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ORIGINAL RESEARCH

# Efficacy and Safety of Diode Laser Transscleral Cyclophotocoagulation in Patients with Glaucoma

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**Purpose:** To evaluate the efficacy and safety of transscleral diode cyclophotocoagulation (TSCPC) at 2 years of follow up.

**Methods:** This is a retrospective review of the records of all adult patients who underwent their first TSCPC treatment between 2014 and 2019 at Unidade Local de Saúde de São João, Porto, Portugal. Data regarding intraocular pressure (IOP), best corrected visual acuity, number of IOP-lowering medications, use of oral acetazolamide, retreatments and complications during a 2-year period following TSCPC were registered. The primary outcome was overall success at 2 years, defined as IOP≥ 6 and ≤21 mmHg, with at least 20% IOP reduction from baseline, with or without IOP-lowering medications (qualified and complete success, respectively), without the development of phthisis bulbi or loss of light perception due to glaucoma and no further glaucoma procedures except TSCPC retreatment.

**Results:** Ninety-six eyes from 96 patients were included, mean age was 63 (±14) years. Mean IOP at baseline was 39.1 (±13.3) mmHg. Mean IOP reduction at 2 years was 18.5 (42.9%) mmHg (±16.0, min −16.0, max 56.0) ($p < 0.001$) and a significant reduction in the number of IOP-lowering medications and use of oral acetazolamide was observed. IOP reduction at 2 years was positively correlated with baseline IOP ($r=0.682$; $p < 0.001$). Overall success (including complete and qualified) was achieved in 42 patients (43.8%), with 34 (35.4%) presenting qualified success. Neovascular glaucoma (NVG) was the predominant diagnosis (n = 30, 31.3%), with a higher mean baseline IOP of 46.3 mmHg (±11.8, min 21.0, max 70.0) and a larger mean IOP reduction at 2 years of 24.7 (51.0%) mmHg (±16.4, min −2.0, max 55.0). Thirteen patients (13.5%) developed persistent hypotony, eight of which converted to phthisis bulbi, of which half had NVG.

**Conclusion:** TSCPC can be an effective IOP-lowering procedure, demonstrating a stronger effect when the preoperative IOP is highest. However, there is a wide variability in the effect (specially in eyes with NVG) and some relevant complications, including 8.3% of patients developing phthisis bulbi after 2 years of follow up.

**Keywords:** intraocular pressure, glaucoma, ocular hypotension, transscleral cyclophotocoagulation, neovascular glaucoma, phthisis bulbi

## Introduction

Glaucoma encompasses a heterogeneous group of eye diseases associated with progressive loss of optic nerve fibers, with consequent loss of corresponding visual field.[1,2] Several risk factors have been identified for the development and progression of this condition, but intraocular pressure (IOP) is still the primary modifiable risk factor.[3]

IOP-lowering can be achieved with eye drops or laser trabeculoplasty (both currently considered to be first line options in most glaucoma cases),[3] or surgery, which is mostly reserved for patients who progress despite non-surgical



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maximal tolerated treatment or if there is a very advanced disease stage or glaucoma type where non-surgical treatment is not expected to be able to lower IOP to the levels that are expected to stop disease progression.[3] The majority of surgeries performed are filtering surgeries,[4] and aim to lower IOP through an increased outflow, but there are also options that aim for a reduction of aqueous humour (AH) production, such as the cyclodestructive or cyclomodulating procedures, which are still usually used as a last resource or when other types of surgery are deemed very likely to be unsuccessful.

In cyclodestructive procedures, unlike other surgeries, the IOP lowering effect is obtained by ablation of the ciliary body with subsequent reduction of AH production.[5] The most widely used technique is Laser Cyclophotocoagulation (CPC),[6] namely the Diode Laser Transscleral Cyclophotocoagulation (TSCPC). During TSCPC, a semiconductor diode laser (810 nm) is transmitted through the overlying sclera and absorbed by melanin in the ciliary processes, leading to selective thermal coagulation of the ciliary body.[7] Despite the simplicity of the procedure (comparing to incisional filtering surgery), cycloablation is feared among some ophthalmologists due to the risk of persistent hypotony, phthisis bulbi and loss of visual acuity.[5] The risk of hypotony with TSCPC can be as high as 18% (namely in cases of neovascular glaucoma (NVG).[8,9] Moreover, the reported success rates are highly variable (36.7–94.4%), possibly due to heterogeneity in methodologies regarding the definitions of patient population, energy settings, success and follow-up duration. It is also important to acknowledge that the majority of the studies only established an upper IOP limit for the definition of success, therefore not excluding patients with hypotony.[10]

