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Micropulse Transscleral Diode Laser Cyclophotocoagulation in Refractory Glaucoma

Short-Term Efficacy, Safety, and Impact of Surgical History on Outcomes

Giancarlo A. Garcia, MD,[1,2] Christine V. Nguyen, MD,[1] Aleksandr Yelenskiy, MD,[1] Goichi Akiyama, MD,[1] Brett McKnight, MD,[1] Vikas Chopra, MD,[1] Kenneth Lu, MD,[1] Alex Huang, MD, PhD,[1] James C.H. Tan, MD, PhD,[1] Brian A. Francis, MD, MS[1]

Purpose: To assess the short-term efficacy and safety of micropulse transscleral diode laser cyclophotocoagulation (MP-TSCPC) in the management of refractory glaucoma and to compare outcomes based on prior glaucoma surgeries.

Design: Retrospective analysis.

Participants: Patients with refractory glaucoma who underwent MP-TSCPC at a single institution by 1 of 4 surgeons.

Methods: Chart review of cases of MP-TSCPC using the Iridex Cyclo G6 (Mountain View, CA) laser with standard parameters and laser duration at the discretion of each treating physician.

Main Outcome Measures: Probability of postoperative success was estimated by the Kaplan-Meier method. Success parameters included intraocular pressure (IOP) 6 to 21 mmHg with or without topical antihypertensive therapy, 20% or more IOP reduction from baseline for any 2 consecutive visits after 3 postoperative months, and no subsequent glaucoma surgery.

Results: One hundred sixteen eyes of 116 patients (mean age, 65.8±16.9 years) were included. Baseline IOP was 22.2±7.9 mmHg, and mean postoperative follow-up time was 6.3±3.4 months (range, 3–12 months.) Postoperative IOP at the final follow up was 15.3±6.6 mmHg ($P < 0.01$), corresponding to a reduction of approximately 6.9 mmHg (31.1%). Most eyes (66.4%) underwent at least 6 months of follow-up. Short-term probability of success was 93.1% at 3 months and 74.3% at 6 months. Eyes that had undergone prior traditional glaucoma surgery (trabeculectomy, tube shunt, excessive pressure-regulating shunt system miniature glaucoma shunt [Alcon, Fort Worth, TX], or a combination thereof) demonstrated a higher probability of success (67.6%) compared with eyes that had not (41.4%; $P = 0.014$). The most common complications were decline in best-corrected visual acuity (7.8%) and hypotony (1.7%).

Conclusions: Micropulse transscleral diode laser cyclophotocoagulation has a significant short-term ocular hypotensive effect and favorable safety profile in eyes with refractory glaucoma. The probability of successful outcome was greater in eyes that had undergone prior traditional glaucoma surgery. *Ophthalmology Glaucoma 2019;2:402-412 © 2019 by the American Academy of Ophthalmology*

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Reduction of intraocular pressure (IOP) is a mainstay in the management of glaucoma, because IOP currently is the only modifiable risk factor. Therapeutic methods include medications, laser treatments, angle-based surgery, and filtration surgery. Cycloablation is a commonly used laser treatment to lower IOP. The 810-nm wavelength used for transscleral diode laser cyclophotocoagulation (TSCPC) and endocyclophotocoagulation causes targeted destruction of the layers of the ciliary epithelium, which leads to reduced aqueous humor secretion and lower IOP.[1] However, traditional TSCPC may be associated with serious complications, including uveitis, vision loss, chronic hypotony, and more rarely, phthisis bulbi and sympathetic ophthalmia.[2,3]

Micropulse TSCPC (MP-TSCPC) differs from traditional TSCPC in that it delivers a series of repetitive short pulses

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of energy with rest periods in between pulses. Micropulse TSCPC has shown promise in treating glaucoma with reduced postoperative complications, while demonstrating reasonably good success rates with more selective targeting and less collateral damage.[4] The device applies a series of short (microsecond) repetitive bursts of energy with rest periods between pulses, allowing the thermal reaction effectively to be confined to the absorbing tissue, eventually reaching the coagulative threshold. The adjacent nonpigmented structures do not reach the coagulative threshold with the cool-off interval, thus minimizing collateral tissue damage.[4] Prior data suggest that MP-TSCPC is effective at lowering IOP, with generally low complication rates.[4–9] In a comparative analysis, Aquino et al[6] demonstrated that MP-TSCPC exerted a more consistent and predictable IOP-lowering effect than traditional TSCPC.

Outcomes of MP-TSCPC may differ depending on a patient's prior surgical history. Prior glaucoma surgical history is a critical factor that can influence the efficacy of subsequent surgeries.[10–13] A large retrospective analysis of intermediate-term results of MP-TSCPC demonstrated a complication rate of only 2% and suggested that MP-TSCPC therefore may complement prior filtration or tube shunt surgeries.[9] However, analyses of the potential differences in efficacy of MP-TSCPC based on history of prior glaucoma surgeries to the authors' knowledge have not been reported.

The authors herein report short-term efficacy and safety outcomes of MS-TSCPC on a large cohort of patients and the results of an assessment of the impact of prior glaucoma surgery. The authors hypothesize that eyes with prior traditional glaucoma surgery—trabeculectomy, tube shunt surgery, excessive pressure-regulating shunt system miniature glaucoma shunt (Alcon, Fort Worth, TX) surgery, or a combination thereof—may demonstrate more profound IOP-lowering effects after MS-TSCPC than those that have not undergone prior traditional surgery. This may be the result of the addition of lowering of aqueous production to a prior aqueous outflow surgical pathway.

Methods

Study Design

This was a retrospective study of patients with refractory glaucoma who underwent MP-TSCPC from August 2016 through January 2018 at Doheny Eye Centers, University of California, Los Angeles. Institutional review board ethical approval was obtained. This study complied with the Health Insurance Portability and Accountability Act and adhered to the tenets of the Declaration of Helsinki. As this was a retrospective chart review, informed consent was not required. Refractory glaucoma in this study was defined as glaucoma that remained uncontrolled despite previous IOP-lowering surgery, laser treatment, maximum tolerated medical treatment, or a combination thereof. At this institution, patients undergoing MP-TSCPC are evaluated before surgery and at the following postoperative time points: 1 day, 1 month, 3 months, 6 months, 9 months, and 12 months. At each visit, best-corrected visual acuity (BCVA), IOP, number of tolerable medications required to maintain the target IOP, and detailed anterior segment examination were recorded. Intraocular pressure was measured using the Goldmann applanation tonometer. To be included in this analysis, eyes were required to fulfill the following characteristics: (1) refractory glaucoma (as defined above) and (2) having undergone MP-TSCPC with at least 3 months of follow-up after surgery. For participants who had undergone treatment for both eyes, only 1 eye was included to establish independence of each data point. In these cases, a random number-generator algorithm in R software version 3.1.1 (The R Foundation for Statistical Computing, Vienna, Austria) was used to select 1 eye randomly for analysis.

