

Tamponade in the surgical management of retinal detachment

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Abstract: Despite treatment advances, rhegmatogenous retinal detachment (RD) can have poor visual outcomes even with prompt and appropriate therapy. Pars plana vitrectomy is a leading management modality for the treatment of RD. This procedure is generally accompanied by the use of internal tamponade. Various gases and silicone oils may yield beneficial outcomes. Heavy silicone oils have been approved in some European nations but are not available in the USA. Different tamponade agents have unique benefits and risks, and choice of the agent should be individualized according to the characteristics of the patient and RD, as well as perioperative and postoperative factors.

Keywords: tamponade, retinal detachment, silicone oil, gas, air, perfluorocarbon liquids

Introduction

Despite continuing advances in vitreoretinal care, rhegmatogenous retinal detachment (RD) remains a major cause of visual loss worldwide. There is geographic variation in the incidence of RD, with reported rates ranging from 6.3 to 17.9 per 100,000 population, with a rate of ~12 per 100,000 in the USA.¹

The most commonly used treatment modalities for the management of RD are scleral buckling, pars plana vitrectomy (PPV), pneumatic retinopexy, and combination techniques.² Overall, these treatment options have been reported to yield a single operation success rate of >90%.³

In recent years, there has been a trend toward PPV as the preferred method of treatment for RD. In the American Society of Retina Specialists (ASRS) 2014 Global Trends in Retina survey, 78% of the US respondents preferred PPV, while only 13% preferred scleral buckling to treat pseudophakic RD without proliferative vitreoretinopathy (PVR). These percentages were 48% and 23%, respectively, for phakic RD without PVR.⁴

When PPV is chosen for the treatment of RD, it is typically accompanied by the use of a postoperative intraocular tamponade agent.

Intraocular tamponade for retinal detachment

Purpose of intraocular tamponade

“Tamponade” is defined as the use of a tampon, which itself is defined as “a plug or tent inserted tightly into a wound, orifice, etc, to arrest hemorrhage”.⁵ In the context of RD surgery, tamponade agents are used to provide surface tension across retinal breaks, which prevents further fluid flow into the subretinal space until the retinopexy (photocoagulation or cryopexy) provides a permanent seal.⁶ Although surgeons may sometimes describe this process to patients as “pushing the retina back into position”, this is not generally true. Gases and silicone oils are the most commonly used classes of tamponade agents.

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History of tamponade in retinal detachment surgery

The first description of the use of tamponade agents in the treatment of RD was given by Ohm in 1911, who reported successful treatment of two patients using intravitreal injection of sterile air, although he did not use the term “tamponade”.⁷ Later, Gonin described the critical role of retinal breaks in the pathogenesis of RD.⁸ Rosengren, in 1938, reported successful treatment of RD with air, and also used the term “tamponade”.⁹ In 1962, Cibis et al reported the use of “liquid silicone” in the management of RD, but they also did not use the word “tamponade”.¹⁰

The inert expansile gas sulfur hexafluoride (SF_6) had been used in the management of pulmonary tuberculosis and pneumothorax because it lasted longer than air. In the early 1970s, Norton reported the use of SF_6 as a vitreous substitute.¹¹

In the 1980s, pneumatic retinopexy was independently introduced by Dominguez in Spain and by Hilton and Grizzard in the USA.^{12,13}

Properties and characteristics of commonly used agents

The most common gas tamponades used in the USA are air, SF_6 , and perfluoropropane (C_3F_8) (Figure 1).¹⁴ In some centers, perfluoroethane (C_2F_6) is used. Air is nonexpansile, while 100% SF_6 expands approximately two times over 1–2 days, 100% C_2F_6 expands approximately three times over 1–2 days, and 100% C_3F_8 expands approximately four times over 3–4 days.¹⁵

Small volumes of undiluted gas are typically used for pneumatic retinopexy, but larger volumes of diluted gas are

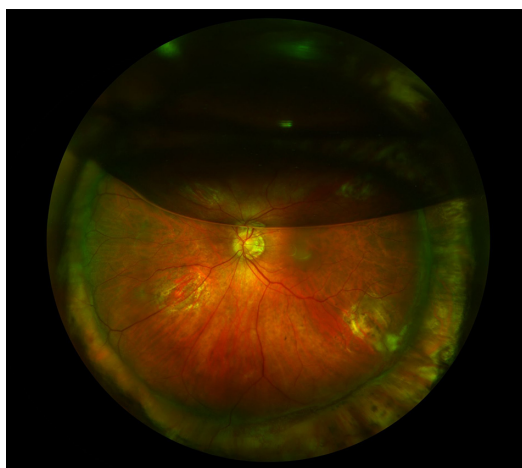


Figure 1 Fundus photograph of left eye.
Note: Demonstrating a partial gas fill following surgery for retinal detachment.

