Original Article

Combining Perfluorobutylpentane (F_4H_5) with Glaucoma Drainage Device Implantation for Silicone Oil-Induced Glaucoma: A Pilot Study

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Abstract

Objectives: Our aim was to perform a perfluorobutylpentane (F_4H_5) washout in conjunction with glaucoma drainage device (GDD) placement in patients with silicone oil (SO)-induced glaucoma. In this report we present our preliminary results concerning the effectiveness in clearing the SO and the safety of the procedure.
Materials and Methods: Eight patients who previously underwent pars plana vitrectomy with SO tamponade due to retinal detachment were selected. Removal of SO was performed on average 10 months after initial surgery. All patients developed glaucoma with evidence of SO remnants in the anterior chamber (AC) and angle. Removal of the remaining SO with F_4H_5 washout was performed in all cases with concomitant insertion of a GDD to treat the refractory glaucoma. Intraocular pressure (IOP), SO remnants, endothelial cell count, and need for glaucoma medications were evaluated up to 12 months after the surgical procedure.
Results: All patients had uneventful surgery with no major complications 12 months postoperatively. A marked reduction of SO remnants in the AC and angle was observed in all cases after surgery. There was a 60.9% decrease in mean IOP 12 months postoperatively ($p<0.05$) and the need for glaucoma medication was lower in all patients (mean topical medicines: 4 preoperatively vs. 0.75±0.89 postoperatively; $p<0.05$). Endothelial cell density showed no significant change (mean 2012±129 cells/mm^2 preoperatively vs. 1985±134 cells/mm^2 postoperatively; $p>0.05$), and there were no signs of corneal edema.
Conclusion: F_4H_5 is an effective emulsifier for removing SO remnants and may be safely used in conjunction with GDD placement in order to control IOP in eyes with silicone oil-induced glaucoma.

Keywords: Glaucoma drainage devices, silicon oil-induced glaucoma, silicon oil remnants, silicon oil removal, perfluorobutylpentane (F_4H_5)

Cite this article as: Kandarakis SA, Petrou P, Doumazos S, Chronopoulou K, Doumazos L, Halkiadakis I, Georgalas I. Combining Perfluorobutylpentane (F_4H_5) with Glaucoma Drainage Device Implantation for Silicone Oil-Induced Glaucoma: A Pilot Study. Turk J Ophthalmol 2023;53:281-288

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Received: 29.10.2022 **Accepted:** 14.02.2023

DOI: 10.4274/tjo.galenos.2023.95825

Introduction

The use of silicone oil (SO) in conjunction with pars plana vitrectomy (PPV) is strongly recommended in some complex vitreoretinal cases.[1] A great variety of vitreoretinal surgeries, including but not limited to proliferative vitreoretinopathy, trauma, recurrent retinal detachment, and retinitis, require the use of SO as an endotamponade medium.[2] Although SO is used to improve the final outcome and to reduce chances of relapse, complications may still occur. The most common complications of PPV with SO include cataract formation, endophthalmitis, retinal detachment, cystoid macular edema, hypotony, and ocular hypertension.[1,3,4] As far as ocular hypertension is concerned, it has been abundantly reported that there is increased risk of developing glaucoma or high intraocular pressure (IOP) following vitrectomy.[5] The overall incidence of glaucoma after uncomplicated PPV has been shown to range between 11.6% and 20%, and the prevalence increases up to 56% when SO is used as an endotamponade agent.[6,7,8,9] This highlights the fact that additional pathophysiologic mechanisms may attribute to acute or chronic IOP elevation secondary to SO use.[10] In a recent retrospective study including 196 patients, Lyssek-Boroń et al.[11] estimated the risk of developing chronic elevated IOP to be 4.7 times higher when SO was used with PPV.