Operative Technique

In this analysis, the charts of 4 surgeons (B.A.F., V.C., K.L., J.C.H.T.) were reviewed. Each of these surgeons use the MicroPulse P3 glaucoma device (Iridex Corporation, Mountain View, CA), which has a ball-lens tip, a customized contact probe (Iris Medical Instruments, Mountain View, CA) emitting 810-nm infrared radiation from a diode source. The probe houses a quartz fiberoptic cable, 600 μm in diameter, with its hemispheric tip protruding 0.7 mm from the hand piece.[5]

In all cases, a similar operative technique was used as per the institution's protocol. Peribulbar anesthesia (3−5 ml 2% lidocaine hydrochloride) was administered before the procedure, along with monitored anesthesia care. The Iridex Cyclo G6 laser (Iris Medical Instruments) was turned on at a power of 2000 mW with 31.3% duty cycle in which the laser was on for 0.5 millisecond (ms) and off for 1.1 ms. The MicroPulse P3 glaucoma device was placed perpendicularly on the sclera adjacent to the limbus, delivering the laser power with a sweeping motion to the superior hemisphere from the 9:30 to 2:30 positions and the inferior hemisphere from the 3:30 to 8:30 positions. The 3- and 9-o'clock meridians were spared, along with any area of thinned sclera. The duration of laser delivery at this institution is at the discretion of the treating physician; 2 of the 4 surgeons used a duration of 180 seconds in all cases, and 2 surgeons tailored the treatment duration based on the severity of the glaucoma, with higher treatment times for more complex and severe cases, and lower times for less complex cases.

After surgery, all eyes received topical prednisolone acetate 1% and ketorolac 0.4% to 0.5% 4 times daily and 2 to 3 times daily, respectively, for a minimum of 1 week, which then could be tapered, depending on the level of inflammation and patient comfort. All preprocedure glaucoma medications were continued until the 1-week visit, then were decreased one at a time if the target IOP was reached. The order of medication decrease was to stop oral carbonic anhydrase inhibitors first, then aqueous suppressants one at a time, and finally prostaglandin analogs.

Statistical Analysis

Statistical analyses were performed using R software version 3.1.1. Mean values were computed with corresponding standard deviation. Statistical significance was assessed using an α level of 0.05. Paired-sample t tests were used to evaluate differences between mean preoperative (baseline) IOP and mean IOP at postoperative follow-up time points.

The Kaplan-Meier method was used to estimate the cumulative probability of success after surgery. Success was defined as IOP between 6 and 21 mmHg with or without topical antihypertensive therapy, no additional medications, 20% or more IOP reduction from baseline for any 2 consecutive visits after 3 postoperative months, no subsequent glaucoma surgery, and no loss of light perception vision or vision-threatening severe complications. An event was defined as the time from surgery to failure. Follow-up time

was measured from the day of surgery to last known status of the participant and was censored at the time of the individual's final follow-up by the end of the observational period or the point after which the patient defaulted from follow-up.

Assessment of comparative outcomes based on subgroups that had received 180 seconds or less versus more than 180 seconds of laser treatment duration was achieved with analysis of covariance (ANCOVA). In these ANCOVA analyses, covariates were baseline IOP, number of medications at time of surgery, number of previous surgeries, and type of glaucoma. Preoperative IOP was compared in these subgroups with an independent *t* test. Homogeneity of variance was assessed with Levene's test. Type of glaucoma was categorized as either primary open-angle glaucoma (POAG) or non-POAG. Eyes without POAG were grouped together, because the individual types of glaucoma within this category were markedly fewer compared with the number of eyes with POAG, and individual comparisons therefore would limit the ability to achieve a robust analysis.

To assess comparative outcomes based on age, baseline-adjusted postoperative IOPs at 3 and 6 months were compared between eyes of patients 45 years of age or younger and those older than 45 years using an ANCOVA. Log-rank analysis was used to compare success between eyes that had undergone prior conventional glaucoma surgery versus those that had not. An independent-sample *t* test was used to assess differences in mean baseline IOP between these 2 subgroups. Baseline-adjusted comparisons of IOP in these subgroups at the final postoperative follow-up were performed with an ANCOVA.

Additional subgroup analyses were performed comparing outcomes among (1) the prior traditional glaucoma surgery subgroup (including eyes that had undergone prior trabeculectomy, tube shunt surgery, excessive pressure-regulating shunt system miniature glaucoma shunt surgery, or a combination thereof), (2) eyes that had undergone at least 1 angle-based minimally invasive glaucoma surgery (MIGS; the prior MIGS subgroup), and (3) eyes that had not undergone any prior glaucoma surgeries. An analysis of variance was used to compare baseline IOP among these 3 subgroups, and an ANCOVA was used to compare postoperative IOP. Pairwise comparisons were assessed with the Fisher least significant difference post hoc test.

Snellen BCVA data were converted to logarithm of the minimum angle of resolution units. Values of 2.0, 2.4, 2.7, and 3.0 were assigned to visual acuities of counting fingers, hand movements, light perception, and no light perception, respectively.[14] Ordinal data (e.g., number of antiglaucoma medications and number of prior surgeries) were compared with the Wilcoxon signed-rank test.

Short-term complication rates and incidence of subsequent glaucoma procedures were assessed on chart review. Assessment of complications by age group was performed for all patients 45 years of age or younger and was compared with those in all patients older than 45 years.

Results

Participants

Charts of a total of 116 patients (116 eyes) met inclusion criteria for this study. Four of these patients had both eyes treated; therefore, only 1 eye from each of these patients was selected randomly and included, with the 4 fellow eyes excluded (see Methods). The mean age of these participants was 65.8±16.9 years (range, 13–94 years). Patient demographic data are displayed in Table 1, and the distribution of glaucoma type is presented in Table 2. All included participants had a minimum of 3 months of postoperative follow-up, with a mean follow-up time of 6.3±3.4 months (range, 3–12 months). The numbers of eyes at the postoperative follow-up time points were 116 (100%) at 3 months, 77 (66.4%) at 6 months, 37 (30.8%) at 9 months, and 20 (16.7%) at 12 months. The most common type of glaucoma was POAG (66/116 [56.9%]). Table 3 summarizes the distribution of prior ocular procedures.

Table 1. Participant Demographic Characteristics (116 Eyes of 116 Patients)

Characteristic	Data
Age (yrs)	
Mean ± standard deviation	65.8±16.9
Range	13–94
Gender, no. (%)	
Male	55 (47.4)
Female	61 (52.6)
Race/ethnicity, no. (%)	
Non-Hispanic white	65 (56.0)
Hispanic	26 (22.4)
Asian	17 (14.7)
Black	2 (1.7)
Other*	6 (5.2)

*Includes Middle Eastern, Indian American, or declined to state.

