Ophthalmol Ther (2023) 12:179–193
https://doi.org/10.1007/s40123-022-00598-5

ORIGINAL RESEARCH

# Assessment of the Effectiveness of Glaucoma Treatment Using MicroPulse Transscleral Cyclophotocoagulation in Patients with Glaucoma Who Have Previously Undergone Vitreoretinal Surgery

Izabela Kuciel-Polczak · Maciej Helemejko · Dariusz Dobrowolski · Dominika Janiszewska-Bil · Katarzyna Krysik · Beniamin Oskar Grabarek · Anita Lyssek-Boroń

Received: September 4, 2022 / Accepted: October 15, 2022 / Published online: November 2, 2022


## ABSTRACT

***Introduction***: This retrospective study aimed to assess the effectiveness of using MicroPulse transscleral cyclophotocoagulation (μP-TSCPC) in patients who had previously undergone pars plana vitrectomy (PPV), depending on the endotamponade used.

***Methods***: For the study, a total of 60 patients were enrolled who underwent PPV followed by tμP-TSCPC as a result of an increase in intraocular pressure (IOP) over the norm of 21 mmHg. In this group of patients, 20 received silicone oil endotamponade during PPV, 20 received sulfur hexafluoride gas SF6, and in another 20 a differentiated balanced salt solution (BSS) was used.

***Results***: The main indications for conducting PPV were (1) retinal detachment (silicone oil endotamponade was used; $n = 12$); (2) dislocation/subluxation of the patient's own or artificial intraocular lens (balanced salt solution (BSS) endotamponade was used; $n = 11$); (3) the presence of an epiretinal membrane and/or a macular hole (BSS endotamponade was used; $n = 9$, or SF6; $n = 20$); and (4) hemorrhage into the vitreous chamber (silicone oil endotamponade was used; $n = 8$).

***Conclusion***: The choice of endotamponade used during PPV was not found to determine the effectiveness of μP-TSCPC treatment. The effectiveness of μP-TSCPC in patients after PPV depended, above all, on the etiology of the disease, for which PPV was previously performed. The lowest effectiveness of μP-TSCPC was noted in cases where the reason for conducting PPV was hemorrhage into the vitreous chamber and silicone oil endotamponade was used, while the highest effectiveness was noted in cases where PPV was conducted owing to the presence of an epiretinal membrane and/or a

I. Kuciel-Polczak (✉) · M. Helemejko · D. Dobrowolski · D. Janiszewska-Bil · K. Krysik · A. Lyssek-Boroń
Department of Ophthalmology, Trauma Centre, St. Barbara Hospital, 41-200 Sosnowiec, Poland
e-mail: i.kucielpolczak@gmail.com

I. Kuciel-Polczak · D. Janiszewska-Bil · K. Krysik · A. Lyssek-Boroń
Department of Ophthalmology, Faculty of Medicine in Zabrze, Academy of Silesia in Katowice, 41-800 Zabrze, Poland

D. Dobrowolski
Chair and Clinical Department of Ophthalmology, Division of Medical Science in Zabrze, Medical University of Silesia in Katowice, 40-760 Katowice, Poland

D. Dobrowolski
Department of Ophthalmology, District Railway Hospital, 40-760 Katowice, Poland

B. O. Grabarek
Department of Histology, Cytophysiology and Embryology, Faculty of Medicine in Zabrze, Academy of Silesia in Katowice, 41-800 Zabrze, Poland

macular hole and SF6 endotamponade was used.

**Keywords:** MicroPulse transscleral cyclophotocoagulation; Pars plana vitrectomy; Endotamponade; Glaucoma; Intraocular pressure

**Key Summary Points**

***Why carry out this study?***

Patients with glaucoma who have previously undergone pars plana vitrectomy (PPV) represent a particular subset of patients with glaucoma.

The aim of the study was to assess the effectiveness of using μP-TSCPC in patients who previously underwent PPV, depending on the endotamponade used.

***What was learned from the study?***

The effectiveness of MicroPulse transscleral cyclophotocoagulation (μP-TSCPC) in patients after PPV depends mainly on the etiology of the disease for which PPV was conducted.

The highest effectiveness was noted in cases where PPV was conducted owing to the presence of an epiretinal membrane and/or a macular hole and SF6 endotamponade was used.

## INTRODUCTION

Glaucoma is a progressive disease that damages the optic nerve, leading to narrowing of the field of view and weakening of visual acuity, and may result in blindness. An increase in intraocular pressure (IOP) is also noted, which results in the loss of retinal ganglion cells [1–3]. It is estimated that primary open-angle glaucoma (POAG) affects approximately 57.5 million people around the world [4], and it is estimated that, in 2040, this number will reach approximately 111.8 million [5]. Therefore, it constitutes a problem not only in a medical context but also in the context of public health [6–10].

The aim of glaucoma treatment is to reduce intraocular pressure by reducing the production of aqueous humor or increasing its outflow through the conventional outflow pathway, uveoscleral outflow pathway, or both [2, 11, 12]. A particular type of patient with glaucoma is one who has previously undergone pars plana vitrectomy [13, 14].

Pars plana vitrectomy (PPV) is a surgical procedure that can be used to treat retinal and vitreous body diseases, such as retinal detachment, epiretinal membranes, macular holes, vitreoretinal traction, or hemorrhage into the vitreous chamber [15, 16]. Common complications following PPV include an increase in IOP, which is predisposed by postoperative inflammation, the type of endotamponade used, and excessive or incorrectly directed laser coagulation [17–20]. Two types of transscleral cyclophotocoagulation (TSCPC), which are used to lower IOP after PPV, can be differentiated, namely traditional continuous-wave (CW-TSCPC) and, more recently, MicroPulse TSCPC (μP-TSCPC) (Iridex, Mountain View, CA, USA). The former method can be considered for advanced glaucoma with a poor visual outcome [21, 22].

The introduction of μP-TSCPC has significantly contributed to the reduction in the number of side effects of classic transscleral cyclophotocoagulation, increasing safety while also enabling the use of this technique at a much earlier stage of glaucoma treatment [23–26]. This results in a reduction in drainage resistance of the aqueous humor at the iridocorneal angle and a reduction in IOP. This treatment is believed to reduce the production of aqueous humor and increase outflow [21, 27, 28].

To the best of our knowledge, the effectiveness of μP-TSCPC in patients who previously underwent PPV has not been described. Therefore, this is the first investigation of its kind.

This retrospective study aimed to assess the effectiveness of using μP-TSCPC in patients who

previously underwent PPV, depending on the endotamponade used.

## METHODS

This retrospective study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institution of the Ethical Committee operating at the Academy of Silesia in Katowice, Poland. No. 03/KEBN/2021 (15 October 2021). Informed consent was obtained from all subjects involved in the study. Written informed consent was obtained from the patient(s) to publish this paper. Medical records from 2017 to 2022 were analyzed.

