Perfluoron and Silicone Oil for Complex Retinal Detachments

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The development of perfluorocarbon liquids for use in vitreoretinal surgery by Stanley Chang, MD, revolutionized the treatment of complex retinal detachments.[1] Perfluoron (perfluoro-n-octane; Alcon), transparent and heavier than water, facilitates intraoperative retinal attachment in a supine patient. Perfluoron's low viscosity makes it easy to inject into the eye and to manipulate during surgery.[2] Its high boiling point allows the use of endolaser therapy through Perfluoron during surgery.[3] Since laser photocoagulation does not form an immediate retinochoroidal adhesion, and since Perfluoron cannot be safely left in the eye postoperatively, gas or silicone oil must be exchanged for the Perfluoron once the retina is attached.[4,5]

Silicone oil or gas can safely remain in the eye to support the retina while a laser adhesion matures. Silicone oil is a useful postoperative tamponade in eyes of patients who cannot position postoperatively (such as children), eyes of patients who need to fly soon after surgery, and commonly in eyes with proliferative vitreoretinopathy.[6] Five thousand-centistoke silicone oil may resist emulsification better than less-viscous 1,000-centistoke silicone oil and may therefore be preferable in eyes requiring long-term tamponade.[7,8]

TWO APPROACHES TO REATTACHMENT

There are two avenues for successfully progressing from a situation where the retina is attached under Perfluoron to a situation where the retina is attached under silicone oil. First, Perfluoron can be exchanged for air, and then the air-filled eye can be filled with silicone oil. Second, Perfluoron can be exchanged for silicone oil directly.[9] In either case, the eye is initially filled not with Perfluoron alone, but rather with a combination of Perfluoron and balanced salt solution (BSS). If either the Perfluoron or the BSS migrates under the retina during the exchange, the retina will redetach.

Before these two techniques of Perfluoron-silicone oil exchange are discussed, the use of Perfluoron and the use of silicone oil will be briefly reviewed.

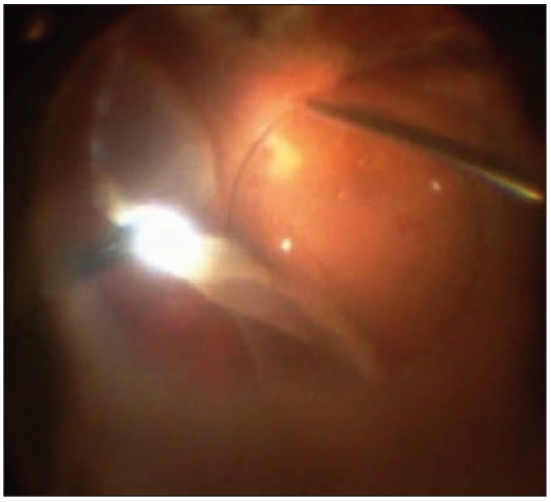

Figure 1. Intraoperative photograph of Perfluoron bubble on macula with retinal detachment and retinotomy on the left of photo.

PERFLUORON OVERVIEW

Perfluoron displaces subretinal fluid anteriorly. Therefore, during Perfluoron infusion, the eye should be rolled so that any retinal defect, such as a retinotomy or retinal tear, is as anterior as possible. Then, as the Perfluoron is injected into the vitreous cavity, the retinal defect remains open, allowing egress of displaced subretinal fluid (**Figure 1**). If Perfluoron occludes the retinal defect before all the posterior subretinal fluid drains, a pocket of subretinal fluid will be trapped posteriorly, preventing complete intraoperative retinal attachment. That trapped subretinal fluid makes retinal slippage more likely when Perfluoron is removed from the eye.