generally used for PPV. Commonly used concentrations are 20% for SF_6 , 16% for C_2F_6 , and 14% for C_3F_8 .¹⁶ Following a complete gas–fluid exchange, gas tamponade agents resorb spontaneously from the vitreous cavity, over a period of 5–7 days for air, ~2 weeks for 20% SF_6 , ~4–5 weeks for 16% C_2F_6 , and ~8 weeks for 14% C_3F_8 .

Unlike gases, silicone oils are permanent and remain in the eye until surgically removed.¹⁶ Gases have both higher surface tension and higher buoyancy than silicone oils;¹⁷ therefore, the reported tension exerted by a gas bubble is ~30 times greater than that of silicone oil.¹⁸

In the USA, commonly used viscosities of silicone oils include 1,000 and 5,000 centistokes (cSt).¹⁹ Silicone oils have a lower specific gravity (0.97 g/mL) than vitreous (1.005–1.008 g/mL),²⁰ and as a result, they float in the vitreous cavity. Similarly, gases also float in the vitreous cavity due to their very low specific gravities (0.001 g/mL) and they have a much greater buoyancy (upward force) than silicone oils.²¹

Therefore, silicone oils and gases provide less effective tamponade for cases with inferior retinal breaks, which has led to the investigation of heavier-than-water tamponades, including heavy silicone oils (HSOs) and perfluorocarbon liquids (Table 1).¹⁵

Effectiveness of various intraocular tamponades

Silicone oil vs gas tamponade

The Silicone Study^{22,23} was a prospective multicenter randomized clinical trial (RCT) comparing 1,000 cSt silicone oil to 20% SF_6 or 14% C_3F_8 in patients with RD associated with PVR. The Silicone Study reported significantly better anatomic and visual outcomes with silicone oil versus SF_6 at 1 year, but no significant differences in anatomic or visual outcomes between silicone oil and C_3F_8 .²¹

A long-term follow-up report on this study reported that, among the original participants who still had macular attachment at 36 months, there were no significant anatomic or visual outcome differences among silicone oil, SF_6 , and C_3F_8 groups after follow-up of up to 6 years.^{24,25}

The European Vitreo-Retinal Society (EVRS) Retinal Detachment Study was a retrospective study comparing the treatment outcomes of complex RD associated with PVR, giant retinal tear, choroidal detachment, or macular hole. A subanalysis of its first report compared the PPV level-1 failure rates, defined as failed reattachment deemed inoperable by the end of the study, between gas and silicone

Table 1 Various tamponade agents used in the treatment of retinal detachment

Silicone oil tamponades	Chemical composition	Viscosity (centistoke)	Specific gravity (g/cm ³)	Interfacial tension (mN/m)	Refractive index	Injection time (9 mL with 20-gauge needle)	
Conventional SO							
1,000 cSt SO	100% PDMS	1,000	0.97	35	1.4	50 seconds	
5,000 cSt SO	100% PDMS	5,000	0.97	35	1.4	240 seconds	
Heavy SO							
Oxane HD	88.1% 5,700 cSt	3,300	1.02	45	1.4	Not available	
Densiron 68	Oxane/11.9% RMN-3 69.5% 5,000 cSt PDMS/30.5% F ₆ H ₈	1,400	1.06	41	1.4	Not available	
Gas tamponades	Chemical formula	Molecular weight (g/mol)	100% gas expansivity	100% gas maximum expansion	Tamponade duration	Isoexpansile concentration	Interfacial tension (mN/m)
Air	N/A	28.97	N/A	N/A	5–7 days	N/A	70
Sulfur hexafluoride	SF ₆	146.06	2×	1–2 days	2 weeks	20%	70
Perfluoroethane	C ₂ F ₆	138.01	3×	1–3 days	4–5 weeks	16%	70
Perfluoropropane	C ₃ F ₈	188.02	4×	3–4 days	8 weeks	14%	70
Perfluorocarbon liquids	Chemical formula	Molecular weight (g/mol)	Specific gravity (g/cm ³)	Viscosity (mPas)	Interfacial tension (mN/m)	Refractive index	
Perfluoro- <i>n</i> -octane	C ₈ F ₁₈	438.06	1.76	1.20	55.0	1.3	
Perfluorodecalin	C ₁₀ F ₁₈	462.08	1.33	5.68	57.8	1.3	

