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*Research article*

# Outcomes of micropulse transscleral cyclophotocoagulation in refractory glaucoma eyes

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## Abstract

***Introduction:*** *Micropulse Transscleral Cyclophotocoagulation (MP-TSCPC) is a new treatment for glaucoma claiming to have lower levels of complications while having comparable efficacy relative to its predecessor, traditional Transscleral Continuous-wave Cyclophotocoagulation (TC-CPC).*

***Objective:*** *To evaluate the clinical efficacy and safety of MP-TSCPC in the treatment of refractory glaucoma eyes.*

***Methods:*** *This uncontrolled interventional study was conducted at the Northampton General Hospital, UK. Patients who were selected to undergo MP-TSCPC due to uncontrolled intraocular pressure (IOP) or visual field progression despite maximum tolerable anti-glaucoma treatment were recruited for the study from February to September 2020. Data related to the patients were collected pre procedure and up to three months post procedure.*

***Results:*** *Of the 37 patients included in the study, 59.5% were females. The mean age of participants was 75.35 (SD=10.37) years. The most common types of glaucoma seen in the sample were primary open angle glaucoma and pseudoexfoliation glaucoma with 67.6% and 16.2% respectively. Mean pre-treatment IOP was 26.62 (SD=8.36) mmHg. Three-month post-treatment mean IOP of 18.47 (SD=7.92) mmHg was a statistically significant (p>0.001) reduction of 7.10 mm Hg. The drop in mean number of anti-glaucoma medications from 2.38 to 2.22 was not significant. Except for four patients with prolonged ocular inflammation and one patient with macular oedema, there were no significant complications following the procedure.*

***Conclusion:*** *MP-TSCPC is an effective and safe treatment option for refractory glaucoma over a 3 month follow up period. More extensive studies with larger sample sizes and longer follow up durations are recommended.*


## Introduction

Glaucoma is defined as a chronic progressive optic neuropathy with characteristic changes in optic nerve head with distinctive patterns of visual dysfunction. Glaucoma is one of the leading causes of irreversible blindness. Of people aged between 40 and 80 years, 3.54% are suffering from glaucoma. The total number of people affected with glaucoma around the world is said to be about 76 million in 2020[1-3].

Primary glaucoma can be due to open angle (POAG, Primary Open Angle Glaucoma) or narrow angles. Secondary glaucoma can develop from trauma, drugs (e.g. corticosteroids), inflammation, tumours, pigment dispersion or pseudoexfoliation.

Intra ocular pressure (IOP) is the main modifiable factor for glaucoma. The intraocular pressure is determined by the balance between aqueous humour production and its drainage via trabecular and uveoscleral pathways.

There are many ways of managing IOP. Traditional Transscleral Continuous-wave Cyclophotocoagulation (TC-CPC) is a treatment option for refractory glaucoma in eyes with poor prognosis. TC-CPC targets ciliary body epithelium, its stroma and vascular core. It reduces the aqueous humour production and facilitates the aqueous humour drainage through trabecular meshwork. This treatment results in diffuse coagulative tissue damage which may progress to development of related side effects such as persistant ocular inflammation, hypotony and vision loss so that, TC-CPC is restricted to eyes with poor visual prognosis.

*Authors were attached to the Department of Ophthalmology, Northampton General Hospital, NHS Trust, NN1 5BD, Northampton, United Kingdom, when the study was done.*

Micropulse Transscleral Cyclophotocoagulation (MP-TSCPC; Iridex Cyclo G6 Laser System) is a novel treatment for glaucoma. MP-TSCPC delivers laser energy into the ciliary body and causes it to develop a low grade ciliary body inflammation by thermal effect. It reduces IOP by increasing aqueous flow in uveoscleral pathway, reduces aqueous production and activates a cellular biochemical cascade. The slight shrinkage of the ciliary body by MP-TSCPC causes ciliary tissue to pull on the trabecular meshwork and Schlemm's canal, which in turn facilitates drainage and reduces IOP. Although it is a variant of traditional TC-CPC, this delivers energy only in a pulsatile manner (Figure 1). It uses 810 nm infrared diode laser radiation in repetitive short pulses. So, MP-TSCPC delivers the laser energy in short bursts and is followed by a rest period ("On" and "Off" cycling mode) so that, it avoids excessive focal heating and burning of the tissues and there is less collateral ciliary body tissue damage. Because of this controlled laser energy delivery with minimal collateral damage, ocular complications such as hypotony, phthisis bulbi, long-term ocular inflammation and vision loss are less likely with MP-TSCPC than TC-CPC[9]. Micropulse Transscleral Cyclophotocoagulation laser delivery probe is designed to deliver laser into parsplana area of the ciliary body. The laser delivery probe (curved edge of the probe) is placed 3 mm away the limbus (Figures 2-4). Since the treatment area is away from the limbus and cornea, there is less damage to the limbal stem cells by Micropulse laser[10-12]. Considering this controlled way of laser delivery action, which minimises side effects, MP-TSCPC can be used for treating any type of glaucoma and for both good and poor prognostic eyes.