Subretinal migration of Perfluoron and emulsification of Perfluoron should be avoided during surgery. Subretinal migration of Perfluoron occurs when it is injected beyond the edge of a retinal defect (retinal tear, retinal hole, retinotomy, or retinectomy) that is under traction and cannot lie flat against the underlying retinal pigment epithelium. Just like when you overfill a glass of milk, the milk spills over the edge of the glass, Perfluoron that is filled beyond a tractionally elevated retinal defect will spill over the edge

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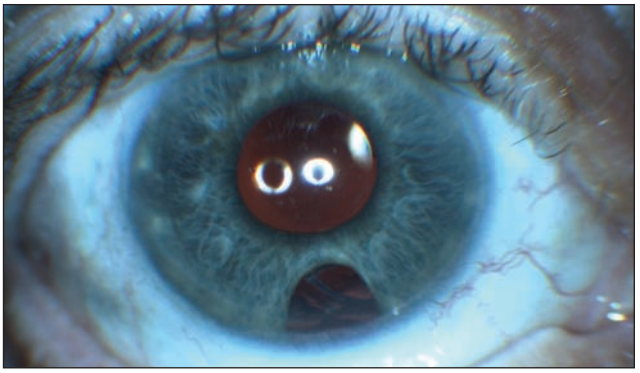

Figure 2. Image showing generous inferior peripheral iridectomy. This patient recovered 20/30 visual acuity after several retinal reattachment surgeries for retinal detachment and proliferative vitreoretinopathy. His silicone oil has been removed. Subtle droplets of silicone oil can be seen on the intraocular lens.

of the defect. The Perfluoron will then settle posteriorly underneath the retina. Similarly, subretinal Perfluoron migration can occur if the globe is rolled during surgery to visualize peripheral retina, causing the Perfluoron to "slosh around" in the eye and spill through a tractionally elevated retinal defect.

Emulsification of Perfluoron occurs when the BSS rapidly flows through the eye during the time Perfluoron is in use. Powerful infusion jets can form in the eye when a sclerotomy or trochar is not occluded. Flow through a sclerotomy occurs when it is not occluded by an instrument or plug or when it has enlarged to a size at which it remains open, even while occupied with an instrument. An eye filled with Perfluoron up to the level of the infusion cannula is also subject to violation of the Perfluoron bubble and emulsification. High-flow infusion aimed at the Perfluoron bubble can break off tens or hundreds of tiny Perfluoron bubbles inside the eye.

Removing Perfluoron completely once it has emulsified is difficult or impossible. Small residual droplets that remain in the eye postoperatively can migrate under the retina or cause chronic inflammation. Some patients are also bothered postoperatively because they see the Perfluoron droplets moving around in their superior visual field.

SILICONE OIL OVERVIEW

If surgeons are fortunate to work in an operating room sufficiently equipped with small-gauge instruments and need to repair a complex retinal detachment using the 23-gauge or 25-gauge vitrectomy systems, then they can use silicone oil as a postoperative tamponade. Many surgeons prefer using 20-gauge systems when working with silicone oil because they infuse more easily through a larger-gauge cannula. The resistance to flow through 23- and 25-gauge infusion tubing is much greater than the resistance to flow through 20-gauge infusion tubing. This is because the resistance to viscous flow through a tube is inversely proportional to the fourth power of the radius of the tube. In other words, a reduction of the inner diameter of a tube by half increases resistance to flow through the tube by a factor of 16. Despite this drawback, several publications have proven that Perfluoron and silicone oil can be successfully used with 25-gauge and 23-gauge vitrectomy systems.

Silicone oil overfill, underfill and anterior chamber fill need to be avoided during surgery. While infusing silicone oil, it is important to periodically palpate the eye to make sure the intraocular pressure is reasonable. During surgery, the silicone oil infusion cannula or needle must be angled away from the anterior chamber to avoid filling the chamber with oil during surgery.

In eyes that are pseudophakic with questionable capsular or zonular integrity or eyes that are aphakic, an inferior iridectomy large enough to stay open postoperatively usually prevents migration of silicone oil into the anterior chamber postoperatively (**Figure 2**).[10] If oil migrates into the anterior chamber during surgery, the oil will sometimes exit the anterior chamber if the surgeon injects viscoelastic into the anterior chamber, removes oil from the posterior chamber, or completely removes the oil from the eye. Ocucoat (Bausch & Lomb) can be left in place; removal causes oil to come forward.