Despite the increasing evidence regarding TSCPC, according to the latest version of the European Glaucoma Society Guidelines, refractory glaucoma (glaucoma for which the tar- get intraocular pressure (IOP) has not been achieved despite maximum tolerated medical treatments and/or conventional, properly performed filtration surgery)[11] or expected incisional surgery failure remain the only formal indications for TSCPC use.[3]

There is a need for more evidence concerning this procedure, in order to try to expand its indications. Therefore, this study intended to provide more data regarding the efficacy and safety of TSCPC, based on a Portuguese population with glaucoma or ocular hypertension treated at a tertiary centre, with a 2-year follow-up post-procedure.

# Methods

## Patient Selection

We retrospectively reviewed all medical records from adult patients diagnosed with glaucoma or ocular hypertension who underwent TSCPC at the Department of Ophthalmology of Unidade Local de Saúde de São João, Porto, Portugal, over a 6-year period, between January 2014 and December 2019. We analysed one eye per patient and, in case of bilateral TSCPC (n = 2), the right eye was chosen for analysis. All patients had to have a minimum follow-up time of two years after TSCPC. We excluded patients under 18 years old (n = 10), with absence of data at two years of follow-up (n = 24), with unavailable medical records (n = 11) and previous TSCPS (n = 8) (Figure 1).

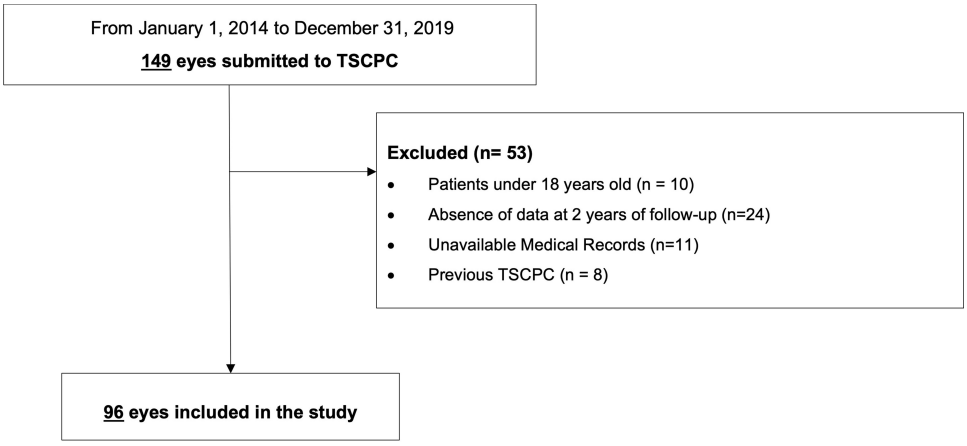


**Figure 1** Flowchart of patients submitted to diode laser transscleral cyclophotocoagulation and exclusion criteria.

The study was approved by the Ethics Review Board of Unidade Local de Saúde de São João (approval 377/21) and conducted in accordance with the Helsinki Declaration. Informed consent was exempted by our ethics committee due to the retrospective nature of the study and since no patient identifiable data were included.

This paper is based on the thesis of João Freitas. The abstract has been published on the institutional website: https://sigarra.up.pt/reitoria/pt/pub_geral.pub_view?pi_pub_base_id=569575.[12]