### Subjects

Sixty eyes of 60 patients who underwent the PPV procedure were examined in this study, which was followed by the μP-TSCPC procedure owing to an increase in IOP above the norm of 21 mmHg (19.3 ± 7.2 months after PPV). In this group of patients, 20 received silicone oil endotamponade during PPV (58.1 ± 11.1 years of age; IOP increase after 18.1 ± 4.2 months after PPV), 20 received sulfur hexafluoride gas SF6 endotamponade (57.8 ± 10.9 years of age; 20.2 ± 7.4 months after PPV), and the next 20 received differentiated balanced salt solution (BSS) endotamponade (62.7 ± 9.1 years of age; IOP increase 18.2 ± 8.1 months after PPV). Table 1 presents the inclusion and exclusion criteria from the study.

In turn, the demographic and clinical characteristics of the patients included in the study are presented in Table 2. The value of best corrected visual acuity was the same before and after the μP-TSCPC procedure.

**Table 1** Inclusion and exclusion criteria for the patients qualified for μP-TSCPC who previously underwent PPV

| Inclusion criteria | Exclusion criteria |
|---|---|
| Over 18 years old | Below 18 years old |
| Open-angle glaucoma, primary open-angle glaucoma, chronic angle closure glaucoma, and secondary glaucoma | Malignant glaucoma, closed-angle glaucoma, absolute glaucoma |
| Cataract previously removed | Previous photocoagulation of the retina |
| Previous pars plana vitrectomy procedure due to retinal detachment or dislocation/subluxation of the patient's own or artificial intraocular lens or epiretinal membrane and/or macular hole or hemorrhage into the vitreous chamber | Clouding of optical medium preventing good-quality OCT scans |
| IOP > 21 mmHg | IOP < 21 mmHg |
| | Diabetic macular edema treated with anti-endothelial growth factor drugs (anti-VEGF) |
| No other coexisting retina diseases | Other coexisting retina diseases, such as age-related macular degeneration or central retinal artery embolism/thrombosis |

*PPV* pars plana vitrectomy, *OCT* optical coherence tomography, *VEGF* vascular endothelial growth factor, *IOP* intraocular pressure

### PPV Procedure

The main indications for conducting PPV were as follows: (1) retinal detachment (silicone oil endotamponade was used; $n = 12$); (2) dislocation/subluxation of the patient's own or artificial intraocular lens [balanced salt solution (BSS) endotamponade was used; $n = 11$]; (3) epiretinal membrane and/or macular hole (BSS endotamponade was used; $n = 9$, or SF6; $n = 20$); and (4) hemorrhage into the vitreous chamber (silicone oil endotamponade was used; $n = 8$).

**Table 2** Demographic and clinical characteristics of the patients included in the study

| Feature | Total number of patients (%) | Indications for conducting PPV | | | |
|---|---|---|---|---|---|
| | | Retinal detachment | Dislocation/subluxation of the patient's own or artificial intraocular lens | Epiretinal membrane and/or macular hole | Hemorrhage into the vitreous chamber |
| Ethnicity | | | | | |
| Caucasian | 60 (100%) | | | | |
| Age (years) | 56.2 (55.2; 58.9) | | | | |
| Ocular comorbidities | | | | | |
| Proliferative diabetic retinopathy | 3 (5%) | 2 | | | 1 |
| Myopia | 6 (10%) | 2 | 3 | 1 | 1 |
| Amblyopia | 1 (2%) | | 1 | | |
| Systemic comorbidities | | | | | |
| Hypertension | 18 (30%) | 10 | 2 | 3 | 3 |
| Diabetes | 13 (43%) | 9 | 0 | 0 | 3 |
| Hypertension + diabetes | 8 (13%) | 7 | 0 | 0 | 1 |
| Bronchial asthma | 2 (3%) | 1 | 0 | 1 | 0 |
| logMAR BCVA | 0 (−0.10; 0.10) | | | | |
| Number of topical antiglaucoma drugs | 3 (2;3) | | | | |
| Number of systematic antiglaucoma drugs | 0 | | | | |
| Previous eye surgery | | | | | |
| Cataracts | 60 (100%) | | | | |
| Lens status | | | | | |
| Pseudophthalmia | 60 (100%) | | | | |

Data are presented as the median (lower quartile; upper quartile)
*BCVA* best corrected visual acuity, *PPV* pars plana vitrectomy

The decision on the type of endotamponade used takes place during the PPV procedure. In situations where the indication for the procedure was retinal detachment or hemorrhage into the vitreous chamber, silicone oil is always used because of its bleeding-inhibiting properties. When no sub-bleeding was noted during

PPV, SF6 was used in cases where the eyeball was flaccid, and BSS was used in other cases.

All PPV surgeries were performed by one vitreoretinal surgeon (A.L.-B.) using the same technique and the same vitreoretinal machine (Constellation, Alcon, Fort Worth, TX, USA).

### Intraocular Pressure Measurement

IOP was measured using the Goldmann tonometer according to the standard protocol. IOP values in the range 11–21 mmHg were assumed to be correct.

All patients were followed up periodically at the hospital eye clinic after PPV. In the situation where an increase in IOP was observed, topical antiglaucoma treatment was applied first, according to current recommendations. According to the guidelines, "IOP reduction with initial monotherapy should be at least 20% from baseline values," and "an IOP reduction of less than 10% should be considered as no response to the drug." In situations where an IOP between 6 mmHg and 21 mmHg could not be achieved, which was associated in some patients with the need to include a third hypotonic drug, laser therapy was considered in accordance with the guidelines of the Polish Ophthalmological Society [29]. Nevertheless, the median number of visits was 4.

Antiglaucoma treatment included dorzolamide hydrochloride, prostamide, brimonidine, brimonidine tartrate, and thymolol.

### Computer-Based Optical Coherence Tomography (OCT)

The OCT procedure was conducted in all patients before the μP-TSCPC procedure (time 0) as well as 30, 90, and 180 days after the procedure. The OCT examination was conducted using the RTVue (Optovue, Fremont, California) device, which is a spectral optical tomograph (spectra-domain OCT, SD-OCT). In the observed group of 60 patients, OCT was important. Despite the unsatisfactory decrease in IOP in 15 cases, the retinal nerve fiber layer (RNFL) values remained at a stable level throughout the observation period.

### MicroPulse Transscleral Cyclophotocoagulation (μP-TSCPC)

The procedures took place in the operating room. Before the operation began, the eye was locally anesthetized using 0.5% proparacaine hydrochloride ophthalmic solution (Alcon, Warszawa, Poland) drops, followed by peribulbar anesthesia using bupivacaine hydrochloride (Grndeks, Riga, Latvia). The procedures were performed in the upper and lower hemispheres, excluding 3 and 9 o'clock, with laser settings of 2500 mW and $2 \times 80$ s for patients with IOPs below 30 mmHg or $2 \times 90$ s for patients with IOPs above 30 mmHg.