Intraocular Pressure and Medical Therapy Outcomes

Mean IOP was statistically significantly lower at the final postoperative follow up (15.3±6.6 mmHg) compared with baseline (22.2±7.9 mmHg; $P < 0.01$; Table 4), corresponding to a reduction of approximately 6.9 mmHg (31.1%). Intraocular pressure decreased most markedly on postoperative day 1 and plateaued thereafter. Postoperative IOP at day 1 and months 1, 3, 6, 9, and 12 was 15.3±6.9 mmHg, 16.0±6.6 mmHg, 15.8±6.9 mmHg, 16.1±7.0 mmHg, 14.9±5.3 mmHg, and 17.0±4.2 mmHg, respectively. A significantly lower IOP was observed at all postoperative visits compared with that observed at the preoperative baseline visit ($P < 0.01$ for each; Fig 1A). Mean reduction in IOP from baseline was 7.0±7.3 mmHg at 1 day, 6.4±8.1 at 1 month, 6.8±8.4 mmHg at 3 months, 5.5±6.4 mmHg at 6 months, 8.4±5.1 mmHg at 9 months, and 6.6±5.3 at 12 months, as depicted in Figure 2A. Kaplan-Meier survival analysis demonstrated that, after surgery, the cumulative probability of success was 93.1% at 3 months, 74.3% at 6 months, 67.5% at 9 months, and 59.6% at 12 months (Fig 3).

The number of antiglaucoma medications (including both topical and oral medications) was significantly less ($P < 0.01$, Wilcoxon signed-rank test) at the final follow up visit (median, 3.0; mean, 2.5±1.3) compared with the preoperative number of medications (median, 3.0; mean, 3.2±1.6; Table 4). The proportion of patients taking an oral IOP-lowering medication decreased from 19.8% (23/116) before surgery to 15.5% (18/116) at the final postoperative visit.

Comparative Outcomes Based on Treatment Duration

Mean treatment time was 212.9±44.6 seconds. Fourteen eyes (12.1%) received less than 180 seconds of total laser time (mean,

Table 2. Distribution of Glaucoma Type (116 Eyes of 116 Patients)

Glaucoma Diagnosis	No. (%)
Primary open angle	66 (56.9)
Chronic angle closure	7 (6.0)
Congenital	6 (5.2)
Juvenile open angle	5 (4.3)
Pseudoexfoliation	6 (5.2)
Other secondary glaucoma	5 (4.3)
Low tension	8 (6.9)
Neovascular	3 (2.6)
Traumatic	3 (2.6)
Mixed mechanism	2 (1.7)
Pigment dispersion	2 (1.7)
Uveitic/inflammatory	2 (1.7)
Aphakic	1 (0.9)

136.4±15.7 seconds; range, 100−160 seconds), 37 of 116 eyes (31.9%) received 180 seconds of treatment, and 65 of 116 eyes (56.0%) received more than 180 seconds of treatment (mean, 246.1±21.9 seconds; range, 210−300 seconds). Comparison of preoperative IOP between subgroups receiving treatment of 180 seconds' duration or less (n = 51 eyes) and more than 180 seconds' duration (n = 65 eyes) demonstrated no significant difference (22.0±6.8 mmHg vs. 22.4±6.4 mmHg, respectively; $P = 0.481$), although the comparison did demonstrate significant differences in the number of medications being taken at time of surgery (180 seconds or less subgroup: median, 3.0; mean, 2.5±1.7; vs. more than 180 seconds subgroup: median, 3.0; mean, 3.5±1.5; $P < 0.01$) and the number of previous surgeries (180 seconds or less subgroup: median, 2.0; mean, 2.1±1.4; vs. more than 180 seconds subgroup: median, 3.0; mean, 2.9±1.3; $P < 0.01$). Further demographic and clinical characteristics of these 2 subgroups are presented in Table S1 (available at www.ophthalmologyglaucoma.org).

Table 3. History of Prior Ocular Procedures (116 Eyes of 116 Patients)*

Prior Procedure	No. (%)
Any glaucoma surgery	105 (90.5)
Trabeculectomy	31 (26.7)
Ex-PRESS miniature glaucoma shunt	5 (4.3)
Tube shunt surgery	57 (49.1)
Trabectome	13 (11.2)
Trabecular microbypass	1 (0.9)
Suprachoroidal microstent	1 (0.9)
Ab interno canaloplasty	1 (0.9)
Ab interno goniotomy†	1 (0.9)
ECP	9 (7.8)
TSCPC	3 (2.6)
Goniotomy	4 (3.4)
Goniosynechialysis	1 (0.9)
LPI	9 (7.8)
Selective laser trabeculoplasty	9 (7.8)
Cataract surgery	79 (68.1)
Penetrating keratoplasty	9 (7.8)
Endothelial keratoplasty	6 (5.2)
Vitreoretinal surgery	13 (11.2)

ECP = endocyclophotocoagulation; Ex-PRESS = excessive pressure-regulating shunt system; LPI = laser peripheral iridotomy; TSCPC = contact transscleral cyclophotocoagulation using continuous wave diode laser.
*Summary of number of prior traditional glaucoma procedures in eyes with prior traditional glaucoma surgery is presented in Table S4 (available at www.ophthalmologyglaucoma.org).
†With Kahook dual blade.

Table 4. Intraocular Pressure, Visual Acuity, and Antiglaucoma Medical Therapy at Baseline and at Final Follow-up (116 Eyes of 116 Patients)

Outcome Measure	Baseline	Final Postoperative Follow-up*	P Value
IOP (mmHg)			<0.01†
Mean	22.2±7.9	15.3±6.6	
Range	8−54	5−50	
BCVA (logMAR)			0.294†
Mean	0.84±0.78	0.86±0.81	
Range	0−3	0−3	
Medications			<0.01‡
Median	3.0	3.0	
Mean	3.2±1.6	2.5±1.3	
Range	0−5	0−6	

BCVA = best-corrected visual acuity; IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution.
*Mean = 6.3±3.4 months after surgery.
†Paired-samples *t* test.
‡Wilcoxon signed-rank test.

Adjusting for baseline IOP, number of medications at time of surgery, number of previous surgeries, and type of glaucoma, a significant difference ($P = 0.03$, ANCOVA) was found in IOP at the final follow-up between these 2 subgroups (14.8±6.4 mmHg vs. 15.6±5.5 mmHg for the less than 180-second subgroup and 180 seconds or more subgroup, respectively). However, Kaplan-Meier survival analysis (Fig S1, available at www.ophthalmologyglaucoma.org) demonstrated that cumulative probability of success was not significantly different between these 2 subgroups (63.1% vs. 57.4%, respectively; $P = 0.174$, log-rank test).

