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New Developments in Silicon Oil-induced Glaucoma versus Clinical Experience – a Review with a Case Series

Natalia Winiarska, Monika Łazicka-Gałecka, Tomasz Gałecki, Anna Zaleska-Żmijewska, Alicja Wosińska, Anna Kamińska, Jacek P. Szaflik

Department of Ophthalmology, Medical University of Warsaw, Poland
Head: Professor Jacek P. Szaflik, PhD, MD
SPKSO Ophthalmic University Hospital in Warsaw, Poland
Head: Professor Jacek P. Szaflik, PhD, MD

Abstract:

Introduction: Silicon oil-induced glaucoma is a serious complication of the pars plana vitrectomy with a silicon oil tamponade. It arises from mechanisms like silicon oil migration, emulsification, and pre-existing risk factors. This study seeks to provide a comprehensive overview of the existing understanding of this disease, including its diagnosis and novel methods of management, while offering clinical insights.

Material and methods: This study consists of a literature review and a retrospective case series. A comprehensive search was performed across numerous medical databases for studies focusing on silicon oil-induced glaucoma management. Additionally, a case series of 6 patients with silicon oil-induced glaucoma is presented.

Results: Articles covering diverse interventions including trabeculectomy, glaucoma drainage devices, Ex-PRESS shunts, and others were identified and summarised. Glaucoma drainage devices demonstrated the most consistent long-term intraocular pressure control. Case series findings aligned with the literature, with the Baerveldt implant achieving sustained intraocular pressure reduction and visual stability in most patients.

Conclusions: Intraocular pressure should be closely monitored long-term after silicone oil tamponade, especially in high-risk patients. Silicone oil-induced glaucoma is a multifactorial condition that requires management by clinicians with substantial expertise and familiarity in this specialised area.

Key words: glaucoma, silicon oils, intraocular pressure, glaucoma drainage implants.

Introduction

Silicon oil (SO) is a commonly used endotamponade material in pars plana vitrectomy (PPV), particularly favoured in complex retinal detachments associated with proliferative vitreoretinopathy, proliferative diabetic retinopathy, or ocular trauma. Additionally, SO acts as a physical barrier, limiting the migration of inflammatory cytokines and providing haemostatic properties [1, 2]. However, the use of SO is associated with the risk of complications such as subretinal and subconjunctival migration of SO, cataract progression, macular oedema, corneal decompensation, and silicon oil-induced glaucoma (SOIG) [1]. The mechanisms of elevated intraocular pressure (IOP) due to SO include SO overfilling, pupillary block, inflammatory responses, pre-existing glaucoma, or SO migration into the anterior chamber (Figs. 1, 2). In late-onset cases, elevated IOP is often associated with SO emulsification, where micro-droplets obstruct the trabecular meshwork (Fig. 3), leading to impaired aqueous outflow and secretion of inflammatory proteins such as interleukin-17, interleukin-6, and tumour necrosis factor-alpha, which cause further emulsification of the SO and lead to persistent trabeculitis [3]. Additional contributing factors include angle closure due to synechiae and neovascular glaucoma secondary to rubeosis iridis or underlying glaucomatous conditions [1, 4, 5]. Moreover, diabetes, myopia, history of uveitis or ocular trauma, aphakia, scleral buckle, previous vitreoretinal surgery, and pre-existing glaucoma are important preoperative factors associated with a greater risk of IOP spikes after PPV surgery with a SO tamponade, which need to be considered in treatment planning [3].

The prevalence of glaucoma resulting from vitreoretinal surgical procedures ranges from 2.2% to 56%, depending on the source [3]. It occurs with decreasing frequency largely due to the introduction of high-viscosity silicone oil, along with progress in surgical techniques and clinical management. Key factors include the implementation of a peripheral iridectomy, postoperative corticosteroid therapy, and the use of lateral or prone positioning [5]. SOIG makes up about 25% of glaucoma cases secondary to vitreoretinal surgeries [3]. SOIG can present with either an open or closed angle, and depending on the type, the treatment options and limitations will differ. In most patients, postoperative IOP elevation can be effectively controlled with antiglaucoma medications, with beta-blockers being the most commonly used [3].