Following restoration of the retinal anatomy after PPV + SO filling, removal of the SO is usually indicated to allow for potential improvement in visual acuity and to establish a normal range of IOP. However, normalization of IOP is not always achieved and patients may require medical treatment or even surgical intervention.[12,13] The incidence of surgical intervention in patients that have undergone PPV + SO filling varies in the literature.[12,14] Trabeculectomy has a low success rate after PPV, especially in SO-filled eyes, which have high rates of failure compared to glaucoma drainage device (GDD) implantation.[9,15,16] The success rate of Ahmed glaucoma valve

insertion to control IOP after PPV is reportedly high (80.7% at 5 years).[17] However, Gupta et al.[16] demonstrated more limited success (37% at 5 years) in PPV + SO-filled eyes.

Furthermore, SO has a propensity to emulsify into smaller droplets which can enter the anterior chamber (AC) and be detected via gonioscopy, appearing like "fish eggs" (shown in Figure 1B) or in more severe cases as an "inverse hypopyon."[18] These SO remnants in the AC can directly block the trabeculum and eventually cause elevation of IOP or even complicate a previous GDD implantation by blocking the drainage tube or leaking into the subconjunctival space.[19,20,21,22]

The complications caused by emulsified SO droplets can be prevented by removing them. A semifluorinated alkane (SFA) solvent can be used to solubilize the SO and enable its removal.[23] Perfluorohexyloctane was the first solvent used, but it yielded suboptimal results because it induced inflammation and was less effective in removing SO remnants.[23] Another solvent, perfluorobutylpentane (F_4H_5) has shown some promising results in washing out SO remnants more efficiently without causing inflammation.[23,24] Stalmans et al.[24] showed that F_4H_5 washout is safe and efficient in reducing SO remnants and seems to reduce postoperative SO-related complications.

In this report we present, to our knowledge for the first time, our preliminary results after combining F_4H_5 washout with GDD implantation in eyes that had uncontrolled IOP and SO remnants in the AC and angle after SO removal.

Materials and Methods

Eight patients were selected as candidates to use F_4H_5 washout in conjunction with GDD insertion (4 male and 4 female, mean age 66.5 years). All patients previously underwent a 23-gauge PPV with SO (5700 centistokes) tamponade for retinal detachment. SO removal was performed after a mean of 10 months (range 8-14 months) with concurrent phacoemulsification and intraocular lens (IOL) implantation. All the vitreoretinal surgeries were uncomplicated. All patients had signs of glaucomatous optical neuropathy with increased cup-to-disc ratio varying from 0.6 to 0.8. The average mean deviation in visual field was -9.3 decibels (±2.1) (Humphrey Field Analyzer 3, Carl Zeiss Meditec AG, Jena, Germany) and the mean retinal nerve fiber layer thickness on optical coherence tomography was 65 µm (±5 µm) (Heidelberg Spectralis, Heidelberg Engineering, Heidelberg Baden-Wurttemberg, Germany). Preoperative and postoperative visual acuity for each patient is shown in Table 1. After the vitreoretinal and phacoemulsification procedures, all patients exhibited high IOP which was not controlled by a maximum medical regimen, making them candidates for GDD insertion. In addition, it was observed (gonioscopy + photography) that SO remnants in the AC may be causing the increased IOP by blocking the trabecular meshwork (Figure 1A, B, Figure 2A, and Figure 3A). This fact made these patients ideal candidates for F_4H_5 washout to remove the SO remnants combined with GDD placement to manage IOP.