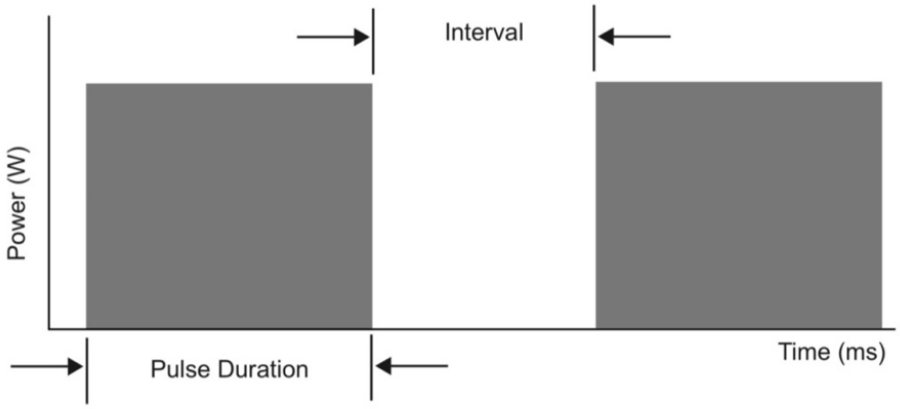
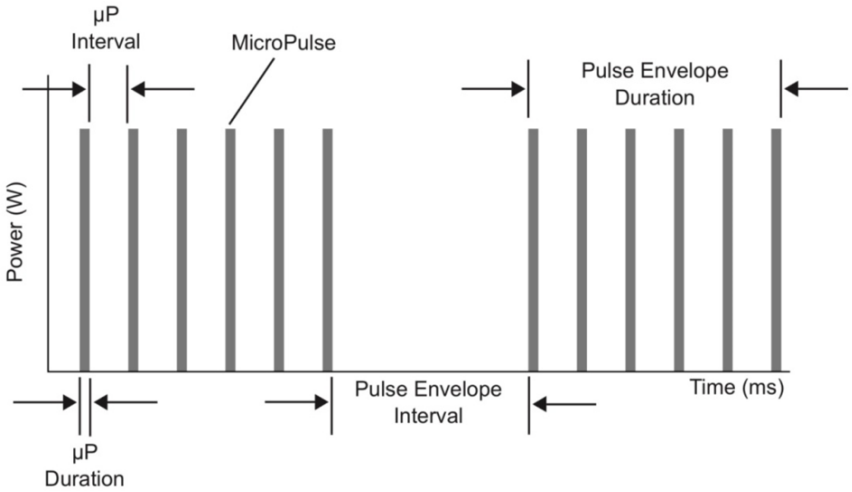



**Figure 1.** *Transscleral Continuous-wave Cyclophotocoagulation (TC-CPC) versus Micropulse Transscleral Cyclophotocoagulation (MP-TSCPC).*



