Silicone Oil Induced Glaucoma

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Silicone oil (SO) is a vitreous substitute which is widely used to provide long term intraocular tamponade in retinal surgery. Transient or permanent rise in intraocular pressure is a common complication of silicone oil injection following pars plana vitrectomy. The underlying mechanisms include pupillary block, infiltration of the trabecular meshwork by silicone bubbles, trabeculitis, synechial angle closure, rubeosis iridis and migration of emulsified and non emulsified silicone oil into the anterior chamber. Most of the cases can be managed medically, however, surgical intervention in the form of silicone oil removal, trabeculectomy with or without Mitomycin C, glaucoma drainage implants and cyclodestructive procedures may be required in cases unresponsive to conservative management.

Abstract

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Vitreo-retinal (VR) surgery is the third most common ocular surgery being performed after cataract and laser vision correction. Secondary glaucoma is a relatively common complication after VR surgery with silicone oil (SO) injection. Secondary glaucoma can occur at any time in the post-operative period and can manifest with a wide range of IOP and vision loss. Gray, Leaver et al have ranked glaucoma second to cataract as a late complication of SO injection. The reported incidence of elevated IOP or glaucoma following SO injection varies from 2.2% to 56.0%. In recent studies, this incidence rate has been found to be lower than previously reported, probably due to improvement in surgical techniques and refinement of surgical materials.

Silicone oil is a vitreous substitute and is used for long term intraocular tamponade in retinal surgery, usually for a period of 2-6 months depending on the type of silicone oil, retinal detachment and surgeon’s choice. In some cases the oil may be left for a long-term period. Silicone oil can tamponade retinal breaks and detachments based on its buoyant force and hydraulic space-occupying properties. It has the ability to maintain adhesion between retina and retinal pigment epithelium (RPE). Silicone oil is immiscible with water and this creates a surface tension at the interface of these two liquids. This surface tension is responsible for the tamponade effect of silicone oil.

There are two main types of SO – ‘lighter than water’ and ‘heavier than water’ (Heavy oil). ‘Lighter than water’ floats in the eye and ‘Heavy oil’ (Densiron 68 and Oxane HD) provides long term tamponade for inferior retinal problems as this oil sinks in the vitreous cavity. Intravitreal silicone oil injection has been associated with a high incidence of complications such as cataract, keratopathy, anterior chamber oil emulsification and glaucoma.

Risk factors and Mechanism of glaucoma

Risk factors associated with elevation of intraocular pressure following silicone oil injection include:

- Aphakia
- Pre-existing glaucoma
- Neovascular glaucoma

Keywords: silicone oil, glaucoma

Introduction

There are several mechanisms by which secondary glaucoma can develop, following the use of silicone oil in VR surgery. Rise of IOP in the early postoperative period may be due to pupillary block and inflammation and pre-existing glaucoma. Migration of silicone oil into the anterior chamber with consequent mechanical impediment to filtration is another known cause of early rise of IOP. Late onset rise in IOP can be due to infiltration of the trabecular meshwork by silicone bubbles, chronic inflammation and trabeculitis’ synechial angle closure and idiopathic open angle glaucoma.

Pupillary Block Glaucoma

Pupillary block glaucoma occurs in 0.9% of all silicone oil filled eyes (Han DP et al, 1989). This condition is more likely to occur in aphakes but it can also occur in 6% of pseudophakic and phakic eyes where the anterior hyaloid face and zonules are disrupted (Riedel et al, 1990, Jackson T et al, 2001). (Figure 1) This complication can be prevented...
by performing prophylactic inferior peripheral iridectomies at the time of pars plana vitrectomy in aphakic eyes and pseudophakic eyes with capsular defects or disrupted lens zonules. However, peripheral iridectomies may close in up to 11-32% of cases and need to be reopened or a new iridotomy created to prevent the development of pupillary block glaucoma.