The procedures were conducted using the IRIDEX MP3 810 nm laser at a 31.3% duty cycle.

The postoperative regimen consisted of topical prednisolone acetate 1% (Pred Forte, Allergan Pte Ltd., Singapore) four times daily for a minimum of 1 week, which could then be tapered depending on the grade of inflammation. All preoperative antiglaucoma medications were continued initially and then adjusted at each follow-up visit according to the IOP level. In case a laser-induced IOP-lowering effect was observed, antiglaucoma medications were reduced in a stepwise manner. Decisions on retreatment or additional incisional surgery were made according to the details of each case and at the clinical discretion of the surgeon.

### Follow-Up

Topical treatment of glaucoma was continued after the μP-TSCPC procedure in all patients in accordance with current standards. Treatment was chosen individually according to the patient's needs and their health. Check-ups took place 7 days, 30 days, 90 days, and 180 days after the procedure. No complications, such as phthisis bulbi, hypotony, hyphemia, visual loss of light perception, macular edema, severe pain, corneal edema, or inflammation, were noted during the ongoing follow-up. The success of the μP-TSCPC therapy used was determined on the basis of the following criteria: (1) an IOP value between 6 mmHg and 21 mmHg and no less than a 20% reduction on

**Table 3** Changes in IOP values depending on the endotamponade used during PPV over the 180-day observation period

| Type of endotamponade | Time | Median number of medications | IOP (mmHg) | | | *p* value (Mann–Whitney *U* test) |
|---|---|---|---|---|---|---|
| | | | Median | Lower quartile | Upper quartile | |
| Oil endotamponade | 0 days | 3 | 27 | 23 | 29 | 0.022 |
| | 180 days | 1 | 16 | 15 | 17 | |
| SF6 endotamponade | 0 days | 3 | 29 | 27 | 31 | 0.008 |
| | 180 days | 1 | 17 | 15 | 19 | |
| BSS endotamponade | 0 days | 3 | 31 | 28 | 32 | 0.025 |
| | 180 days | 1 | 20 | 19 | 21 | |

the 180th day of follow-up with or without IOP-lowering drugs; (2) no need for repeat surgical treatment or laser therapy; (3) incidence of postoperative complications, including persistent hypotony and deterioration of visual acuity; (4) need for an increase in topical antiglaucoma drugs or the need to include systemic treatment.

## Statistical Analysis

Statistical analysis was conducted using the STATISTICA 13 PL program (StatSoft, Cracow, Poland), assuming a statistical threshold of $p < 0.05$. Quantitative variables were first assessed in terms of distribution normality using the Shapiro–Wilk test ($p < 0.05$). Therefore, in further statistical analysis, non-parametric tests were included—the Kruskal–Wallis mean rank analysis test followed by Dunn's post hoc test (assessment of independent variables, i.e., comparing groups of patients at the same time; $p < 0.05$) as well as the Friedman analysis of variance (ANOVA) test with use of Friedman's post hoc ANOVA test (assessment of dependent variables, i.e., changes in IOP in the same group of patients over time; $p < 0.05$). To compare two independent variables (two different endotamponades used during PPV for the same reason), the Mann–Whitney *U* test was used ($p < 0.05$). In turn, qualitative variables were assessed using the chi-squared test ($p < 0.05$).

**Table 4** The effectiveness of the μP-TSCPC procedure in patients after PPV depends on the endotamponade used during the procedure

| Time after μP-TSCPC procedure | Type of endotamponade | | | $\chi^2$ $p < 0.05$ |
|---|---|---|---|---|
| | Oil endotamponade ($n = 20$) | SF6 endotamponade ($n = 20$) | BSS endotamponade ($n = 20$) | |
| 180 days | 15 (75%) | 19 (95%) | 17 (85%) | $\chi^2 = 3.1373$ |
| | | | | $p = 0.2083$ |

*n* number of cases, $\chi^2$ chi-squared test results, *p* *p* value
Data are presented as the number of patients and their percentage

**Table 5** Changes in IOP values after the μP-TSCPC procedure depending on the etiology of the disease for which PPV was previously performed

| Reason for PPV | Endotamponade | 0 days | 7 days | 30 days | 90 days | 180 days | *p* value | |
|---|---|---|---|---|---|---|---|---|
| | | IOP (mmHg) presented as median (Q1; Q3) | | | | | | |
| Retinal detachment | Oil | 25 (24; 26) | 23 (22; 25) | 16 (15; 17) | 15 (14; 16) | 15 (14; 16) | 0.018[a,b] | |
| | | | | | | | 0.017[c] | |
| | | | | | | | 0.041[d] | |
| | | | | | | | 0.041[e] | |
| | | | | | | | 0.042[f] | |
| Hemorrhage into the vitreous chamber | Oil | 29 (27; 30) | 25 (24; 26) | 18 (17; 19) | 19 (18; 20) | 17 (16; 18) | 0.022[a] | |
| | | | | | | | 0.021[b] | |
| | | | | | | | 0.020[c] | |
| | | | | | | | 0.047[f] | |
| Dislocation/subluxation of the patient's own or artificial intraocular lens | BSS | 30 (28; 31) | 29 (28; 30) | 26 (25; 27) | 24 (23; 26) | 21 (20; 22) | 0.015[b] | |
| | | | | | | | 0.012[c] | |
| | | | | | | | 0.005[f] | |
| Retinal membrane and/or macular hole | BSS | 32 (30; 33) | 31 (30; 32) | 28 (27; 28) | 24 (22; 25) | 19 (18; 20) | 0.002[a] | 0.035[g] |
| | | | | | | | 0.001[b] | 0.021[h] |
| | | | | | | | 0.001[c] | 0.018[i] |
| | SF6 | 29 (27; 31) | 26 (27; 28) | 21 (19; 23) | 19 (17; 20) | 17 (15; 19) | 0.011[f] | |

Data are presented as the median and upper quartile
[a]Statistically significant differences in IOP values between days 0 and 30 in the group
[b]Statistically significant differences in IOP values between days 0 and 90 in the group
[c]Statistically significant differences in IOP values between days 0 and 180 in the group
[d]Statistically significant differences in IOP values between days 7 and 30 in the group
[e]Statistically significant differences in IOP values between days 7 and 90 in the group
[f]Statistically significant differences in IOP values between days 7 and 180 in the group
[g]Statistically significant differences in IOP values in the group, depending on the type of endotamponade, at 7 days
[h]Statistically significant differences in IOP values in the group, depending on the type of endotamponade, at 30 days
[i]Statistically significant differences in IOP values in the group, depending on the type of endotamponade, at 90 days