**Laser is delivered to more anterior part of ciliary body and close to the limbus**

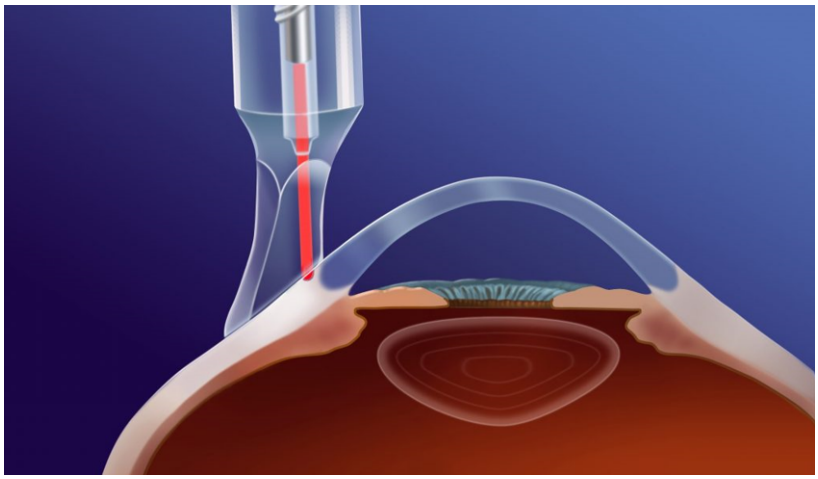


**Figure 2.** *Application of Traditional Transscleral Continuous-wave Cyclophotocoagulation (TC-CPC) to eye – G probe.*

**Delivered to parsplana area of the ciliary body (3 mm from the limbus)**
**Perpendicular to globe surface**

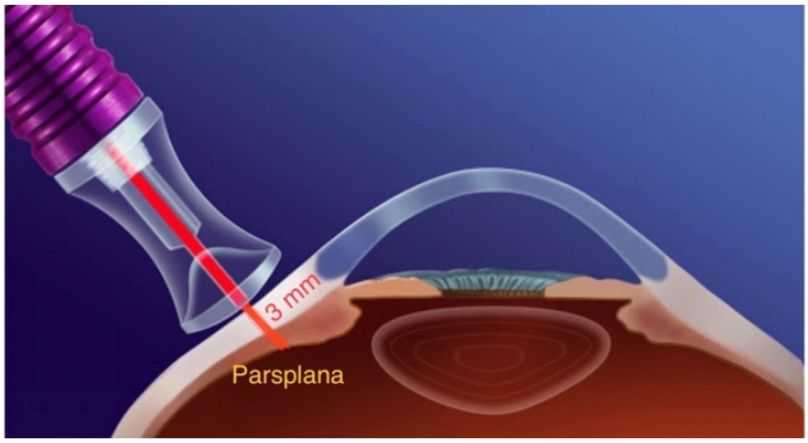



**Figure 3.** *Application of Micropulse Transscleral Cyclophotocoagulation (MP-TSCPC) to eye.*

**Position of the probe when making sweeping movements on the globe**

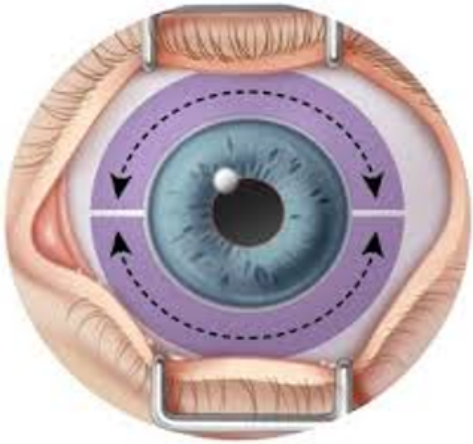


**Figure 4.** *Micropulse Transscleral Cyclophotocoagulation (MP-TSCPC) coverage area in eye.*

## Objectives

### General objective

To evaluate the efficacy and safety of Micropulse Transscleral Cyclophotocoagulation in the treatment of refractory glaucoma eyes at the Glaucoma Unit, Department of Ophthalmology, Northampton General Hospital, UK.

### Specific objectives

- To quantitatively assess the level of intraocular pressure reduction by Micropulse Transscleral Cyclophotocoagulation in refractory glaucoma eyes three months following the procedure.
- To identify complications and their frequency following Micropulse Transscleral Cyclophotocoagulation for refractory glaucoma eyes.
- To identify factors associated with intraocular pressure reduction by Micropulse Transscleral Cyclophotocoagulation in refractory glaucoma eyes.

## Methodology

This is a single centre prospective uncontrolled inter ventional study. Participating patients were those with refractory glaucoma eyes scheduled to be treated with MP-TSCPC at the Glaucoma Unit, Department of Ophthalmology, Northampton General Hospital, NHS Trust, Northampton, NN1 5BD, United Kingdom, between the months of February and September 2020. The patients who were recruited into this study were above 18 year of age, diagnosed as having glaucoma who have failed to achieve target IOP or with visual function deterioration (progressive visual field changes) in spite of maximum tolerable anti-glaucoma treatment for the preceding three months, and who had been offered and agreed to undergo MP-TSCPC. Patients below 18 years, those diagnosed with having congenital, juvenile, neovascular or inflammatory glaucoma, eyes with previous history of MP-TSCPC and patients who had not given consent were excluded from this study. All consecutive patients fulfilling the above inclusion criteria within the recruitment period were considered for the study without randomisation.

Before the procedure, eyes were examined for best corrected visual acuity distant (with standard Snellen visual acuity chart), IOP (with Goldmann applanation tonometry), anterior and posterior segment examination (with slit lamp, 90D and 78D lenses) and pupil examination for relative afferent pupillary defect (RAPD). Visual field and optical coherence tomography (OCT) of optic nerve were done for relevant patients using standard machines. Immediate pre-operative IOP was taken as the baseline IOP. These findings were also entered into a separate data sheet.

The MP-TSCPC was given as an operating room procedure. Before the procedure, eyes were anaesthetised with sub-tenon's 2% Lidocaine 3 ml. The procedure was done in standard operating room sterile conditions. The eye was retro-illuminated by the light of indirect ophthalmoscope to localise the ciliary body.

The apparatus used for delivery of treatment at the unit is Cyclo G6® Glaucoma Cyclophotocoagulation laser system (IRIDEX) machine with Micro Pulse P3® glaucoma device (Figure 5). The laser probe has curved and flat edges. The curved edge is placed on the limbus with flat area towards the lid. The MP-TSCPC is applied to the superior and or inferior 180 degrees of sclera without involving 3 o'clock and 9 o'clock areas (Figure 4). Duration of treatment is 90 seconds for superior and 90 seconds for inferior sclera. Laser is applied in a sweeping movement, about 10-20 seconds for one sweep. The probe is placed perpendicular to the surface of the globe (Figure 3). The settings used in the treatment would be 1500 – 2000 mW laser power with duty cycle (the percentage of each cycle during which the laser energy is on) of 31.3%. The "on" time was 0.5 ms while "off" time was 1.1 ms for every case in the study.