When operating on an eye where silicone oil injection is planned, the surgeon should avoid violating the anterior chamber of the eye. Any anterior-chamber incision that is not completely sealed at the end of surgery (including needle tracks) can allow aqueous to drain from the anterior chamber, facilitating the migration of silicone oil from the posterior chamber into the anterior chamber.

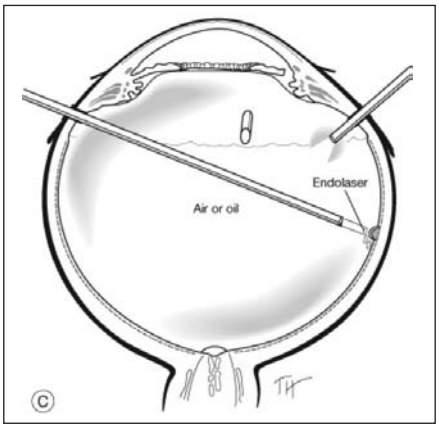

Figure 3. Perfluorocarbon liquid–silicone oil exchange: "sandwich" technique for subretinal fluid removal. Subretinal fluid loculated anterior to the retinal break is displaced posteriorly by silicone oil infusion (or air infusion) and removed through the retinal break.

PERFLUORON–AIR–SILICONE OIL EXCHANGE

Most retinal detachments have an anterior component that retains subretinal fluid after Perfluoron has been infused to displace the posterior component of the retinal detachment. As air is infused into the eye, a soft-tipped cannula can be used to remove as much BSS anterior to the Perfluoron as possible. Subsequently,

FIGURE 3 IS REPRINTED FROM *RETINA*, 4TH ED., RYAN S.J, HINTON D.R, SCHACHAT A.P, WILKINSON C.P, EDS., COPYRIGHT 2005, WITH PERMISSION FROM ELSEVIER.

while minimally rolling the eye to maintain the Perfluoron bubble posteriorly, the soft-tip cannula can be used to drain subretinal fluid from the edges of any retinal defects. Often, subretinal fluid that was pushed anteriorly by the Perfluoron or that was there from the initial retinal detachment will be forced posteriorly as the air pressure reattaches the anterior retina. That fluid should be removed through any opening in the retina prior to removing the Perfluoron (**Figure 3**).[6]

After the anterior retina has reattached and the edges of any retinal defects have been dehydrated, the Perfluoron can be removed by placing the soft-tip cannula over the optic nerve. Since Perfluoron's refractive index is 1.27 and the refractive index of BSS is 1.3345, the edge of the Perfluoron bubble becomes visible during its removal.

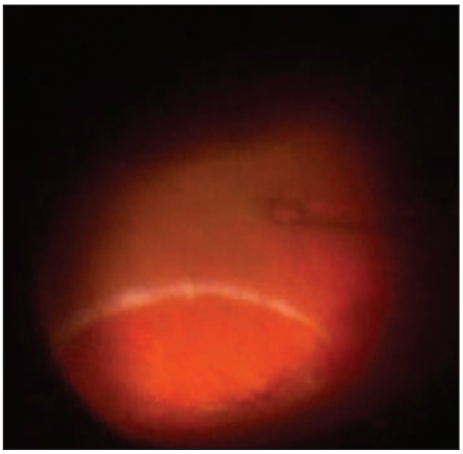

Figure 4. A retinal tear edge can be seen in white, and it has been pushed posteriorly by air.

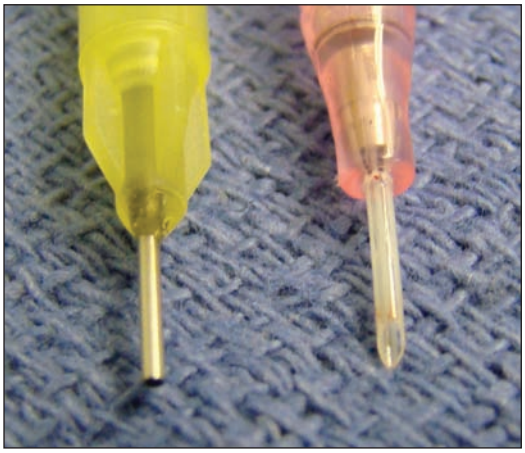

Figure 5. The cut edge of a 20-gauge angiocatheter has a larger inner diameter than the 20-gauge silicone oil needle.