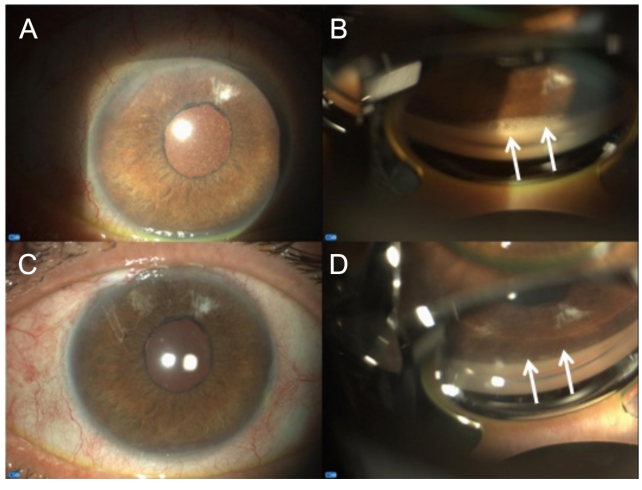

Figure 1. Patient 1: (A) Evidence of silicone oil (SO) remnants in the anterior chamber after SO removal. (B) Evidence of SO remnants (white arrows) in the superior aspect of the angle after SO removal possibly contributing to elevated intraocular pressure. (C) Anterior chamber 12 months after perfluorobutylpentane (F_4H_5) washout with concomitant Baerveldt 350-mm^2 implantation. (D) Superior angle 12 months after F_4H_5 washout with concomitant Baerveldt 350-mm^2 implantation, showing significantly fewer SO droplets present (white arrows)

All procedures were approved by the Ethics Committee of the G. Gennimatas Hospital in Athens (decision no: RN:#12042021004, date: 12/04/2021) and were conducted in accordance with the Declaration of Helsinki. Written consent was obtained from all patients both for the procedure and publication of their images. All patients underwent the same washout procedure of the AC with F_4H_5 (F_4H_5® WashOut, FLUORON GmbH, Germany) and concurrent GDD placement. Five patients received a 350-mm^2 103 Baerveldt implant (BAERVELDT® BG 103-250, Johnson & Johnson Surgical Vision, Inc., New Brunswick, New Jersey, United States) while 3 patients received an Ahmed valve implant (Ahmed® Glaucoma Valve FP7, Rancho Cucamonga, California, United States). Specifically, under sub-Tenon's anesthesia, a conjunctival peritomy was performed in the superotemporal quadrant followed by extensive conjunctival dissection. After identifying the superior and lateral rectus muscles, a 350-mm^2 Baerveldt implant was secured under the muscles using 10-0 nylon sutures. In eyes that received an Ahmed valve, after appropriate priming, the valve was secured in the superotemporal quadrant between the superior and lateral rectus muscles using 9-0 nylon sutures. Cautious cautery was used when necessary. Before tube insertion into the AC, a 2.4-mm corneal incision and paracentesis incision were created and a 27-gauge cannula was used to inject 2 mL of F_4H_5 into the AC for 5 min. The irrigation was performed towards the angle (360 degrees) and towards the pupil and IOL. Irrigation/aspiration (I/A) was then performed using a coaxial I/A metallic tip. A second irrigation of F_4H_5 was performed using the same procedure, followed by I/A. A small amount of cohesive viscoelastic was injected into the AC and the incisions were hydrated.

Tube insertion was performed using a 23-gauge cannula extending approximately 2 mm into the AC. The entry site

was posterior to Schwalbe's line and parallel to the iris as per standard technique. The tube was then secured to the sclera using 10-0 nylon sutures. In eyes that received a 350-mm^2 Baerveldt drainage device, the following additional steps were performed: a 4-0 Prolene (polypropylene) suture was inserted into the lumen of the tube, an 8-0 Vicryl (polyglactin 910) suture was used to securely watertight the lumen, and temporary fenestrations were made using a 30-gauge needle. For all GDDs, an alcohol-preserved scleral graft 2.5 mm x 2.5 mm was used to cover the tube at the entry site and was secured with nylon sutures. Finally, the conjunctiva was closed using 8-0 Vicryl sutures.

Clinical and photographic documentation was performed preoperatively (Figure 1A, B, Figure 2A, Figure 3A), at postoperative day 1, and at 1, 6, and 12 months postoperatively (Figure 1C, D, Figure 2B, Figure 3C). During the follow-up period, the patients were checked for IOP (Goldmann applanation tonometry), complications, SO remnants in AC, specifically

Table 1. Pre- and postoperative intraocular pressure (mmHg) and visual acuity (Snellen) values and postoperative medical treatment