Oil in the anterior chamber

SO takes a spherical form in the posterior chamber of aphakic eyes and does not enter the anterior chamber. In presence of pupillary block, the aqueous accumulates in the lower part of the posterior chamber. Aqueous pressure thus builds up in the posterior chamber and forces SO through the pupil into the anterior chamber which may block the outflow from the angles. (Figure 2,3) A PI at 6-o’clock usually solves this problem but it is seen that despite a patent PI, forward migration of the oil was found in 11%. This could be due to several reasons - improper size, improper location, low aqueous turnover, occurrence of choroidal detachment that decreases the volume of the vitreous cavity. It is usually difficult to detect the presence of oil in oil filled anterior and posterior chambers since the oil is transparent and is like a single large globule occupying the chambers. One way of detecting presence of oil is by seeing the cells in the chamber which have become stagnant. Oil in the anterior chamber leads to stagnation of cells which otherwise keep circulating due to the aqueous convection currents. Oil in the anterior chamber should be removed early to prevent glaucoma and care must be taken to ensure that the oil from the vitreous cavity doesn’t come forward during the removal of the oil in the anterior chamber. This can be done with the use of 2 anterior chamber paracentesis. Through one opening viscoelastic is injected into the AC pushing the oil towards the other paracentesis site from where it is removed. After the removal of oil, the patient should be kept on anti glaucoma drugs until the viscoelastic is reabsorbed. If only one paracentesis is used to aspirate the oil from the AC, the oil in the vitreous cavity can come forward to replace it, resulting in more oil in the AC.

Silicone Oil Emulsification

Emulsification is a known complication of silicone oil use and is clinically significant due to its adverse effects on all ocular structures. Understanding the forces and factors that lead to silicone oil emulsification is crucial in minimizing its occurrence.

Silicone oil emulsification occurs at interface between the oil bubble and ocular tissues or aqueous forming small droplets of emulsified oil. (Figure 4) These small droplets of silicone oil tend to separate from the large central reservoir of silicone oil, and can be seen in the anterior chamber or at the angle, appearing like “fish eggs.” If emulsification is extensive, it can manifest as an “inverse hypopyon,” visualized in the upper part of the anterior chamber. (Figure 5)
These emulsified oil droplets may block the trabecular meshwork or cause inflammatory cells to impede outflow through the meshwork resulting in IOP elevation. SO emulsification occurs in 0.7-56% of cases and is a poor prognostic factor for control of IOP.

Factors leading to silicone oil emulsification

1. **Surface Tension**: Surface tension is the tendency of a liquid to acquire the least surface area possible. Surfactants (e.g., Serum, fibrin, and fibrin-ogen) facilitate emulsification by decreasing the surface tension or lowering the interfacial tension between two media. Surfactants may also promote emulsification through increased repulsion, creating a film around the silicone oil that causes the globules to repel each other.

2. **Viscosity and molecular weight**: These are two important physical factors affecting rate of emulsification. It is seen that less viscous silicone oils emulsify earlier than oils with higher viscosities. As molecular weight and viscosity are directly related, lower molecular weight molecules possessing lower viscosity, are more prone to emulsification.

3. **Perfluorocarbon liquid (PFCL)**: Use of PFCL in a direct PFCL-oil exchange may promote oil emulsification. This is hypothesized to occur due to turbulence at the interface of the PFCL and silicone oil. A shorter duration of contact between PFCL and oil and decreased turbulence during the PFCL-oil exchange may minimize emulsification.

4. **Duration of silicone oil in the eye**: It has the strongest correlation with the occurrence of emulsification. The longer the duration of SO in the eye, more is likelihood of emulsification. In one study, signs of emulsification were seen in eyes between 5 and 24 months after vitrectomy with silicone oil injection, with an average time of onset of 13 months after surgery. In another study, emulsification was seen in all eyes that has SO for at least 1 year. Thus it is recommended to remove silicone oil within one year postoperative, unless there is a risk of re-detachment.

**Management**

1. **Medical therapy**: Medical therapy aims at reducing the aqueous production and inflammatory response. Cycloplegics and corticosteroids decrease inflammation and topical aqueous suppressants reduce the pressure. Prostaglandin analogues are less frequently used as first-line therapy postoperatively due to concerns about inducing intraocular inflammation and cystoid macular edema. Topical and systemic anti-glaucoma medications can control IOP in 30%-78% of eyes with glaucoma after PPV and silicone oil injection.