## Procedure Description

Continuous laser TSCPC treatments were performed in an operating room environment. The anesthetic technique varied from peribulbar, subtenon or general, depending on the surgeon's experience and/or the patient's clinical profile. The procedure was performed using the Oculight® SLx semiconductor diode 810 nm laser and the contact G-probe device (Iris Medical Inc, Mountain View, California USA). The G probe footplate was placed on the conjunctiva with the short side adjacent to the anterior margin of the ciliary body. At each location, the ciliary body was identified with transillumination and the placement of the G probe was adjusted accordingly. Procedure power and extension were defined at surgeon´s discretion, considering the patient's clinical parameters. We used similar laser parameters as other researchers for conventional TSCPC.[13] In most cases, power ranged from an initial setting of 1800 mW, gradually increasing to a maximum of 2500 mW.[13,14] Nonetheless, it has been described that power could vary from a minimum of 800 mW and up to 2700 mW.[13] In a standard procedure, a total of 14–20 applications, lasting 2 seconds each, were distributed over 360°, sparing the 3 o'clock and 9 o'clock locations for preservation of the ciliary nerves and arteries. When an audible pop was heard, energy was lowered 100 mW. Patients with best corrected visual acuity (BCVA) ≥0.1 were treated with lower power and extension, most of them with the applications distributed solely over 180°.

Post-TSCPC eyes were treated in an ambulatory regimen including topical therapy with antibiotic 5 times a day for 1 week, corticosteroids 5 times a day tapered over one month, and, in some cases, oral corticosteroids and atropine. Previous ocular hypotensive medications were never stopped, in order to properly evaluate the IOP-lowering effect and were then tapered according to post-procedure IOP values.

Retreatment with repeat TSCPC or other glaucoma surgeries was performed when the clinical outcome was deemed insufficient and according to the clinician´s and patient´s expectations.

## Collected Data and Outcomes

Data regarding baseline demographic and clinical characteristics including age, sex, type of glaucoma, BCVA, IOP (preoperative, on maximally tolerated medical therapy) ocular hypotensive topical and/or oral medication, previous glaucoma surgeries and other ocular surgeries were collected from clinical records.

Our primary outcome was overall success (all cases of success, regardless of being complete or qualified) at 2 years post-procedure, defined as IOP ≥6 and ≤21 mmHg, with at least 20% IOP reduction from baseline, with (qualified success) or without (complete success) IOP-lowering medications, without the development of phthisis bulbi or loss of light perception due to glaucoma. The need for additional glaucoma surgeries (not including the need for more cycles of TSCPC) was considered a failure.

Data regarding IOP and number of ocular hypotensive medications were gathered from postoperative visits at 1, 3, 6, 12 and 24 months after TSCPC, when available. All patients were required to have a minimum follow-up period of two years after TSCPC, with data available at least at baseline and at 2 years of follow-up. Patients who developed phthisis bulbi during the 2 year follow-up were also included, but no further IOP data was provided after the diagnosis was made. BCVA was only recorded at 6, 12 and 24 months. Data on postoperative complications, retreatments with TSCPC or other glaucoma surgeries were also collected. Persistent hypotony was defined as two measurements of IOP <6 mmHg in two different visits, separated by at least three months. Prolonged inflammation was considered as a complication if anterior chamber signals (eg presence of flare or cells) or corneal disease (including keratitis or corneal oedema) were documented at visits more than one month after TSCP without any preoperative description and without a more likely reason for their appearance.[14]

## Statistical Analysis

Statistical analysis was performed using the IBM SPSS® Statistics Version 28 (SPSS Inc, Chicago, IL, USA). The sample's characteristics were summarized, and data was expressed as counts and proportions for categorical variables,

and continuous variables were described as mean and standard deviation unless otherwise stated. Kolmogorov–Smirnov test and normality probability plots were used to evaluate the type of distribution of data and adjust the statistical tests chosen accordingly. Paired-samples *t*-test was used to compare differences in mean IOP and IOP reduction between baseline and follow-up visits. Wilcoxon signed rank test was used to compare the number of IOP-lowering drops throughout the follow-up time. Independent-samples *t*-test was used to compare differences between groups. Chi-square analysis and Fisher's exact test (when appropriate) were used for analysis of categorical variables (complications and need for oral acetazolamide) throughout the follow-up period. Pearson's correlation coefficient was calculated between baseline IOP and reduction of IOP at 2 years. A level of statistical significance was set for a $p$-value<0.05.

# Results

## Patients' Characteristics and Baseline Data

During the 6-year period of recruitment, 149 patients were treated with TSCPC. Considering exclusion criteria, we included a total of 96 eyes from 96 patients in our study. Excluded patients and motives are shown in Figure 1.