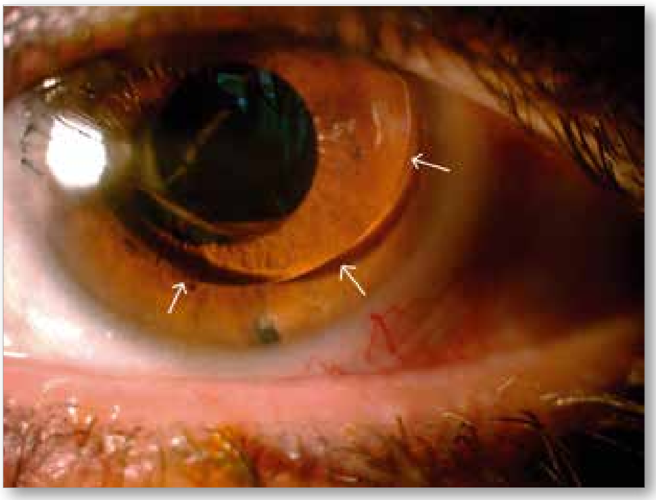

Fig. 1. Silicon oil in the anterior chamber.

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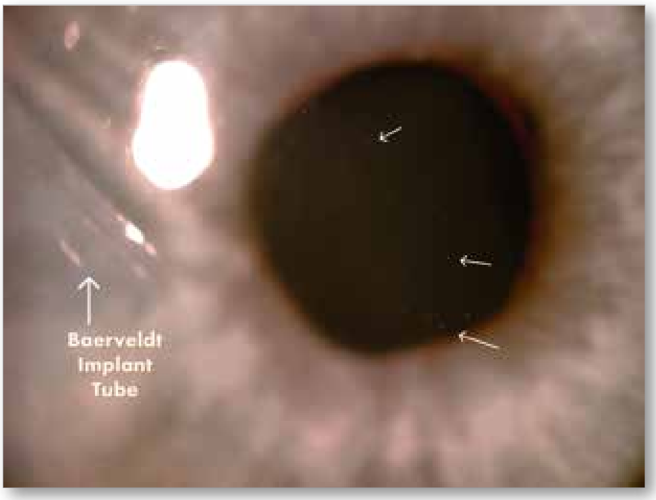

Fig. 2. Silicon oil micelles in the anterior chamber.

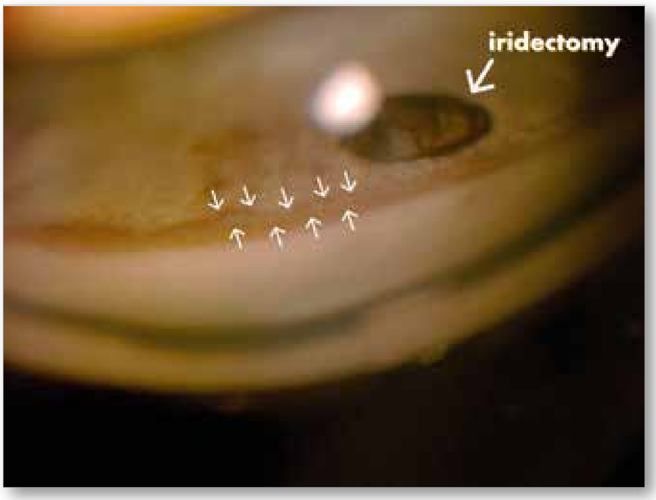

Fig. 3. Emulsified silicon oil viewed in gonioscopy.