Abbreviations: N/A, not applicable; SO, silicone oil; RMN-3, a partially fluorinated olefin; PDMS, polydimethylsiloxane.

oil tamponade among patients with PVR, and reported no significant differences.²⁶

Other smaller studies, however, demonstrated a benefit of silicone oil over gas or vice versa for certain groups of patients. In a retrospective study comparing silicone oil versus C₃F₈ in the treatment of RD among highly myopic eyes (mean refractive error of −15.40 D) with posterior staphyloma, it was reported that C₃F₈ was associated with significantly better initial success rates and significantly better visual outcomes.²⁷

In a retrospective series of 56 eyes with recurrent RD associated with PVR and treated with PPV and retinectomy, silicone oil tamponade yielded significantly higher success rates than did gas.²⁸ In this study, 88% of eyes underwent scleral buckle placement or revision during retinectomy, but scleral buckling did not significantly affect anatomic success rates.

In a retrospective study of 97 eyes with rhegmatogenous RD, the Pan-American Collaborative Retina Study (PACORES) group reported that among phakic and non-phakic eyes, the rates of recurrent RD were similar in both the C₃F₈ and 1,000 cSt silicone oil groups ($P > 0.05$). Further results showed that among patients receiving C₃F₈, recurrent RD occurred significantly less frequently among nonphakic eyes compared with phakic eyes (4.5% vs 28.6%; $P = 0.01$). The same trend was also seen within the silicone oil group but it did not reach statistical significance ($P = 0.20$).²⁹

Air vs other gas tamponades

Two recent studies have evaluated the efficacy of air vs longer-acting gases with conflicting results. In a retrospective study of 524 eyes with primary rhegmatogenous RD,³⁰ it was reported that there were no significant differences overall in the success rates of PPV with air or 20% SF₆ tamponade. In a subanalysis, however, among eyes with inferior RD, air was associated with a lower primary success rate than that of gas.

In a prospective, randomized, comparative study of 64 eyes with RD associated with inferior retinal breaks, there were no significant differences between air and C₃F₈ tamponade in terms of primary or overall anatomic success rates.³¹

Conventional silicone oil: 1,000 vs 5,000 cSt

In a retrospective series of 325 eyes with complex RD (defined as RD associated with cytomegalovirus retinitis, giant retinal tear, proliferative diabetic retinopathy, PVR, or trauma), there were no significant differences in anatomic success rates or visual outcomes between 1,000 and 5,000 cSt silicone oil.³²

In another retrospective series of 82 eyes with complex RD, however, the use of 5,000 cSt silicone oil was associated with a significantly higher rate of recurrent RD following silicone oil removal.³³

Heavy silicone oil vs conventional silicone oil tamponade

Due to low density and high floatation force, conventional silicone oils (and gases) are relatively less effective in the treatment of inferior RD. Heavy silicone oils (HSOs) with higher specific gravities have been investigated for this purpose. Two HSOs that are currently available for clinical use in some European nations, but not approved for use in the USA, are Densiron 68 (a mixture of silicone oil and perfluorohexyloctane; Fluoron, Neu-Ulm, Germany) and Oxane HD (a mixture of silicone oil and partially fluorinated olefin, RMN-3; Bausch + Lomb, Toulouse, France).

The HSO Study³⁴ was an RCT comparing Densiron 68 with conventional silicone oil (either 1,000 or 5,000 cSt per surgeon preference) among patients with inferior RD associated with PVR. The interim analysis of this study reported that, at 12 months, there were no significant differences in the anatomic success rates or visual outcomes between HSO tamponade and conventional silicone oil tamponade. At this time, the final HSO Study results have not been published.

Another randomized, prospective, comparative study that compared PPV with Densiron 68 to 1,000 cSt conventional silicone oil among 61 consecutive eyes with primary RD due to inferior breaks also reported no significant anatomic or functional differences between the two groups.³⁵

To date, there have been no large RCTs evaluating the efficacy of Oxane HD. In a prospective, comparative study, PPV with Oxane HD tamponade was compared to conventional silicone oil among patients with complex inferior RDs. The investigators reported no significant differences in anatomic or visual outcomes.³⁶