**IRIDEX Cyclo G6® Glaucoma Laser System at Department of Ophthalmology, Northampton General Hospital, UK**


**Figure 5.** *Micropulse Transscleral Cyclophotocoagulation Glaucoma Laser System.*

**MicroPulse P3® laser delivery probe.**

After the treatment, they were followed up at one-week, two-week, one-month, two-month and three-month post laser periods. At each follow up visit, relevant post procedure data were collected. These include: symptoms experienced by patient (visual changes, eye pain etc.), details on the number of anti-glaucoma medications currently prescribed, ocular examination findings (best corrected visual acuity distant, IOP, anterior chamber findings and posterior segment findings),visual field, OCT optic nerve and OCT macula for relevant patients. During each visit, particular attention was paid to assess features of ocular inflammation (conjunctival chemosis, flair in anterior chamber, number of inflammatory cells in anterior and posterior chambers). Anterior chamber inflammation was classified based on standard SUN (Standardization of Uveitis Nomenclature) grading (Table 1) using a slit-lamp light beam size of 1 mm × 1 mm. Features of ocular hypotony (IOP < 6 mmHg, choroidal folds, choroidal detachment, maculopathy) and phthisis bulbi were also assessed at each follow up visit. Maculopathy was assessed clinically and using OCT macula, when required. The data thus collected was entered into a separate spreadsheet database prior to being analysed. If a patient were to require further laser treatment within the follow-up period, it was decided that only post-procedure findings prior to this (first procedure's findings) would be considered for analysis.

## Results

A total of 37 participants that fulfilled the selection criteria were recruited within the study period. The majority of patients were female (59.5%). Participants' ages ranged from 49 to 89 years, with a mean of 75.35 (SD=10.37) years. Figure 6 shows the age distribution of study participants.

**Table 1. Anterior chamber inflammation grading in standard SUN (Standardization of Uveitis Nomenclature) grading**

| *Cells in field* | *Grading of anterior chamber inflammation* |
|---|---|
| < 1 | 0 |
| 1-5 | 0.5+ |
| 6-15 | 1+ |
| 16-25 | 2+ |
| 26-50 | 3+ |
| >50 | 4+ |

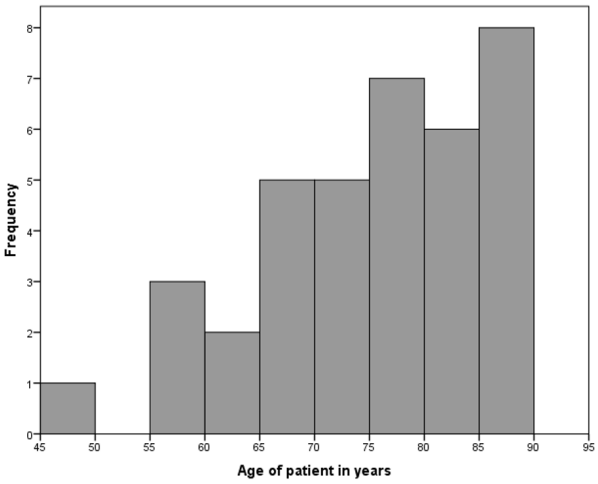



**Figure 6.** *Age distribution of study participants.*

The type of glaucoma seen most in the sample was primary open angle glaucoma (67.6%). The second highest number were of pseudoexfoliation glaucoma (16.2%). Table 2 provides a complete list of the types of glaucoma observed in patients of the study.

At the time of undergoing MP-TSCPC, most patients were on either two or three anti-glaucoma medications. There were eight (21.6%) patients who were prescribed only a single medicine, while six had been using four anti-glaucoma drugs at the beginning of the study (see Table 3). The mean and median number of pre procedure glaucoma drugs used were 2.38 and 2 respectively.

**Table 2. Types of glaucoma among participants of the study**

| *Glaucoma type* | *Frequency (Percent)* |
|---|---|
| Primary open angle glaucoma | 25 (67.6%) |
| Pseudoexfoliation glaucoma | 6 (16.2%) |
| Narrow angle glaucoma | 2 (5.4%) |
| Secondary glaucoma | 2 (5.4%) |
| Angle closure glaucoma | 1 (2.7%) |
| Pigmentary glaucoma | 1 (2.7%) |
| **Total** | **37 (100.0%)** |

**Table 3. Pre procedure number of medications used by patients of the study**

| *Number of medications* | *Frequency (Percent)* |
|---|---|
| 1 | 8 (21.6%) |
| 2 | 13 (35.1%) |
| 3 | 10 (27.0%) |
| 4 | 6 (16.2%) |
| **Total** | **37 (100.0%)** |

The left side eye was affected in 58.3% of the cases which underwent MP-TSCPC in the study. According to the pre procedure visual acuity assessment of the participants, values in the affected eyes ranged from 0.0 LogMAR (6/6 Snellen) to only being able to identify hand movements (HM). The median visual acuity was 0.3 LogMAR. Table 4 shows the frequencies of visual acuity levels seen prior to undergoing MP-TSCPC in the sample of effected eyes in study patients.