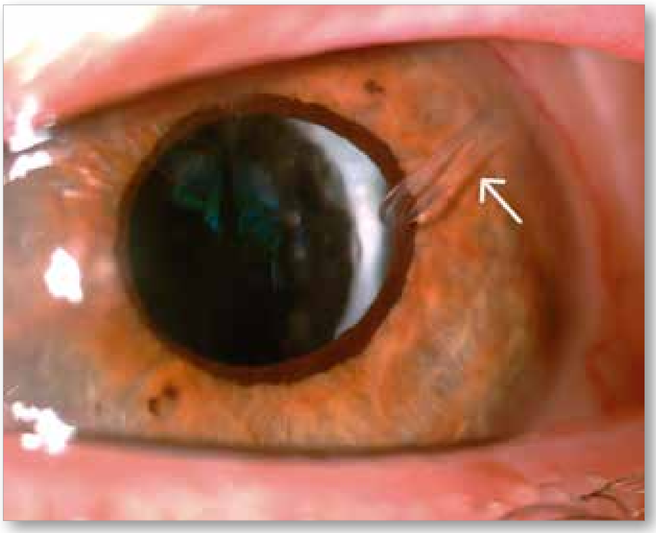

Fig. 4. Baerveldt implant tube in the anterior chamber.

In cases where local treatment fails to achieve adequate pressure reduction, surgical intervention becomes necessary. Such procedures should be performed promptly, and they should be customised based on the underlying cause of the IOP increase. There is a wide selection of procedures with varying degrees of invasiveness that have been previously established in this indication, including trabeculectomy, glaucoma drainage devices (GDDs) such as Ahmed, Baerveld (Fig. 4), and Molteno implants, Ex-PRESS shunts, gonioscopy-assisted transluminal trabeculotomy (GATT), transscleral cyclophotocoagulation (CPC), and selective laser trabeculoplasty (SLT) [2, 3].

SOIG overlaps the area of vitreoretinal surgery and glaucoma; therefore, managing such a niche disease may be clinically problematic, and it may require interdisciplinary cooperation. This study aims to present a cohesive summary of current knowledge regarding silicon oil glaucoma, and its diagnosis and management, while providing a useful clinical insight.

Material and methods

This article consists of 2 parts: a review of currently used methods in SOIG treatment and a case series presenting our clinical experience treating patients affected by this disease.

For the review part of this study, we searched the bibliographic databases PubMed, Embase, and Web of Science using specially designed search engines with keywords such as "silicon oil" and "glaucoma". The aim was to identify articles focused on currently commonly used and new treatment methods for SOIG with the clinical question framework based on PICO (Tab. I). Filters included studies on humans and in English language. There was a limit regarding the publication date set between 2015 and 2025. The publications were screened by their titles and abstracts. Articles not mentioning SOIG management or with an underage study population were excluded. The reference lists of included articles were also cross-checked for topic-related studies.

The presented case series concerns patients with SOIG who were treated at the Public Ophthalmic Clinical Hospital in Warsaw.

Population	Patients with SIOG
Intervention	Any treatment method
Comparison	None or other treatment methods
Outcome	Change in IOP, complications

Tab. I. PICO.

Results

Review

After the database search and preliminary screening, we identified 17 articles that matched the inclusion criteria. Fifteen articles were found in their originally published versions and were included in the review [6–20]. They included randomised comparative studies [10, 20], prospective studies without control groups [17– 19], retrospective cohort studies [6, 11, 12, 14, 15], and case series [7– 9, 13].

The authors presented different methods of treatment for SOIG such as trabeculectomy [10, 13, 18, 20], deep sclerectomy [10, 13], Ex-PRESS shunt [7, 10, 20], GDD (Paul, Ahmed, Baerveldt, eyeWatch) [6, 8, 9, 10, 15, 16, 17, 19], Xel gen stent implant [11], CPC [6, 12], and micropulse transscleral cyclophotocoagulation (MP-CPC) [14].

It is worth noting that the described success rate was not uniform among the included studies. The procedure was classified as successful when the IOP post surgery was below a set limit (<19–22 mmHg) [6, 10–12, 14–18, 20] and/or when the IOP was reduced by a specific percentage (>20%) [10, 11, 14]. In some papers, it was regardless of the need to use topical medications [14–17], while others distinguished a complete success category when the medication was not needed and a qualified success category where the patient had to use topical medication [6, 10–12, 18, 20]. In a few articles, the methodology did not specify when a treatment was considered effective [7–9, 13, 19].

