Low-Energy Transscleral Diode Laser Cyclophotocoagulation: Is It Effective?

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ABSTRACT

Purpose: To evaluate short-term effects of low-energy transscleral diode laser cyclophotocoagulation (TSCPC) in refractory glaucoma patients and compare the results with the literature.

Materials and Methods: Between October 2017 and May 2021, cases that underwent TSCPC for refractory glaucoma were retrospectively analyzed. Total energy application of 80J and lesser levels per eye are defined as low- energy and those eyes treated with low-energy included. Characteristics of the patients and eyes, preoperative and postoperative visual acuity, intraocular pressure levels (IOP), antiglaucomatous molecules, number of laser sessions, and laser settings were recorded. Preoperative and postoperative data compared with paired groups t-test and Wilcoxon signed-rank test.

Results: Low-energy TSCPC was applied to 23 eyes. Nineteen of patients were male (82.6%). In eyes undergoing TSCPC, visual levels were counting fingers at 1 meter in 1 patient (4.3%), hand movement in 7 (30.4%), light perception(+) in 8 (34.7%) and light perception (-) in 7 patients (30.4%). 17 patients (73.9%) had neovascular glaucoma and 7 patients (26.1%) had secondary glaucoma other than neovascular glaucoma. The mean preoperative IOP values of the patients were 34.3±6.7 mmHg, and the mean number of antiglaucomatous drugs used was 3.6 ±0.5. Mean total energy applied per eye was found to be 37.6±19.1 J (9.6-80). Postoperative 1st day, 1st week, and 2nd month mean IOP values were 31.9, 26.0, and 23.9 mmHg, respectively ($p<0.05$). The mean number of drugs in the postoperative 2nd month was 2.7±0.7($p<0.001$).

Conclusion: Low energy TSCPC reduces IOP and drug exposure in eyes with refractory end-stage glaucoma.

Keywords: refractory glaucoma, transscleral cyclophotocoagulation, intraocular pressure.

INTRODUCTION

Refractory glaucoma is a type of glaucoma that has restricted visual potential and treatment modalities are offered to preserve remaining vision, to lower the medical burden of the eye, or to palliate painful red eyes. Glaucoma drainage tube implantation, trabeculectomy, and cycloablative procedures are among the treatment options. In selected cases, cycloablative procedures are more advantageous as they are less invasive, cheaper, and technically easier. Transscleral diode laser cyclophotocoagulation (TSCPC), endoscopic cyclophotocoagulation (ECP), and micropulse transscleral diode laser cyclophotocoagulation (MP-TSCPC) are the cycloablative procedures that are most commonly used in recent years.

TSCPC utilizes diode laser energy to destroy the ciliary body epithelium and reduces the production of aqueous humor thus intraocular pressure (IOP) decreases.[1-3] A diode laser emits light that is near the infrared spectrum of light at a wavelength of 810 nm. The laser light is absorbed by the melanin pigment in the ciliary epithelium. Thus, the energy emitted from TSCPC targets melanin and leads to coagulative tissue changes in both the pigmented and non-pigmented epithelium, so the rate of aqueous humor production decreases.[4-5] Meanwhile, collateral damage to adjacent structures including the ciliary stroma and ciliary muscle may occur.[5] This is the reason why some postoperative complications like uveitis, vision loss, chronic hypotony, phthisis bulbi, and sympathetic ophthalmia are seen. Because of the risk of these complications, TSCPC is generally reserved for the end-stage refractory glaucoma.

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The total amount of energy used, the type of glaucoma, iris color, age, sex, and previous surgeries may affect complications.[6] Concerns about postoperative complications must be balanced against overall efficacy, as studies show 40-80% mean intraocular pressure (IOP) reduction can be obtained.[7-9] Some studies reported a strong correlation between complications and the number of laser burns and total energy applied.[6-10] Ishida et al[6] reported that TSCPC-related complications rarely occur below the energy levels of 80 mj.