Sometimes, the residual preretinal Perfluoron can be washed off of the retinal surface by first allowing small amounts of BSS through the infusion cannula to wet the retina and subsequently removing the fluid from the eye and any residual Perfluoron it contains. Finally, to obtain a complete fluid-air exchange, a five- to 15-minute waiting period can be observed, and then the residual preretinal fluid can be removed from over the optic nerve with a soft-tipped extrusion cannula.

During the Perfluoron-air exchange, there is a greater chance that the edge of a giant retinal tear, retinotomy, or retinectomy may slip posteriorly than during a Perfluoron–silicone oil exchange (**Figure 4**). The force acting on the edge of the retinal defect as the air-BSS interface passes over it is generated primarily by the surface tension of BSS in air, which is approximately 60 dyne/cm (600 μN/cm).[11] This is much greater than the force acting on the edge of the retinal defect as silicone oil-BSS interface passes over it. This force is generated primarily by the interfacial tension of silicone oil in BSS, which is approximately 33 dyne/cm (330 μN/cm).[11]

If a retinectomy edge slips posteriorly after Perfluoron-air exchange, the surgeon can attempt to reposition the slipped edge. The retina can be gently unfolded anteriorly by stroking it with a silicone-tipped extrusion cannula under gentle suction.[12] Alternatively, the eye can be slightly underfilled with silicone oil (this is only advisable for giant tears or retinotomies that are not located in the inferior half of the retina), and the patient can be instructed postoperatively to perform rolling maneuvers that can smooth the slipped retina back into place. If all else fails, the eye can be refilled with BSS and then reattached with Perfluoron, and a direct Perfluoron-silicone oil exchange can subsequently be performed.

After a complete Perfluoron-air exchange, silicone oil is injected into the air-filled eye. The nasal sclerotomy can be sutured or left open for air egress. Then the globe is rotated slightly nasally so the infusion cannula is as anterior as reasonably as possible. Some surgeons preplace sclerotomy closing sutures in the open sclerotomy and sometimes also around the infusion sclerotomy. Then the air infusion pressure is elevated briefly so the needle on the silicone oil syringe can be inserted into the superotemporal sclerotomy. Subsequently, the air infusion pressure is decreased and the oil is infused. Infusion of especially high-viscosity silicone oil is faster if a trimmed 18- or 20-gauge angiocatheter is used instead of the blunt needle provided with the silicone oil kit (**Figure 5**). The intraocular pressure can be checked periodically with palpation.

When the eye is nearly filled with oil, the oil will move across the pupil or the back of the lens, and then the infusion cannula will start to fill with oil. At that moment, the infusion is stopped, the oil needle is removed, and the sclerotomy is closed. If there is a trapped air bubble in the front of the vitreous cavity, a 30-gauge needle can be inserted into the air to remove it from the eye, which allows oil that has refluxed into the low-pressure, air-filled infusion cannula to fill the eye. Then the infusion cannula is removed and the sclerotomy quickly closed.

PERFLUORON-SILICONE OIL EXCHANGE

Once the retina is attached under Perfluoron, the silicone oil syringe is connected to the high-pressure infusion cannula in place of the BSS. Care is taken to make sure the

Luer-Lock is tight so the oil does not spray all over the operating room and not into the eye. The eye is briefly soft during this maneuver, so it must be done quickly. Then, as soon as the oil syringe is snugly attached to the infusion, the foot-pedal–controlled, high-pressure infusion pump can be used to infuse the oil into the vitreous cavity. The infusion needle must remain directed posteriorly or the anterior chamber will fill with oil. Using a wide-angle viewing system, the BSS can be passively or actively removed from the vitreous space, just behind the infusing oil (**Figure 6**). I prefer the Charles 20-gauge flute needle attached to a backflush handpiece for these exchanges (**Figure 7**).