Mean age was 63 (SD ± 14.0) years and 60.4% (n = 58) of the patients were male. A high prevalence of amaurotic eyes (no light perception) at baseline was noticed, (40.6%, n = 39), and only 6.3% (n = 6) of the eyes presented a BCVA ≥ 0.1. The dominant types of glaucoma were neovascular glaucoma (NVG) (n = 30, 31.3%), post-vitrectomy glaucoma (n = 19, 19.8%), primary open-angle glaucoma (POAG) (n = 15, 15.6%), pseudoexfoliative glaucoma (PXFG) (n = 10, 10.4%), and other secondary glaucoma (n = 19, 19.8%). These included, mainly, post-keratoplasty glaucoma (n = 9, 9.3%) and trauma-associated glaucoma (n = 4, 4.2%). Other less common causes included uveitis (n = 1), familial amyloid polyneuropathy (n = 1), glaucoma related to a complicated cataract surgery (n = 1), choroidal hemangioma (n = 1) and limbus-infiltrative amoeba (n = 1). All included eyes were cases of glaucoma refractory to prior surgery and/or maximal tolerated medical therapy (including cases with expected incisional surgery failure). Mean preoperative IOP and number of IOP-lowering drug classes was 39.1 (±13.3) mmHg and 3 (±1), respectively. More than a third of patients were taking oral acetazolamide (n = 36, 37.5%). Previous glaucoma surgery or laser procedures (excluding previous TSCPC) was reported in 47 (48.9%) patients, and 8 (8.3%) of them had been submitted to at least two different procedures. These procedures included trabeculectomy, posterior glaucoma drainage device or laser trabeculoplasty or iridotomy. More in-depth information can be found in Table 1.

## Success Rates and Failure

Overall success after 2 years was achieved in 42 patients (43.8%) with a mean of 1.2 TSCPC treatments (8 of 42 (19.0%) needed two or three TSCPC treatments). Eight (8.3%) patients achieved complete success and 34 (35.4%) qualified success. At 12 months of follow-up, overall success was achieved in 36 patients (37.5%), with 5 (5.2%) and 31 (32.3%) patients reaching complete and qualified success, respectively. We observed that 75% (n = 27) of the patients who achieved overall success after 12 months also accomplished this outcome at 2 years. If we had considered repeat TSCPC as failure, overall success at 2 years would have been achieved in 34 patients (35.4%). A total of 21 patients (21.9%) needed retreatment with TSCPC, with a mean number of 1.2 ± 0.4 procedures during follow-up, performed within 7.1 ± 5.2 months (mean ± SD) after the first TSCPC.

Overall success was higher in the POAG (9 of 15, 60.0%) and post-vitrectomy (12 of 19, 63.2%) groups. On the other hand, the group with the lowest success rate was NVG (9 of 30, 30.0%). Patients with PXFG and other types of secondary glaucoma achieved an overall success of 40.0% (4 of 10) and 38.9% (7 in 18), respectively.

## IOP and Number of IOP-Lowering Medications

TSCPC treatment significantly reduced IOP by a mean of 18.5 (±16.0) mmHg (42.9%) by month 24 ($p < 0.001$, paired *t*-test). IOP reduction at 6 (15.8 ± 13.7 mmHg, 38.3%) and 12 months (17.3 ± 15.1 mmHg, 40.4%) was also significant ($p < 0.001$, paired *t*-test). The average number of IOP-lowering drug classes showed a significant reduction, varying from 3.0 (±1.0) at baseline to 2.2 (±1.3) at 24 months ($p < 0.001$, Wilcoxon signed rank test). We also reported an important drop (although not statistically significant, $p = 0.153$, Fisher's exact test) in the number of patients taking oral acetazolamide, decreasing from 36 (37.5%) patients to 4 (4.2%) by month 24. Mean IOP values, mean IOP reduction, number of IOP-lowering drops and use of oral acetazolamide at 6, 12 and 24 months are presented in Table 2. Figure 2

