Retained Intraocular Perfluoro-n-octane After Valved Cannula Pars Plana Vitrectomy for Retinal Detachment

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BACKGROUND AND OBJECTIVE: To investigate cases of retained intraocular perfluoro-n-octane (PFO) after pars plana vitrectomy (PPV) for retinal detachment (RD).

PATIENTS AND METHODS: Retrospective, noncomparative case series of six eyes with retained intraocular PFO after RD repair. Clinical data were supplemented with an experimental silicone eye model.

RESULTS: A cluster of six cases of retained intraocular PFO after PPV for RD repair were noted shortly after transitioning to valved cannulas. PFO was noted in the anterior chamber (AC) and/or vitreous and removed with AC paracentesis, AC wash-out, and/or PPV. A silicone eye model demonstrated that PFO levels are maintained anterior to cannula insertion with valved cannulas only.

CONCLUSION: The authors hypothesize that anterior PFO fill using valved cannulas can lead to sequestration within the AC, zonules, ciliary sulcus, ciliary teeth, and/or capsular bag. They suggest vigilance in not overfilling PFO, particularly when transitioning to use of valved cannulas, to minimize the risk of intraocular retention.


INTRODUCTION

Perfluorocarbon liquids have been widely adopted as an instrument in vitreoretinal surgery. Due to their chemical and physical properties including transparency, high specific gravity, and immiscibility with water, they offer advantages, especially for retinal detachment (RD) surgery.1 They are used most commonly to displace subretinal fluids, flatten retinal folds, and aid in retinal stabilization.

The most widely used perfluorocarbon is perfluoro-n-octane (PFO). Small residual amounts of PFO inadvertently left in the anterior chamber (AC) or vitreous after pars plana vitrectomy (PPV) have been reported at rates from 4% to 5% and seem to be well tolerated.2,3 Large amounts of retained perfluorocarbon have rarely been reported, but prolonged retention can be associated with toxic sequelae, including secondary glaucoma,4 winter-flake degeneration characterized by white flocculent material on various intraocular structures,5 a macrophage-driven foreign body response,6 and bullous keratopathy with corneal inflammation.7,8 In a rabbit eye model, Chang et al observed photoreceptor changes, narrowing of the outer plexiform layer and macrophage accumulation in the inferior retina after PFO retention greater than 1 week.9 Similarly, Eckardt et al found histologic changes including rarefication of photoreceptor nuclei in the inferior rabbit retina after 1 to 2 months of perfluorocarbon exposure.9,10

Small-gauge (23- or 25-gauge) sutureless PPV has been widely adopted in clinical practice with favorable efficiency and safety profiles compared to traditional 20-gauge systems.11,12 One of the key advanc-
es in small-gauge vitrectomy is the development of transconjunctival cannulas, which facilitate instrument exchange. More recently, valved cannulas have been introduced for small-gauge PPV. While advantages including improved fluidic stability have been realized, to our knowledge, no valve-associated complications have been reported.  

Shortly following the transition to valved cannulas at our institution, we noticed an unusual cluster of eyes with retained intraocular PFO after retinal detachment surgery. The purpose of the current study is to analyze the preoperative characteristics of these eyes, review surgical techniques employed during the implicated cases, and evaluate postoperative outcomes in order to better understand risk factors for this complication, which we hypothesize resulted from changes in fluidics introduced by valved cannula utilization.

**PATIENTS AND METHODS**

The study protocol was approved by the institutional review board of the Duke University School of Medicine. We performed a retrospective review of eyes with retained intraocular PFO after small-gauge valved PPV performed at the Duke Eye Center from May 16, 2012, through January 7, 2013. Data collected included demographics, RD type, RD repair method, clinical course, PFO removal technique, and anatomic or functional outcomes.