Classic trabeculectomy with MMC did not prove successful in long-term IOP management in SOIG. The overall success rate after one year was 36.9% [18]. Factors such as the time between vitreoretinal surgery and silicone oil removal, initial IOP, and the surgical site did not significantly influence the success rate. Visual acuity (VA) declined throughout the observation period, but the change was not statistically significant [18].

In a comparative randomised study, El-Saied et al. examined the efficacy of trabeculectomy, deep sclerectomy, Ahmed implant, and Ex-PRESS shunt in secondary glaucoma after PPV with SO tamponade. They reported that Ex-PRESS minishunt had the highest complete success rate (100%) and was associated with no postoperative complications. The Ahmed valve also showed a high complete success rate (80%) but was accompanied by a notable incidence of hypotony (50%). Trabeculectomy and deep sclerectomy both achieved a total success rate of 50%. However, the patients with emulsified SO were excluded due to poor prognosis, which significantly reduces the quality of the study and its clinical usefulness in this indication. Correspondingly, in a different study Ex-PRESS implantation was more effective than trabeculectomy in controlling IOP in SOIG at 2-year follow-up (73% vs. 40% success rate, respectively) [20].

Two studies observed the efficacy of Ahmed glaucoma valve (AGV) [16, 17]. Gupta et al. described a success rate of 62% at 12 months, decreasing to 37% at 5 years. Complications occurred in 48% of cases, with 22% classified as vision-threatening. An analysis of potential risk factors, including patient age, the time between vitreoretinal surgery and silicone oil removal, the interval between vitreoretinal surgery and AGV implantation, and phakic status, revealed no significant association with increased failure rates [17]. Erçalık et al. achieved surgical success in 84.4% of cases; however, there were many postoperative complications described, such as bleb encapsulation, early hypotony, hyphaemia, decompression retinopathy, choroidal detachment, intraocular haemorrhage, and late endophthalmitis. Interpretation of the data is impaired by the inclusion of patients with both SOIG and neovascular glaucoma, without sub-group analysis for most of the data [16].

While comparing PAUL glaucoma implant (PGI) and AGV there was no statistically significant difference in the average IOP throughout the entire observation period or the incidence of complications ($p > 0.05$). Surgical success was achieved in 94% of the PGI group and 89% of the AGV group. While overall outcomes were comparable between the 2 groups, complications requiring medical or surgical management were less frequent in the PGI group [15].

Albahlal et al. [6] compared GDD vs. CPC. While both methods achieve an IOP reduction at one year after the procedure, the overall success rate was significantly higher for GDD (94.1% vs. 53.8%). Moreover, patients who undergo CPC may need a subsequent treatment later on. However, due to the lower technical difficulty and accessibility of CPC, this technique should not be disregarded. In this study, only 10.7% of secondary glaucoma after PPV with SO was SOIG, and all the data were presented in an aggregate form, so conclusions should be drawn with caution.

Boscia et al. [11] reported the effects of Xen gel stent implant. A significant decrease in IOP was observed relative to baseline values ($p < 0.01$), while BCVA showed no statistically significant change ($p = 0.21$). The procedure was described as successful overall; however, needling was necessary in 50% of cases, with 25% requiring a second procedure and one patient (8%) needing additional surgery (Ex-PRESS shunt). One patient developed hypotony and hyphaemia, both of which resolved spontaneously within one week. Moreover, in 50% of patients, resuming intraocular pressure-lowering medication was needed to maintain target IOP levels.

In a study assessing the CPC effectiveness in SOIG [12], the researchers found that IOP reduction demonstrated a gradual decline over the 6-month follow-up period and was achieved in 77.6% of cases; however, the glaucoma treatment applied before laser therapy was maintained during the post-laser period and was gradually reduced based on IOP levels. Age, gender, and preoperative IOP were found to be significantly associated with postoperative IOP control ($p < 0.05$). Patients aged 50 years or younger demonstrated greater treatment efficacy, and female patients also exhibited more favourable outcomes.

Similarly, MP-CPC was described to have comparable results. A significant decrease in IOP was observed ($p = 0.004$), with a success rate of 72% with preserved visual acuity. At the same time, the number of antiglaucoma medications did not show a significant change from baseline [14].