If the surgery is not done with trochars, the sclerotomies must be tight on the instruments to avoid excess spillage of silicone oil around the instruments through the sclerotomies and to assure adequate pressure inside the eye to drive the BSS and Perfluoron up the flute needle and out of the eye. Sometimes a suture needs to be placed to tighten a sclerotomy before commencing the silicone oil-Perfluoron exchange.

The tip of the aspiration needle is initially placed just behind the silicone oil. Silicone oil has a refractive index of 1.40. (BSS, as noted, has a refractive index of 1.3345.) This makes visualization of the interface between the oil and BSS possible until the oil fills the front of the eye and the posterior surface of the oil bubble-BSS interface flattens out.

Sometimes moving the needle from the back to the front and then to the back of the eye helps to find the interface. Once the oil has infused back to the edge of any retinal tears or retinotomies, time can be taken to remove as much BSS from those areas as possible to assure complete retinal reattachment (**Figure 8**).[9] The eye is rotated as little as possible toward the breaks during this maneuver, so the benefit of the Perfluoron pressure on the posterior retina is maximized. After the meniscus of the silicone oil advances beyond the edge of the retinotomy or tear, the remaining Perfluoron can be removed from the posterior pole near the optic nerve.

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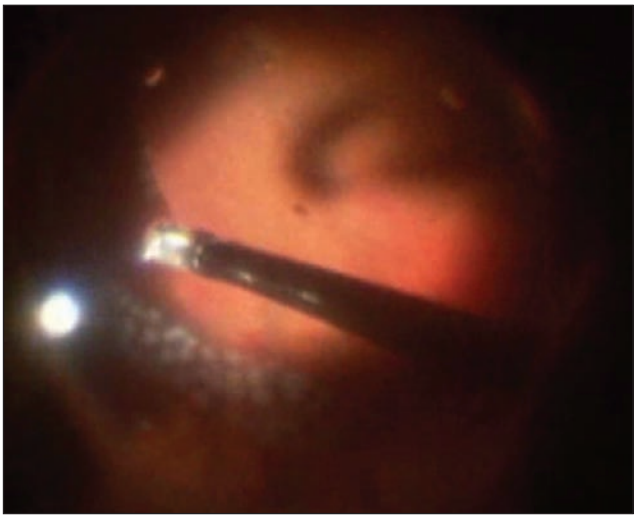

Figure 6. Oil is being infused from the right of the picture. The edge of the oil can be seen and the extrusion needle is being positioned with the tip immediately next to the infusing oil to remove the underlying BSS.

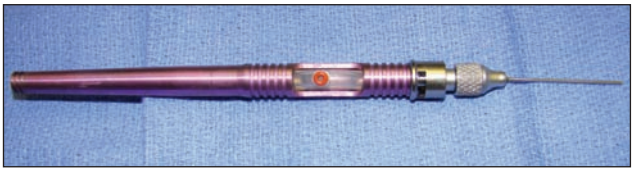

Figure 7. Charles fluted 20-gauge needle on backflush passive aspiration handpiece.

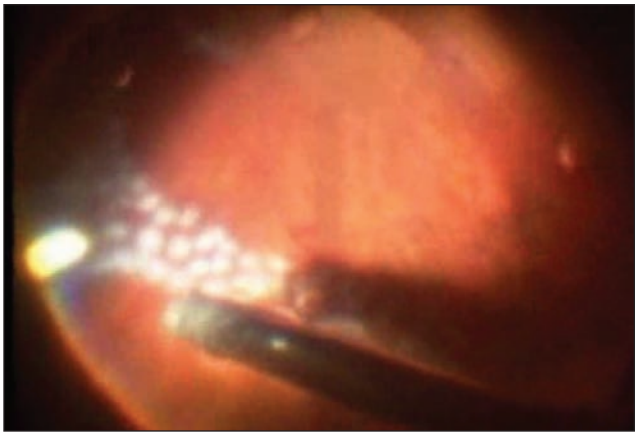

Figure 8. Time is taken to drain as much BSS from the eye at the edge of the retinotomy, as the Perfluoron posteriorly and the silicone oil anteriorly push the subretinal fluid out from under the retina through the break.

