Heavy liquids for postoperative tamponade

Heavy liquids (characterised by a high specific gravity relative to aqueous or subretinal fluid) have gained wide acceptance as intraoperative tools which aid and simplify vitreoretinal surgical manoeuvres in a variety of settings. These include anterior retinal breaks, giant retinal tears, proliferative vitreoretinopathy, and dislocated lenses or lens implants. Blinder and colleagues in this issue report on the use of heavy liquids for postoperative tamponade.

Postoperative tamponade agents such as air, gas, silicone oil, and, now, heavy perfluorocarbon liquids (PFCL) are used in vitreoretinal surgery because of their high interfacial surface tension in water, albeit a slightly lower surface tension in biological fluids. This means that they will obstruct fluid transfer through retinal breaks when in apposition to the break, thus maintaining retinal apposition until a secure laser or cryopexy scar is formed. A tamponade agent will achieve internal closure of a break if its volume is sufficient, the contact angle is favourable, and the eye is appropriately directed with respect to location of the retinal break and the relative density of the tamponade agent used. The unusual postoperative ‘postures’ required of vitreoretinal patients regularly provoke amusement, surprise, and sympathy while serving to emphasise the importance retinal surgeons place on maintaining break closure.

The contact angle and relative weight or buoyancy of a tamponade agent dictate how much of a given volume will be in contact with the retinal surface; the contact angle of silicone oil (40°) is similar to that of C,F₃ gas (37°) but the contact area of a 1 ml gas bubble is much greater (205 mm²) than a silicone oil bubble of the same volume (68 mm²) because of the greater buoyancy of gas. PFCLs have a much higher contact angle (105° for 1,3-dimethylcyclohexane) and this, together with the greater density disparity relative to water, results in a very high contact area (262 mm² for a 1 ml bubble). PFCLs are therefore able to provide extremely effective tamponade especially for retinal breaks in the lower half of the retina (assuming an upright patient).

These comparisons imply that silicone oil, with its modest specific gravity disparity (0-95) and, therefore, low contact area should be a substandard tamponade agent, and yet it is clinically effective. Furthermore, the great majority of retinal breaks in mobile retinas can be closed with any internal tamponade agent. Why then have Blinder and colleagues reported the use of a high specific gravity tamponade? There is little doubt that postoperative PFCL tamponade will be of value in selected patients who are unable, or unwilling, to comply with post-surgical posturing; patients with inferior breaks are, however, relatively uncommon.

Whether PFCLs will prove more effective than current agents in the setting of proliferative vitreoretinopathy (PVR) will determine their real value.

Despite similar surface tension effects in aqueous (40–50 ergs/cm²), PFCLs appear to be more effective than silicone oil in resisting tractional retinal detachment in experimental models of PVR. This intriguing finding implies that the transretinal force exerted by the tamponade agent (0-06 g upward force for a 1-0 ml silicone oil bubble compared with 0-25 g downward force for a 0-3 ml PFC bubble) must be a significant factor limiting retinal detachment in the setting of experimental retinal traction. If such an effect can also be demonstrated in the clinical setting, it could prove highly beneficial in the management of PVR.

While a low viscosity is advantageous when using an intraoperative tamponade fluid since it aids injection, manipulation, and removal, this feature contributes to the complications associated with postoperative tamponade. Low viscosity is associated with an exaggerated tendency to emulsification, and also contributes to displacement of the fluid into the anterior chamber. If heavy liquids are to have a place in the postoperative management of retinal detachments, therefore, it is possible that the ideal characteristics of a postoperative heavy liquid could be quite different from those of an intraoperative heavy liquid. The high density and low viscosity of PFCLs mean that the fluid can be readily displaced within the eye. Though the surface tension is high, this cannot prevent a large mass of fluid passing through large ‘holes’ including the pupil (thus filling the anterior chamber). While this occurred in only one of Blinder’s six aphakic eyes, Sparrow et al have observed that aphakic eyes are highly susceptible to displacement of vitreous cavity PFC into the anterior chamber, which can result in severe endothelial cell damage. Since the greatest use of postoperative PFCLs might be expected in eyes with PVR, almost all of which are aphakic, this could represent a major limitation.

The finding that silicone oil may absorb retinol, which is lipid soluble, from the retina, implies that long term oil-retina contact may be undesirable. The question of the solubility of retinal metabolites in PFCLs is also of great interest, therefore, in relation to prolonged postoperative heavy liquid tamponade. Although PFCLs are not lipid or water miscible, they can dissolve large volumes of gases and selected low molecular weight molecules, so these properties could be expected to affect local retinal metabolism and function.

In addition to metabolite absorption from the retina, molecular exchange can occur between the tamponade agent and the retina and preretinal fluid. Impurities in intraocular tamponade agents are associated with cellular chemotract-
tion and re-proliferation, thus emphasising the importance of achieving high degrees of purity for PFCs. Recently the concept of chemical exchange between intravitreal compartments has been extended to the use of postoperative tamponade agents such as silicone oil as depots for the gradual release of antiproliferative drugs such as 5-fluorouracil and retinoic acid. Since intravitreal depot drug release may become an important part of our management of PVR in the future, the question arises: which antiproliferative drugs could conceivably be delivered to proliferating cells from a PFC depot? Perfluorocarbons, such as the perfluorophenanthrene used by Blinder's group, are totally immiscible with water, and largely oleophobic. This presents a major impediment to storage of biologically active drugs, which must have some degree of water or lipid solubility in order to achieve cell entry. Highly perfluorinated drugs are soluble in PFCs, and an antiproliferative drug with these properties could be useful. However, on theoretic grounds, none of the antiproliferatives currently under study (daunorubicin, retinoic acid, sodium butyrate, and fluorouracil derivatives) are likely to be highly soluble in PFC liquids, though this question requires further study. Since PVR is the major problem currently facing vitreoretinal surgeons, this could be an important limiting factor. One solution would be to combine a PFC bubble with a low specific gravity tamponade such as silicone oil, which could also act as a drug delivery medium while acting on the superior retina.

Considerations other than that of interfacial surface tension may thus govern our choice of intravitreal tamponade agent in the future. The effects of viscosity, specific gravity, retinal metabolic exchange, and possible drug depot functions may assume greater importance in those settings where prolonged postoperative tamponade is required. As a result it is likely that in some situations single agent tamponade may no longer be the rule. Combined silicone oil and PFCL tamponade reduce the rate of retinal detachment in experimental PVR as well as reducing emulsification and displacement of heavy liquid into the anterior chamber.

The advent of postoperative heavy liquid tamponade raises major new questions for vitreoretinal surgeons. Careful prospective studies should illuminate those clinical settings in which these new properties can be used to greatest advantage.

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