To reduce complications of TSCPC, the micropulse diode laser system is developed recently. The system has an "on" cycle in which multiple (microsecond) repetitive bursts of laser are emitted and an "off" cycle.[2] While on-cycles causes an increase of thermal energy in pigmented tissues, inducing coagulative necrosis, off cycles provide the non-pigmented tissues to never attain a coagulative threshold and also some time to cool off during the "off" cycle. In this way, "off" cycles provide IOP reduction for the eyes with lesser laser duration and lower energy levels.[2]

In the current study, we aimed to investigate continuous-wave TSCPC surgeries with low energy levels within the scope of energy applied, IOP reducing effect, and complications.

MATERIALS AND METHODS

Patients who underwent continuous-wave transscleral diode laser cyclophotocoagulation (TSCPC) from October 2017 to May 2021 in one tertiary ophthalmology clinic were reviewed retrospectively. Data belonging to the patients were collected from the hospital records. We determine the low energy TSCPC when the energy applied per eye per session was less than 80 J.[6] Energy applied per eye per session was calculated and all procedures under the energy level of 80 J were included in the study. All cases with the available preoperative, operative, and postoperative at least 2 months of data included for the analysis. Any visual levels including light perception (-), patients of any age, and any etiology including neovascular glaucoma, primary and secondary glaucoma were included. In the case of unavailable data, we did not include the case in the study. Demographic characteristics of the patients, glaucoma type, vision, past eye surgeries, preoperative IOP, preoperative glaucoma medications, postoperative 1st day, 1st week, and 2nd month IOP readings, 2nd month vision, drugs used, and any complications related to TSCPC procedures were noted.

All procedures were performed in the operating room by the same glaucoma surgeon under the retrobulbar regional anesthesia (except for one pediatric patient who had general anesthesia)using 3.5-5 ml 2% lidocaine and 0.5% bupivacaine mixture. Routine periocular skin cleansing with 10% povidone-iodine and eye draping was followed by eyelid retraction. Then 5% povidone-iodine was applied into the conjunctival sac, left for 2 minutes, and washed away. All procedures were performed by diode laser system (IRIS Oculight SLx, IRIS Medical Instruments Inc., Mountainview, CA, USA machine). The laser was applied 1.2 mm from the limbus by G-probe, approximately 270 degrees, avoiding 3 and 9 o'clock directions to spare long ciliary nerve bundles. In the case of conjunctival bleb or glaucoma drainage device tubes, the laser was not applied to them. Initial laser settings including duration and power were noted. Laser power was increased until the pop sound was heard; if heard, then power was reduced by 100 mW until no sound was heard, and if not maximum settings of 2000mW and 2000ms were applied. At the end of procedures following topical antibiotic ointment and eye patching, the number of shots, laser settings, and whether the pop sound was heard or not were noted. On discharge, topical 1% prednisolone acetate was prescribed for 1 month, and cyclopentolate and nepafenac were prescribed for 1 week. Routine check-up schedules were as 1 day, 1 week, and first and second months. If needed one more session of TSCPC was applied within the 1st month.

The laser settings including laser power in mW, laser duration in ms, number of shots, and complications attributable to the TSCPC were recorded. Total energy applied per eye was calculated by the formula of joule = seconds X watt X number of shots and the effectiveness of the TSCPC and levels of energy and number of laser sessions analyzed. In the case of multiple laser sessions, mean of laser settings are involved in the analysis.

To analyze the effectiveness of TSCPC, we examined IOP and the number of glaucoma medication changes before and after the procedures. All statistical analyses were carried out using SPSS (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.). For all tests, $p < 0.05$ was considered statistically significant. Frequency, percentage, mean±SD, median, and range were used to describe the data. Compliance with normal distribution was investigated with the Shapiro Wilk test. Normally distributed (parametric) paired groups were compared using the paired groups t-test, while paired groups without normal distribution (nonparametric) were compared using the Wilcoxon signed-rank test. This study received local ethical committee approval and obeys the rules of the Declaration of Helsinki and its recent revisions.