			Preoperative			Postoperative				
Patient	Age (y)/sex	Eye	VA	IOP	GDD	IOP at 1 month	IOP at 6 months	IOP at 12 months	Topical Medicines	VA
#1	65/M	Right	8/10	38	Baerveldt	18	13	13	β-blocker	8/10
#2	63/F	Left	9/10	35	Baerveldt	15	9	9	None	9/10
#3	67/F	Right	7/10	28	Baerveldt	12	14	13	β-blocker	7/10
#4	68/M	Right	8/10	27	Baerveldt	10	12	15	None	8/10
#5	66/M	Left	7/10	46	Ahmed	14	16	17	β-blocker + CAI	7/10
#6	70/M	Right	6/10	29	Ahmed	8	10	9	None	7/10
#7	65/F	Left	8/10	35	Ahmed	11	9.5	14	β-blocker + CAI	8/10
#8	68/F	Left	9/10	28	Baerveldt	22	15	14	None	9/10
Mean ± SD			33.3±6.58		13.8±4.56	12.3±2.63	13±2.78	0.75±0.89		

VA: Visual acuity, IOP: Intraocular pressure, GDD: Glaucoma drainage device, M: Male, F: Female, SD: Standard deviation

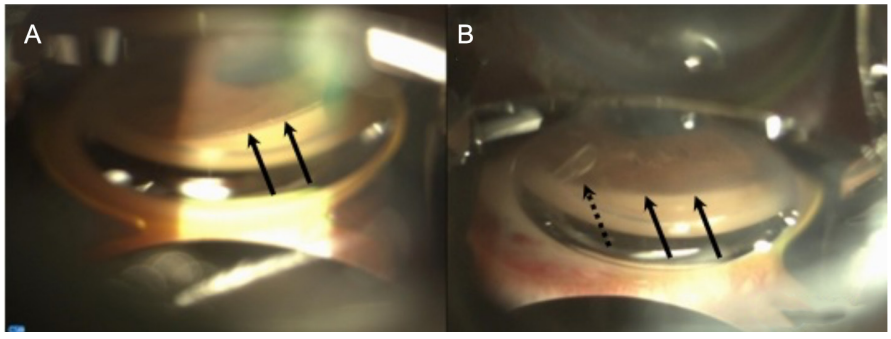

Figure 2. Patient 2: (A) Emulsified silicone oil droplets in the superior angle resembling "fish eggs" (black arrows). (B) Postoperative gonioscopy in the same patient, showing absence of silicone oil (black arrows) and appropriately placed tube (dashed arrow)

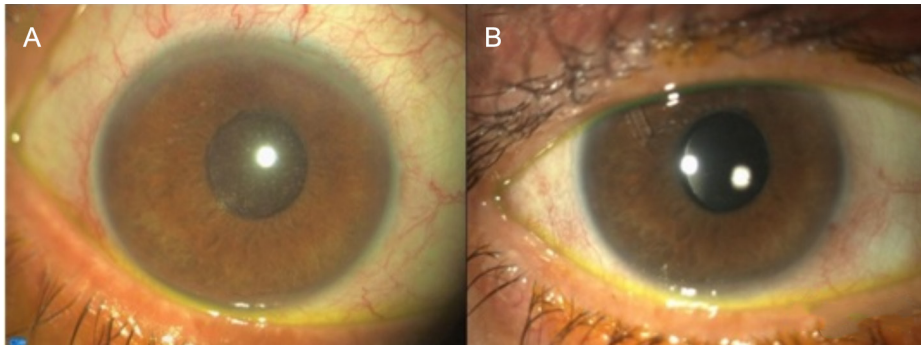

Figure 3. Patient 3: Anterior chamber with circulating silicone oil droplets prior to perfluorobutylpentane (F_4H_5) washout (A) and after F_4H_5 washout and Baerveldt 350-mm^2 placement (B)

at the angle (gonioscopy), and postoperative endothelial cell density (ECD) (CellChek X™ Specular Microscope; Konan Medical, Irvine, CA, USA). All glaucoma surgical procedures were performed by the same surgeon (S.K.) at the 1st Department of Ophthalmology of the National and Kapodistrian University of Athens at the G. Gennimatas General Hospital. IOP measurements were performed by two separate residents and mean IOP was used for documentation. If there was a difference of more than 3 mmHg between the two measurements, a third was taken by a consultant and that value was used.