# RESULTS

## Changes in IOP Values Depending on the Endotamponade Used during PPV

After μP-TSCPC, the number of antiglaucoma drugs used immediately after laser therapy decreased from 3 to 1. Antiglaucoma drugs after μP-TSCPC were discontinued depending on the IOP value, with 3 patients (5%) discontinuing them after 30 days, 18 patients (30%) discontinuing them after 90 days, and 30 patients (50%) discontinuing them on the 180th day of follow-up. In nine patients (15%), owing to an increase in IOP, an increase in the number of topical antiglaucoma drugs was necessary according to the recommendation. In none of

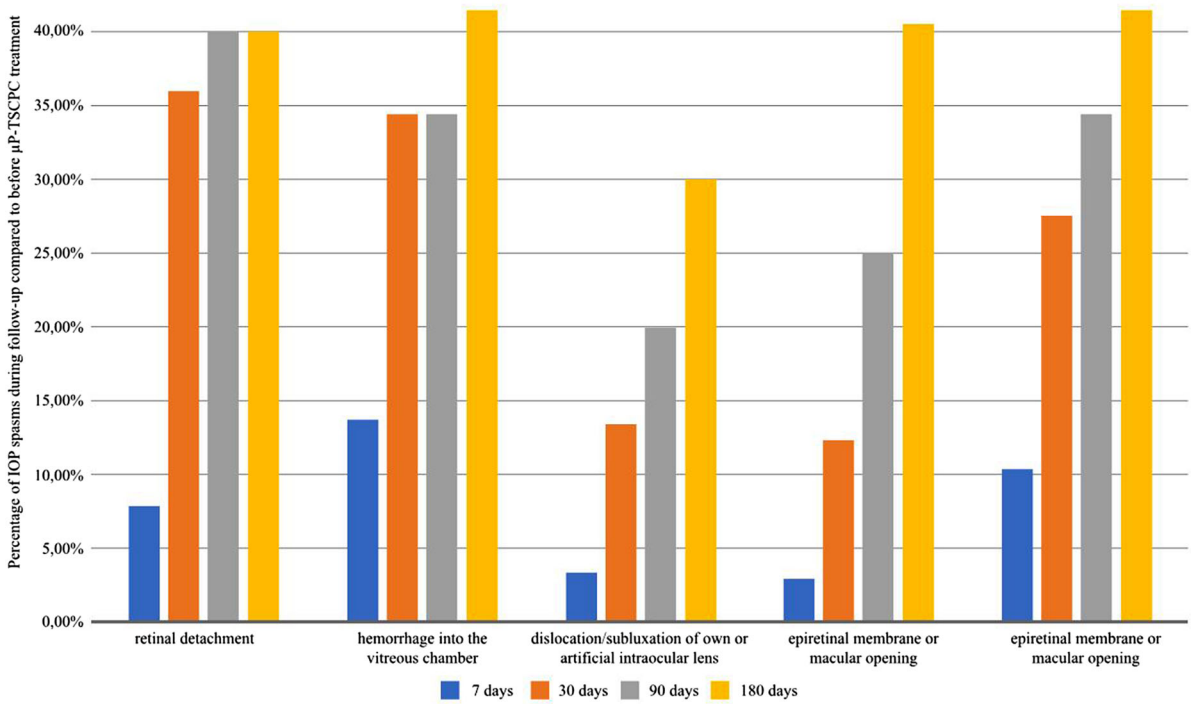


**Fig. 1** Percentage decrease in IOP in patients after µP-TSCPC, depending on the reason for conducting PPV and the endotamponade used. *µP-TSCPC* MicroPulse transscleral cyclophotocoagulation, *IOP* intraocular pressure, *PPV* pars plana vitrectomy

the patients was it necessary to include systemic therapy.

Statistical analysis showed that, regardless of the type of endotamponade used, there was a statistically significant decrease in IOP 180 days after the µP-TSCPC procedure (Table 3, $p < 0.05$). For patients who used oil endotamponade, there was a decrease in pressure of 11 mmHg, or 41%, compared with IOP values before the µP-TSCPC procedure. For patients who used SF6 endotamponade, the median decrease in IOP was 12 mmHg, equivalent to 42%, and when BSS endotamponade was used, the decrease in IOP was 11 mmHg, equivalent to a 36% decrease compared with baseline. In addition, the number of topical hypotensive drugs was reduced, and there was no need for systemic treatment (Table 3).

In the following stage, we determined the effectiveness of the µP-TSCPC procedure in three groups during the conducted observation. The choice of endotamponade used during the PPV procedure was not found to determine the effectiveness of µP-TSCPC treatment (75%). However, in the group of patients in whom silicone oil endotamponade was used, the percentage of patients in whom treatment was ineffective was the highest out of all three groups (chi-squared test; $p > 0.05$; Table 4).

### *Changes in IOP Values after the µP-TSCPC Procedure, Depending on the Etiology of the Disease for Which PPV was Previously Performed*

Net, we assessed whether the reason behind conducting PPV had a statistically significant influence on the increase in IOP, which was the reason for which µP-TSCPC was conducted, as well as its effectiveness. First, it can be determined that, regardless of the disease etiology, a statistically significant reduction in IOP was noted in all patients within 180 days of observation (Table 5). In the case of patients whose cause of PPV was the epiretinal membrane or macular hole, the type of endotamponade used during PPV was found to significantly influence the IOP values after µP-TSCPC at the time of observation ($p > 0.05$). Patients from this group

**Table 6** The results of statistical analysis of the effectiveness of the μP-TSCPC procedure in patients following PPV depending on the reason for conducting PPV

| Comparison group | $\chi^2$ | *p* value |
|---|---|---|
| Retinal detachment | | |
| Hemorrhage into the vitreous chamber | 0.2778 | 0.5982[a] |
| Retinal detachment | | |
| Dislocation/subluxation of the patient's own or artificial intraocular lens | 0.1442 | 0.7061[a] |
| Hemorrhage into the vitreous chamber | | |
| Dislocation/subluxation of the patient's own or artificial intraocular lens | 0.6417 | 0.4231[a] |
| Retinal detachment | | |
| Epiretinal membrane/macular hole | | 0.805[b] |
| Hemorrhage into the vitreous chamber | | |
| Epiretinal membrane/macular hole | | 0.00772[b] |
| Dislocation/subluxation of own or artificial intraocular lens | | |
| Epiretinal membrane/macular hole | | 0.0619[b] |

[a]$\chi^2$ chi-squared test results with Yates correction
[b]Results of the Fisher extract test

who used SF6 gas endotamponade in the first 180 days of observation had significantly lower IOP values after the μP-TSCPC procedure than those in whom BSS was used (Mann–Whitney *U* test; $p < 0.05$). However, no such relationship was found in the case of silicone oil endotamponade, regardless of the disease etiology, which was the prerequisite for PPV (Mann–Whitney *U* test; $p > 0.05$). Detailed results of changes in the IOP values, depending on the disease etiology, a re presented in Table 5.