RESULTS

Between October 2017 to May 2021, 23 glaucoma patients underwent low-energy continuous wave transscleral diode laser cyclophotocoagulation. Nineteen cases (82.6%) were male, and 4 (17.3%) were female aging between 7 to 84 years (mean 60.52± 21.6). Of the eyes operated, 14 (60.8%) were left and 9 (39.1%) were right eyes. Visual acuity was finger counting at 1 meter in 1 eye (4.3%), hand movement in 7 eyes (30.4%), light perception in 8 eyes (34.7%), light perception negative in 7 (30.4%) eyes. The most common cause of refractory glaucoma was neovascular glaucoma (NVG) accounting for 17 (73.9%) eyes, and the rest had secondary glaucoma other than NVG. Of the eyes, 5 (21.7%) had previous trabeculectomy and 2 (8.6%) had previous tube implantation.

Mean preoperative medicated intraocular pressure measured by applanation tonometry was 34.3±6.7 (18-45) mmHg. The mean preoperative antiglaucomatous medications used, including oral acetazolamide, was 3.6±0.5. Mean laser power was 1406.5±445.5 (500-2000) mW, mean laser duration was 1652.1±351.5 (1000-2000) ms, and the mean shot number was 15.4±2.8 (10-20). The mean energy given per eye was 37.6±19.1 J (9.6-80). The pop sound is heard only in 8 (34.7%) eyes. The mean session number was 1.2±0.5 (1-3) and 5 (21.7%) patients needed more than one session of TSCPC.

IOP measurements are seen in Table 1 and IOP changes at check-up visits are seen in Figure 1. Mean postoperative intraocular pressure was 31.9±5.7 mmHg (19-45); 26±6.6 mmHg (11-38); and 23.9±7.6 mmHg (13-50) on the 1st postoperative day, 1st postoperative week and 2nd postoperative month from the first session, respectively. Preoperative and postoperative 1st day IOP values showed a statistically significant decrease (Paired samples t-test; $p<0.05$) (Table 1). Preoperative and postoperative 1st week