Potential mechanisms of PFO retention were further evaluated using a silicone eye model of fluid-PFO exchange. Valved or non-valved 23-gauge cannulas (Alcon, Fort Worth, TX) were placed through the approximate pars plana location (4 mm from the limbus) in silicone model eyes (Vit-Ret Eye, Phillips Studios, Redland, UK), infused via an infusion line with a bottle height of 40 cm of H2O. PFO was then filled anterior to the level of cannula insertion. Instruments were removed from the cannulas to observe possible egress of fluids. The final level of PFO could be compared by external visualization through the silicone eye wall. Experiments were repeated with the infusion line both open and clamped.

**RESULTS**

Six cases with intraocular retained PFO after small-gauge PPV for RD repair were documented during the study period. PPV was performed by four different surgeons. Duke University transitioned to valved cannulas for PPV in May 2012. Valved cannulas were used in all cases. Baseline clinical information, surgical details, and management of PFO retention are outlined in the Table. Median patient age was 58 (range: 35 to 71 years). Four eyes (66%) were pseudophakic, two (33%) aphakic, and none were phakic. All pseudophakic eyes had a posterior chamber intraocular lens (IOL). The posterior lens capsule was intact in two eyes (50%). Median time to clinical detection of retained intraocular PFO was 21.5 days (range: 1 to 361 days). Five eyes (83%) underwent prompt removal of PFO; the sixth (16%) was initially observed but later underwent removal of PFO during repair of a recurrent RD. PFO removal was complete in five (83%) of six cases; in the sixth case, further removal was deferred due to poor visual prognosis. Median follow-up was 479 days (range: 410 to 651 days). Each case is summarized below.

**Case 1**

A 53-year-old pseudophakic woman presented with a macula-sparing rhegmatogenous retinal detachment (RRD). She underwent 23-gauge valved PPV with PFO, endolaser, and SF6 tamponade. At the 1 month follow-up visit, multiple PFO bubbles were detected in the AC and inferior vitreous. She subsequently underwent PFO removal via 23-gauge valved PPV with AC wash-out, during which numerous PFO bubbles were seen to emerge from the residual lens capsule and ciliary sulcus. Winter-flake deposits were noted in areas of residual peripheral vitreous and were likewise removed. Postoperatively, no residual PFO bubbles were visualized. However, the patient continued to have “small bubbles” in her vision and eventually developed a visually significant epiretinal membrane. She underwent 23-gauge valved PPV with membrane peel, at which time a repeat AC wash-out revealed several more tiny residual PFO bubbles. At her most recent visit, visual acuity (VA) was 20/25. Residual PFO was not evident on examination, and there were no signs of inflammation or toxicity.

**Case 2**

A 35-year-old pseudophakic woman with a history of a recent complex tractional retinal detachment (TRD) repair in the left eye presented with vitreous hemorrhage and bare light perception (LP) postoperatively. Ultrasonography demonstrated a complete TRD-RRD, and a revision 23-gauge valved PPV was performed with scleral buckle, iris hooks, membrane peeling, PFO, 180° inferior retinectomy, endolaser, and silicone oil tamponade. On postoperative day 1, a large PFO bubble was noted in the AC. PFO was removed via 30-gauge needle paracentesis at the slit lamp at the 1-month follow-up visit. On further examinations, no residual PFO was visualized, however a chronic inferior TRD was noted, which was observed. She also developed several recurrent episodes of iritis.
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**Case 2**

A 53-year-old woman with a history of a childhood open-globe injury who had undergone multiple surgeries was subsequently aphakic in the right eye. She presented with decreased vision in the right eye. VA was hand motion (HM) with corneal scarring and an inferior macula-involving RRD with multiple holes in the far periphery and a chronic macular hole. She underwent encircling scleral buckle placement, 23-gauge valved PPV with PFO, endolaser, and C3F8 tamponade. At the 1-month follow-up visit, a small amount of PFO was detected in the AC. In the absence of inflammation, this was observed. Three months later, the patient returned with a total RD due to a giant retinal tear and grade C proliferative vitreoretinopathy. She underwent vitrectomy with 23-gauge valved PPV with PFO endolaser, and C3F8 tamponade. At the most recent visit, VA remained HM with sustained retinal attachment and no evidence of retained PFO.