Comparative Outcomes Based on Age

Forty-seven eyes of 47 patients 45 years of age or older (mean age, 35.4±4.1 years) were compared with 69 eyes of 69 patients older than 45 years (mean age, 74.1±7.9 years). Mean pretreatment IOP was 20.4±6.9 mmHg in the younger group and 25.0±7.4 mmHg in the older group ($P < 0.01$). In the younger group, mean postoperative IOP was 15.4±7.0 mmHg at 3 months and 15.7±7.1 mmHg at 6 months. In the older group, mean postoperative IOP was 16.1±7.9 mmHg at 3 months and 16.4±6.4 mmHg at 6 months. Although postoperative IOP was numerically lower in the younger group, adjusting for baseline IOP, there was no statistically significant difference between the 2 groups at 3 and 6 months ($P = 0.384$ and $P = 0.510$, respectively, ANCOVA).

Comparative Outcomes Based on Prior Surgeries

Seventy-nine eyes (68.1%) had undergone at least 1 prior trabeculectomy, tube shunt surgery, excessive pressure-regulating shunt system surgery, or a combination thereof, whereas 37 eyes (31.9%) had not. Demographic and clinical characteristics of these subgroups are

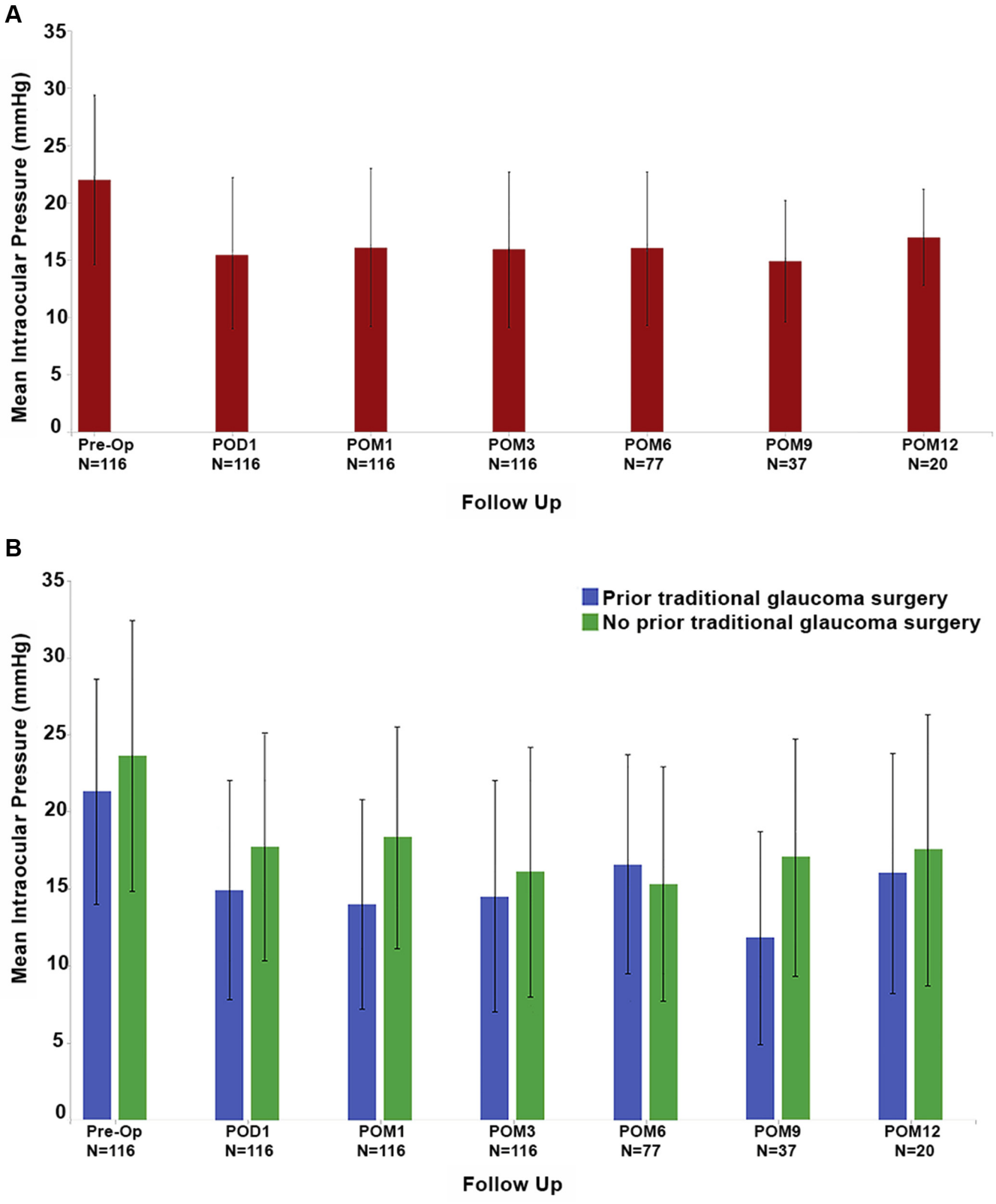


Figure 1. Graphs showing mean intraocular pressure (IOP) at preoperative (Pre-Op) baseline and over the follow-up period in (**A**) all eyes and in (**B**) subgroups based on surgical history. As depicted in (**A**), the most marked IOP lowering occurred at postoperative day (POD) 1; IOP plateaued thereafter. Intraocular pressure was significantly lower at all postoperative time points compared with preoperative baseline ($P < 0.01$ for each). Error bars represent standard deviation. (**B**) The blue columns represent mean IOP in the subset of eyes with at least 1 prior traditional glaucoma surgery (defined as at least 1 trabeculectomy, tube shunt surgery, miniature glaucoma shunt surgery [Ex-PRESS; Alcon, Fort Worth, TX], or a combination thereof); the green columns represent mean IOP of the subset of eyes with no prior traditional glaucoma surgeries. POM = postoperative month.