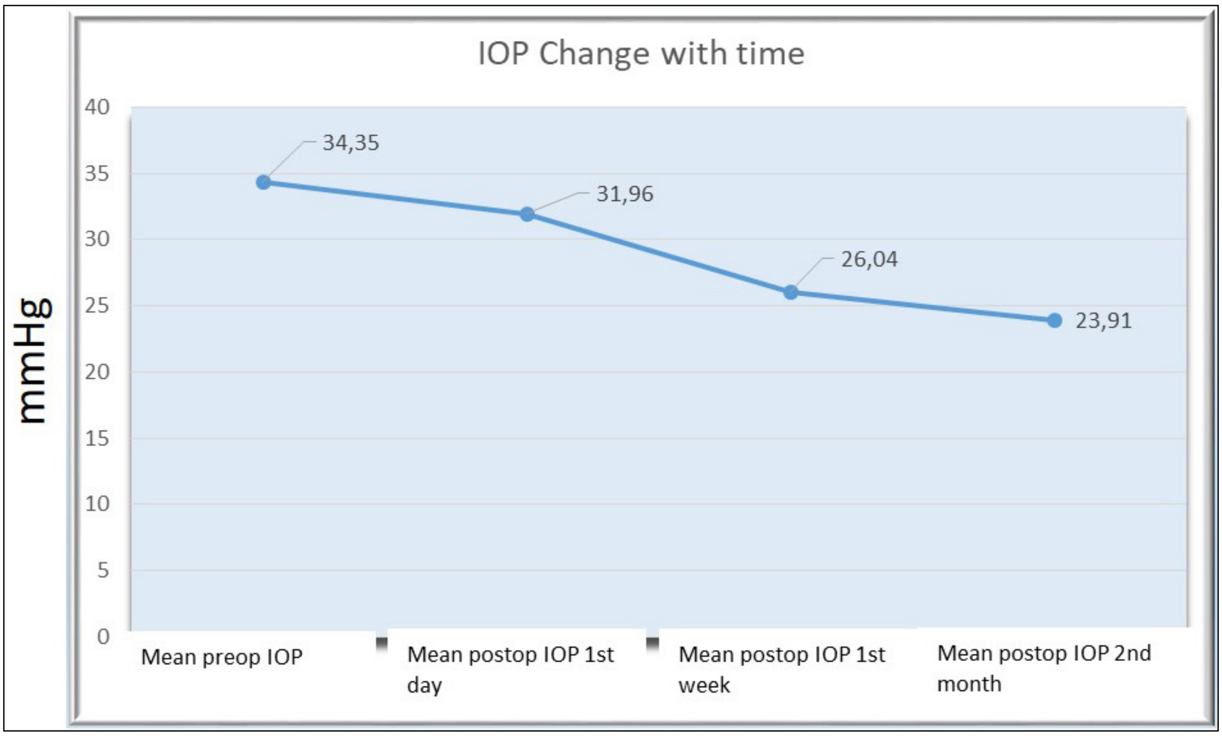

Figure 1: *Preoperative, postoperative 1st day, 1st week, and 2nd month mean IOP change curve.*
Abbreviations; IOP: intraocular pressure, preop: preoperative, postop: postoperative

Table 1: *Preop and postop IOP measurements.*

	N	Min.	Max.	mean	SD	t	p
Preop IOP (mmHg)	23	18	45	34,35	6,7		
Postop 1st day IOP (mmHg)	23	19	45	31,96	5,7	2,190	0,039*
Postop 1st week IOP (mmHg)	23	11	38	26,04	6,6	4,180	<0,001*
Postop 2nd month IOP (mmHg)	23	13	50	23,91	7,6	z -3,287	0,001**

Abbreviations; IOP: intraocular pressure, preop: preoperative, postop: postoperative
*Paired samples t test, **Wilcoxon signed ranks test

IOP values showed also a statistically significant decrease (Paired samples t-test; $p<0.001$) (Table 1). Finally, from the baseline, postoperative 2nd month IOP values had a statistically significant decrease (Wilcoxon signed ranks test; $p<0.01$) (Table 1). At all time points, the reduction in IOP from baseline was statistically significant though it was greatest in the 2nd month. The mean number of antiglaucomatous medications used in the 2nd month was 2.7±0.7 (1-4) which reduced from the preoperative mean number of 3.6 and this reduction was statistically significant (p:0.001).

Complications related to the intervention were seen in 2 (8.6%) patients. One had an epithelial defect treated successfully with medication and the other had an endothelial deficiency and corneal edema requiring corneal transplantation. This patient had end-stage neovascular glaucoma with a history of vitrectomy, multiple intravitreal injections, and Ahmed glaucoma valve implantation.

DISCUSSION

TSCPC is one of the treatment alternatives to decrease IOP in refractory glaucoma patients. Compared to other surgical techniques, TSCPC has several advantages; it is minimally invasive, technically easy, and low cost.[11,12] But because of its potential complications and unpredictable effect, cyclodestructive procedures are only reserved for eyes with poor visual prognosis.[13]

Complications attributable to TSCPC include hypotony, phthisis bulbi, loss of vision, pain, transient IOP increase, atonic pupil, intraocular hemorrhage, cataract formation, pigment dispersion, prolonged inflammation, and uveitis.[11,14] TSCPC provides a reduction in IOP by inducing coagulation necrosis in the pigmented ciliary epithelium as well as other tissues affected to some degree.[15] Moreover, the extent of thermal damage changes with melanin pigment density. So, the low predictability of the procedure leads to a tendency to start with lower laser settings and repeat the procedure if needed, despite requiring more patient scheduling, more time, and costs.

In 2018, Shah et al.[11] reported a study investigating the effect of TSCPC on patients with good vision above 20/40. They reported a 48.3% reduction in IOP from baseline at 12 months. But significant vision loss, defined as BCVA≥2 lines, occurred in 33% of patients. Their laser settings were as follows; the power of 1487.9 mW, laser duration of 3783.1 ms, and shot number of 17.7 equating to approximately 99.5 J.

An extensive literature review about results and complications of cyclophotocoagulation reported by Ishida in 2013[6] suggested that the risk of hypotony and phthisis are related to the amount of laser energy delivered in a treatment session. High pretreatment IOP, treatment range, NVG, and uveitic glaucoma were found to increase the risk. In the same report, the treatment protocols employing less than 80 J per treatment session were almost free of hypotony and phthisis, except for NVG.

