

# Transscleral Diode Laser Cyclophotocoagulation

## A Comparison of Slow Coagulation and Standard Coagulation Techniques

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**Purpose:** To compare the outcomes of standard pop-titrated transscleral cyclophotocoagulation (TSCPC) and slow-coagulation TSCPC in the treatment of glaucoma.

**Design:** Retrospective case series.

**Participants:** Seventy-eight eyes with glaucoma of any type or stage that underwent TSCPC as part of their treatment course.

**Methods:** This study compared 52 eyes treated with slow-coagulation TSCPC with 26 eyes treated with standard pop-titrated TSCPC. Patient demographics, treatment course, surgical techniques, settings, and outcomes were assessed.

**Main Outcome Measures:** Visual acuity (VA), intraocular pressure (IOP), and postsurgical complications.

**Results:** The initial mean VA was 1.94 logarithm of the minimum angle of resolution (logMAR; standard deviation [SD], 0.73 logMAR) in the slow-coagulation TSCPC group and 1.71 logMAR (SD, 0.90 logMAR) in the standard TSCPC group ( $P = 0.507$ ). Initial IOP was 37 mmHg (SD, 13 mmHg) in the slow-coagulation group and 39 mmHg (SD, 13 mmHg) in the standard group ( $P = 0.297$ ). The follow-up periods were 16.36 and 24.68 months for the slow-coagulation and standard groups, respectively ( $P = 0.124$ ). Visual acuity remained better than light perception in 71.1% of slow-coagulation TSCPC patients and 65.0% of standard TSCPC patients ( $P = 0.599$ ). Intraocular pressure remained less than 20 mmHg in 46% of slow-coagulation TSCPC patients and 44% of standard TSCPC patients ( $P = 0.870$ ). The mean number of complications was higher in the standard group (1.46; SD, 1.24) versus the slow-coagulation group (0.62; SD, 0.75;  $P = 0.002$ ). The incidence of the need for a second procedure (slow-coagulation group, 28.8%; standard group, 23.1%;  $P = 0.588$ ) and maximum number of medications needed to control IOP after surgery ( $P = 0.771$ ) were similar between the 2 groups.

**Conclusions:** In this case series, slow-coagulation TSCPC and standard pop-titrated TSCPC resulted in similar VA and IOP outcomes in the treatment of glaucomatous eyes. The complication profiles of the techniques also were comparable, although standard TSCPC showed a higher incidence of prolonged inflammation after surgery. This study suggests that slow-coagulation TSCPC may achieve equivalent control of IOP while reducing the incidence of prolonged postoperative inflammation—a feared complication of TSCPC—when compared with standard pop-titrated TSCPC. *Ophthalmology Glaucoma* 2018;1:115-122 © 2018 by the American Academy of Ophthalmology

Cyclodestructive procedures achieve their intraocular pressure (IOP)-lowering effects through damaging the secretory epithelium of the ciliary body processes, thereby leading to reduced aqueous production. Multiple methods have been used for cyclodestruction since the concept was popularized in the 1930s, including cyclodiathermy,<sup>1,2</sup>  $\beta$ -irradiation,<sup>3</sup> cycloelectrolysis,<sup>4,5</sup> excision,<sup>6</sup> therapeutic ultrasound,<sup>7,8</sup> microwave,<sup>9</sup> and cyclocryoblation. Laser cyclophotocoagulation was first attempted with ruby laser<sup>10</sup> but did not gain popularity until neodymium:yttrium–aluminum–garnet<sup>11</sup> and later diode<sup>12</sup> lasers were used.

A lack of consensus exists regarding the indications for diode laser cyclophotocoagulation. Traditionally, cyclophotocoagulation has been used in the management of refractory glaucoma with uncontrolled elevation of IOP in the presence of poor vision or limited visual potential, particularly in the setting of failed previous glaucoma surgery with conjunctival scarring hindering further filtration surgery or glaucoma drainage device implantation. Pain relief for a blind painful eye is another common indication.<sup>13</sup> More recently, cyclophotocoagulation has shown promise as an initial glaucoma procedure in eyes with

moderate to severe IOP elevation that are unresponsive to medical therapy alone or in eyes with a relatively good visual potential, especially in populations with limited resources or access to glaucoma filtration surgery.<sup>14–20</sup> However, the prevailing view of the unpredictability of results and complications and the short-lived IOP-lowering effects of cyclophotocoagulation, especially in light of the paucity of data supporting efficacy, predictability, and reproducibility, has limited widespread use of this potential therapy as an initial surgery. A great need exists to determine the efficacy of cyclophotocoagulation in a large study.