**Case 3**

A 53-year-old woman with a history of a childhood open-globe injury who had undergone multiple surgeries was subsequently aphakic in the right eye. She presented with decreased vision in the right eye. VA was hand motion (HM) with corneal scarring and an inferior macula-involving RRD with multiple holes in the far periphery and a chronic macular hole. She underwent vitrectomy with 23-gauge valved PPV with PFO endolaser, and C3F8 tamponade. At the 1-month follow-up visit, a small amount of PFO was detected in the AC. In the absence of inflammation, this was observed. Three months later, the patient returned with a total RD due to a giant retinal tear and grade C proliferative vitreoretinopathy. She underwent vitrectomy with 23-gauge valved PPV with PFO endolaser, and C3F8 tamponade. At the most recent visit, VA remained HM with sustained retinal attachment and no evidence of retained PFO.

**Case 4**

A 65-year-old woman was referred for a recurrent RRD in the left eye. She had an initial RD repair complicated by postoperative endophthalmitis, treated with intravitreal antibiotics. She subsequently underwent recurrent HM with no retinal attachment and no evidence of retained PFO.

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**TABLE**

**Baseline Data and Clinical Course for Eyes With Retained Intraocular PFO After Valved-Cannula Pars Plana Vitrectomy**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age, Sex</th>
<th>RD Type</th>
<th>Lens Status</th>
<th>RD Repair</th>
<th>Time to PFO Detection (days)</th>
<th>PFO Location</th>
<th>Management</th>
<th>Outcome</th>
<th>Follow-Up (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53, F</td>
<td>RRD</td>
<td>Pseudophakia (PC open)a</td>
<td>23g PPV/PFO/SF6</td>
<td>5</td>
<td>AC/vitreous</td>
<td>23g PPV/AC wash-out twiceb</td>
<td>Remaining PFO (subjectively)</td>
<td>651</td>
</tr>
<tr>
<td>2</td>
<td>35, F</td>
<td>TRD/RRDc</td>
<td>Pseudophakia (PC intact)</td>
<td>SB/iris-hooks/23g PPV/MP/retinectomy 360°/PFO/PI/ISO</td>
<td>1</td>
<td>AC</td>
<td>Slit lamp AC paracentesisb</td>
<td>Complete removal of PFO</td>
<td>493</td>
</tr>
<tr>
<td>3</td>
<td>53, F</td>
<td>RRD</td>
<td>Aphakia</td>
<td>SB/23g PPV/PFO/PV/CF38</td>
<td>30</td>
<td>AC/vitreous</td>
<td>Initial observation, then 23g PPV (for recurrent RRD)</td>
<td>Complete removal of PFO</td>
<td>492</td>
</tr>
<tr>
<td>4</td>
<td>63, F</td>
<td>RRDd</td>
<td>Aphakia</td>
<td>Sulcus IOL removal/23g PPV/retinectomy 360°/PFO/MP/ISO exchange</td>
<td>13</td>
<td>AC/vitreous</td>
<td>Slit lamp AC paracentesis five times, further observation (poor visual prognosis)</td>
<td>Remaining intraocular PFO, further surgery deferred</td>
<td>430</td>
</tr>
<tr>
<td>5</td>
<td>71, M</td>
<td>RRD</td>
<td>Pseudophakia (PC intact)</td>
<td>SB/23g PPV/PFO/CF38</td>
<td>36</td>
<td>AC/vitreous</td>
<td>23g PPV/AC wash-outb</td>
<td>Complete removal of PFO</td>
<td>466</td>
</tr>
<tr>
<td>6</td>
<td>63, M</td>
<td>RRD</td>
<td>Pseudophakia (PC open)a</td>
<td>SB/23g PPV/PFO/CF38</td>
<td>361</td>
<td>AC</td>
<td>AC wash-outb</td>
<td>Complete removal of PFO</td>
<td>410</td>
</tr>
</tbody>
</table>