An undeniable advantage of both these procedures is that they are technically straightforward and cost-effective, making it accessible and affordable for patients in low-resource settings.

Savastano et al. [9] describe the use of the eyeWatch implant – a GDD that features a mechanism that enables controlled compression of its internal elastic tube, allowing adjustment of fluid resistance. This modulation is achieved noninvasively using the single-use eyeWatch Pen during surgery or a reusable office version postoperatively. In a case series, they achieved stable IOP and BCVA from 2 weeks post-operatively through the observation period of up to 6 months. Notably, the study included only 2 patients, whose VA was counting fingers and 0.05 before surgery. It is worth further research to test the device on a wider cohort before drawing definitive conclusions.

An interesting approach was presented by Kandrakis et al. In patients with SOIG residual SO was removed using perfluorobutylpentane (F4H5) combined with a Baerveld implant. All surgeries were completed without complications, and no major adverse events were reported at the 12-month follow-up. A significant reduction in SO remnants in the anterior chamber and angle was observed in every patient. Mean IOP decreased by 60.9% at 12 months ($p < 0.05$), and all patients required fewer glaucoma medications (average of 4 preoperatively vs. 0.75 ± 0.89 postoperatively; $p < 0.05$). Endothelial cell density remained stable, and no corneal oedema was detected. The conclusion was that F4H5 is an effective agent for emulsifying and clearing residual silicone oil, and it appears to be safe for use alongside GDD implantation [19].

Some authors presented novel surgical techniques of known procedures to optimise their effectiveness [7, 8, 13]; however, because they are based on case reports and individual skills of the operating surgeons, further studies are necessary to determine the usefulness of applying these techniques in everyday practice.

Case series

All described patients were treated at the Public Ophthalmic Clinical Hospital in Warsaw due to SOIG. A summary of every case is presented in Table II.

Case I

A 45-year-old male with a history of childhood blunt trauma to the right eye and aphakia underwent pars plana vitrectomy (PPV) with SO tamponade for retinal detachment in March 2023 at an external facility. He developed elevated IOP and underwent SO removal with anterior chamber flushing 2 months later. Despite maximal topical therapy, the IOP was still elevated. The patient did not tolerate oral acetazolamide and had multiple IV mannitol infusions to lower the IOP. The patient was referred to our centre and underwent trabeculectomy. Postoperatively, IOP ranged between 9 and 14 mmHg, with a single spike to 32 mmHg, which

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Case	Age	Sex	Eye	Surgical Intervention	IOP before (mmHg)	IOP afger (mmHg)	Medications before	Medications after	BCVA before	BCVA after	Observation	Complications Others
I	45	M	R	Trabeculectomy	28	14	4	0	0,02	0,01	17 months	*
II	52	M	R	Baerveldt Implant	26	7	4 + 750 mg acetazolamid	2	0,1	0,2	20 months	**
III	55	F	L	Baerveldt Implant	63	10	2 + 500 mg acetazolamid	0	HM	0,05	11 months	
IV	78	M	L	Baerveldt Implant	33	8	4 + 500 mg acetazolamid	0	0,2	0,2	14 months	
V	36	M	R	Baerveldt Implant	23	14	3 + 500 mg acetazolamid	2	0,05	0,2	4 months	***
VI	57	F	R	Observation	20	18	1	2	0,25	0,32	12 months	

* IOP spike resolved with massage and needling; ** Choroidal detachment, resolved spontaneously; *** The patient had 3 previous procedures – CPC, trabeculectomy, revision of trabeculectomy

Tab. II. Case series summary.

was managed by needling and massage. IOP and best-corrected visual acuity (BCVA) have remained stable over a 17-month follow-up.

Case II

A 52-year-old male experienced retinal detachment in the right eye in September 2022, followed by a series of procedures including oil removal, gas tamponade, and repeat PPV with SO due to re-detachment. By October 2023, despite maximal topical therapy and 750 mg of oral acetazolamide, IOP remained elevated at 22–26 mmHg. The patient was referred to our hospital and received a Baerveldt implant by November 2023. Initially, the IOP dropped to 4 mmHg, which was complicated by choroidal detachment that resolved spontaneously over time. IOP gradually increased over 2 months. Brimonidine and timolol were added sequentially. The patient has maintained stable IOP and BCVA over a 20-month follow-up.