Different approaches and laser settings influence the outcome of cyclophotocoagulation.<sup>21,22</sup> One technique uses the G-Probe handpiece (Iridex Corp., Mountain View, CA) to deliver the laser energy in an incremental fashion guided by a pop sound that signifies tissue coagulation and destruction to the ciliary body of the eye. The ciliary body produces aqueous humor that partly regulates IOP. However, the slow-coagulation laser settings and technique of Gaasterland<sup>23</sup> use fixed low-energy settings depending on degree of iris pigmentation and, in our clinical experience, seem to have similar IOP-lowering outcomes and minimal side effects. This study assessed this clinical observation quantitatively.

In this study, we retrospectively reviewed diode trans-scleral cyclophotocoagulation (TSCPC) cases over a 15-year period and compared patient demographics; diode laser settings (slow-coagulation vs. standard pop-titrated settings); pain; and clinical outcomes in terms of vision, IOP, need for additional laser treatments, and glaucoma medications or other surgeries associated with the treatment of glaucoma after cyclophotocoagulation treatment. The results of this study may provide information to guide optimization of cyclophotocoagulation parameters and may help to lay the foundation for future prospective controlled studies to assess the feasibility of expanding the indications for diode TSCPC.

## Methods

A retrospective chart review was performed of patients who underwent diode TSCPC at the Bascom Palmer Eye Institute from July 1, 1995, through June 30, 2015. The study was approved by the institutional review board of the University of Miami, and the tenets of the Declaration of Helsinki were followed. All patients who underwent diode TSCPC during this period were eligible for inclusion, regardless of glaucoma type or stage. Exclusion criteria included major charting deficiencies and loss to follow-up before 6 months after TSCPC. Data collection included patient demographics, treatment course, surgical techniques, and outcomes. Outcomes of interest included visual acuity (VA), IOP, and postprocedural complications. Snellen VA measurements were converted to logarithm of the minimum angle of resolution (logMAR) VA to standardize intervals between changes in VA over time. Complications included loss of VA, reduction of VA (change,  $\geq 0.2$  logMAR), prolonged postprocedural inflammation, hyphema, high IOP (defined as IOP  $>21$  mmHg), hypotony (defined as IOP  $<6$  mmHg), conjunctival burns and scarring, and pain.

Inflammation was assessed by review of the documented slit-lamp examination results in the medical record at postoperative

visits. Any degree of cell or flare documented at visits more than 1 month after surgery was considered prolonged postoperative inflammation. Additionally, failure to taper topical steroids and need for an increase in topical steroid use were considered indicative of severe or prolonged inflammation. Conjunctival burns and scarring were assessed grossly based on the documented slit-lamp examination results. Pain was assessed by noting the subjective report of pain from the patient, as documented in the medical record of postoperative visits, regardless of degree.

Fifty-two patients treated with slow-coagulation TSCPC and 26 treated with standard pop-titrated TSCPC were assessed. The decision to perform slow-coagulation versus standard pop-titrated TSCPC was based on provider preferred practice patterns at the time the procedure was performed; recently, more providers at Bascom Palmer Eye Institute have tended to use slow-coagulation settings. Diode laser was applied to the ciliary body (identified using a retroillumination technique) using the G-Probe after application of topical and injected periocular anesthesia. For standard coagulation, a starting power of 1.75 W and a 2.0-second duration were used, and the laser energy was titrated such that the minimum power required to produce a pop was applied. The slow-coagulation method was conducted according to a technique proposed by Gaasterland.<sup>23</sup> Power was based on iris pigmentation, which serves as an estimation of laser energy absorption in the ciliary body. For dark or light brown irises, 1.25 W and a 4.0- to 4.5-second duration were used. Eyes with other iris pigmentation received 1.5 W and a 3.5- to 4.0-second duration treatment. Of note, in our experience pops are not typically heard during slow-coagulation TSCPC. When pops do occur, this is usually related to improper probe positioning rather than excessive power, and probe repositioning typically prevents additional pops. In this retrospective study, while reviewing operative notes, pops were mentioned rarely for the patients who underwent the slow-coagulation technique. Poor documentation of a patient in whom a pop did occur was a concern, and therefore we do not report or analyze the incidence of pops that occurred during slow-coagulation TSCPC.