Figure 1 shows the percentage decrease in IOP on specific days of observation after the μP-TSCPC procedure, depending on the reason for conducting PPV, according to the type of endotamponade, if used. IOP on day 0 of the observation was adopted as 100% for each of the three groups. An approximate 40% reduction in IOP after 180 days of observation in four of the five groups was observed, whereas when the reason for conducting PPV was dislocation/subluxation of the patient's own or artificial intraocular lens, IOP reduction was 30%. Furthermore, the reduction in IOP was larger on later days of observation (Fig. 1).

Next, we indicated that the μP-TSCPC procedure was most effective in the group of patients who had previously undergone PPV owing to the epiretinal membrane and/or macular hole (effectiveness 100%; $n = 29$), while the lowest effectiveness was noted in patients in whom PPV was conducted owing to hemorrhage into the vitreous chamber (effectiveness 62.55%; $n = 5$). On the other hand, in the group of patients in whom when PPV was conducted owing to dislocation/subluxation of their own or artificial intraocular lens, the effectiveness of treatment was 85%, $n = 9$. Table 6 presents the results of statistical analysis of the effectiveness of the μP-TSCPC procedure in patients following PPV depending on the reason for conducting PPV at 180 days of follow-up ($p < 0.05$).

## DISCUSSION

A significant, common complication of PPV is a repeated rise in IOP above the normal limit, i.e., 21 mmHg. The risk factors include, among others, postoperative infection, use of gas as endotamponade, excessive or incorrectly directed laser coagulation and transient cystoid macular edema [18, 19].

In the available literature, information can be found that indicates that the type of endotamponade used is related to the risk of developing glaucoma. It has been noted that silicone oil, which has been used for over 50 years in the case of retinal detachment, ensuring a long durability of endotamponade, relatively often leads to keratopathy, glaucoma, or cataracts [30]. One of the most common complications that follows the use of silicone oil endotamponade is glaucoma, which occurs as the result of several pathophysiological mechanisms, namely pupillary block, inflammatory angle

closure by synechiae, rubeosis of the iris, and migration of emulsified and nonemulsified silicone oil to the anterior chamber. The pathophysiology of silicone-induced secondary open-angle glaucoma (OAG) is believed to be driven by infiltration and occlusion of the trabecular reticulum [31–34]. The materials used for endotamponade now vary, with sulfur hexafluoride (SF6) and perfluoropropane (C3F8) gas being used at least as often as silicone oil; however, this depends on the indications as well as surgical experience and preference. A transient postoperative increase in intraocular pressure (IOP), which is associated with the displacement of the lens iris diaphragm, as well as the development of closed-angle glaucoma (CAG), which can occur with or without retinal blockage, are some of the most frequently observed complications associated with the use of gas endotamponade. The use of this gas endotamponade also presents other risks, such as OAG [35, 36]. Reasons for these complications include, among other things, the development of inflammation, metabolic damage of the reticulum by gas particles, infusion of fluids, cells, cytokines, proteins, and particulate material [37–39]. Following PPV, a transient or permanent increase in IOP is not a rare occurrence and has been described since this surgical procedure was developed [40]. IOP fluctuation has been reported in patients who underwent retinal detachment PPV ; however, good control of IOP has been successfully achieved in most cases [41].

In our study, we noted that the increase in IOP at a similar timepoint after the PPV procedure and the IOP value, regardless of the endotamponade used, were at a similar level. Nevertheless, we found the most significant therapeutic success after μP-TSCPC in patients where SF6 endotamponade was used (95% effectiveness), while the lowest was noted when silicone oil endotamponade was used (effectiveness between 75% and 80%). However, statistical analysis did not indicate statistically significant dependencies when the type of endotamponade used was adopted as a division criterion, which can be explained by the relatively small populations of each group and the relatively low failure rate, which in turn resulted in the small percentage of differences in the failure rate, depending on the endotamponade used.

On the other hand, when the reason for conducting PPV was taken into account, the highest IOP output values were determined in cases where the reason for the procedure was an epiretinal membrane or a macular hole (median IOP 31 mmHg), and the lowest such values were determined in cases where there was retinal detachment (median IOP 25 mmHg) or hemorrhage into the vitreous chamber (median IOP 29 mmHg), obtaining a reduction in IOP on a similar level within 180 days of observation, 41% and 42%, respectively. The conducted statistical analysis confirmed that the effectiveness of the μP-TSCPC procedure did not depend on the type of endotamponade used during the procedure, when the reason for conducting PPV was an epiretinal membrane and/or a macular hole, whereas the lowest (66.25%) effectiveness was noted when the reason for PPV was hemorrhage into the vitreous chamber. This conclusion is appropriate as complete effectiveness of treatment for PPV complications, conducted owing to an epiretinal membrane and/or a macular hole, was obtained regardless of whether SF6 or BSS was used.

Habash et al. conducted a nonrandomized, prospective study covering a period of 24 months, of which 12 months was the follow-up period after the μP-TSCPC procedure in a group of 68 patients (39 men, 29 women) with various forms of glaucoma. The study included neovascular glaucoma (NVG) in 24 patients (33.8%), primary open-angle glaucoma in 15 patients (21.1%), and secondary glaucoma in a total of 14 patients (19.7%), including 3 cases of aphakic glaucoma, 1 case of post-trauma, 1 case of iridocorneal endothelial syndrome, 6 cases of keratoplasty glaucoma, 1 case of keratoprosthesis, and 1 case of cyst excision. Other cases included glaucoma of undetermined etiology (one patient, 1.4%), chronic angle closure glaucoma (nine patients, 12.7%), pseudoexfoliation glaucoma (four patients, 5.6%), microphthalmos (two patients, 2.8%), uveitic glaucoma (two patients, 2.8%), and congenital glaucoma (one patient, 1.4%). The median IOP of patients at baseline was 35.0 mmHg (21.0–70.0 mmHg),

and after 12 months of follow-up, the IOP value decreased to 16.0 mmHg (8.0–32.0 mmHg) and was statistically significant ($p < 0.001$). The treatment success rate was 90%, with no statistically significant differences in treatment success in cases of primary open-angle glaucoma, chronic angle-closure glaucoma, NVG, and secondary glaucoma ($p > 0.05$). In addition, it was shown that age, sex, number of antiglaucoma medications used at the beginning of follow-up, baseline IOP, and prior surgery did not significantly affect the success of μP-TSCPC treatment ($p > 0.05$). The authors also noted a statistically significant reduction in the number of topical antiglaucoma medications used from 5 (range 3–5) at the beginning of the follow-up period to 4 (range 2–4) at 12 months of follow-up ($p < 0.001$) and no need for systematic glaucoma medication (acetazolamide) after 12 months of treatment ($p < 0.05$). Otherwise, no complications, such as phthisis bulbi, hypotony, hyphemia, visual loss of light perception, macular edema, severe pain, or corneal edema, were noted during the follow-up. Only one patient was found to develop inflammation. Nevertheless, approximately 18.7 months after the procedure, there was a recurrence of IOP increase in 19 patients, of whom 2 patients underwent μP-TSCPC again, another 2 patients underwent Ahmed valve implantation, 1 patient underwent deep sclerectomy, 7 patients had their treatment increased by 1 topical antiglaucoma drug, and 7 patients had their increased IOP resolve spontaneously [42].