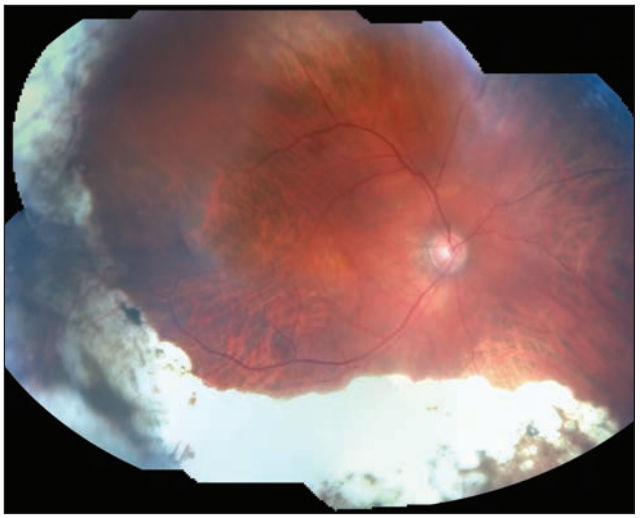

Figure 9. Montage fundus photograph of a retina following retinal detachment repair, with an inferior retinectomy and silicone oil tamponade following silicone oil removal. The eye has 20/30 visual acuity even though there are small oil droplets on the posterior-chamber intraocular lens (seen in Figure 2).

visual acuity in the right eye was 20/50. Spectralis HR-OCT demonstrated vitreomacular traction and a small foveal cyst, consistent with a grade 1 macular hole (**Figure 2**).

> Advances in OCT have made it a most valuable tool for the detection and staging of macular holes.

Three months later, there was no change in metamorphopsia in the left eye and visual acuity was stable at 20/200, but upon examination, it seemed that the hole was closed. Stratus OCT demonstrated complete PVD with closure of the macular hole in the left eye. Foveal contour returned to an almost normal configuration, and a small subretinal cyst, photoreceptor discontinuity, and an operculum attached to the detached vitreous are all that remained of the once full-thickness macular hole (**Figure 3**). Over five months of follow-up, visual acuity of the left eye improved to 20/50, and Spectralis HR-OCT demonstrated almost complete absorption of the cyst and restoration of the normal foveal contour. Only a subtle discontinuity of the photoreceptor layer was still noticeable — a fact that may explain the still decreased visual acuity (**Figure 4**). The right eye remained unchanged during this period.

CONCLUSION

As documented by Spectralis HR-OCT, these images depict a rare clinical course of a grade 2 full thickness macular hole, regressing almost completely over a period of five months, with significant improvement of visual acuity. RP

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The eye should be rotated, if possible, to avoid suction at or near the fovea. Intraocular pressure should be checked with palpation to make sure it is under control. Following complete removal of Perfluoron, the sclerotomies are closed while the oil infusion maintains a reasonable intraocular pressure. While closing the first sclerotomy, the second sclerotomy can be plugged.

Alternatively, if trochars were used, they are removed at this point and the integrity of the self-sealing sclerotomies is ascertained. Sutures can be placed in the trochar holes if necessary. Finally, when all other sclerotomies are sealed, the silicone oil infusion is removed and the infusion sclerotomy is closed as quickly as possible. If the intraocular pressure is high, oil can be passively leaked through this final sclerotomy prior to its closure. Anterior chamber-taps are not advisable since they can induce anterior-chamber migration of silicone oil.

FINISHING UP

At the conclusion of any case in which silicone oil is used, the surface of the eye must be thoroughly washed with salt solution to remove any residual oil. Postoperatively, the patient should be positioned face down to encourage resumption of aqueous humor flow into the anterior chamber and posterior settling of the silicone oil bubble. Using the techniques described in this article, it is possible to repair complex retinal detachments with proliferative vitreoretinopathy, sometimes achieving remarkable visual results, such as the retina pictured in **Figure 9** of a patient with 20/30 visual acuity after four retinal surgeries. RP

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