Total energy applied during TSCPC sessions was calculated for the 2 groups using the equation: Total energy (joules) = power (watts)  $\times$  time (seconds)  $\times$  number of spots. An independent *t* test assuming equal variance was used to compare the total energy between the 2 groups. Visual acuity and IOP measurements at baseline and final visits were compared for each of the groups using paired *t* tests.

Event-triggered data analysis was used in this study. Event triggers included whether any of the following occurred at a follow-up visit: VA loss in eyes with hand movements vision or better (to light perception [LP] or no light perception [NLP]), VA decline (loss of 2 logMAR lines or more), IOP of 15 mmHg or less, IOP of more than 15 mmHg, IOP of more than 21 mmHg, need for a glaucoma surgical procedure, need for increased number of medications, and occurrence of 1 or more complications. Only those with baseline VA better than hand movements were eligible for event-triggered VA analysis. The chi-square test was used to analyze these categorical data.

For each patient, the number of postprocedural complications, number of increased medications from baseline, maximum number of medications used, and months of follow-up were noted. Comparison of these nonparametric data between the slow-coagulation and standard coagulation groups was performed using the Mann–Whitney *U* test.

The timing of the occurrence of these events also was compared between the 2 groups. Six Kaplan–Meier survival analyses were performed. These compared the time after the initial TSCPC procedure until (1) VA loss (VA of LP or NLP) occurred (and only included people whose VA at the time of cyclophotocoagulation

was not LP or NLP), (2) a second TSCPC, (3) a second TSCPC or another treatment, (4) VA reduction occurred, (5) IOP increased to more than 15 mmHg, and (6) IOP increased to more than 21 mmHg. The type and cumulative frequency of the complications that occurred in each group also were compared. Statistics were performed using SPSS software version 22.0 (IBM, Armonk, NY). A  $P$  value of 0.05 was used to determine statistical significance for all analyses comparing the 2 groups.

## Results

Retrospective chart review identified a total of 78 eyes with glaucoma that underwent TSCPC at Bascom Palmer Eye Institute between July 1, 1995, and June 30, 2015, who met criteria for the study (Fig 1). Fifty-two of these eyes underwent slow-coagulation TSCPC. These eyes were compared with 26 eyes that underwent standard pop-titrated TSCPC. Demographic characteristics of the 2 groups were similar in terms of patient age ( $P = 0.181$ ) and gender ( $P = 0.518$ ). Initial VA, IOP, and baseline number of glaucoma medications of the eyes also were similar between the 2 groups. There was a statistically significant difference between the 2 groups in total energy (in joules) applied during the initial TSCPC procedure (slow-coagulation group: mean, 101.16 J [SD, 28.78 J]; standard pop group: mean, 77.55 J [SD, 33.99 J];  $P = 0.002$ ). Baseline demographics and characteristics of the eyes are presented in Table 1.

There was a statistically significant increase in VA between the initial and final visits of 0.21 logMAR (SD, 0.51 logMAR;  $P = 0.001$ ) in both groups combined. This increase was statistically significant in both the slow-coagulation group (mean, 0.18 logMAR; SD, 0.47 logMAR;  $P = 0.032$ ) and standard pop group (mean, 0.32 logMAR; SD, 0.56 logMAR;  $P = 0.015$ ). The final logMAR VA was similar between the 2 groups ( $P = 0.592$ ). There was a

statistically significant decrease in IOP between the initial and final visits of 17.77 mmHg (SD, 13.63 mmHg;  $P < 0.001$ ) for both groups combined. These decreases were statistically significant in both the slow-coagulation group (mean, 17.19 mmHg; SD, 13.31 mmHg;  $P < 0.001$ ) and the standard coagulation group (mean, 18.86 mmHg; SD, 14.47 mmHg;  $P < 0.001$ ). The final IOP at last follow-up was similar between the groups (slow-coagulation group: 18.84 mmHg [SD, 9.46 mmHg]; standard pop group: 18.95 mmHg [SD, 12.10 mmHg];  $P = 0.969$ ). These results are shown in Table 2.