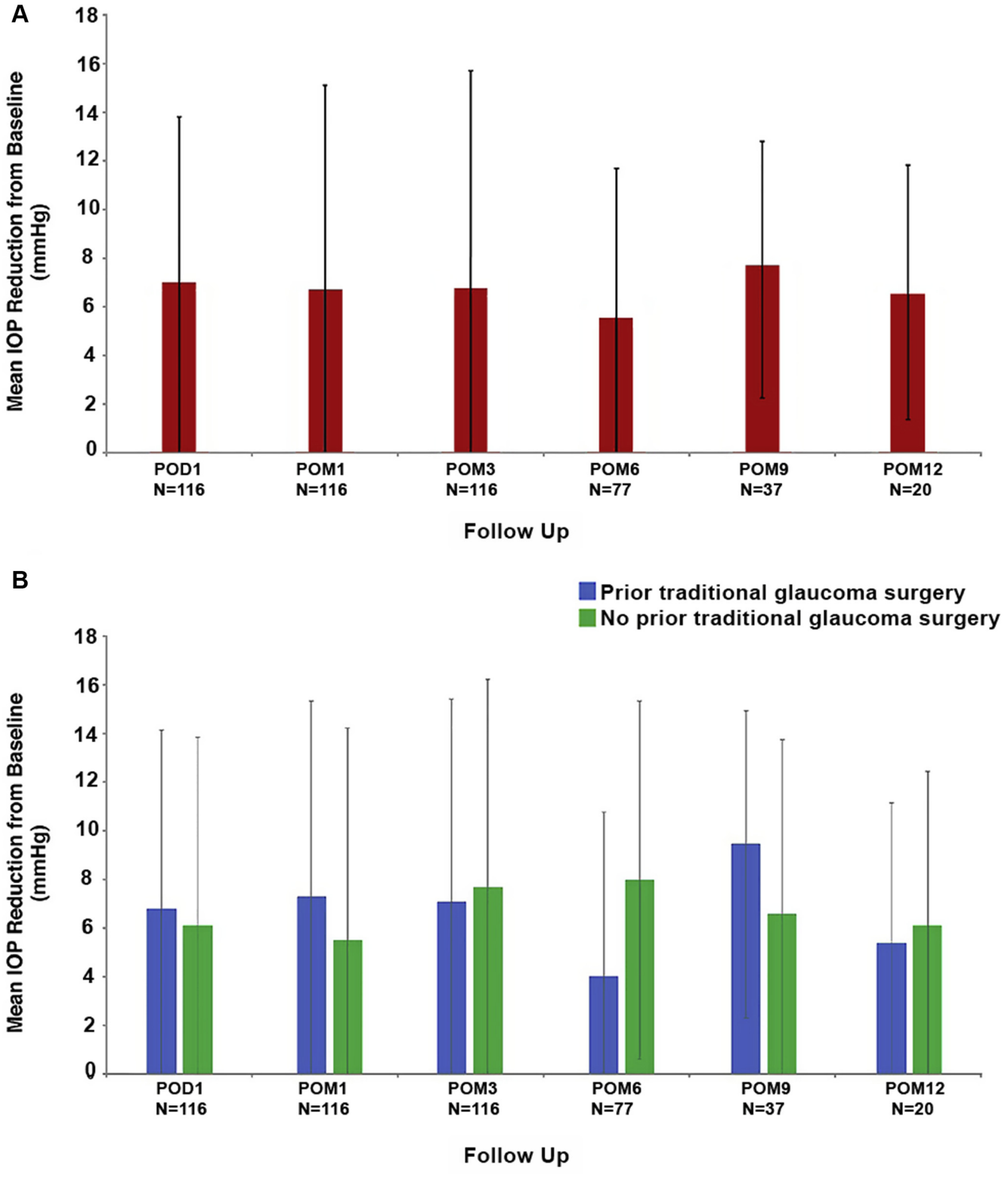


Figure 2. Graphs showing mean intraocular pressure (IOP) reduction from preoperative baseline over the follow-up period in (**A**) all eyes and in (**B**) subgroups based on surgical history. Error bars represent standard deviation. Prior traditional glaucoma surgery was defined as at least 1 trabeculectomy, tube shunt surgery, miniature glaucoma shunt surgery (Ex-PRESS; Alcon, Fort Worth, TX), or a combination thereof. POD = postoperative day; POM = postoperative month.

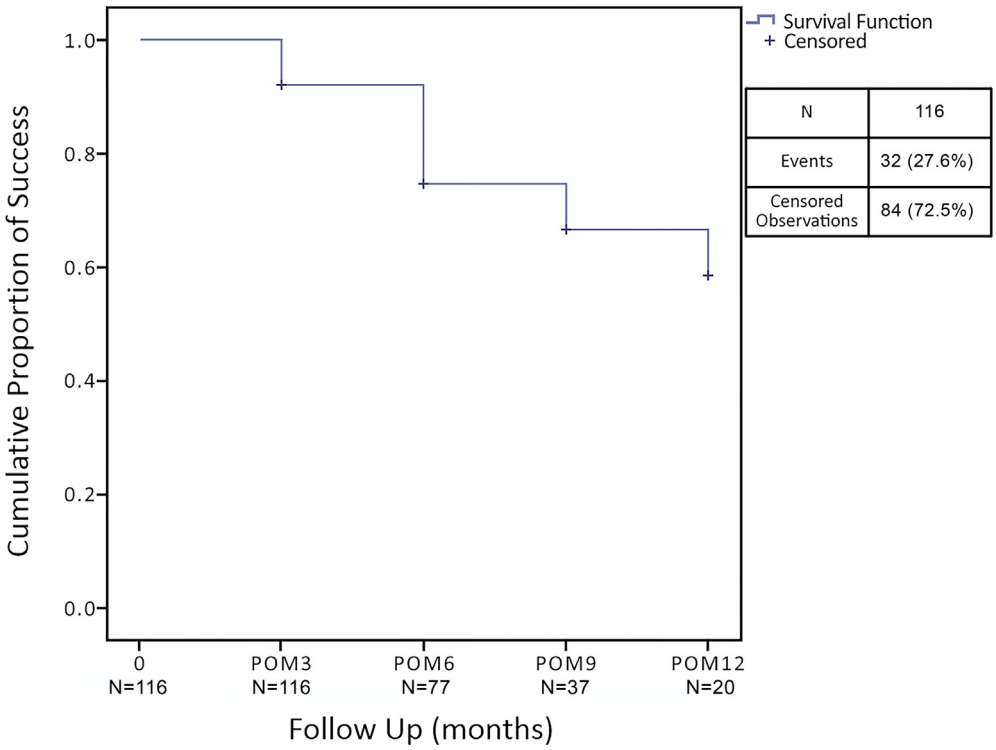


Figure 3. Graph showing Kaplan-Meier survival analysis after micropulse contact transscleral cyclophotocoagulation surgery. Cumulative probability of success after surgery was estimated to be 93.1% at 3 months, 74.3% at 6 months, 67.5% at 9 months, and 59.6% at 12 months. At each time point, the number of eyes with follow-up is specified on the x-axis. Cross-hatches represent censored data. POM = postoperative month.

described in Table S2 (available at www.ophthalmologyglaucoma.org), with additional clinical characteristics and postoperative outcomes of these 2 subgroups presented in Tables S3 and S4 (available at www.ophthalmologyglaucoma.org). The number of preoperative antiglaucoma medications (including both topical and oral medications) was not significantly different between eyes with (median, 3.0; mean, 2.9±1.9) and without (median, 3.0; mean, 3.2±1.8) prior traditional surgery ($P = 0.296$).

Kaplan-Meier survival analysis of the subgroup of eyes that had undergone prior traditional glaucoma surgery compared with the subgroup that did not is depicted in Figure 4. After 12 months of follow-up, the cumulative probability of success was significantly higher in eyes that had undergone prior incisional surgery (67.6%) versus those that did not (41.4%; $P = 0.014$, log-rank test).