**Table 1** Baseline Demographic and Clinical Characteristics of the Patients (n = 96) Treated with TSCPC

| **Baseline Characteristics (n = 96)** | |
|---|---|
| Age, years (mean ±SD) | 63 ± 14 |
| Sex - Male (n, %) | 58 (60.4) |
| No. of IOP-lowering topical medications (mean ± SD) | 3 ± 1 |
| Oral acetazolamide (n, %) | 36 (37.5) |
| Baseline IOP, mmHg (mean± SD) | 39.1 ± 13.3 |
| Baseline BCVA (n, %) | |
| Without LP | 39 (40.6) |
| LP | 14 (14.6) |
| Hand motion | 23 (24.0) |
| Counting fingers | 14 (14.6) |
| Decimal 0.1–1.0 | 6 (6.3) |
| Lens status - pseudophakic | 60 (62.5) |
| Glaucoma type (n, %) | |
| NVG | 30 (31.3) |
| Post-vitrectomy | 19 (19.8) |
| Other secondary | 19 (19.8) |
| POAG | 15 (15.6) |
| PXFG | 10 (10.4) |
| CACG | 2 (2.1) |
| Congenital glaucoma | 1 (1.0) |
| Previous glaucoma surgery (n, %) | 47 (48.9%) |
| Trabeculectomy | 16 (16.7) |
| Shunt/ tube | 8 (8.3) |
| SLT | 10 (10.4) |
| Laser iridotomy | 21 (21.9) |

**Abbreviations**: BCVA, Best corrected visual acuity; CACG, Chronic angle closure glaucoma; IOP, intraocular pressure; LP, Light perception; NVG, Neovascular glaucoma; POAG, primary open-angle glaucoma; PXFG, Pseudoexfoliative glaucoma; SLT, Selective laser trabeculoplasty; TSCPC, Transscleral cyclophotocoagulation.

**Table 2** Mean IOP, Mean IOP Reduction, Percentage of IOP Reduction from Baseline, Number of IOP-Lowering Drops, Use of Oral acetazolamide and BCVA at Baseline, 6, 12 and 24 Months

| | **Baseline** | **6 months** | **12 months** | **24 months** |
|---|---|---|---|---|
| IOP, mmHg (mean ± SD) | 39.1 ± 13.3 | 23.0 ± 13.3* | 20.6 ± 11.2* | 20.1 ± 11.9* |
| IOP reduction from baseline, mmHg (mean ± SD) | – | 15.8 ± 13.7* | 17.3 ± 15.1* | 18.5 ± 16.0* |
| % of IOP reduction from baseline (mean± SD) | – | 38.3 ± 31.0 | 40.4 ± 35.8 | 42.9 ± 33.5 |
| No. of IOP-lowering drops (mean± SD) | 3.0 ± 1.0 | 2.5 ± 1.2** | 2.3 ± 1.3** | 2.2 ± 1.3** |
| Oral acetazolamide, n (%) | 36 (37.5) | 10 (10.4)*** | 8 (8.3) | 4 (4.2) |
| BCVA (n, %) | N=96 | N=89 | N=94 | N=96 |
| Without LP | 39 (40.6) | 42 (43.8) | 46 (47.9) | 53 (55.2) |
| With LP | 14 (14.6) | 14 (14.6) | 19 (19.8) | 20 (20.8) |
| Hand motion | 23 (24.0) | 17 (17.7) | 12 (12.5) | 10 (10.4) |
| Counting fingers | 14 (14.6) | 11 (11.5) | 11 (11.5) | 8 (8.3) |
| Decimal 0.1–1.0 | 6 (6.3) | 5 (5.2) | 6 (6.3) | 5 (5.2) |

**Notes**: *p value < 0.001, paired t-test; **p value <0.05, Wilcoxon signed rank test; ***p value < 0.05, Chi square's test.
**Abbreviations**: BCVA, Best corrected visual acuity; IOP, intraocular pressure; LP, Light perception; No, number; % percentage.

shows the mean IOP, number of IOP-lowering drops and percentage of patients taking oral acetazolamide through follow-up.