Based on the final measurement prior to the procedure, the involved eyes had a mean IOP of 26.62 (SD=8.36) mmHg. The highest pre procedure IOP was 48 mmHg. There were some patients with IOP values less than 20 mmHg, including two individuals having 14 mmHg readings. The reason for these cases with relatively normal IOP values to be chosen for MP-TSCPC was mostly based on the presence of progressive visual field defects in the glaucoma eyes. Figure 7 shows the pre procedure IOP value distribution in the sample.

**Table 4. Pre procedure visual acuity of affected eyes in LogMAR**

| *Visual acuity* | *Frequency (Percent)* |
|---|---|
| 0.0 | 3 (8.1%) |
| 0.2 | 10 (27.0%) |
| 0.3 | 10 (27.0%) |
| 0.5 | 2 (5.4%) |
| 0.6 | 3 (8.1%) |
| 0.8 | 3 (8.1%) |
| 1.0 | 4 (10.8%) |
| HM | 2 (5.4%) |
| **Total** | **37 (100.0%)** |

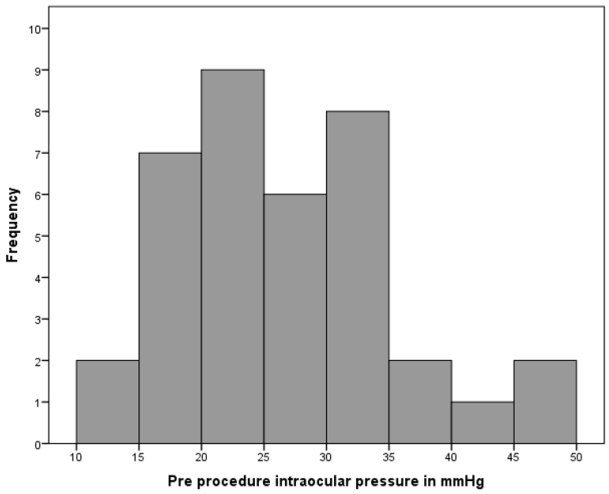



**Figure 7.** *Pre procedure intraocular pressure distribution of study participants.*

After undergoing MP-TSCPC, the patients were assessed at review examinations for the study in one week, two weeks, one month, two months and three months. All 37 patients attended the review after the first week. But, in the subsequent follow up periods there were some defaulters. Therefore, the number of patient assessments carried out in the second week, first, second and third month follow ups were 32, 28, 32 and 30 respectively. Considering the possible short-term variability of IOP measurements, no attempt was made to replace values missing due to nonattendance of follow up, by carrying forward the last known observation in the analysis relevant to the primary objective of the study. Yet, this was done in relation to some of the other analyses performed later on.

**Table 5. Changes and statistical significance in intraocular pressure measurements of participants within the study period**

| | | *Pre procedure* | *Post procedure* | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Week 1* | *Week 2* | *Month 1* | *Month 2* | *Month 3* |
| Mean (SD) | | 26.62 (8.36) | 24.73 (9.06) | 24.22 (9.17) | 22.04 (7.98) | 21.44 (9.16) | 18.47 (7.92) |
| Minimum | | 14 | 12 | 10 | 12 | 10 | 9 |
| Maximum | | 48 | 46 | 46 | 46 | 46 | 40 |
| Mean difference from pre value | | | 1.89 | 3.09 | 5.29 | 6.34 | 7.10 |
| **Paired sample t-test** | t value | | 1.852 | 2.934 | 5.395 | 5.184 | 5.054 |
| | Degrees of freedom | | 36 | 31 | 27 | 31 | 29 |
| | Two-tailed significance | | p=0.072 | p=0.006 | p>0.001 | p>0.001 | p>0.001 |

As shown in Table 5, the mean IOP of participants gradually reduced over the follow up period to reach 18.47 (SD=7.92) mmHg. Which means, that by the 3rd month after undergoing MP-TSCPC, a mean drop of 7.10 (95% Confidence Interval: 4.23 to 9.97) mmHg was observed. Based on the paired sample t-test, from the second week onwards there was a statistically significant difference in IOP after the procedure. Figure 8 gives a graphic representation of how much the IOP dropped relative to the baseline value at each follow up point.