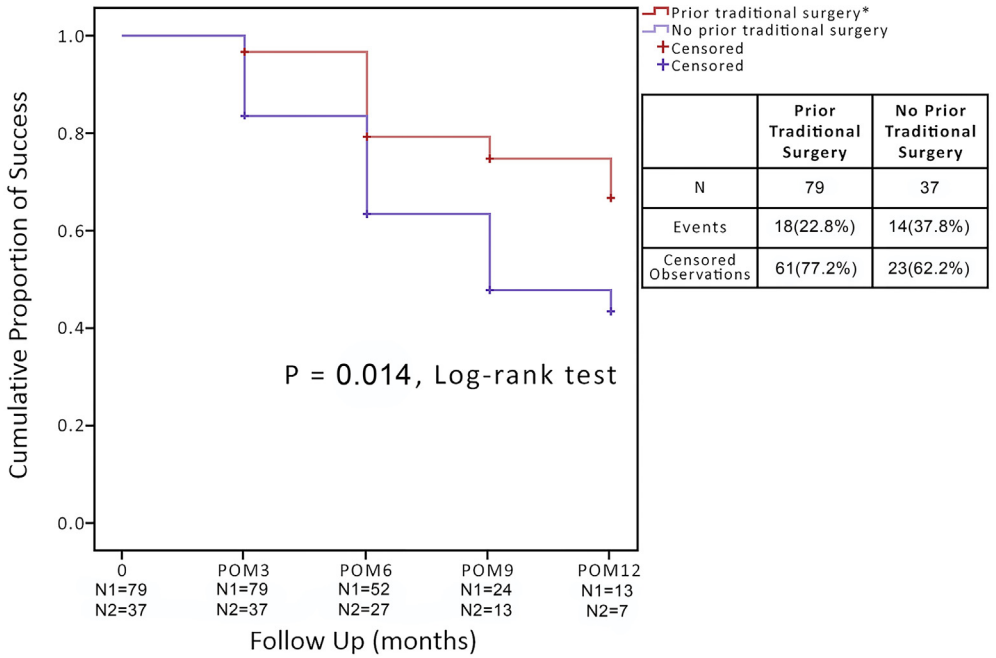
Mean preoperative IOP was numerically lower for the prior traditional surgery subgroup compared with the subgroup with no prior traditional surgery (21.5±7.6 mmHg vs. 23.6±8.4 mmHg, respectively), although this difference was not statistically significant ($P = 0.319$). Baseline-adjusted mean IOP at the final follow-up was statistically significantly lower ($P < 0.01$) in the prior traditional surgery subgroup (14.0±5.8 mmHg vs. 17.8±7.2 mmHg, ANCOVA). Figure 1B depicts mean IOP at baseline and through each follow-up interval for both subgroups, and Figure 2B demonstrates mean reduction in IOP from baseline in each subgroup at these intervals.

The number of antiglaucoma medications was significantly less at the final follow-up visit for both subgroups compared with the preoperative number of medications ($P < 0.01$ for each; Table S4). The number of antiglaucoma medications was lower after surgery in eyes with (median, 3.0; mean, 2.3±1.4) versus without (median, 3.0; mean, 2.7±1.2) prior traditional surgery ($P < 0.01$). Best-corrected visual acuity was not significantly different after surgery in either subgroup (Table S4).

Among the eyes that had not undergone prior traditional glaucoma surgery, 20 of 116 (17.2%) had undergone at least 1 MIGS procedure, whereas 17 of 116 (14.7%) had undergone no prior glaucoma surgeries. Pretreatment IOP was not significantly different ($P = 0.493$) among the prior traditional surgery subgroup, the prior MIGS subgroup (23.4±9.2 mmHg), or the subgroup with no prior glaucoma surgeries (23.8±8.7 mmHg, analysis of variance). Mean postoperative IOP was statistically significantly lower in the prior traditional surgery subgroup (14.1±5.4 mmHg) compared with both the prior MIGS subgroup (18.4±6.9 mmHg; $P < 0.01$) and the subgroup with no prior glaucoma surgeries (18.9±5.7; $P < 0.01$, ANCOVA). Postoperative IOP was numerically lower in the prior MIGS subgroup compared with that in subgroup with no prior glaucoma surgeries, although this difference was not significant ($P = 0.513$, ANCOVA).

Safety Outcomes and Complications

Mean postoperative BCVA at the final follow-up (0.86±0.81 logarithm of the minimum angle of resolution) was not significantly different compared with preoperative BCVA (0.84±0.78 logarithm of the minimum angle of resolution; $P = 0.294$). Nine eyes (7.8%) experienced a decline in BCVA from baseline at the



	Prior Traditional Surgery	No Prior Traditional Surgery
N	79	37
Events	18(22.8%)	14(37.8%)
Censored Observations	61(77.2%)	23(62.2%)

Figure 4. Graph showing Kaplan-Meier survival analysis after micropulse contact transscleral cyclophotocoagulation surgery for subgroups based on surgical history. Cumulative probability of success at 12 postoperative months was significantly higher in the subgroup of eyes that had undergone prior traditional glaucoma surgery (67.6%; red curve) versus those that had not (41.4%; purple curve). Difference in success between the 2 subgroups was assessed with the log-rank test. *Prior traditional glaucoma surgeries include trabeculectomy, tube shunt surgery, Ex-PRESS (Alcon, Fort Worth, TX) miniature glaucoma shunt surgery, or a combination thereof. Cross-hatches represent censored data. At each time point, the number of eyes with follow-up is specified on the x-axis. N1 = number of eyes with follow-up in prior traditional surgery subgroup; N2 = number of eyes with follow-up in the subgroup without prior traditional surgery. POM = postoperative month.

last follow-up visit. Eight of these eyes (6.9%) demonstrated a reduction of 2 lines or more in BCVA, and 1 of 116 eyes (0.9%) underwent a reduction from light perception to no light perception.

Fifteen eyes experienced ocular complications, corresponding to an ocular complication rate of 12.9% (Table 5). The most common complications were decline in BCVA from baseline (9/116 [7.8%]) and hypotony (2/116 [1.7%]). Twenty-two eyes underwent subsequent glaucoma procedures (19.0%). Comparisons of complications rates and additional procedures grouped by laser treatment duration, age subgroups, and surgical history are presented in Table S5 (available at www.ophthalmologyglaucoma.org).

Complications seemed to be more frequent in the higher treatment duration subgroup (11/65 [16.9%]) compared with the lower treatment duration subgroup (4/51 [7.8%]). The number of additional glaucoma procedures was similar between these 2 subgroups (13/65 [20.0%] vs. 9/51 [17.6%], respectively).

Among the entire sample, a total of 47 of 116 eyes (40.5%) were noted in patients 45 years of age or younger, with the remaining 69 of 116 eyes (59.5%) in participants older than 45 years. The total number of complications was similar in the younger age range (6/47 [12.8%]) compared with the older age subgroup (9/69 [13.0%]), with the number for subsequent glaucoma procedures similar as well between these 2 subgroups (10/47 [21.3%] and 12/69 [17.4%], respectively). Further, the total number of complications was similar in the prior traditional surgery subgroup (8/79 [10.1%]) and the subgroup with no prior traditional surgery (7/37 [18.9%]). The number of additional glaucoma procedures also was similar between these 2 subgroups (9/79 [11.4%] and 13/37 [35.1%], respectively).