NVG showed the highest mean preoperative IOP values, 46.3 (±11.8) mmHg, when compared with all the others collectively, 35.9 (±12.8) mmHg ($p$-value<0.001, independent $t$-test; Table 3). We also noticed that these values remained

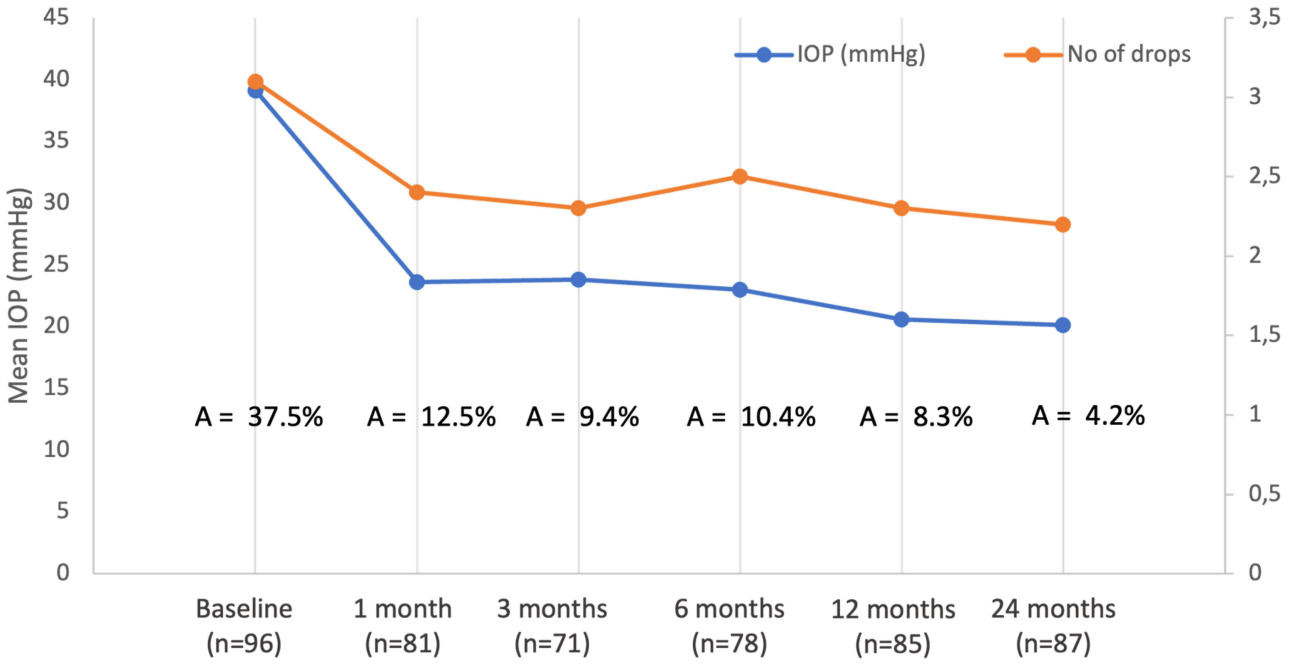


**Figure 2** Mean values of intraocular pressure (IOP), number (No) of IOP-lowering medications and percentage of patients using oral Acetazolamide (A) during follow-up. At 2 years n = 87 since there were 8 cases oh phthisis and one evisceration due to painful corneal disease with already no light perception.

significantly higher during the first 6 months of follow-up (27.9±13.0 and 21.0 ± 13.0, respectively, $p = 0.018$; independent *t*-test). This difference disappeared after the first year of follow-up (22.5 ± 13.4 and 19.8 ± 10.2, respectively, $p = 0.158$; independent *t*-test). NVG also presented the highest IOP decrease, with an absolute mean IOP reduction of 24.7 (±16.4) mmHg at 24 months, when compared with all other non-NVG (16.0 ± 15.3, $p = 0.011$; independent *t*-test). There were no differences between the NVG and non-NVG groups regarding the number of IOP-lowering medications or the use of oral acetazolamide. Findings on mean IOP at baseline and mean IOP reduction at 24 months are described in Table 3.

Lastly, we verified that IOP reduction at 24 months was moderately correlated with baseline IOP, with a higher preoperative IOP being linked with a higher decrease in IOP (Pearson's correlation: $r = 0.682$; $p < 0.001$).