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*PFO = perfluoro-n-octane; RD = retinal detachment; d = days; F = female; M = male; RRD = rhegmatogenous retinal detachment; TRD = tractional retinal detachment; PC = posterior lens capsule; PPV = pars plana vitrectomy; SF6 = sulfur hexafluoride; PI = peripheral iridectomy; SO = silicone oil; SB = scleral buckle; MP = membrane peel; C3F8 = octafluoropropane; AC = anterior chamber.*

*aCases 1 and 6 had an open posterior capsule status post YAG capsulotomy.*

*bAnterior chamber PFO removal was performed in the office at the slit lamp for cases 2 and 4; and in the operating room for cases 1, 5 and 6.*

*cCases 2 and 4 had recurrent RD repairs.*

*dCase 4 had sulcus intraocular lens explantation concurrent with retinal detachment surgery.*
ment. Postoperatively, she developed a recurrent RD, which was repaired with an encircling scleral buckle, PPV, and silicone oil tamponade. Upon presentation at our institution, VA was HM with a recurrent RRD associated with grade C proliferative vitreoretinopathy and multiple breaks in the far periphery. She underwent revision 23-gauge valved PPV with 360° retinectomy, PFO, endolaser, and direct PFO-silicone oil exchange. The sulcus IOL and residual capsule had to be removed due to poor visualization. At postoperative week 1, PFO was noted to fill the fluid phase inferior to an approximately 80% silicone oil fill in the AC. At postoperative week 2, significant PFO was also noted within the AC, which was removed via paracentesis at the slit lamp. This was repeated at four subsequent visits. Although PFO was still visible in the AC, further intervention was deferred given her guarded visual prognosis. At her most recent follow-up, VA was HM, IOP was 3 mm Hg with band keratopathy, and persistent PFO was noted in the AC. She had a small pocket of submacular fluid but otherwise sustained retinal attachment.

Case 5

A 71-year-old pseudophakic man presented to our institution with an inferior macula-involving RRD with multiple breaks in the far periphery in the left eye. He underwent 23-gauge valved PPV, PFO, endolaser, and C3F8 tamponade. On postoperative day 1, ocular hypertension refractory to medical therapy was noted, necessitating a vitreous tap with partial gas removal. Four weeks later, a large PFO bubble was evident within the vitreous cavity (Figure 1). PFO removal via 23-gauge valved revision PPV with AC wash-out was performed at postoperative month 3. During this surgery, PFO was noted to emerge from the ciliary sulcus as well as posterior lens capsule. Winter-flake deposits were removed from the peripheral vitreous. Postoperatively, the eye remained quiet, and no residual PFO was detected. VA at the most recent visit was 20/25. Neither inflammation nor toxicity was noted.

Case 6

A 63-year-old pseudophakic man presented with a nasal macula-involving RRD. He underwent encircling scleral buckle and 23-gauge valved PPV, PFO, endolaser, and C3F8 tamponade. At postoperative week 1, he was found to have elevated IOP of 44 with iridocorneal touch that required a vitreous tap with partial gas removal. He subsequently developed hypotony (IOP of less than 2 mm Hg) with choroidal dals, which fully resolved at postoperative month 6. At 1-year follow-up, the patient reported chronically
blurred vision (VA of 20/64) despite an intact foveal contour. He was, however, noted to have persistent inferior paracentral iris-cornea adhesions and posterior synechiae with secondary astigmatism. A few PFO bubbles in the AC were also noted. The eye appeared otherwise quiet. Posterior synechiolysis was performed in the operating room with concurrent AC wash-out for PFO removal. One month after synechiolysis, VA improved to 20/32, with evidence of mild postoperative cystoid macular edema treated topically. No residual PFO was present.

Silicone Eye Model

As a proof of concept, a silicone eye experiment was performed as demonstrated in Figure 2. Using both non-valved (Figure 2A) and valved cannulas (Figure 2D), PFO was successfully filled anterior to the level of cannula. During instrument removal, PFO rapidly leaked through the non-valved cannulas (Figure 2B), and the meniscus reached the level of the canulas within seconds (Figure 2C). With valved cannulas, the PFO level remained stable at a height anterior to cannula insertion despite instrument removal (Figures 2D-F). PFO leakage through non-valved cannulas was similar whether the infusion line was open or clamped (data not shown).