Discussion

The results of this study suggest that MP-TSCPC is safe and effective in the short term for the treatment of refractory glaucoma in a large cohort of patients. Significant IOP reduction was noted as early as the first postoperative day and was sustained over 6 postoperative months in most patients, with a mean IOP reduction at the final postoperative follow-up of 31.1% from baseline (6.9 mmHg). The magnitude of IOP lowering in this cohort was similar to that observed in prior studies at the last postoperative follow-up.[4–9] In addition, the IOP reduction achieved by MP-TSCPC was associated with a significant reduction in the number of postoperative antiglaucoma medications required by participants in this study.

Furthermore, Kaplan-Meier survival analysis demonstrated that, after surgery, the likelihood of success ranged from 93.1% at 3 months to 59.6% at 12 months, which was similar to the success determined by a prior reported survival analysis.[6] Interestingly, there were no significant differences in postoperative IOP in younger versus older participants with similar pretreatment IOP. The IOP-lowering effect of

Table 5. Additional Glaucoma Procedures and Complications (116 Eyes of 116 Patients)

Procedures and Complications	No. (%)
Additional glaucoma procedures	
Tube shunt surgery*	8 (6.9)
Repeat micropulse TSCPC	4 (3.4)
Trabeculectomy*	4 (3.4)
ECP	2 (1.7)
Trabectome	2 (1.7)
Trabeculotomy	1 (0.9)
Subconjunctival implant	1 (0.9)
Other complications	
Decline in BCVA from baseline†	9 (7.8)
Hypotony‡	2 (1.7)
Prolonged AC inflammation§	1 (0.9)
Choroidal effusions	1 (0.9)
Corneal abrasion	1 (0.9)
Cystoid macular edema	1 (0.9)

AC = anterior chamber; BCVA = best-corrected visual acuity; ECP = endocyclophotocoagulation; TSCPC = contact transscleral cyclophotocoagulation.
*Includes revisional surgeries.
†Defined as a 2-line reduction or greater in BCVA or reduction to no light perception, as measured at last follow-up visit.
‡Intraocular pressure <5 mmHg.
§Defined as a 1+ grade or higher of cell and flare in a 1×1-mm slit-lamp beam based on the Standardization of Uveitis Nomenclature Working Group's consensus on grading inflammation persisting for more than 4 weeks with topical steroids.

treatment duration was significantly greater in eyes receiving 180 seconds or less of laser treatment, when adjusting for baseline IOP, number of medications at the time of surgery, number of previous surgeries, and type of glaucoma. However, Kaplan-Meier analysis demonstrated that there was no difference in the probability of success between laser treatment duration subgroups. The effect of treatment duration therefore may be considered inconclusive in this sample. Although longer treatment duration may correspond with lower postoperative IOP, it was not associated with higher probability of surgical success as defined by this model.

Prior glaucoma surgery had a significant impact on the short-term efficacy of MP-TSCPC in the participants in this analysis. The probability of success was statistically significantly higher in eyes that had undergone prior traditional glaucoma surgery (67.6%) versus those that did not (41.4%). Furthermore, baseline-adjusted postoperative IOP was lower at the final postoperative follow-up for the prior traditional surgery group. The basis for these differences is unclear, but the authors hypothesize that eyes with an existing external filtration system may achieve lower IOP more readily in the context of reduced aqueous production after MP-TSCPC compared with those without such outflow.

Consistent with this theory is the finding that baseline-adjusted postoperative IOP was lower at the final postoperative follow-up in the prior traditional surgery subgroup compared with both the prior MIGS and no prior surgery subgroups. Incisional surgery potentially allows for greater outflow enhancement compared with bleb-independent procedures, and postoperative IOP reduction generally is more profound after traditional incisional surgery as compared with alternatives.[15,16] Of note, however, the data herein demonstrated no difference in IOP reduction at the final postoperative follow-up between the MIGS subgroup and the subgroup with no prior glaucoma surgery, although these individual sample sizes were small.

The short-term complication rate in this study (12.9%) was similar compared with that observed in prior studies.[4–6] The most frequent complication was decline in BCVA from baseline (9/116 [7.8%]). Rates of vision change seem to vary widely after MP-TSCPC. Emanuel et al,[7] for example, found a decline in visual acuity in 41% of eyes at 3 postoperative months, whereas others have reported no loss in BVCA in any eyes.[5] Hypotony (1.7%) and persistent anterior chamber inflammation (0.8%) were uncommon in this study. Only 22 eyes (19.0%) underwent subsequent glaucoma procedures. There were more complications in eyes with treatment duration of more than 180 seconds compared with eyes receiving 180 seconds or less, although there were no apparent differences in complications based on age group or surgical history. There was no substantial difference in need for additional surgeries among any of these groups.

This retrospective analysis was intended to assess the short-term safety and efficacy of MP-TSCPC, with particular attention to the impact of surgical history on outcomes. Short-term safety and efficacy of MP-TSCPC are of particular clinical interest because this treatment method often is used as a short-term therapy while other potential treatment options are being explored. Despite the clinical relevance of short-term outcomes, however, longer-term outcomes are indeed of interest as well, and therefore a limitation of this study is that despite an initial sample size of 116 eyes, 12-month follow-up data were available for only 20 eyes. As such, the longer-term impact of surgical history remains to be assessed. Nonetheless, the IOP reduction from baseline at the 12-month follow-up interval was statistically significant, and Kaplan-Meier analysis determined a success rate of 59.6% at this time point. Most eyes in this study (66.4%) completed at least 6 months of follow-up. At the time of this review, clinical follow-up of most patients in this study is ongoing, and longer-term results are to be reported in a subsequent analysis. Because the present analysis reports only short-term safety data and complications, subsequent analyses will assess long-term safety and complication rates of MP-TSCPC in these patients.

An additional limitation is that because this was a retrospective review, there was no standardized operative protocol in that the laser duration was at the discretion of the treating physician. In many cases, the surgeon is believed to have chosen a longer treatment duration for more complex cases, which therefore may have had a lower likelihood of success. This is reflected in the finding that patients with

longer treatment duration were taking a larger number of preoperative medications and had undergone a higher number of prior surgeries, although interestingly, treatment duration did not seem to be associated with baseline IOP or type of glaucoma. This discrepancy likely is reconciled by the fact that not all surgeons in this analysis used similar criteria in selecting treatment duration. Prospective analyses with standardized treatment durations are warranted.