Event-triggered outcomes between the 2 groups were compared (Table 2). The only significant difference detected between the groups was in the incidence of complications. The slow-coagulation group included fewer eyes that experienced 1 or more complications (48.1% vs. 73.1%;  $P = 0.036$ ). The need for additional procedures, reduction in VA (change,  $\geq 0.2$  logMAR), loss of vision (VA of LP or NLP), and IOP outcomes were similar between the 2 groups. Forty-two percent of patients in the slow-coagulation group and 35% of those in the standard group did not experience a significant decrease in VA throughout the duration of the follow-up. Intraocular pressure remained at or less than 21 mmHg for the entirety of the follow-up in 46% of patients in the slow-coagulation group and 44% of patients in the standard group ( $P = 0.870$ ). Less than 30% of all patients required a second TSCPC session or other procedure, with similar rates in both groups ( $P = 0.588$ ).

The differences in the number of complications, need for increased medications, maximum number of medications, and months of follow-up between the study groups are displayed in Table 2. The slow-coagulation group experienced a significantly lower number of complications (mean, 0.62 vs. 1.46;  $P = 0.002$ ). The mean follow-up period was longer for the standard treatment group (mean, 24.68 months vs. 16.36 months) because this procedure was introduced earlier in clinical practice. Patients received

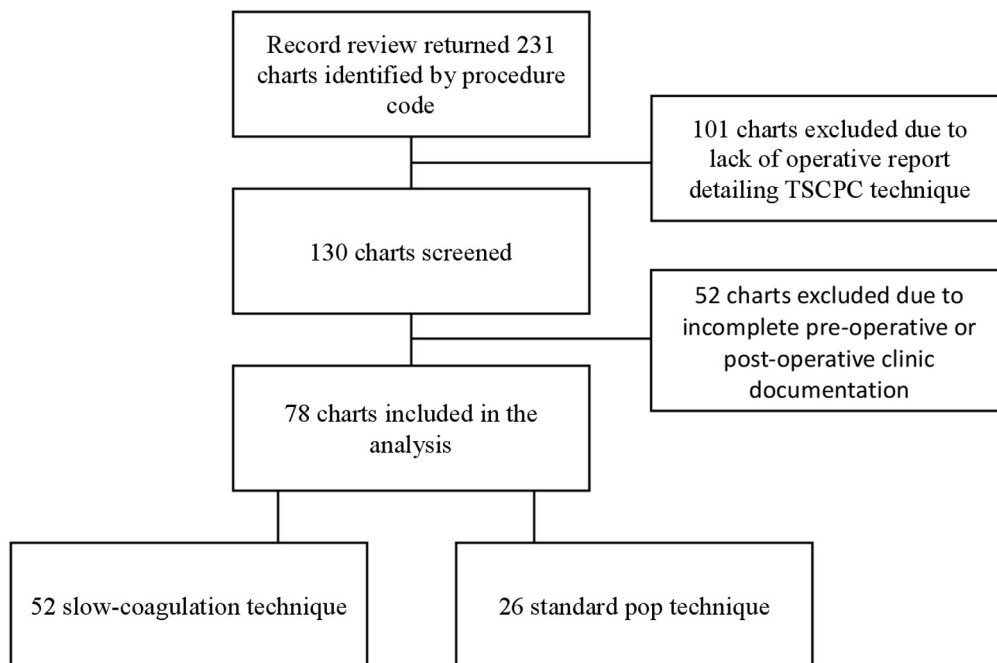


Figure 1. Patient inclusion and exclusion flowchart. TSCPC = transscleral cyclophotocoagulation.