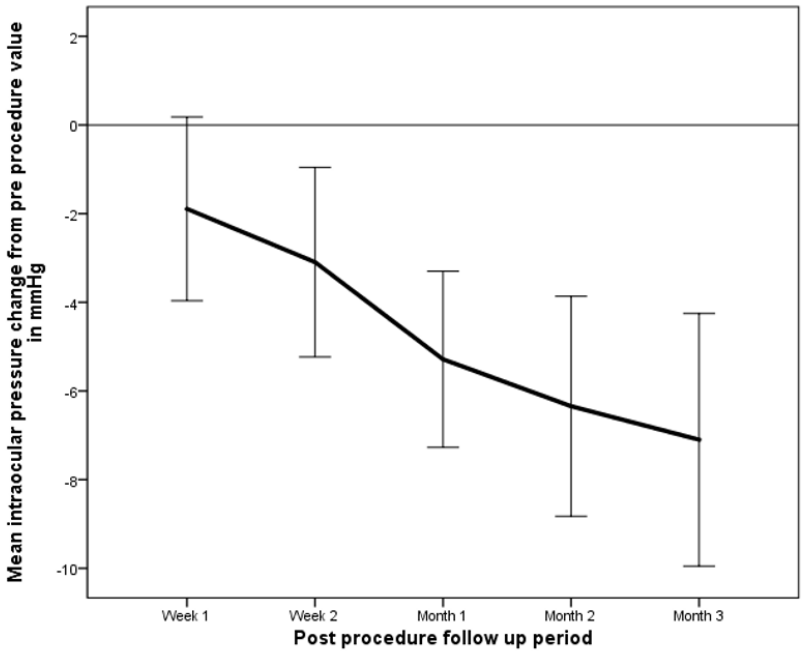



**Figure 8.** *Mean change in intraocular pressure, from pre procedure value with 95% confidence intervals at each follow up period.*

By the end of the study period the percentage of patients on three or four anti-glaucoma medications had decreased (10.8% and 18.9% respectively) from the pre procedure values. Additionally, the percentage on two drugs had increased (51.4%)(see Table 6). Mean number of anti-glaucoma drugs at the final post procedure assessment was 2.22, while the median value was 2. Considering the change in number of medications used at an individual level, it was seen that the vast majority of patients (83.8%) did not have any change in the number of drugs by the third month. Two patients (5.4%) had their drugs cut by two, while a reduction of the number of drugs by one was seen in three patients (8.1%). There was a single patient in the study that required increase in the number of anti-glaucoma medications by one (see Table 7). The mean drop in the number was 0.16 and the median drop was 0. This difference was not statistically significant according to the Wilcoxon signed rank test (p=0.084).

**Table 6. Post procedure number of medications used by patients of the study**

| *Number of medications* | *Frequency (Percent)* |
|---|---|
| 1 | 7 (18.9%) |
| 2 | 19 (51.4%) |
| 3 | 7 (18.9%) |
| 4 | 4 (10.8%) |
| **Total** | **37 (100.0%)** |

**Table 7. Change in the number of medications used from pre procedure value among patients of the study**

| *Change in number* | *Frequency (Percent)* |
|---|---|
| +1 | 1 (2.7%) |
| 0 | 31 (83.8%) |
| -1 | 3 (8.1%) |
| -2 | 2 (5.4%) |
| **Total** | **37 (100.0%)** |

When considering the study's last visual acuity assessment at the three month follow up point, the missing values resulting from patients that had not attended were replaced by the last observation being carried forward (from the two month follow up). This was considered as an appropriate option since it is not expected that visual acuity would change within a short period of time. As with the pre procedure observations, the values in the final visual acuity assessment also ranged from 0.0 LogMAR to HM with the median visual acuity being 0.3 LogMAR. Table 8 shows the frequencies of final visual acuity levels measured in the study. It was found that, relative to the pre procedure visual acuity measure, 31 (83.8%) had no change at the last follow up measurement after undergoing MP-TSCPC. Only 2 (5.4%) patients experienced an improvement in their visual acuity, while 4 (10.8%) observed worsening of visual acuity after the procedure, within the study's follow up period. The two improvements were 0.1 and 0.2 Log MAR in value. Of the four cases with decline in visual acuity, two had a worsening of 0.1 LogMAR, while one had a 0.2 LogMAR worsening. The fourth patient with worsening in visual acuity showed a drop from pre procedure 1.0 LogMAR to HM at the first follow up assessment, which persisted from then onwards.

**Table 8. Post procedure visual acuity of study participants in LogMAR**

| *Visual acuity* | *Frequency (Percent)* |
|---|---|
| 0.0 | 3 (8.1%) |
| 0.2 | 9 (24.3%) |
| 0.3 | 11 (29.7%) |
| 0.5 | 2 (5.4%) |
| 0.6 | 3 (8.1%) |
| 0.8 | 3 (8.1%) |
| 1.0 | 3 (8.1%) |
| HM | 3 (8.1%) |
| **Total** | **37 (100.0%)** |

There were only five instances of complications identified within the three month follow up period among the patients that underwent MT-TSCPC. These involve four cases of prolonged ocular inflammation (4/37=10.8%; 95% confidence interval: 1% to 21%)

identified with the anterior chamber examination, and one case of macular oedema (1/37=3%; 95% confidence interval: 0% to 8%) detected by Optical Coherence Tomography (OCT). All four cases of ocular inflammation seen at the first month follow up assessment was categorised as 1+ using the SUN grading and had completely resolved in subsequent follow ups. The macular oedema in one of the sampled eyes was detected at the second month follow up visit. As the patient defaulted attendance in the third month follow up, it is not known if the macular oedema resolved or persisted. Complications such as immediate vision loss following laser treatment, ocular hypotony or phthisis bulbi were not observed among the participants within the study period.

To find out about possible factors that may be associated with the effectiveness of MT-TSCPC, final observed reduction in IOP was used as the dependent variable. Even though IOP reduction from the baseline value, in the third month was the final observed reading in most of the patients, missing values due to patients who did not attend the three month follow up were replaced with the last observation carried forward from a previous reading. The second month value was available to be used as replacement values in all the 7 missing observations of the third month follow up. This was done with the aim of maximising the number of observations, so that the power of the used statistical tests could be optimised.