The reduction in IOP during the observation conducted by Habash et al. [42] was higher than that in our study; however, it should be borne in mind that the patient population assessed by Habash et al. had not previously undergone a PPV procedure [42]. Habash et al. [42] reported no complications after μP-TSCPC during our follow-up period, although the percentage of patients (27%) requiring follow-up treatment after μP-TSCPC was higher than that in our study.

Additionally, in a retrospective study, Emanuel et al. evaluated the efficacy of the μP-TSCPC procedure in a group of 84 patients (36 men, 48 women) during a mean follow-up of 12 months. The preoperative mean IOP was 27.7 mmHg. At the 6th month of follow-up, the authors showed a reduction in IOP to 13 mmHg, an increase of 53.6%, and at the 12th month, the mean IOP was 11.1 mmHg ($p < 0.05$), indicating a reduction from baseline of 59.93% ($p < 0.05$). There was also a reduction in the number of topical antiglaucoma medications used from an average of 3.3 at baseline to 2.0 and 2.3 at 6 and 12 months of follow-up, respectively. These authors showed that five patients required further interventions to reduce their IOP. In addition, complications such as hypotony, IOP spike, hyphemia, serous choroidal detachment, persistent inflammation persisting for more than 3 months, and vision loss were noted [23].

In contrast, Kuchar et al. evaluated the efficacy of the μP-TSCPC procedure in 19 patients with glaucoma (8 men, 11 women) during a mean follow-up of 60.3 days. The mean IOP at the start of follow-up was 37.9 mmHg and had dropped to a value of 22.7 mmHg, that is, decreased by 40.1% at the end of follow-up. The rate of treatment success was 73.7% (14 patients). The authors indicated a reduction in topical antiglaucoma medications from 2.6 before surgery to 1.9 after surgery. In three patients, μP-TSCPC had to be repeated, resulting in a renewed decrease in the IOP to baseline values. The other two patients had hypotonia after the procedure. The only complication was corneal edema in one patient. In conclusion, the authors stated that short-term observation of the results of μP-TSCPC in patients with glaucoma indicated that this method is effective in this group of patients. However, longer-term follow-up is necessary [43]. Our results with regard to the efficacy of μP-TSCPC treatment as measured by a decrease in IOP and a decrease in antiglaucoma medication are similar to the observations of Habash et al. [42], Emanuel et al. [23], and Kuchar et al. [43]. However, we did not note any complications during the 180-day follow-up period.

Furthermore, Tan et al. indicated the safety and effectiveness of μP-TSCPC in patients with refractory glaucoma. These authors noted a reduction in IOP from $39.3 \pm 12.6$ mmHg to $25.8 \pm 14.5$ mmHg 6 months after the procedure, at the same time obtaining a reduction in IOP of 32.35% [28]. Moreover, Zaarour et al.

noted a μP-TSCPC procedure effectiveness of 81.4% 6 months after the procedure, adopting an IOP value between 6 mmHg and 21 mmHg or an over 20% reduction in IOP, compared with the values before the procedure, as indicators of success [44].

Williams et al., adopting the same success criteria as Zaarour et al. [44], determined successful treatment in 66% of patients during a 6-month observation [45]. Aquino et al. adopted an IOP value in the range 6–21 mmHg and a decrease of at least 30% in its value in 12 months as success criteria, noting successful treatment in 75% of patients (24 eyes).

In our study, we did not observe any serious complications, such as hypotonia. Williams et al. noted a significantly higher number of side effects, namely 7 patients developed hypotonia, 21 patients developed prolonged acute inflammation for $\geq$ 3 months, 13 patients developed loss of $\geq$ 2 lines of corrected distance visual acuity (CDVA) for $\geq$ 3 months, and 2 patients developed phthisis [45]. Additionally, in a study by Emanuel et al., the occurrence of postoperative inflammation was noted in 46% of patients during a 3-month observation in addition to loss of > 2 lines of CDVA in 26.2% of patients [23]. Regarding the studies by Williams et al. and Emanuel et al., it should be borne in mind that their patients were non-white individuals; the proportion of African American patients in the study conducted by Williams et al. was 30.4%, while that in the study by Emanuel et al. was 29%, which may account for the higher percentage of reported cases of postoperative inflammation and other complications in those studies.

Aquino et al., in a randomized, comparative, explanatory study of a group of 48 patients (48 eyes) with refractory, end-stage glaucoma (IOP > 21 mmHg), compared the safety and efficacy profiles of CW-TSCPC and μP-TSCPC during 18 months of follow-up. When both eyes met the eligibility criteria for surgery, the CW-TSCPC or μP-TSCPC procedure was performed on the eye with the higher IOP. The initial mean IOP in both groups was similar (μP-TSCPC 36.5 mmHg versus CW-TSCPC 35.0 mmHg; $p > 0.05$). The success of therapy, defined by the authors as (1) a decrease in IOP to between 6 and 21 mmHg and at least a 30% reduction in IOP at the final follow-up with or without IOP-lowering medications, (2) the number of complications during 18 months of follow-up was 52% for μP-TSCPC (12 eyes) and 30% for CW-TSCPC (7 eyes), respectively. There was a higher number of complications after the CW-TSCPC procedure than after the μP-TSCPC procedure ($p < 0.01$). Thus, μP-TSCPC is a safer and more effective treatment for elevated IOP than CW-TSCPC [27].

Although we did not compare the efficacy of the two methods in this study, as in Aquino et al. [27], our observation indicates that μP-TSCPC treatment is safe. Therefore, the effectiveness of the μP-TSCPC procedure, as well as the percentage decrease in IOP after the procedure, seems to depend on the baseline IOP and prior treatment. The ethnic background of the patients (race) and the parameters of the laser operation during the procedure also seem essential. In our study, all patients underwent the same standard procedure protocol, taking into account the laser parameters. On the other hand, Emanuel et al. and Williams et al. utilized a nonstandard, nonunified μP-TSCPC treatment protocol for all patients. Williams et al. utilized an average treatment time of 300 s in their study, ranging from 120 to 360 s, while Emanuel et al. had an average treatment time of 319 s, which ranged from 180 to 360 s [23, 45].

