Intraocular pressure changes during and after silicone oil endotamponade (Review)

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Abstract. Silicone oil (SIO) has rapidly become an indispensable adjunct in vitreoretinal surgery. Constant improvements in purity and also in viscosity have not totally prevented specific complications that may occur during endotamponade. Results of *in vitro* studies that suggested that higher viscosity silicone oil might be superior in terms of stability and safety are confirmed in real life only if endotamponade lasts for more than 6 months. Intraocular pressure changes induced by the silicone oil endotamponade or oil extraction are documented from its very first use and are potentially threatening vision. The purpose of this review is to update current knowledge on the incidence, risk factors, pathogenesis, and management of secondary silicone oil glaucoma. Also, in a retrospective evaluation on cases with complex retinal detachments that underwent 23G vitrectomy and high viscosity SIO endotamponade, we have noticed that a considerable number of cases developed significant intraocular pressure changes during SIO endotamponade and after SIO removal, especially in early postoperative period.

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1. Introduction

Silicone oil (SIO) and perfluorocarbon liquids (PFCLs) are one of the most important adjuncts used in vitreoretinal surgery. Due to their systematic use during pars plana vitrectomy, the majority of complicated forms of retinal detachments can be fixed and stabilized. While PFCL usage is restricted only intraoperatively, SIO provides the desired long-term postoperative endotamponade and has expanding indications such as ocular trauma, advanced diabetic retinopathy, viral retinitis, macular holes, or chronic uveitis (1-3). Also, SIO is the preferred option in patients unable to maintain positioning or have to travel by air in the early postoperative period. Maintaining significant adhesion of neurosensory retina to the retinal pigment epithelium is the direct consequence of surface tension, SIO being immiscible with water. Increased viscosity provides more surface tension and also less emulsification rate as indicated by *in vitro* studies (1,4,5). In real life, these advantages might not be clinically significant if endotamponade lasts no more than 6 months (4).

Despite their highest degree of purity emulsification can still occur, unpredictably and irrespective of SIO viscosity (1000 or 5000 cs). Longer direct contact of SIO with PFCL during vitrectomy or with different biological emulsifiers inside the eye during endotamponade (blood, proteins, or inflammatory mediators) has been associated with an increased risk of emulsification (6,7). Although lower viscosity SIO is easier to be removed during modern Micro-Incisional Vitreoretinal Surgery (MIVS), many surgeons still prefer to use higher viscosity SIO due to increased surface tension and lower emulsification rate, especially when longer endotamponade is

anticipated. To achieve efficient endotamponade to the inferior retina, a particular heavier than water SIO was created (Densiron 68 and Oxane HD). In this review, we will restrict the discussion to the most commonly used SIO, which is lighter than water and currently has a viscosity between 1,000 (MW 37 kDa) and 5,000 cs (MW 65 kDa).

Although the literature does not indicate a precise timing for extraction, SIO is usually removed after 3 to 6 months postoperatively, to prevent complications especially related to emulsification. Of course, the anatomical result is the key factor influencing the surgeon's judgment regarding the best timing.

Many complications have been associated with SIO endotamponade. While refractive change is a perturbing yet harmless feature during endotamponade, more severe complications may occur as macular pucker, cystoid macular edema, and rubeosis iridis (8). Long-standing SIO endotamponade is associated with significant ocular complications such as cataract formation, corneal decompensation, band keratopathy, and orbital leakage (9,10). Silicone oil neuropathy is the consequence of the direct toxic effect on the optic nerve. Retrolaminar, chiasmal, and even brain migration of SIO vacuoles have been documented (11-15).

Among all complications related to SIO endotamponade intraocular pressure (IOP) changes induced by tamponade itself or by SIO extraction are one of the most common and will be evaluated in this review.