Table 1. Baseline Variables

Variables	Transscleral Cyclophotocoagulation Method		P Value
	Slow Coagulation (n = 52)	Standard Pop (n = 26)	
Gender, no. (%)			
Male	24 (46.2)	10 (38.5)	0.518
Female	28 (53.8)	16 (61.5)	
Age (yrs), mean (SD)	57.07 (26.33)	65.07 (20.69)	0.181
Initial visual acuity (logMAR)			
Mean (SD)	1.94 (0.73)	1.71 (0.90)	0.507
Median	2.3	2.3	
Initial intraocular pressure			
Mean (SD)	37.0 (13.0)	39.0 (13.0)	0.297
Median	36	38	
Initial no. of medications			
Mean (SD)	3.62 (1.37)	3.62 (1.47)	0.887
Median	4	4	
Total energy applied during initial TSCPC (joules), mean (SD)	101.16 (28.78)	77.55 (33.99)	<b>0.002</b>

logMAR = logarithm of the minimum angle of resolution; SD = standard deviation; TSCPC = transscleral cyclophotocoagulation. Boldface indicates statistical significance.

an average of 0.42 additional glaucoma medications after TSCPC on last follow-up in both groups, with less than 25% of the patients included in the study requiring additional medication for IOP control after TSCPC.

The cumulative proportions of eyes with need for additional treatment, reduction in VA (change,  $\geq 0.2$  logMAR), vision loss (VA of LP or NLP), and achievement of certain IOP ranges were analyzed with Kaplan-Meier survival analysis (Table 2). Patients in both groups maintained VA at or near the baseline for a mean duration of 23 months in both groups. For those patients who showed a decrease in vision (to LP or NLP vision), this occurred after a mean of 39.9 months in the slow-coagulation group and 42.7 months for the standard group. There were no significant differences found in any of these survival analyses.

Table 3 shows the complication profile for each technique and comparison of frequencies of each complication between the groups. Inflammation was the most common complication in both groups but occurred at a significantly lower frequency in the slow-coagulation group (34% vs. 73%;  $P = 0.002$ ). Pain was the next most frequent complication in both groups, and the slow-coagulation group trended toward showing a lower incidence ( $P = 0.078$ ). The only other complication that occurred with frequency of more than 10% was hyphema in the standard group: 12% of patients experienced postprocedural hyphema, compared with 2% in the slow-coagulation group ( $P = 0.102$ ). High IOP, hypotony, conjunctival burns, and conjunctival scarring all occurred in less than 10% of patients in both groups; no statistically significant differences were detected with these complications, although the study likely was underpowered to detect small differences in these infrequent complications.

## Discussion

This study compared the outcomes of eyes that underwent TSCPC with slow-coagulation versus standard TSCPC diode laser settings. Primary outcome measures included VA and IOP. These outcomes largely were similar in both

groups. Both groups experienced clinically significant decreases in IOP from baseline to final visits. Postprocedural complications were the other primary outcome measure. The average number of complications for patients in the slow-coagulation group was lower compared with the standard TSCPC group, a difference primarily driven by a reduction in prolonged postoperative inflammation in the slow-coagulation group.

Study of the efficacy, safety, and optimization of diode laser TSCPC is ongoing and not well reported, thereby making the present results relevant for the clinician. Traditionally, TSCPC has been reserved as a treatment for refractory glaucoma in eyes with poor VA or poor visual potential and blind, painful eyes associated with high IOP.<sup>24</sup> This is primarily because of a common view that TSCPC has significant complications, such as prolonged inflammation, pain, and even phthisis.<sup>25</sup> Severe complications associated with earlier cyclodestructive procedures, such as neodymium:yttrium–aluminum–garnet TSCPC and cyclocryodestruction, are likely behind this misconception. Recent literature review and the results of this study suggest that diode laser TSCPC is a minimally invasive intervention that offers the potential for significant IOP reduction and a favorable complication profile in the management of refractory cases of glaucoma.<sup>15–17,26,27</sup>