2. **Prophylactic peripheral iridectomy**

   Concept of inferior peripheral iridectomy (PI) in aphakic and pseudophakic eyes was introduced by Ando to reduce the incidence of pupillary block glaucoma. (Figure 6) It is usually done inferiorly when ‘lighter than water’ oil is used and superiorly when heavy oil is used as heavy oil remains inferiorly and can block an inferior PI. If the patient is phakic, the lens usually prevents pupillary block glaucoma and no PI is required. Size of PI should be at least 150-200µ to prevent angle closure glaucoma. PI larger than this may allow forward migration of the oil.

3. **Silicone oil removal**

   The benefit of silicone oil removal following the increase in IOP is controversial. Some studies have shown normalization of IOP after removal of oil whereas other reports suggested that removal of silicone oil alone may be insufficient to alleviate the glaucoma. It is, however, generally accepted...
that wherever possible prompt removal of silicone oil will minimize its potential ocular side effects but it carries some risk of retinal re-detachment. Early removal of the emulsified oil probably causes reversal of mechanical trabecular blockage by the oil particles, and/or contains damage to the filtration channels and thus helps better control of IOP. With increasing duration of contact between the emulsified silicone bubbles and the trabecular meshwork, silicone oil removal may have no role in controlling IOP.

There are several major factors underlying post silicone oil removal rise in intraocular pressure.
1. There is edema in the trabecular meshwork as a result of postoperative inflammation.
2. The mechanical impact of balanced salt solution during silicone oil removal may split the silicone oil droplets into much smaller drops, which are more likely to obstruct the trabecular meshwork.\(^{35}\)

The length of SO tamponade is associated with increased incidence of SO induced glaucoma. This suggests that SO should be removed as soon as there is no further need for it. The optimal timing for the silicone oil removal still remains unknown and recommendations range from 3 to 6 months of sustained retinal attachment.\(^{31,34}\)

4. Glaucoma Surgery
Conventional filtration surgery has a limited role and success rate in the management of glaucoma after pars plana vitrectomy and silicone oil injection.\(^4\) Trabeculectomy is technically difficult because of conjunctival scarring from the vitreoretinal surgery, and carries a poor prognosis. Success of trabeculectomy is a result of severe inflammation induced by the silicone oil droplets in the trabecular meshwork, scleral ostium, and the subconjunctival space after surgery. An inferior trabeculectomy is avoided because of the high risk of complications such as endophthalmitis.

5. Glaucoma drainage devices
Glaucoma drainage implants offer a good surgical option in cases of refractory glaucoma associated with silicone oil especially in eyes with extensive conjunctival scarring.\(^6\) Inferior placement of the GDD can control the IOP in majority of eyes by preventing SO from blocking the ostium but there is still a possibility of silicone oil escape via the glaucoma drainage tube. Even if the oil is removed before placement of a GDD, residual SO bubbles may still block it (Figure 7).

6. Cyclodestructive Procedures
Cyclodestructive procedures are used when all other standard glaucoma surgical options fail or are not feasible. Cyclocryotherapy, while often effective in pressure reduction, is commonly associated with marked intraocular inflammation and is difficult to titrate with a high incidence of subsequent hypotony.\(^{35}\) Cycloamide treatment does however carry a lower incidence of complications compared to cyclocryotherapy.\(^{36}\) Transcleral cyclophotocoagulation can provide good IOP control with success rates of 66-82% at 1 year.\(^{37-39}\) Multiple treatments may be required to attain intraocular pressure control, and since there is a risk of visual loss, it is reserved for eyes with poor visual potential. An additional, although extremely rare, complication of the cyclophotocoagulation is sympathetic ophthalmia.\(^{33,40}\)

Conclusion
IOP elevation can occur any time after pars plana vitrectomy with silicone oil injection, therefore careful postoperative monitoring is mandatory. Understanding the pathogenesis and risk factors may serve to minimize the damage caused by silicone oil injection. Since the underlying mechanism is mostly multifactorial, patients should be closely followed for the development of glaucoma as timely diagnosis and adequate management can salvage useful vision in the eye.

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