Our study has both strengths and weaknesses. Undoubtedly, to the best of our knowledge, this is the first analysis of the effectiveness of μP-TSCPC in patients after PPV. Existing studies have described the use of this technique in patients in whom an increase in IOP was unrelated to PPV. We also used a modern but, above all, safe method of treating PPV-induced glaucoma in our patients. Significantly, the PPV procedure, as well as the μP-TSCPC procedure, were conducted by the same team of ophthalmologists specializing in vitreoretinal microsurgery.

Of course, the next stage should be the consideration of expanding the investigation to a multicenter study, possibly involving patients of different races in whom PPV is conducted followed by a noted increase in IOP, which becomes the prerequisite for conducting μP-

TSCPC. Another limitation is the observation period. Therefore, extending this period, as well as monitoring the long-term effects of the treatment procedure, should be considered. This will be a valuable supplement to existing research. In addition, it would be advisable to include patients who have not followed the recommendations.

## CONCLUSION

The effectiveness of μP-TSCPC in patients after PPV probably depends on the etiology of the disease for which the PPV is conducted. The lowest effectiveness of μP-TSCPC was observed in cases where the reason behind conducting the PPV procedure was hemorrhage into the vitreous chamber and silicone oil endotamponade was used, while the highest effectiveness was shown in cases where PPV was conducted owing to an epiretinal membrane and/or a macular hole and SF6 endotamponade was used.

## ACKNOWLEDGEMENTS

***Funding.*** No funding or sponsorship was received for this study or publication of this article. The authors funded the journal's Rapid Service Fee.

***Medical Writing and Editorial Assistance.*** We would like to thank Oskar Ogloszka for English proofreading and editing and Sonia Banaszak for graphics assistance.

***Authorship.*** All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

***Author Contributions.*** Conceptualization, Izabela Kuciel-Polczak and Maciej Helemejko.; methodology, Maciej Helemejko; software, B.O.G.; formal analysis, Dariusz Dobrowolski; data curation, Beniamin Oskar Grabarek; Anita Lysssek-Boroń.; writing—original draft preparation, Maciej Helemejko; writing—review and editing, Anita Lysssek-Boroń; Dariusz Doborwowlski, Dominika janiszewska-Bil; Katarzyna Krysik.; supervision, Anita Lyssek-Boroń. All authors have read and agreed to the published version of the manuscript.

***Disclosures.*** Izabela Kuciel-Polczak, Maciej Helemejko, Dariusz Dobrowolski, Dominika Janiszewska-Bil, Katarzyna Krysik, Beniamin Oskar Grabarek, and Anita Lyssek-Boroń declare no conflicts of interest.

***Compliance with Ethics Guidelines.*** This study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the institutional ethics committee operating at the Academy of Silesia in Katowice, Poland, No. 03/KEBN/2021 (15.10.2021). Informed consent was obtained from all subjects involved in the study. Moreover, written informed consent was obtained from the patients to publish this paper.

***Data Availability.*** All data generated or analyzed during this study are included in this published article.

# REFERENCES


1. Allison K, Patel D, Alabi O. Epidemiology of glaucoma: the past, present, and predictions for the future. Cureus. 2020;12(11):e11686

2. Schuster AK, Erb C, Hoffmann EM, Dietlein T, Pfeiffer N. The diagnosis and treatment of glaucoma. Dtsch Ärztebl Int. 2020;117(13):225.

3. Stein JD, Khawaja AP, Weizer JS. Glaucoma in adults—screening, diagnosis, and management: a review. JAMA. 2021;325(2):164–74.

4. Kreft D, Doblhammer G, Guthoff RF, Frech S. Prevalence, incidence, and risk factors of primary open-angle glaucoma—a cohort study based on longitudinal data from a German public health insurance. BMC Public Health. 2019;19(1):851.

5. Wiggs JL, Pasquale LR. Genetics of glaucoma. Hum Mol Genet. 2017;26(R1):R21–7.

6. Shahid ZS. Medical management of primary angle closure glaucoma. J Bangladesh Glaucoma 2013;1: 41–44.

7. Senjam SS. Glaucoma blindness—a rapidly emerging non-communicable ocular disease in India: addressing the issue with advocacy. J Fam Med Prim Care. 2020;9(5):2200.

8. Hashemi H, Mohammadi M, Zandvakil N, Khabazkhoob M, Emamian MH, Shariati M, et al. Prevalence and risk factors of glaucoma in an adult population from Shahroud. Iran J Curr Ophthalmol. 2019;31(4):366–72.

9. Founti P, Bunce C, Khawaja AP, Doré CJ, Mohamed-Noriega J, Garway-Heath DF, et al. Risk factors for visual field deterioration in the United Kingdom Glaucoma Treatment Study. Ophthalmology. 2020;127(12):1642–51.

10. Kim JH, Rabiolo A, Morales E, Yu F, Afifi AA, Nouri-Mahdavi K, et al. Risk factors for fast visual field progression in glaucoma. Am J Ophthalmol. 2019;207:268–78.

11. Cvenkel B, Kolko M. Current medical therapy and future trends in the management of glaucoma treatment. J Ophthalmol. 2020;2020:1–14. https://downloads.hindawi.com/journals/joph/2020/6138132.pdf.

12. Yadav KS, Rajpurohit R, Sharma S. Glaucoma: current treatment and impact of advanced drug delivery systems. Life Sci. 2019;221:362–76.

13. Jo J, Sung KR, Kim YJ. Influence of vitrectomy-related factors on the outcome of Ahmed glaucoma valve implantation. Korean J Ophthalmol. 2018;32(5):400–8.

14. Quan AV, Yannuzzi N, Chen J, Wang YE, Townsend J, Chang TC. Gonioscopy-assisted transluminal trabeculotomy (GATT) in patients with secondary open angle glaucoma following vitreoretinal surgery. J Glaucoma. 2020;29(4): e23.

15. Berrocal MH, Acaba-Berrocal L. Early pars plana vitrectomy for proliferative diabetic retinopathy: update and review of current literature. Curr Opin Ophthalmol. 2021;32(3):203–8.

16. Popovic MM, Muni RH, Nichani P, Kertes PJ. Pars plana vitrectomy, scleral buckle, and pneumatic retinopexy for the management of rhegmatogenous retinal detachment: a meta-analysis. Surv Ophthalmol. 2022;67(1):184–96.

17. Fujikawa M, Sawada O, Kakinoki M, Sawada T, Kawamura H, Ohji M. Long-term intraocular pressure changes after vitrectomy for epiretinal membrane and macular hole. Graefes Arch Clin Exp Ophthalmol. 2014;252(3):389–93.

18. Mansukhani SA, Barkmeier AJ, Bakri SJ, Iezzi R, Pulido JS, Khanna CL, et al. The risk of primary open-angle glaucoma following vitreoretinal surgery—a population-based study. Am J Ophthalmol. 2018;193:143–55.