**Table 9. Independent sample t-test for intraocular pressure change between categories of binary variables**

| *Variable* | *Categories* | *Mean IOP reduction* | *Independent sample t-test* | | |
|---|---|---|---|---|---|
| | | | *t value* | *Degrees of freedom* | *Two-tailed significance* |
| Sex of patient | Male | 6.33 | 0.490 | 35 | p=0.627 |
| | Female | 7.50 | | | |
| Eye involved | Right | 6.27 | 0.731 | 34 | p=0.470 |
| | Left | 8.00 | | | |

**Table 10. Comparison of intraocular pressure change between glaucoma types**

| | *Source of variability* | *Sum of Squares* | *Degrees of freedom* | *Mean Square* | *F Value* | *Significance* |
|---|---|---|---|---|---|---|
| **One-way ANOVA** | Between Groups | 408.700 | 2 | 204.350 | 5.056 | p=0.012 |
| | Within Groups | 1374.273 | 34 | 40.420 | | |
| | Total | 1782.973 | 36 | | | |

| **Multiple Comparisons using Least Significant Difference (LSD) method** | *Type of glaucoma* | *Mean IOP reduction* | *Number of cases* | *Significance of difference with glaucoma type* | | |
|---|---|---|---|---|---|---|
| | | | | *POAG** | *PXFG*** | *Other* |
| | POAG* | 5.32 | 25 | - | p = 0.644 | p = 0.003 |
| | PXFG** | 6.67 | 6 | | - | p = 0.040 |
| | Other | 14.50 | 6 | | | - |

* POAG - Primary open angle glaucoma
** PXFG -Pseudoexfoliation glaucoma

**Table 11. Pearson correlation for intraocular pressure change with continuous variables**

| *Variable* | *Intraocular pressure change* | |
|---|---|---|
| | *Pearson correlation coefficient* | *Two-tailed significance* |
| Age of patient | -0.010 | p=0.953 |
| Baseline intraocular pressure | 0.424 | p=0.009 |

**Table 12. Mean intraocular pressure values for different glaucoma types**

| *Type of glaucoma* | *Number of cases* | *Mean pre procedure IOP* | *Mean month 3 post procedure IOP* | *Mean IOP change* |
|---|---|---|---|---|
| Primary open angle glaucoma | 25 | 24.36 | 18.36 | 5.32 |
| Pseudoexfoliation glaucoma | 6 | 23.67 | 17.00 | 6.67 |
| Narrow angle glaucoma | 2 | 38.00 | 29.00 | 9.00 |
| Pigmentary glaucoma | 1 | 30.00 | 20.00 | 10.00 |
| Secondary glaucoma | 2 | 42.00 | 29.50 | 12.50 |
| Angle closure glaucoma | 1 | 44.00 | 10.00 | 34.00 |
| **Total** | **37** | **26.62** | **19.14** | **7.03** |

## Discussion

The present study was conducted with the aim of evaluating the efficacy and safety of MT-TSCPC in the treatment of refractory glaucoma at Northampton General Hospital in UK. Based on 37 patients that underwent the treatment and followed up for a period of three months, a significant reduction in mean IOP, along with relatively low rates of complications were observed.

The mean IOP reduction of 7.10 mmHg seen at 3 months was statistically significant (p>0.001). In a similar study conducted in Lebanon by Zaarour et al[9] reported an almost identical level of IOP reduction (7.6 mmHg) at 3 months following the procedure. However, other researches with comparable study design have reported greater IOP reductions at a similar follow up period. These include: 9.0 mmHg by Sarrafpour et al[14], 13.0 mmHg by Tan et al[15], 13.1 mmHg by Emanuel et al[10] and 17.1 mmHg by Williams et al[16]. The above values related to the mentioned publications were either directly calculated or rationally estimated based on the information provided in them.

The only complications observed within the study period of the current research were: prolonged ocular inflammation (10.8%; 95% confidence interval: 1% to 21%) and macular oedema (3%; 95% confidence interval: 0% to 8%). Even among the other studies, persistent inflammation of the anterior chamber was the most common complication following MT-TSCPC. The highest rate (46%) of this complication was seen in the study reported by Emanuel et al, followed by Williams et al (26.6%), and Tan et al (10%)[10,15,16]. Macular oedema was only reported by Williams et al at a prevalence of 5%[16]. Even though not observed in the present study, ocular hypotony had been observed at rates of 13.1% and 8.8% in the studies by Emanuel et al and Williams et al respectively[10,16]. Only the paper by Williams et al reported a case of phthisis bulbi in their study[16]. Interestingly, no serious complications were reported from the studies by Sarrafpour et al and Zaarour et al[9,14], while also being the two studies with the lowest relative mean reduction in IOP. More details on comparison between these studies are shown in Table 13.