Statistical Analysis

Microsoft Excel was utilized to collect the data and statistical calculations were performed using statistical software R (version 3.5.1, Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics of the study population are reported as mean ± standard deviation for continuous variables. IOP differences at all postoperative visits, differences in the number of glaucoma medications and differences in ECD at 12-month follow-up were assessed using paired t-tests. All statistical tests were two-sided and p values less than 0.05 were considered statistically significant.

Results

All patients underwent successful F_4H_5 washout in conjunction with either Baerveldt 350 mm^2 or Ahmed valve implantation in the superior quadrant. None of the patients who received a Baerveldt 350 mm^2 implant required removal of the 4-0 Prolene intraluminal suture and no significant complications were observed.

The patients' mean preoperative IOP was 33.25 mmHg (±6.58) with maximum topical therapy and oral carbonic anhydrase inhibitor (CAI) therapy (250 mg twice daily, Acetazolamide 250 mg, Crescent Pharma Ltd, Basingstoke, England). The mean IOP was decreased by 60.9% at postoperative 12 months, reaching 13 mmHg (±2.78) ($p<0.05$). At 1-month follow-up, the mean IOP fell significantly to 13.75 mmHg (±4.56), a 58.6% drop compared to preoperative levels ($p<0.05$), while at 6 months after surgery the mean IOP was 12.3 mmHg (±2.63) (Figure 4). These results indicate a sustained low IOP for at least 12 months postoperatively.

The amount of topical therapy also decreased significantly after F_4H_5 washout with GDD implantation. The number of topical medicines prescribed was 4 per patient preoperatively and fell significantly to a mean of 0.75 (±0.89) postoperatively (81.3% reduction) ($p<0.05$). Specifically, patients 1 and 3 required a topical β-blocker drop (twice daily, Temserin 0.25%, Vianex, Athens, Greece) to maintain the low IOP, while patients 5 and 7 required both topical β-blocker (twice daily) and CAI drops (twice daily). The remaining 4 patients did not require any postoperative medical treatment for at least the duration of our maximum follow up period. Pre- and postoperative IOP results and postoperative treatments are presented in Table 1.

ECD quantified before and after the procedure showed no significant change in any of the patients. The mean ECD was 2012.38 cells/mm^2 (±129) preoperatively and 1985.13 cells/mm^2 (±134) postoperatively ($p>0.05$). No signs of corneal edema were evident in any of the patients. The patients' ECD values are presented in Table 2.

In all patients, there was a marked reduction in residual SO droplets in the AC and angle as evaluated by a masked ophthalmologist (D.P.) and evidenced in their postoperative photographs (Figure 1A, D, Figure 2A, B, Figure 3A, C).

Discussion

Combining PPV with SO filling remains a common surgical approach for patients with multiple retinal pathologies.[1] Removal of the SO usually follows and is sometimes combined with phacoemulsification and IOL implantation.[1] While acute IOP