In a small, prospective, RCT involving 20 consecutive patients, PPV with conventional 1,300 cSt silicone oil combined with scleral buckling was compared to PPV with Oxane HD alone in patients with inferior RD associated with PVR. Following silicone oil removal, there were no significant differences in outcomes.³⁷ A recent systematic review of conventional silicone oil versus HSO in the treatment of RD reported a trend toward higher rates of ocular hypertension in eyes treated with HSO ($P=0.02$ in a fixed effect model and $P=0.06$ in a random effect model).³⁸

Perfluorocarbon liquids

Perfluorocarbon liquids are a group of heavier-than-water liquids that are used intraoperatively to reattach the retina, and they are typically removed by the end of the surgery.³⁹ These liquids are considered biologically inert but some evidence exists that they may be toxic when retained in

the eye for longer periods of time.⁴⁰ Despite these toxicity concerns, some studies have reported beneficial results using perfluorocarbon liquids as short- to medium-term tamponade agents in patients with inferior or complex RD.

In a retrospective series of 62 eyes with giant retinal tear, temporary use of perfluorocarbon liquids (mean of 7.5 days, then exchanged for gas or silicone oil) resulted in a final success rate of 93.5% with no serious complications reported.⁴¹

In another retrospective study of 39 eyes with RD with giant retinal tear or multiple breaks in more than one retinal quadrant, perfluorocarbon liquids were retained for a median of 11 days and exchanged for gas or silicone oil.⁴² The authors reported a 100% reattachment rate.

Complications of silicone oil or gas tamponade

The use of silicone oil and gas tamponade is associated with several important complications. The Silicone Study reported that chronic postoperative elevated intraocular pressure (IOP) and hypotony occurred in both the C₃F₈ gas and silicone oil groups, with elevated IOP significantly more common with silicone oil and hypotony significantly more common with gas.⁴³

Another Silicone Study report evaluated the corneal complications (including corneal edema, corneal opacity, or need for corneal transplant) of silicone oil and gas tamponade. At 24 months, the overall rates of corneal abnormalities were not significantly different between the silicone oil and gas tamponade groups.⁴⁴

Cataract formation is also another common complication associated with both gas and silicone oil tamponade, with reported rates of up to 100%.⁴⁵ Venous air embolization secondary to fluid–air exchange during vitrectomy has been simulated in donor eyes⁴⁶ following three separately published cases (one fatal) reporting this phenomenon.⁴⁷ Complications unique to silicone oil tamponade include RD associated with silicone oil removal, silicone oil microemulsification, and subconjunctival or suprachoroidal silicone oil.^{48–50}

In some cases, the use or removal of silicone oil is associated with unexplained visual loss. One series reported seven such patients who lost three or more lines of Snellen visual acuity associated with the loss of foveal depression on optical coherence tomography.⁵¹ Another series of 188 eyes reported rates of unexplained visual loss (greater than two Snellen lines) after successful surgery for macula-on rhegmatogenous RD in 0.7% of eyes treated with gas and 29.7% of

eyes treated with silicone oil ($P=0.001$); the silicone oil-treated eyes demonstrated a small scotoma using microperimetry.⁵² Another series of 421 consecutive eyes treated with silicone oil removal reported a rate of unexplained visual loss of 3.3% overall, and 50% in patients with prior macula-on RD associated with giant retinal tear.⁵³

Conclusion

Numerous studies have reported that use of silicone or gas tamponade in the management of RD is generally associated with very favorable outcomes. Among gas tamponades, the Silicone Study demonstrated that both C_3F_8 and silicone oil yielded better outcomes compared to SF_6 in eyes with RD associated with PVR.

While HSOs are approved in certain European nations, they are not available for routine clinical use in the USA. The off-label use of short- to medium-term tamponade with perfluorocarbon liquid has been reported in certain patients with inferior or complex pathology.

The choice of tamponade agent should be individualized based on the location and characteristics of RD, expected patient compliance with postoperative positioning requirements, and other factors. Silicone oil may be preferable in patients unlikely to comply with postoperative positioning (such as children or the mentally impaired), in monocular patients desiring faster visual rehabilitation, or in patients planning air travel shortly after surgery. Using these guidelines, generally favorable outcomes may be obtained for most patients.

Acknowledgments

This study was partially supported by National Institutes of Health (NIH) Center Core Grant P30EY014801 and an unrestricted grant from Research to Prevent Blindness, New York, NY, USA.

Disclosure

Dr Schwartz has received consulting fees from Alimera and Bausch + Lomb, speakers' fees from ThromboGenics, and writers' fees from Vindico. All other authors have no financial disclosures and report no conflicts of interest in this work.

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