Case III

A 55-year-old female presented with vitreous haemorrhage in the left eye caused by diabetes in April 2022. She underwent PPV with gas endotamponade in July and again in November 2022 due to recurrent haemorrhage and uncontrolled IOP, this time with SO tamponade. SO was later removed, but IOP remained critically elevated at 63 mmHg despite dual topical therapy and 500 mg acetazolamide orally. The patient was referred to our hospital and underwent Baerveldt implantation in September 2023. Postoperatively, IOP stabilised around 7 mmHg without medication. BCVA improved from hand movements to 0.05. The observation time is currently 11 months.

Case IV

A 78-year-old male was referred to our centre in May 2024 after a left eye injury caused by a champagne cork, resulting in rhegmatogenous retinal detachment and lens dislocation. He underwent PPV with SO tamponade, followed by SO removal 3 months later. On maximal medical therapy, including 500 mg of acetazolamide orally, IOP remained elevated. A Baerveldt implant was placed, resulting in a stable IOP of around 8 mmHg without ongoing medication. The patient has been under observation for 14 months.

Case V

A 36-year-old male underwent PPV for retinal detachment in the right eye in May 2023, followed by SO removal in January 2024. The patient experienced persistent high IOP and underwent CPC, followed by trabeculectomy and its revision. The patient was referred to our centre with an IOP of 10 mmHg on triple topical therapy. On the first visit, an early bleb fibrosis was noted, the patient remained under observation. Five months later, IOP rose to 23 mmHg and acetazolamide 500 mg was initiated. The patient was qualified for Baerveldt implantation, performed in March 2025. Since surgery, IOP has remained stable at around 15 mmHg on 2 topical agents.

Case VI

A 57-year-old female was admitted in July 2024 with retinal detachment and vitreous haemorrhage in the right eye, treated with PPV and SO tamponade. Two weeks post-op, IOP rose to 21 mmHg, and the patient was started on brimonidine. Due to persistent IOP around 20 mmHg and associated headaches, micropulse MP-CPC was considered. A second topical agent was added, but as IOP remained stable and no glaucomatous changes were observed, surgical intervention was deferred. The patient remains under regular observation.

In all patients who have had a Baerveldt implant, a temporary spike in IOP was observed. This was due to a blocking suture that is placed around or within the tube of the Baerveldt implant to temporarily restrict aqueous humour flow and prevent early postoperative hypotony. It also allows the formation of a fibrous capsule around the implant's plate. After the rise in IOP, the blocking suture was removed and in all the cases the IOP returned to normal. This is not described as a complication of the procedure but an expected postoperative outcome.

Our clinical experience is consistent with data from the literature. Although different methods of IOP control in patients with SOIG are implemented, the highest success rate so far is presented by patients who received a Baerveld implant. However, every case needs to be considered separately and take into consideration patients' individual requirements and preferences.

Discussion

Silicone oil is frequently used in pars plana vitrectomy, especially for complex retinal detachments. It provides mechanical support and reduces inflammatory cytokine migration.

Despite its benefits, SO is linked to complications such as cataract progression, corneal decompensation, macular oedema, and silicone oil-induced glaucoma. IOP can rise due to overfilling, pupillary block, SO migration into the anterior chamber, or pre-existing glaucoma. Emulsified SO droplets may block the trabecular meshwork and limit the aqueous outflow and cause further inflammation. With improved surgical techniques and preventive measures including inferior iridectomy, corticosteroids, and proper postoperative care, SOIG rates decreases; however, the patients need to be carefully monitored for this complication.

Most cases of SOIG respond to topical antiglaucoma therapy. If that approach fails, we can currently offer a range of therapeutic options with varying degrees of invasiveness [1–5], depending on the mechanism of the SOIG and whether it presents with an open or closed angle.