19. Rahman R, Marler J, Stephenson J, Gillibrand W. Risk factors for elevated intraocular pressure on first day postoperative review following pars plana vitrectomy. J Vitreoretin Dis. 2017;1(6):397–400.

20. Wu L, Berrocal MH, Rodriguez FJ, Maia M, Morales-Canton V, Figueroa M, et al. Intraocular pressure elevation after uncomplicated pars plana vitrectomy: results of the Pan American Collaborative Retina Study Group. Retina Phila Pa. 2014;34(10): 1985–9.

21. Ramli N, Htoon HM, Ho CL, Aung T, Perera S. Risk factors for hypotony after transscleral diode cyclophotocoagulation. J Glaucoma. 2012;21(3): 169–73.

22. Schlote T, Derse M, Rassmann K, Nicaeus T, Dietz K, Thiel HJ. Efficacy and safety of contact transscleral diode laser cyclophotocoagulation for advanced glaucoma. J Glaucoma. 2001;10(4):294–301.

23. Emanuel ME, Grover DS, Fellman RL, Godfrey DG, Smith O, Butler MR, et al. Micropulse cyclophotocoagulation: initial results in refractory glaucoma. J Glaucoma. 2017;26(8):726–9.

24. Michelessi M, Bicket AK, Lindsley K. Cyclodestructive procedures for non-refractory glaucoma. Cochrane Database Syst Rev. 2018;4:CD009313.

25. Abdelrahman AM, El Sayed YM. Micropulse versus continuous wave transscleral cyclophotocoagulation in refractory pediatric glaucoma. J Glaucoma. 2018;27(10):900–5.

26. Hooshmand S, Voss J, Hirabayashi M, McDaniel L, An J. Outcomes of initial and repeat micro-pulse transscleral cyclophotocoagulation in adult glaucoma patients. Ther Adv Ophthalmol. 2022;14: 25158414211064430.

27. Aquino MCD, Barton K, Tan AMWT, Sng C, Li X, Loon SC, et al. Micropulse versus continuous wave transscleral diode cyclophotocoagulation in refractory glaucoma: a randomized exploratory study. Clin Experiment Ophthalmol. 2015;43(1):40–6.

28. Tan AM, Chockalingam M, Aquino MC, Lim ZIL, See JLS, Chew PT. Micropulse transscleral diode laser cyclophotocoagulation in the treatment of refractory glaucoma. Clin Experiment Ophthalmol. 2010;38(3):266–72.

29. Szaflik, Jacek, Dobrowolski, Dariusz, Grabska-Liberek, Iwona, Kamińska, Anna, Misiuk-Kominek, Ewa, Przybek-Skrzypecka, Joanna, et al. Wytyczne diagnostyki i leczenia jaskry (aktualizacja 2022) [Internet]. https://www.pto.com.pl/wytyczne. Accessed 30 Sep 2022

30. Nemet A, Moshiri A, Yiu G, Loewenstein A, Moisseiev E. A Review of innovations in rhegmatogenous retinal detachment surgical techniques. J Ophthalmol. 2017;2017:4310643.

31. Shah MA, Khan B, Rehman M, Nawaz F. Frequency of complications of silicone oil in the surgical treatment of rhegmatogenous retinal detachment. Pak J Ophthalmol [Internet]. 2017 Jun 1 [cited 2022 Aug 1];33(2). https://pjo.org.pk/index.php/pjo/article/view/62. Accessed 30 Sep 2022

32. Karacorlu M, Hocaoglu M, Sayman Muslubas I, Ersoz MG, Arf S, Uysal O. Primary vitrectomy with short-term silicone oil tamponade for uncomplicated rhegmatogenous retinal detachment. Int Ophthalmol. 2019;39(1):117–24.

33. Barr CC, Lai MY, Lean JS, Linton KL, Trese M, Abrams G, et al. Postoperative intraocular pressure abnormalities in the Silicone Study. Silicone Study Report 4. Ophthalmology. 1993;100(11):1629–35.

34. Sahoo NK, Balijepalli P, Singh SR, Jhingan M, Senthil S, Chhablani J. Retina and glaucoma: surgical complications. Int J Retina Vitr. 2018;4(1):29.

35. Sakamoto H, Mashima T, Kizaki A, Dan S, Hashimoto Y, Naito M, et al. Glyoxalase I is involved in resistance of human leukemia cells to antitumor agent-induced apoptosis. Blood. 2000;95(10): 3214–8.

36. Yamamoto K, Iwase T, Terasaki H. Long-term changes in intraocular pressure after vitrectomy for rhegmatogenous retinal detachment, epi-retinal membrane, or macular hole. PLoS ONE. 2016;11(11): e0167303.

37. Kapetanakis VV, Chan MPY, Foster PJ, Cook DG, Owen CG, Rudnicka AR. Global variations and time trends in the prevalence of primary open angle glaucoma (POAG): a systematic review and meta-analysis. Br J Ophthalmol. 2016;100(1):86–93.

38. Katz LJ, Erb C, Carceller Guillamet A, Fea AM, Voskanyan L, Giamporcaro JE, et al. Long-term titrated IOP control with one, two, or three trabecular micro-bypass stents in open-angle glaucoma subjects on topical hypotensive medication: 42-month outcomes. Clin Ophthalmol Auckl NZ. 2018;12:255–62.

39. Diabetes Pathology and Risk of Primary Open-Angle Glaucoma: Evaluating Causal Mechanisms by Using Genetic Information-PubMed [Internet]. [cited 2022 Aug 1]. https://pubmed.ncbi.nlm.nih.gov/26608880/. Accessed 30 Sep 2022

40. Aaberg TM, Van Horn DL. Late complications of pars plana vitreous surgery. Ophthalmology. 1978;85(2):126–40.

41. Tranos P, Asaria R, Aylward W, Sulivan P, Franks W. Long term outcome of secondary glaucoma following vitreoretinal surgery. Br J Ophthalmol. 2004;88(3):341–3.

42. Al Habash A, AlAhmadi AS. Outcome of Micro-Pulse® transscleral photocoagulation in different types of glaucoma. Clin Ophthalmol. 2019;13: 2353–60.

43. Kuchar S, Moster MR, Reamer CB, Waisbourd M. Treatment outcomes of micropulse transscleral cyclophotocoagulation in advanced glaucoma. Lasers Med Sci. 2016;31(2):393–6.

44. Zaarour K, Abdelmassih Y, Arej N, Cherfan G, Tomey KF, Khoueir Z. Outcomes of micropulse transscleral cyclophotocoagulation in uncontrolled glaucoma patients. J Glaucoma. 2019;28(3):270–5.

45. Williams AL, Moster MR, Rahmatnejad K, Resende AF, Horan T, Reynolds M, et al. Clinical efficacy and safety profile of micropulse transscleral cyclophotocoagulation in refractory glaucoma. J Glaucoma. 2018;27(5):445–9.