Although optimization of TSCPC settings has been studied previously, a paucity of data comparing the slow-coagulation and standard TSCPC techniques exists in the literature.<sup>21</sup> A study by Alzuhairy et al<sup>28</sup> aimed to compare the outcomes of slow-coagulation versus standard TSCPC techniques. Consistent with the results of the present study, the authors found that the slow-coagulation and standard techniques had comparable IOP-lowering effects; that is, no clear benefit of further IOP reduction with the slow-coagulation technique was found. In terms of complications, the study reported greater inflammation in the early postoperative period for the slow-coagulation group, but this difference was not seen after 1 year of follow-up. This

Table 2. Outcome Variables in the Slow-Coagulation and Standard Groups

Variable	Transscleral Cyclophotocoagulation Method		P Value
	Slow Coagulation (n = 52)	Standard Pop (n = 26)	
Comparisons of events			
Patient needed second TSCPC, no. (%)			
No	38 (73.1)	20 (76.9)	0.714*
Yes	14 (26.9)	6 (23.1)	
Patient needed second TSCPC or other treatment, no. (%)			
No	37 (71.2)	20 (76.9)	0.588*
Yes	15 (28.8)	6 (23.1)	
Patient needed increased no. of medications, no. (%)			
No	40 (76.9)	20 (76.9)	1.000*
Yes	12 (23.1)	6 (23.1)	
Patient had 1 or more complications, no. (%)			
No	27 (51.9)	7 (26.9)	0.036* <sup>†</sup>
Yes	25 (48.1)	19 (73.1)	
Patient experienced VA loss (VA of LP or NLP), no. (%) <sup>‡</sup>			
No	27 (71.1)	13 (65.0)	0.636*
Yes	11 (28.9)	7 (35.0)	
Patient experienced reduced VA (change ≥0.2 logMAR), no. (%) <sup>‡</sup>			
No	16 (42.1)	7 (35.0)	0.599*
Yes	22 (57.9)	13 (65.0)	
Patient experienced IOP <15 mmHg, no. (%) g			
No	22 (44.0)	8 (32.0)	0.317*
Yes	28 (56.0)	17 (68.0)	
Patient experienced IOP >15 mmHg, no. (%) g			
No	12 (24.0)	4 (16.0)	0.425*
Yes	38 (76.0)	21 (84.0)	
Patient experienced IOP >20 mmHg, no. (%) g			
No	23 (46.0)	11 (44.0)	0.870*
Yes	27 (54.0)	14 (56.0)	
Comparisons of amounts			
No. of complications			
Mean (SD)	0.62 (0.75)	1.46 (1.24)	0.002 <sup>§,  </sup>
Median	0	1	
No. of increased medications			
Mean (SD)	0.42 (0.94)	0.42 (0.95)	0.989 <sup>§</sup>
Median	0	0	
Maximum no. of medications			
Mean (SD)	4.04 (1.14)	4.04 (1.34)	0.771 <sup>§</sup>
Median	4	4	
Months of follow-up			
Mean (SD)	16.36 (20.1)	24.68 (28.58)	0.124 <sup>§</sup>
Median	11	16	
Comparisons of time-to-events			
Survival time to second TSCPC (mos)			
Mean (SE)	44.4 (4.8)	49.6 (7)	0.642 <sup>¶</sup>
Median (SE)	62.1 (32.7)	#	
Survival time to second TSCPC or another treatment (mos)			
Mean (SE)	42.7 (4.9)	49.6 (7)	0.504 <sup>¶</sup>
Median (SE)	62.1 (32.8)	#	
Survival time (mos) to VA loss <sup>‡</sup>			
Mean (SE)	39.9 (8)	42.7 (7.2)	0.466 <sup>¶</sup>
Median (SE)	24.1 (1.3)	43.9 (7.3)	
Survival time (mos) to VA reduction <sup>‡</sup>			
Mean (SE)	23 (5.2)	23 (6.8)	0.998 <sup>¶</sup>
Median (SE)	12.6 (4.9)	4.9 (7.4)	
Survival time (mos) to IOP >15 mmHg			
Mean (SE)	7.9 (1.4)	5.4 (1.8)	0.290 <sup>¶</sup>
Median (SE)	2.8 (0.8)	1.6 (0.2)	
Survival time (mos) to IOP >21 mmHg			
Mean (SE)	28.5 (4.7)	30.3 (6.9)	0.926 <sup>¶</sup>
Median (SE)	7.8 (3.6)	6.5 (2.6)	

(Continued)



Table 2. (Continued.)