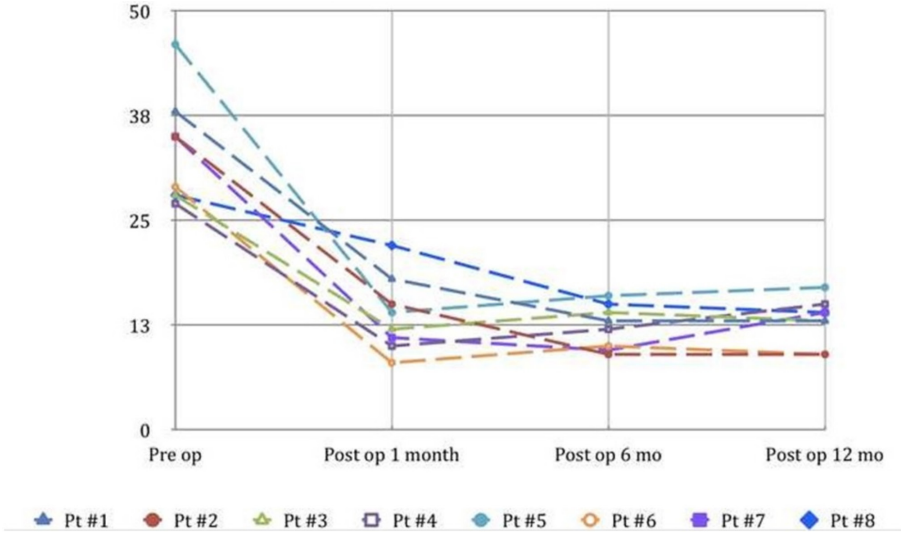

Figure 4. Graphical representation of intraocular pressure measurements of each patient preoperatively (preop) and during the postoperative (postop) follow-up period at 1 month, 6 months, and 12 months

Table 2. Pre- and postoperative epithelial cell density (ECD) values (cells/mm²)		
Patient	**Preoperative ECD**	**Postoperative ECD**
1	1947	1902
2	2159	2120
3	1983	2050
4	1826	1751
5	1902	1899
6	2205	2167
7	2090	1997
8	1987	1995
Mean ± SD	2012±129	1985±134
SD: Standard deviation		

rise is frequently due to SO overfilling, aqueous misdirection, iris-lens diaphragm shifting, and AC inflammation, chronic IOP elevation is commonly associated with angle synechiae, neovascularization, and emulsified SO droplets in the AC infiltrating the trabeculum.[2,5,21]

Potential mechanisms of SO-induced glaucoma mainly include the migration of emulsified SO particles into the AC, which can cause mechanical blockage or inflammation of the trabecular meshwork, impairing aqueous humor outflow.[9,10,18,21] Reported rates of late-onset glaucoma in eyes that received SO varies widely, from 2.2% to 56%.[9] Risk factors include preexisting glaucoma, diabetes mellitus, and aphakia, while the role of cataract extraction in postoperative IOP remains uncertain.[6,7,8] It has been hypothesized that the natural lens has a protective role against oxidative stress, which could potentially cause alterations in the trabecular meshwork and impair aqueous outflow.[6] On the other hand, some reports dispute the assumption that vitrectomy increases the risk of glaucoma or that the lens has a protective role.[25,26]

Emulsification of SO occurs due to factors that decrease its surface tension within a medium, causing it to initially disperse and subsequently emulsify.[27] These proteins or other molecules are surface acting particles (surfactants) which are usually present in inflammatory, infectious, or hemorrhagic conditions. These are often the complex and challenging conditions for which SO use is usually indicated, thus increasing the chances of emulsification.[21,28] However, the crucial factor affecting SO emulsification is the duration of SO tamponade in the eye. Some studies have shown that initial signs of SO emulsification occurred on average at 13.2 months of SO tamponade, while others indicated that emulsification can occur as early as 5 months after SO injection in some cases.[21,27,28] Although higher viscosity SO has been shown to be more resistant to deformation and thus less likely to disperse and eventually emulsify, it is also more difficult to remove, especially using small-gauge cannulas (sub-25 gauge).[21]

In our study, all patients included underwent SO removal combined with cataract extraction on average 10 months after the initial SO injection and developed refractory glaucoma. Whether lens removal contributed to the postoperative IOP rise remains unclear, although in all cases SO remnants were evident in the AC and the angle, thus identifying a well-documented cause for IOP elevation.[9,10,21,29,30,31,32] Since all patients had inadequate IOP control despite maximum medical treatment, GDD implantation was indicated.

However, the presence of SO remnants after SO removal represents a great challenge for glaucoma surgeons who are asked to surgically reduce IOP, given the potential risk of SO blockage of the tube lumen when a GDD is implanted.[14,19] Interestingly, cases where SO has migrated under the conjunctiva through the tube have also been described, highlighting the problem even further.[19,22,31,32,33]

According to the literature, there is no gold standard method on how a surgeon should approach these cases, including only SO removal, GDD implantation, or a combination of both. Honavar et al.[29] in a retrospective analysis of 150 eyes showed that adequate IOP control was not achieved in any of the cases by SO removal alone, but there was an overall 45.5% success rate when additional antiglaucoma medication was used. In contrast, Nguyen et al.[30] showed that 8 out of 14 eyes (57%) had IOP control after performing SO removal alone.