In addition, most participants in these analyses were white, Hispanic, or Asian, with black patients—a crucial demographic with unique risk factors for glaucoma—composing only 1.7% of the sample. Therefore, the applicability of these results for black patients cannot be determined definitively. A further limitation is that sample sizes of the MIGS subgroup and the subgroup with no prior glaucoma surgeries were relatively small. Larger-scale analyses over longer follow-up intervals may identify differences in the efficacy of MP-TSCPC between these subgroups.

In conclusion, micropulse TSCPC yielded short-term IOP reductions in patients with refractory glaucoma and was associated with a favorable short-term safety profile. Interestingly, eyes that had undergone prior traditional filtration or aqueous shunting demonstrated more profound IOP lowering compared with eyes naïve to previous conventional surgeries. There was no significant difference in IOP lowering in eyes with prior MIGS compared with eyes with no prior glaucoma surgery. Consideration of a patient's history of prior glaucoma surgery therefore may be useful in determining the potential efficacy of MP-TSCPC.

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[1] Doheny Eye Institute, Stein Eye Institute, David Geffen School of Medicine, University of California, Los Angeles (UCLA), Los Angeles, California.

[2] Byers Eye Institute, Stanford University, Palo Alto, California.

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Author Contributions:

Conception and design: Garcia, Nguyen, Yelenskiy, Akiyama, McKnight, Chopra, Lu, Huang, Tan, Francis

Analysis and interpretation: Garcia, Nguyen, Yelenskiy, Akiyama, McKnight, Chopra, Lu, Huang, Tan, Francis

Data collection: Garcia, Nguyen, Yelenskiy, Akiyama, McKnight, Chopra, Lu, Huang, Tan, Francis

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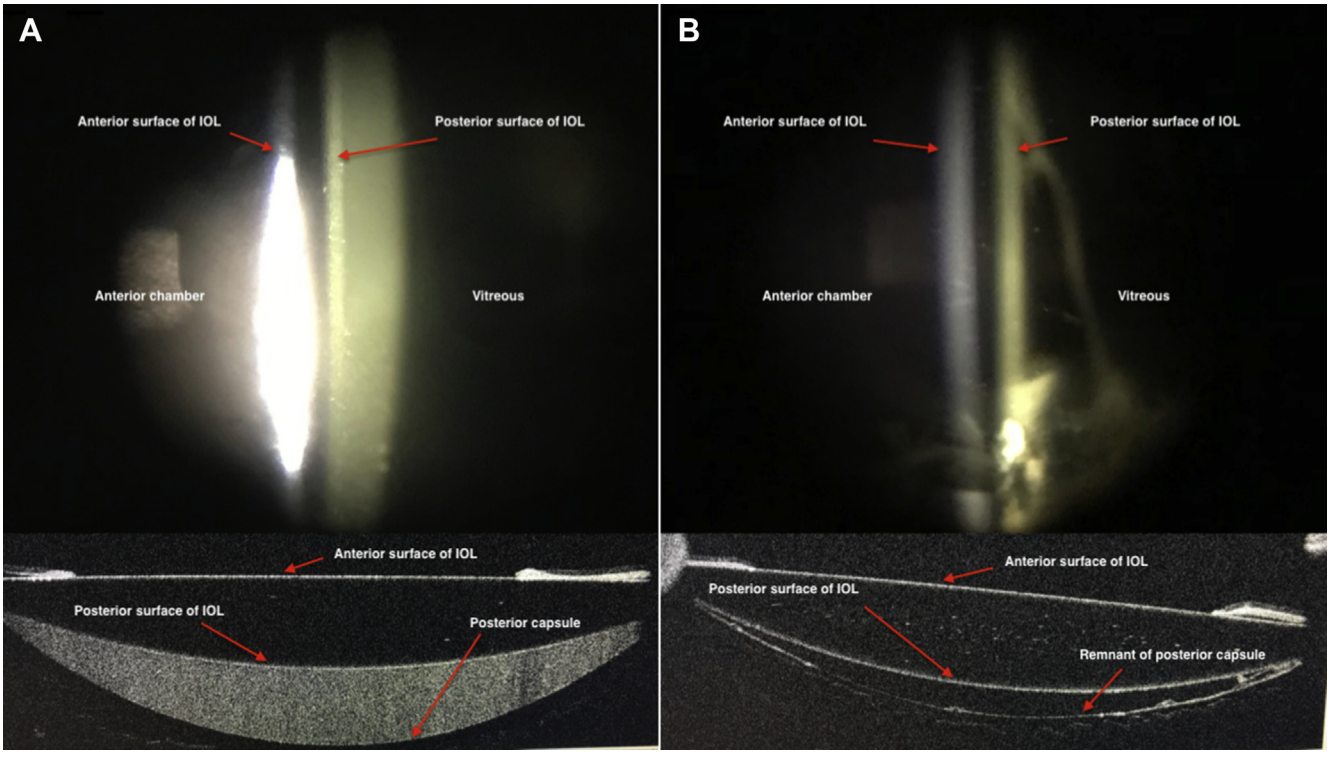
Overall responsibility: Garcia, Nguyen, Yelenskiy, Akiyama, McKnight, Chopra, Lu, Huang, Tan, Francis

Abbreviations and Acronyms:
ANCOVA = analysis of covariance; **BCVA** = best-corrected visual acuity; **IOP** = intraocular pressure; **MIGS** = minimally invasive glaucoma surgery; **MP-TSCPC** = micropulse transscleral diode laser cyclophotocoagulation; **POAG** = primary open-angle glaucoma; **TSCPC** = transscleral diode laser cyclophotocoagulation.

Correspondence:
Brian Francis, MD, MS, Glaucoma Service, Doheny Eye Institute, Stein Eye Institute, David Geffen School of Medicine, University of California, Los Angeles (UCLA), 800 Fairmount Avenue, Suite 215, Pasadena, CA 91105. E-mail: bfrancis@mednet.ucla.edu.

Pictures & Perspectives



Delayed Rapid-Onset Capsular Bag Distension Syndrome

A 72-year-old man presented with 2 months of "smoky vision" in his right eye (OD) after normal examination 3 months prior. He underwent uncomplicated cataract surgery 6 years previously without other ocular surgery or disease history. Examination revealed 20/20-1 visual acuity OD with a 0.5 diopter myopic shift. Dense yellow material was present between the intraocular lens (IOL) and posterior capsule (PC) without PC opacification (**A**, top: slit-lamp photo). Anterior-segment OCT revealed hyperreflective material between the IOL and PC (**A**, bottom). Anterior and posterior segments were otherwise unremarkable. YAG capsulotomy was performed with same-day examination (**B**, top: slit-lamp photo) and OCT revealing resolution (**B**, bottom). (Magnified version of Fig **A**-**B** is available online at www.ophthalmologyglaucoma.org)

Mark Goerlitz-Jessen, MD[1]
Manesh Dagli, MD[2]
[1]*Duke Eye Center, Durham, North Carolina;* [2]*Charles George VA, Asheville, North Carolina*