Variable	Transscleral Cyclophotocoagulation Method		P Value
	Slow Coagulation (n = 52)	Standard Pop (n = 26)	
Visual acuity and intraocular pressure outcomes			
Final VA, mean (SD)	2.05 (0.81)	1.90 (0.94)	0.592** <sup>††</sup>
Increase in VA from baseline, mean (SD)	0.18 (0.47)	0.32 (0.56)	
Final IOP (mmHg), mean (SD)	18.84 (9.46)	18.95 (12.10)	0.969** <sup>††</sup>
Decrease in IOP from baseline (mmHg), mean (SD)	17.19 (13.31)	18.86 (14.47)	

g = any time after initial surgical date; IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; LP = light perception; NLP = no light perception; SD = standard deviation; SE = standard error; TSCPC = transscleral cyclophotocoagulation; VA = visual acuity. Boldface indicates statistical significance.

\*Chi-square test.

<sup>†</sup>P ≤ 0.05.

<sup>‡</sup>Includes only cases with initial VA better than LP.

<sup>§</sup>Mann-Whitney U test.

<sup>||</sup>P ≤ 0.01.

<sup>¶</sup>Kaplan-Meier log-rank test survival analysis.

<sup>#</sup>No estimate of the median was possible.

\*\*Paired t test.

<sup>††</sup>Final VA and IOP for each group were compared with baseline values with paired t tests (see text).

finding differs from the results of this study, in which we found the slow-coagulation group to have a lower incidence of postprocedural inflammation. The slow-coagulation technique, using a lower amount of energy applied over a longer duration, is theorized to result in a decrease of tissue destruction and inflammation outside the ciliary body; thus, our results showing a significantly lower incidence of prolonged inflammation in the slow-coagulation group are more consistent with what would be expected based on this theory.<sup>23</sup> Interestingly, we found this to be the case despite the slow-coagulation group receiving significantly more total energy during the TSCPC procedures on average. The pop sound in the standard technique is known to signify tissue coagulation to the ciliary body epithelium. To the best of our knowledge, the mechanism of action of the slow-coagulation technique and the resulting pathophysiologic changes in the treated tissues have not been studied or reported in the literature. However, we hypothesize that the lack of the pop indicates that the coagulative threshold is never reached during treatment, minimizing the

possible inflammatory reaction that accompanies tissue coagulation.

This study presents several significant findings regarding the complication profile of TSCPC. As previously noted, concern over the potential complications of cyclodestructive procedures has limited more widespread use. However, the complication profiles seen in this study are encouraging for both groups, and even more favorable in the slow-coagulation group. Although several eyes did experience a loss of VA, there was no net loss of VA in either group; in fact, there was a significant net gain in final VA compared with initial VA in both groups. We suspect loss of VA in large part was the result of the end-stage nature of the disease in many of the eyes before receiving TSCPC, although we cannot presume that the procedure did not play a role in vision loss. Likewise, we do not propose that TSCPC improves vision, and suspect the net gain in vision seen in our results may be the result of variation in VA measurement in eyes with end-stage disease. Incidence of conjunctival burning and scarring was very low using both techniques. In

Table 3. Comparison of the Rates of Complications

Variable	Transscleral Cyclophotocoagulation Method		P Value
	Slow Coagulation (n = 52)	Standard Pop (n = 26)	
Patient experienced reduced VA (change ≥0.2 logMAR)	22 (57.9%)	13 (65.0%)	0.599
Patient experienced VA loss (to VA of LP or NLP)	11 (28.9%)	7 (35.0%)	0.636
Prolonged inflammation	18 (34)	19 (73)	<b>0.002</b>
Hyphema	1 (2)	3 (12)	0.102
High IOP (>21 mmHg) at final follow-up	5 (9)	1 (4)	0.658
Conjunctival burn	0 (0)	2 (8)	0.106
Pain	8 (15)	9 (35)	0.078
Hypotony (IOP <6 mmHg)	2 (4)	0 (0)	1
Conjunctival scarring	0 (0)	2 (8)	0.106

IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; LP = light perception; NLP = no light perception; VA = visual acuity.