In 2021, Sahin and Kayikcioglu[16] reported results for 49 patients with refractory glaucoma with an overall IOP reduction to ≤22 mmHg in 37 of 49 eyes (75.5%). Phthisis developed in 3 patients in that study (6.1%). The mean energy they used was 59.7±22.3 J. They found no significant correlation between energy given and IOP reduction. No significant correlation was detected between complications and energy level used or the presence of pop sound.

Kaushik et al.[17] reported results of a prospective interventional study with 66 eyes with refractory glaucoma in 2008. The mean energy they applied per eye was 87.8±31.8 J. They reported the response rate was 88%, the success rate was 78%, and a 16.7% rate of re-treatment. The mean IOP reduction was 20.8 mmHg (57.1%) They summarized their study as showing good results for TSCPC with a treatment protocol strictly titrated according to the audible evidence of intraocular tissue explosion. They found pigmented eyes appeared to require less energy than reported for Caucasian eyes with a similar outcome.

In 2003, Chang et al.[18] reported a study comparing two treatment protocols with different energy levels and varied the number of laser shots number in Chinese patients. One protocol used 135 J per session with 27 shots, whereas the other protocol used 165 J with 55 shots. By 6 months, there was no significant difference in mean IOP reduction between the two groups. They concluded that to achieve greater IOP reduction with TSCPC, an increase in energy per pulse may be more effective than an increase in total shot numbers.

In 1999, Spencer and Vernon[9] reported the results of IOP reduction in refractory glaucoma including 58 eyes following TSCPC with repeatable standard protocol and energy level of 55.5 J per eye per session regardless of pop sound.[9] In the report, the procedure was found to be successful for IOP reduction at a mean of 19 months, with needs for retreatment in 45% of eyes. They reported no phthisis bulbi but for eyes with pretreatment visual acuity of 6/60 or better, 12 (32%) lost more than two lines of Snellen. They concluded that lower energy levels and lower shot numbers, with applications repeated if necessary, were safe and effective for the control of refractory glaucoma.

Sanchez et al's[19] report describe the results of several clinical studies about MP-TSCPC with different energy levels, ranging from 62 to 225 J. They concluded that studies that used 112 to 150 J obtained a moderate IOP decrease of 35% for up to 15 months with few or no complications. 100 J and lower energy levels of MP-TSCP caused no side effects but yielded lesser IOP reductions and shorter survival of effect. On contrary, 200 J and above energy levels yielded greater IOP reduction, as well as more severe complications, were more prevalent.

In our study, the laser settings ranged between 1000-2000 ms, 500-2000 mW (maximum power), and 11-20 shots with a mean energy of 37.2 J which is much lower than the literature. In the study, lower energy levels were achieved by not exceeding 20 shots per eye per session and 2000 ms duration of laser per shot. We used the pop sound to titrate the protocol and lower energy levels were used after the sound was heard. Mean medicated preoperative IOP reduced from 33.3 to 23.9 mmHg (30.39%) in the 2nd month with the mean session of 1.26. In the 2nd month, the mean number of medications used was 2.7 which was reduced from 3.6. In our study, we obtained less IOP reduction with lower energy levels than in the literature. However, all patients included in the study had refractory glaucoma with low vision; just 1 patient had vision counting fingers at 1 meter and the rest had lower levels of vision. No vision loss and no phthisis bulbi were seen in this study. Low energy level cyclophotocoagulation has lower effectiveness but may spare eyes from complications in this special low vision group. The effectiveness of the procedure will be increased with repeated procedures.

Our study has a lot of limitations including its retrospective design, low patient number, short follow-up time, and does not have a control group. But the study may be helpful for the low vision group in deciding on energy level for IOP reduction. Whenever MP-TSCPC is not available, low-energy TSCPC could be an alternative treatment choice with a good safety profile.

In conclusion, low-energy level TSCPC results in lower IOP reduction, and less severe complications related to the procedure seen. Despite this, it’s still effective in reducing IOP and antiglaucomatous drug usage.

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