On the other hand, according to Chan et al.,[28] evidence of emulsified SO particles in the AC seen on slit-lamp biomicroscopy only partially reflects the magnitude of the emulsified SO and indicates the presence of many more small emulsified droplets which may be associated with complications such as open-angle glaucoma. In addition, electron microscopy of enucleated eyes previously filled with SO showed evidence of tiny emulsified SO droplets within the trabecular meshwork, suggesting that simply removing the visible bulk of SO does not necessary mean that the trabecular meshwork is free of SO and that IOP will drop.[34] Budenz et al.[13] argued that SO removal alone to control IOP tends to result in uncontrolled IOP with an increased need for glaucoma surgery. Furthermore, Moisseiev et al.[12] reported that after SO removal alone, IOP control could not be achieved in their patients even after glaucoma surgery was performed.

To reduce the aforementioned potential side effects of SO remnants, F_4H_5 has successfully and safely been used previously as a rinse in routine SO removal.[24] Specifically, F_4H_5 is a liquid SFA which is a colorless, physically and chemically inert

compound with a low density. In addition, it has excellent properties of low interface and surface tension, as well as being amphiphilic. Its chemical formula is $C_4F_9C_5H_{11}$ and it has an RFRH configuration. The RF segment gives the lipophobic properties of the compound while the RH segment (alkane) provides its lipophilic properties. Thus, lipophobia increases with the length of the RF segment while lipophilia increases with the length of the RH segment. F_4H_5 as well as other SFA are efficient and biocompatible solvents of SO. According to the general properties of SFAs, the longer the RH group and lower the viscosity of the SO, the better their solubility in each other.[35] However, F_4H_5 is able to dissolve SO more efficiently than other SFAs, as both *in vitro* and *in vivo* studies have previously shown.[23,36] Specifically, its superiority lies in the fact that admixtures of SO and F_4H_5 do not demonstrate phase separation (oil-in-water effect), and at room temperature these substances are mixable at every ratio, producing a transparent and homogenous solution.[23,35]

In our study, we evaluated the efficacy of SO remnant removal using F_4H_5 as a washout solution with simultaneous glaucoma valve implantation to maximize IOP lowering and avoid complications associated with SO remnants in the AC. To our knowledge, this is the first time published in the literature that F_4H_5 washout was performed in combination with GDD implantation in eyes that underwent SO removal and still had evident SO remnants in the angle and AC as well as glaucoma while under maximum medical treatment.

Our preliminary results, although limited, show that F_4H_5 washout may be successfully combined with either a Baerveldt 350-mm^2 or an Ahmed valve implantation. Overall, the postoperative course was uneventful, with no complications. IOP was significantly lower and remained under control for at least 12 months in all patients, with an average reduction in IOP of 60.9% after 12 months ($p<0.05$). Additionally, the need for IOP-lowering medications was significantly less than preoperatively, as we went from maximum topical treatment (4 IOP-lowering drugs) to an average of 0.75 (±0.89) drugs per patient. Specifically, patient 5 had the highest initial IOP in our study before surgery (46 mmHg). After F_4H_5 washout and Ahmed valve implantation, this patient's IOP fell by 29 mmHg (63%) to 17 mmHg after 12 months, albeit with dual medical treatment (β-blocker + CAI twice daily). The smallest IOP reduction was observed in patient 4, whose IOP dropped 12 mmHg (44.4%) after the surgical procedure to reach 15 mmHg, although this was achieved without the need for medical treatment. The largest percentage drop in IOP after our washout procedure in combination with a Baerveldt implantation was observed in patient 2, who had a 74.3% drop in IOP from 35 to 9 mmHg. Interestingly, patients receiving an Ahmed valve had a higher percentage drop in IOP at the end of our follow-up period (63.6%) than patients receiving the Baerveldt drainage device (58.9%). However, patients receiving the Ahmed valve required an average of 1.3 topical medications to control IOP, whereas those who received a Baerveldt device required an average of only 0.4. Therefore, even from our preliminary data it is clear that we achieved the desired IOP-lowering effect while reducing the need for IOP-lowering medication.

