (48.4%)	
Female	33 (51.6%)	
Pretreatment IOP (mmHg)	68	36.3 $\pm$ 10.1
Pretreatment medications	67	3.4 $\pm$ 1.0
Pretreatment VA > 20/200	8 (11.8%)	
Previous glaucoma laser treatment	20 (29.4%)	

IOP = intraocular pressure; VA = visual acuity.

Table 3

Glaucoma Subtypes of the Study Population

Primary Diagnosis	No. of Eyes (%)
Primary open-angle glaucoma	24 (35.3%)
Neovascular glaucoma	21 (30.9%)
Secondary open-angle glaucoma	10 (14.7%)
Chronic angle-closure glaucoma or mixed mechanism glaucoma	13 (19.1%)

Table 4
Mean Intraocular Pressure and Number of Medications at Baseline and Follow-up

	Intraocular Pressure (mmHg)		P Value*	Medications		P Value*
	n	Mean (Standard Deviation)		n	Mean (Standard Deviation)	
Pretreatment	68	36.3 (10.1)		67	3.4 (1.0)	
Year 1	49	22.6 (11.3)	<0.001	24	2.8 (1.3)	0.023
Year 5	31	21.8 (13.3)	<0.001	24	2.6 (1.3)	0.015
Year 10	28	18.9 (12.2)	<0.001	15	2.6 (1.1)	0.047
Final [†]	58	22.0 (13.8)	<0.001	26	2.4 (1.2)	0.001

* P value for paired *t* test compared with pretreatment values.

[†] Based on the value recorded for each eye at the final visit.

Table 5

Cumulative Number (%) of Eyes with Vision Loss, Hypotony, Second Interventions, and Failure within the Period of Follow-up

	Eyes with No Light Perception	Hypotony[*]	Second Interventions	Failure[†]
Year 1	0	1 (1.5%)	21 (30.9%)	27 (39.7%)
Year 5	2 (2.9%)	2 (2.9%)	24 (33.8%)	31 (45.6%)
Year 10	6 (8.8%)	3 (4.4%)	30 (44.1%)	35 (51.5%)

^{*} Intraocular pressure < 3 mmHg.

[†] Second intervention, intraocular pressure > 25 mmHg or < 3 mmHg.

Table 6

Second Interventions by Diagnostic Groups

Diagnosis	Intervention during Years 0–5 (%)	Intervention during Years 6–10 (%)	Total (%)
POAG	6/24 (25.0%)	4/18 (22.2%)	10/24 (41.7%)
NVG	8/21 (38.1%)	1/13 (7.7%)	9/21 (42.9%)
SOAG	5/10 (50.0%)	2/5 (40.0%)	7/10 (70.0%)
CACG/MMG	2/13 (15.4%)	2/11 (18.2%)	4/13 (30.8%)
Total	21/68 (30.9%)	9/47 (19.1%)	30/68 (44.1%)

CACG/MMG = chronic angle-closure glaucoma or mixed mechanism glaucoma; NVG = neovascular glaucoma; POAG = primary open-angle glaucoma; SOAG = secondary open-angle glaucoma.