## Complications and BCVA

Regarding complications, we found a clinically relevant rate of occurrences. The most reported events were persistent hypotony (n = 13, 13.5%) and prolonged inflammation/eye surface disorders (n = 10, 10.4%). Of the 13 eyes with persistent hypotony, 8 (8.3%) ended up progressing to phthisis bulbi. Six (46.2%) of the eyes with persistent hypotony and half of the eyes with phthisis bulbi had NVG (conversely, 13.3% of the eyes with NVG). Of the remaining cases of

**Table 3** Baseline IOP and 2 Years After Treatment with Transscleral Cyclophotocoagulation (TSCPC) According to Glaucoma Type

| | Baseline IOP (Mean ± SD) | IOP at 24 Months (Mean±SD) | Mean Reduction of IOP After 24 Months (Mean ± SD) | % of IOP Reduction After 24 Months (Mean±SD) |
|---|---|---|---|---|
| POAG (N=15) | 34.7 ± 13.3 | 18.1 ± 9.6 | 16.6 ± 14.0** | 42.3 ± 27.9 |
| PXFG (N=10) | 35.7 ± 13.4 | 20.5 ± 11.8 | 15.2 ± 20.9* | 30.1 ± 52.4 |
| NVG (N=30) | 46.3 ± 11.8 | 21.5 ± 13.1 | 24.7 ± 16.4** | 51.0 ± 30.6 |
| Post-vitrectomy (N=19) | 32.8 ± 12.2 | 17.8 ± 15.4 | 15.1 ± 9.0** | 47.9 ± 34.8 |
| Other secondary (N=19) | 36.6 ± 10.5 | 22.4 ± 10.1 | 14.3 ± 11.2** | 37.3 ± 25.0 |

**Notes**: *p value < 0.05, paired t-test; **p value < 0.001, paired t-test.
**Abbreviations**: POAG, primary open-angle glaucoma; PXFG, Pseudoexfoliative glaucoma; NVG, Neovascular glaucoma; SD, standard deviation.

phthisis bulbi, two had post-vitrectomy glaucoma and two had other types of secondary glaucoma (Acanthamoeba keratitis with intraocular spread and post-penetrating keratoplasty). The mean baseline IOP of the 13 eyes with persistent hypotony was 43.4 mmHg (SD±11.8, min 27, max 60). At baseline, eleven had no light perception, one had light perception and the other one had counting fingers vision. Five of the 8 eyes with phthisis bulbi were submitted to evisceration (4 due to ocular pain or discomfort and 1 due to imminent risk of perforation). There was also another case of evisceration in an eye without phthisis bulbi but without light perception and with painful corneal disease. A total of 15 among 57 (26.3%) patients converted from LP or better BCVA (hand motion and counting fingers) to without LP during the follow-up time (Table 2). Patients that lost LP had a mean baseline IOP of 54.8 (±9.5) mmHg, 60% of them were on oral acetazolamide and were mainly from other secondary glaucoma (40%) and NVG (33.3%) groups.

## Discussion

The results of our study demonstrated a significant effect of TSCPC in reducing both IOP and the need for IOP-lowering topical and/or oral medications in the management of patients with glaucoma. The overall success rate was 37.5% at 12 months and 43.8% at 24 months. The majority (23 patients, 64%) of patients with overall success after 12 months also achieved success at 24 months without the need of additional TSCPC, suggesting a sustained effect of this procedure between the first and second year. Nonetheless, the rate of complications observed is not negligible, with 13 (13.5%) of the patients developing persistent hypotony, and of these, 8 evolved to phthisis bulbi. Regarding BCVA, 26.3% of patients with vision (light perception, hand motion and counting fingers) progressed to no light perception.