The effectiveness of oil removal in managing IOP elevation remains debated. While some authors reported that IOP normalised in up to 93.4% of cases following oil removal, suggesting it as a preferred intervention, other studies point to no improvement in IOP after the procedure. Additionally, the removal process itself may lead to IOP elevation by breaking the oil into smaller droplets, which can more easily block the trabecular meshwork, and there is an added risk of potential retinal detachment [21].

Research shows that in SOIG classic trabeculectomy is less effective than alternative options [18, 20]. This is largely due to associated conjunctival scarring from the previous surgery and emulsified oil droplets obstructing the trabecular meshwork and compromising the function of the filtration pathway [22]. GDD or ExPRESS shunts present more promising results, but they are not as widely available and are associated with specific complications [7, 10, 17]. For instance, bleb encapsulation, resulting from excessive fibrous tissue proliferation, is a common cause of tube shunt failure following implantation. Postoperative hypotony is another significant complication, particularly with non-valved implants, and may lead to outcomes such as choroidal detachment. Additionally, silicone oil can migrate through the tube into the subconjunctival space, triggering inflammatory responses [7]. Despite that, patients who undergo tube shunt surgery have a higher likelihood of maintaining stable intraocular pressure and avoiding complications such as persistent hypotony, or the need for additional glaucoma surgery compared to those who received trabeculectomy, although the rates of serious complications requiring reoperation or leading to vision loss are similar between the 2 surgical approaches [23]. However, due to regulatory changes by the Food and Drug Administration (FDA), the ExPRESS shunt was removed from the market and is no longer available for implantation. The choice of surgical procedure is influenced by several factors, including the patient's visual function, gonioscopic findings, degree of intraocular pressure elevation, and the condition of the conjunctiva [22].

Although CPC and MP-CPC proved to be less effective than the alternative treatment options and commonly require subsequent topical medications or additional surgeries, they are still a viable choice. These procedures are primarily indicated for patients with poorer visual potential or ones not eligible or unwilling to undergo more invasive procedures. They can also serve as a bridge therapy while waiting for planned surgery in cases where it is temporarily unavailable or needs to be postponed [6, 12, 14].

Endoscopic cyclophotocoagulation (ECP) is a variation of CPC, performed using either a limbal or pars plana approach. It provides a more comprehensive view of the ciliary processes, which improves the precision of photocoagulation and leads to better IOP control. It has not been tested specifically in SOIG, but the results of this procedure in eyes after PPV are promising and deserve further research [24].

The role of minimally invasive glaucoma surgery (MIGS) in the management of silicone oil-induced glaucoma remains largely unexplored. There are reports of the use of Xen gel stent or GATT [2], but they are based on retrospective studies with small populations, and further research is needed before implementing them in clinical practice. Similarly, reports of newly developed techniques, while clinically interesting, need confirmation of effectiveness in studies with improved methodology.

Because of these risk factors and the complex mechanisms behind silicone oil-induced glaucoma, strict intraocular pressure monitoring is essential following vitreoretinal surgery. Early detection of IOP elevation allows for timely intervention, reducing the risk of irreversible optic nerve damage. Clinicians must be well-informed about both non-invasive treatment options, such as topical antiglaucoma medications, and various possible surgical interventions. It is equally crucial to recognise the appropriate time to refer a patient to a specialised centre to ensure appropriate, multidisciplinary care and optimal long-term outcomes.

Conclusions

Careful monitoring of intraocular pressure is crucial after silicone oil tamponade, especially in patients presenting with predisposing risk factors, and it should be continued for an extended period after surgery due to possible pressure spikes even years after a successful procedure.

Glaucoma drainage devices or Express shunts are the preferred treatment methods when topical therapy is insufficient, but the decision is based on multiple preoperative factors and final visual prognosis.

Silicon oil-induced glaucoma is a complex disease that should be managed by clinicians with extensive knowledge and experience on the subject.

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Disclosure

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Reprint requests to:
Natalia Winiarska, MD (e-mail: natalia.winiarska@wum.edu.pl)
SPKSO Ophthalmic University Hospital in Warsaw, Poland
Józefa Sierakowskiego 13, 03-709 Warszawa, Poland