**Table 13. Comparison of findings between current study and previous research**

| | *Wijayasiri-wardana 2020 (current study)* | *Zaarour et al 2019* | *Sarrafpour et al 2019* | *Williams et al 2018* | *Emanuel et a. 2017* | *Tan et al 2010* |
|---|---|---|---|---|---|---|
| Country | UK | Lebanon | USA | USA | USA | Singapore |
| Study year | 2020 | 2016 -18 | 2014-16 | 2014-16 | Not mentioned | 2006 |
| Number of cases | 37 (37 eyes) | 69 (75 eyes) | 62 (73 eyes) | 79 (79 eyes) | 84 (84 eyes) | 38 (40 eyes) |
| Female percentage | 59.5% | 46.4% | 64.4% | 61% | 57% | 21.1% |
| Mean age | 75.4 | 55.5 | 73.7 | 70.2 | 74 | 62.6 |
| Main glaucoma types* (%) | POAG (68%)<br>PXFG (16%)<br>2ryG (5%) | POAG (35%)<br>2ryG (13%)<br>ACG (8%) | POAG (86%)<br>NVG (12%)<br>PXFG (1%) | POAG (51%)<br>ACG (23%)<br>PXFG (11%) | POAG (58%)<br>2ryG (14%)<br>PXFG (10%) | NVG (40%)<br>ACG (25%)<br>POAG (22%) |
| Pre Rx mean IOP | 26.6 | 26.0 | 25.5 | 31.9 | 27.7 | 40.1 |
| Post Rx mean IOP 3rd month | 18.5 | 18.4 | 16.5 | 14.8 | 14.6 | 27.1 |
| Post Rx adverse effects** | POI (10.8%),<br>CMO (3%) | None | None | POI (26.6%)<br>Hypt (8.8%)<br>CMO (5%)<br>Phthi (2.5%) | POI (46%)<br>Hypt (13%)<br>IOP ↑ (4%) | POI (10%) |
| Pre Rx mean number of drugs | 2.37 | Drops - 3.53 | 3.1 | 2.3 | 3.3 | 2.1 |
| Post Rx mean number of drugs 3rd month | 2.21 | Drops - 3.25 | 2.5 | 1.3 | 2.0 | 18 months – 1.3 |

* Main glaucoma types: POAG – Primary open angle glaucoma, PXFG - Pseudoexfoliation glaucoma, 2ryG – Secondary glaucoma, ACG – Angle closure glaucoma, NVG – Neovascular glaucoma.

** Post treatment adverse effects: POI - Persistent ocular inflammation, CMO – Cystoid macular oedema, Hypt – Hypotony, IOP ↑ – Intraocular pressure spike, Phthi – Phthisis bulbi.

The present study was able to find that the level of reduction in IOP following MT-TSCPC was associated with type of glaucoma and baseline IOP. Compared to primary open angle glaucoma and pseudoexfoliation glaucoma, other glaucoma types (together) showed a significantly higher reduction in IOP. A similar finding was shown by Tekeli and Köse, where significantly greater IOP drop was seen with secondary glaucoma than primary open angle glaucoma and pseudo-exfoliation glaucoma[17]. But, it must be noted that few highly influential observations may have contributed to the difference observed between glaucoma types in the current study, which therefore requires caution when being interpreted. However, the positive correlation between IOP reduction following intervention and the baseline IOP was much stronger. Which means, that cases with higher IOP at the beginning are likely to get bigger reductions in IOP than those with relatively lower baseline IOP. This has been also shown in the study by Sarrafpour and colleagues, where a pre procedure IOP was found to be a significant predictor of the post procedure IOP reduction, independent of the laser power magnitude used in the treatment[14].

In terms of visual acuity and number of anti-glaucoma drugs used, there was no considerable difference observed at the end of the study period compared to pre procedure values.

## Limitations

There are two main limitations in this study worth noting. The first one is the relatively low sample size. Even though the number of patients in this research was adequate in assessing some of the main objectives, a larger sample would have allowed for more extensive analyses to be performed. While the current study had to limit itself to bivariate analyses when studying associations, a larger sample size would have provided the opportunity to carryout analyses such as multiple linear regression to identify significant baseline predictors, adjusting for other variables. It would have also made the effect of individual glaucoma types clearer, without having to arbitrarily group them together. But, considering the practical difficulties in having a longer study recruitment period and/or using multiple centres, the current study had to restrict itself to collecting data for eight months at a single centre.

The second main limitation in the study was the short duration of follow up. Some of the effects following MT-TSCPC would have been more prominent beyond the 3 month follow up used in this instance. It is not clear if more complications would have appeared later on. The reduction in IOP seen within this period may have either further improved or perhaps regressed. Especially, if longer term effects of the treatment are to be evaluated, a follow up period more than one year should have been considered. However, it was not possible for the present study to go for such an extensive follow up duration considering the limited study period available.

## Conclusions

Micropulse Transscleral Cyclophotocoagulation is effective and relatively safe in treating refractory glaucoma at the Northampton General Hospital in UK. It appears to have a greater impact when the baseline IOP is high.

Prospective studies with larger sample sizes and longer follow up periods may provide more detailed evidence on the safety and efficacy of this relatively new treatment option for glaucoma.

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