DISCUSSION

This report details a cluster of six cases with PFO retention occurring shortly after surgeon transition to small-gauge valved cannulas for PPV. We had not experienced such a cluster of events prior to the introduction of valved canulas at our institution.

We hypothesize that retention in the described cases may be related to alterations in fluidics occurring during instrument exchange. With non-valved cannulas, PFO anterior to the cannulas rapidly escapes through open cannulas during instrument exchange, resulting in a PFO meniscus no higher than the level of cannula insertion. In contrast, with valved cannulas, PFO levels anterior to the cannula sites can be maintained after instrument removal, as corroborated by our silicone eye experiment (Figure 2). With a more anteriorly located meniscus, PFO has access to the anterior chamber, zonules, ciliary sulcus, ciliary teeth, and/or capsular bag, where it can subsequently be sequestered, particularly with rotational eye movements during ensuing surgical maneuvers (Figure 3). During intraoperative PFO removal in cases 1 and 5, PFO was visualized emanating from the ciliary sulcus and the lens capsule, supporting the hypothesis of sequestration in these locations.

While retinal detachment is more common in pseudophakic and aphakic eyes, it is interesting that all our patients were either pseudophakic or aphakic. The absence of the crystalline lens may facilitate sequestration in the lens capsule and/or anterior chamber in contrast to phakic eyes, whose lens capsule and zonules are generally not violated. Interestingly, we observed retained PFO in pseudophakic eyes with both an open and intact posterior lens capsule, suggesting that the status of the posterior lens capsule may not play a role in PFO sequestration. In aphakic and some pseudophakic eyes with an open communication between the AC and vitreous, we noted PFO to migrate freely between the two compartments, depending on patient positioning.

Poor intraocular visualization is a known risk factor for PFO retention and was documented in cases 3 and 4; in the other cases, compromised visualization was not reported, and the individual surgeons did not feel that limited view contributed to PFO retention. Interestingly, a gas overfill postoperatively was noted in two patients. It is unclear whether this has contributed to the PFO retention or was simply incidental, but it warrants further investigation.
The described six cases consist of both primary retinal detachments and complex, recurrent retinal detachments. This case mix is consistent with that of a tertiary referral center and demonstrates that these findings can occur regardless of complexity. Of note, all cases described in this report underwent 23-gauge as opposed to 25-gauge PPV, but this likely represents practice patterns at our institution rather than an implication of 23-gauge versus 25-gauge vitrectomy. Similarly, the use of PFO in both complex and non-complex retinal detachment repair is a routine practice at our institution.

Evaporation of PFO after fluid-air exchange can facilitate its clearance, and reduced evaporation with valved cannulas may also contribute to PFO retention. However, it is unlikely that decreased evaporation could explain retention of the large amounts of PFO seen here.

In summary, shortly following the introduction of small-gauge valved cannulas at our institution, we observed an unusual cluster of cases with postoperative retained intraocular (AC and/or vitreous) PFO after RD repair. We propose that a likely contributing factor for retained intraocular PFO is the ability to maintain a PFO meniscus anterior to the cannula insertion site using valved cannulas. Such anteriorly located PFO may facilitate sequestration of PFO within the AC, zonules, sulcus, ciliary teeth, or capsule bag. All cases occurred within a 7-month period after introduction of valved cannulas at our institution. With improved vigilance to prevent PFO overfill, no further cases have been reported at our institution. We acknowledge several limitations to this study, most notably the retrospective, non-comparative design and use of non-uniform surgical techniques. Further studies comparing rates of retained PFO in valved versus non-valved cannulas are under way. As surgeons transition to use of valved cannulas, we urge care to prevent overfilling of PFO, particularly in pseudophakic and aphakic eyes, to minimize the risk of retained intraocular PFO.

REFERENCES