Photographic documentation obtained before and after surgery demonstrated the level of SO remnants in the AC (Figure 1A, D, Figure 2A, B, Figure 3A, B). The presence of SO was significantly reduced in the AC and angle, while no signs of SO were evident under the conjunctiva or obstructing the tube in any of the patients, suggesting the high success of F_4H_5 in binding and dissolving small SO droplets. This was also confirmed by a masked ophthalmologist who independently examined the patients for the presence of SO remnants in the AC and angle before and after surgery.

Previous studies where an Ahmed glaucoma valve was placed in eyes filled with SO have shown favorable results.[37] Ishida et al.[37] published a 70.2% success rate after Ahmed valve implantation in SO-filled eyes while highlighting that eyes containing SO have increased risk of failure compared to eyes without SO. Notably, they reported that in 40% of eyes with SO there were SO droplets evident in the tube, 10% of which eventually failed. Eyes without SO had a success rate of 87.2%.[37] Another study showed similar success rates (76% at 1 year) after Ahmed valve placement in SO-filled eyes.[38] More comparable to our cases, Gupta et al.[16] reported a 59.3% success rate in IOP control after placing an Ahmed glaucoma valve in eyes after SO removal, achieving an average of 56.9% IOP reduction. As the reasons are multifactorial, we cannot safely conclude as to why the success rate of Gupta et al.[16] was lower than in cases without SO. However, one reason may be the direct effect of SO on the trabeculum, as well as SO remnants as in our cases. In addition, given our current results we cannot also assume that our washout technique was solely or primarily responsible for the success of the GDD in reducing IOP. However, according to the previous reports mentioned above together with our own experience, SO remnants can greatly affect the outcome of GDD placement. Even the procedure itself can affect the success, as the maneuvering and fluidics during tube placement can shift remaining SO to other parts of the trabeculum, negatively affecting IOP even further. We believe a safe, quick, and efficient wash of the AC with F_4H_5 may prove to be an essential step before glaucoma surgery in such patients.

Even though F_4H_5 has been shown to be biocompatible with no significant toxic effects on the eye, it has been suggested that SFA could have a potentially negative effect on the endothelial cells.[35,39,40] A study on porcine corneas by Wenzel et al.[40] showed that short-term exposure to F_4H_5 had no significant toxic effect on endothelial cells, while prolonged exposure (over 60 minutes) increased morphological changes. In the present study, ECD measured pre- and postoperatively showed no significant changes (Table 2). This indicates that a short F_4H_5 washout up to 10 minutes (5 min x 2) in duration is safe and effective in removing the residual SO particles from the AC and, as evidenced from the IOP results, it may also contribute to overall IOP control.

Study Limitations

The limitations of this study undoubtedly include the small sample size. However, due to our promising results, we presented our preliminary data in this report. In addition, this study was not multicentered and all surgical procedures were conducted by a single surgeon. The follow-up time was relatively short (12 months), but in our view this is sufficient to be able to draw some reasonable conclusions from this work.

Conclusion

In conclusion, F_4H_5 is an SFA that can be safely used in combination with GDD placement. An AC washout may be performed prior to conventional Baerveldt 350-mm^2 or Ahmed valve implantation to reduce SO presence in the AC and angle in an effort to reduce the risk of tube blockage and the general adverse effects of SO remnants. Randomized controlled studies with larger numbers of patients are needed in the future to enable definitive conclusions on the safety and efficacy of the technique.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of the G. Gennimatas Hospital in Athens (decision no: RN:#12042021004, date: 12/04/2021) and was conducted in accordance with the Declaration of Helsinki.

Informed Consent: Obtained.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: S.A.K., P.P., Concept: I.G., Design: S.D., L.D., Data Collection or Processing: K.C., Analysis or Interpretation: I.H., I.G., Literature Search: K.C., S.D., L.D., Writing: S.A.K., S.D.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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