2. Current state of knowledge regarding intraocular pressure changes during and after silicone oil endotamponade

Cases with raised IOP were reported soon after SIO started to be massively used for long-term endotamponade in complex retinal detachments. Although the Silicone Study indicated an elevated IOP in only 8% of eyes with conventional SIO endotamponade after 36 months (16), literature data largely vary on this topic. Thus, in different reports, the percentage of elevated IOP or secondary glaucoma related to SIO endotamponade varies from 2.2 to 56.0% (17,18). Obviously, significant advances in vitrectomy technique and adjuncts purity explain, at least in part, the decreasing rate of secondary glaucoma in more recent reports.

Secondary glaucoma can develop in both the early and late postoperative stages of endotamponade (19-23).

In the early postoperative period, the IOP elevation can be secondary to an overfill of silicone oil, a pupillary block, the migration of SIO into the anterior chamber, postoperative inflammation and/or steroid-induced ocular hypertension. The main risk factors for early secondary glaucoma are preexisting glaucoma, aphakia, iris neovascularization and chronic uveitis (24).

In late postoperative stages, secondary glaucoma might occur due to a pupillary block, synechial angle closure, rubeosis iridis and migration of non-emulsified SIO into the anterior chamber. Progressive SIO emulsification and migration of emulsified droplets into the anterior chamber are responsible for the chronic elevation of IOP.

The overfill of silicone oil is a frustrating situation responsible for an immediate increase of IOP and often requires partial removal of SIO as only a limited number of cases respond to lowering medication.

With an estimated incidence of around 1%, pupillary block glaucoma can develop in both early and late postoperative period and is more frequent in early stages in aphakic patients if a prophylactic inferior iridectomy has not been previously performed (25,26). The iridectomy must have between 150-200 microns, large enough to be efficient but not too large to allow forward migration of the oil. Late-onset pupillary glaucoma can occur anytime during endotamponade and is mainly related to the closure of existing peripheral iridectomies. As up to 35% of iridectomies progressively close in time, a strict follow-up is required and a YAG-Laser reopening or new iridectomy is necessary in these cases. If the laser treatment fails, a new surgery has to be performed.

In aphakic patients, but also in phakic and pseudophakic patients with disrupted lens zonule or capsular defects, a SIO bubble can migrate into the anterior chamber right at the end of surgery. This complication is easily prevented in aphakic and pseudophakic eyes by performing an inferior iridectomy during pars plana vitrectomy before SIO implantation. In phakic eyes, the migration of a SIO bubble into the anterior chamber at the end of surgery or later on is a challenging situation as SIO aspirated through paracentesis is quickly replaced from behind, sometimes resulting in more SIO in the anterior chamber.

Emulsification of the SIO is one of the most common causes of secondary glaucoma during endotamponade. The results of *in vitro* studies indicating that higher viscosity is associated with better long-term stability due to a lower rate of emulsification (1,4,27) have been contested in real-life. The only randomized, double-blinded, controlled study to date, conducted on patients with complicated retinal detachments, has shown that low viscosity SIO has a non-significant higher rate of emulsification on short and medium-term (up to 6 months) but much higher emulsification rate in endotamponades over this time as compared with higher viscosity SIO (28). Emulsification is not exclusively related to the physicochemical properties of SIO. As mentioned before, SIO contact with other chemical compounds during surgery (as PFCL) or with different biological emulsifiers inside the eye during endotamponade can precipitate emulsification (29). Also, eye movements induce a shear force on the SIO bubble that might enhance emulsification, especially in cases of SIO under-filling (30). The presence of an encircling band that provides indentation and reduces SIO velocity seems to provide a protective effect against emulsification (31).

While emulsification time is believed to largely vary between 5 and 24 months postoperatively (32), some reports emphasize that first signs of SIO emulsification appear in the first 3 months postoperatively (33) and even earlier, in the first month postoperatively (28). Since most of the cases have a certain degree of SIO emulsification within the first year postoperatively, there is a large consensus on the necessity to remove the SIO during this interval.