Data are no. (%) unless otherwise indicated. Boldface indicates statistical significance.

fact, no eyes in the slow-coagulation group showed gross conjunctival burns or scarring documented on slit-lamp examination. This is important when considering the possibility of performing future filtering surgery on eyes that previously underwent TSCPC, which may be difficult or impossible with grossly damaged conjunctiva. However, we do acknowledge that microscopic or histologic changes, or both, may occur in the conjunctiva after undergoing TSCPC, and without more detailed analysis of conjunctiva after TSCPC, we cannot be sure of the effect that TSCPC may have on the success of filtering surgery later, even in the absence of gross conjunctival damage. The incidence of hypotony in this study also was very low, with only 2 of 78 eyes experiencing this complication. Transscleral cyclophotocoagulation causes permanent destruction of the ciliary body tissues, making irreversible hypotony a concern. However, our results and those in the literature suggest that with the judicious application of transscleral laser energy, this potential complication largely can be avoided.<sup>29</sup> Conservative application of laser energy during initial TSCPC is advisable because additional application can always be applied later as needed. In this study, 26.9% of slow-coagulation eyes and 23.2% of standard coagulation eyes did require additional TSCPC.

Limitations of the present study include: (1) its retrospective nature introduces potential sources of bias, (2) the end-stage nature of most eyes included in the study precludes the application of the results to the large population of glaucoma patients who maintain more functional vision, (3) its reliance on proper documentation in the medical record for detailed procedural reports and for outcome measures such as postprocedural inflammation and pain, and (4) the fact that the study is underpowered to detect small but potentially significant differences in a number of the outcome measures. Further studies addressing these issues may be worthwhile.

There are several reasons that further study of TSCPC is essential. There has been limited study regarding the use of TSCPC as a primary procedure.<sup>14,16,18,19</sup> Expanding the indications of TSCPC to include primary intervention would be particularly beneficial in managing patients in underserved communities and populations reached through community outreach programs and medical mission work, because their financial, geographic, and sociodemographic situations may limit access to traditional glaucoma surgery. Transscleral cyclophotocoagulation does not require an expensive operating room and can be performed in a clinic setting, making it a very feasible alternative.

At present, minimally invasive glaucoma surgery is an area of significant research interest, with numerous new devices and techniques recently introduced and currently in trials. Study of the efficacy of these minimally invasive glaucoma surgery procedures compared with TSCPC would be worthwhile, because TSCPC may provide an even less invasive (perhaps the only true noninvasive glaucoma procedure currently available), low-cost, and effective alternative. Transscleral cyclophotocoagulation also has been investigated as a treatment option for glaucomatous eyes with good VA and potential, eyes in which minimally invasive glaucoma surgery procedures have become quite

popular.<sup>17,20,30</sup> The VA outcomes of TSCPC in these studies are promising. Micropulse TSCPC is another, newer approach to the application of cyclophotocoagulation that is important to mention because it has shown promising results when compared with continuous-wave TSCPC, which was used in this study.<sup>30,31</sup> Of note, to our knowledge, micropulse TSCPC has yet to be compared with slow-coagulation, continuous-wave TSCPC.

In conclusion, the results of this study are significant in that they (1) add to the current literature demonstrating diode TSCPC as a noninvasive method of reducing IOP with limited postprocedural complications in the treatment of refractory glaucoma, regardless of the technique used, and (2) provide evidence that using the slow-coagulation technique may reduce the incidence of postprocedural complications while maintaining similar VA and IOP outcomes in comparison with the standard technique. Further study is needed to continue to improve on the application of TSCPC and to better define its role in the treatment of glaucoma.

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## Footnotes and Financial Disclosures

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Abbreviations and Acronyms:

**IOP** = intraocular pressure; **logMAR** = logarithm of the minimum angle of resolution; **LP** = light perception; **NLP** = no light perception; **SD** = standard deviation; **TSCPC** = transscleral cyclophotocoagulation; **VA** = visual acuity.

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