Prior reviews regarding this procedure[10,15] have shown a wide variability of success rates (ranging from 37% to 95%). Recent studies reported higher success rates, around 70%.[13,16–18] However, there are considerable differences between these studies and ours, especially in two key points: a) the studied population; and b) the definition of success. The two largest studies ever carried out, from Quigley et al[18] and Rasmuson et al,[13] with a total of 236 and 300 patients, respectively, presented better efficacy and safety outcomes. However, these studies showed a lower proportion of NVG (16% and 22%, respectively) and higher prevalence of POAG[18] and PXFG.[13] Additionally, the criteria defined by these articles were considerably less restrictive than ours, not considering the percentage of IOP reduction, the loss of LP and the need for glaucoma surgeries other than TSCPC as criteria for failure. Our results were consistent with studies presenting similar baseline patient characteristics and success definition criteria, with a success rate ranging from 36.7% to 54%.[19–21] Another important aspect observed was the correlation between the magnitude of decrease in the mean IOP value by month 24 and the preoperative IOP (Pearson's correlation: $r = 0.682$; $p < 0.001$), suggesting that patients with the highest baseline IOP presented the greatest benefit of treatment, as is seen in other glaucoma treatment modalities.[22] In our study, the eyes who had the highest baseline IOP and the greatest IOP reduction were mainly NVG cases. However, six (20%) of these NVG eyes eventually developed phthisis bulbi (out of the 8 cases of phthisis we report). Interestingly, recently, Sari et al[23] observed that NVG presented the lowest success rate, with only one eye developing phthisis bulbi (1.2% of eyes with NVG). IOP reduction rate was 47.7% in the NVG group, but there were no significant differences in IOP reduction rates between the different types of glaucoma groups. In contrast, we observed a statistically higher amount of IOP reduction in eyes with NVG (51.0%), although with a higher number of cases developing phthisis bulbi (13.3%). Other studies with elevated proportions of NVG also reported a higher rate of these complications.[9,19,24] In the study carried out by Ramli et al,[19] it was concluded that NVG patients had a significantly higher probability of hypotony and a more unpredictable dose–response relationship. Several hypotheses were advocated. The combination of severely impaired outflow by the fibrovascular tissue and the untitrable damage to the ciliary body aqueous production makes eyes with NVG more vulnerable and prone to hypotony.[19,25] In comparison with other types of glaucoma, NVG has in fact a disproportionate outflow resistance, while the aqueous humour production can already be impaired by ischemia. Consequently, any cyclodestructive procedure can disturb the balance between outflow resistance and the aqueous production, resulting in hypotony.[26,27]

The greatest limitation of our study was its retrospective nature, resulting in a considerable number of missing data on BCVA, IOP measurements and other variables, such as laser power used in each eye. Moreover, a selection bias was observed since the majority of our patients presented advanced disease with a low (or inexistent) preoperative BCVA. There is still a tendency to perform this procedure as a last resource. However, recent evidence encourages the earlier use

of cycloablative procedures in patients with better baseline BCVA.[28] Finally, it was not possible to assess ocular pain relief. Success rates only took IOP reduction, BCVA preservation and avoidance of major complications or retreatments into account, not considering pain relief as a success outcome. However, in eyes with poor visual potential or no vision at all, pain control should be considered as a parameter of efficacy. Another concern raised pertains to laser parameters. We used similar laser parameters as other researchers for conventional TSCPC,[13] but we recognize that other studies are using lower energy parameters. Duerr et al[14] suggested that slow-coagulation TSCPC may achieve equivalent IOP control while reducing the incidence of prolonged postoperative inflammation compared to standard pop-titrated TSCPC. Likewise, Gasterland et al are currently conducting a prospective double-blinded randomized controlled trial comparing an experimental group using 1250 mW for 4 seconds and conventional cyclophotocoagulation using 2000 mW for 2 seconds.[29] We acknowledge that different laser parameters may raise concerns regarding efficacy and safety, but our analysis encompassed TSCPC procedures performed before 2019. Future works involving alternative parameters are encouraged.

In conclusion, our study shows that TSCPC can be an effective IOP-lowering procedure, demonstrating a stronger effect when preoperative IOP is highest. We confirm that there is a wide variability in the effect and a considerable amount of postoperative complications, such as persistent hypotony and phthisis bulbi, which are more pronounced in certain glaucoma types such as NVG. More studies are required, ideally with less advanced cases, to establish appropriate energy levels, duration and extension, based on each patient's clinical characteristics, thus allowing for higher success rates, more predictability and less complications.

## Disclosure

Margarida Ribeiro and João Nogueira Freitas are co-first authors for this study. The authors report no conflicts of interest for this work.

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