Once emulsification has started, small oil droplets migrate and induce complications on all ocular and extraocular structures. Secondary glaucoma, cataract and keratopathy are the direct consequence of oil droplet interference with the metabolism of anterior segment structures. In early stages, small droplets, like ‘fish eggs’ can be noticed in the anterior chamber or the angle. When emulsification is extensive, a typical image of ‘inverse hypopyon’ can be observed in the

upper part of the anterior chamber. Despite this mechanical outflow obstruction, intraocular pressure remains normal in many cases (34,35). Further infiltration of micro-droplets into the trabecular meshwork is responsible for local inflammation (trabeculitis) and chronic IOP elevation (36).

Secondary glaucoma during SIO endotamponade can be efficiently controlled in up to 80% of the cases with topical and systemic anti-glaucomatous medication. Topical aqueous suppressants are commonly recommended as first-line treatment as prostaglandin analogs might promote intraocular inflammation and cystoid macular edema (37). Topical cycloplegics and corticosteroids are recommended to decrease local inflammation in selected cases.

Removal of SIO with systematic irrigation of emulsified droplets from the anterior chamber offers heterogeneous influence on intraocular pressure, largely ranging from normalization of IOP in >90% of cases (22) to persistent IOP elevation in all cases (38). A more realistic outcome on PIO value is better to be expected later postoperatively, as small droplets and trabecular meshwork inflammation gradually disappear in time.

One complication related to SIO removal is the postoperative transient hypotony, with an incidence ranging between 5 and 40% of the cases (22,39). An intraocular pressure less than 6 mmHg can induce various choroidal detachments that usually resolve spontaneously within 1 week with topical steroidal medication (40). While 23 G vitrectomy is associated with a lower incidence of postoperative hypotony, eyes with longer axial length are considered to be at risk (41).

Glaucoma surgery is required when significant trabecular meshwork damage has been produced. As conventional filtration surgery has a limited success rate in the management of secondary glaucoma, glaucoma drainage implants and cyclodestructive procedures have to be considered as a better option (42,43). Mechanical angle closure due to iris tissue can be improved by surgical pupilloplasty with a single-pass four-throw technique (44).

In a retrospective evaluation of 98 consecutive cases with complex retinal detachments that underwent 23G vitrectomy and high viscosity SIO endotamponade (Oxane® 5700) we noted significant IOP changes during both SIO endotamponade and after SIO removal (8). In 52 out of 98 cases (53.06%) with no preexisting glaucoma, IOP increased over 21 mmHg requiring topical antiglaucomatous medication during endotamponade. Most of the cases developed increased IOP during the first month (34 cases-65.38%). The main duration of SIO endotamponade was 5.46 months (3-16 months). An early postoperative hypotony was noted in 38 out of the 98 eyes (38.77%) after SIO removal, leading to transient choroidal detachments in 8 eyes (8.16%). IOP gradually decreased after SIO removal and at 12 months follow-up, only 16 out of 98 eyes (16.32%) still required lowering medication. None of the cases required glaucoma surgery during or after SIO endotamponade.

3. Conclusions

Silicone oil endotamponade is an important risk factor for IOP changes after pars plana vitrectomy in a percentage that largely varies. Among all mechanisms of secondary glaucoma development, pupillary block and anterior migration of emulsified or non-emulsified SIO are the most frequent. A careful follow-up is mandatory during endotamponade as a rise in IOP can occur at any time. Prompt SIO removal at first signs of emulsification does not guarantee IOP restoration to normal values in all cases. Also, SIO removal can be followed by significant hypotony, usually transient but responsible for choroidal detachments. Chronic elevation of IOP in advanced stages, regardless of the medical treatment, requires complex glaucoma surgery.

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DCB and FB contributed to the study design, participated in the entire review process and prepared the manuscript. MAM, DEB and CIB contributed to the literature research, data analysis and revised the manuscript critically. ADM and GS conceived the review and modified the manuscript. All authors read and approved the final version of the manuscript.

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Not applicable.

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Competing interests

All the authors declare that they have no competing interests.

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