# Tamponades for vitreoretinal surgery

**Dr Douglas Clarkson** looks at developments in the use of tamponades in maintaining ocular anatomical integrity during and after surgery

From the earliest days of vitreoretinal surgery, the removal of vitreous material would necessitate its replacement with a suitable tamponade material to preserve the pressure within and therefore the integrity of the eye. In addition, there has been identified the benefit of tamponade material which through surface tension effects can act to repair holes and breaks in the retina – preventing retinal pigment epithelium absorbing subretinal fluid. This surface tension effect is probably acting to improve the outcome of interventions such as cryotherapy or laser retinal treatment for retinal detachment. Sigler[1] described the early use of air as such a tamponade material by Ohm[2] and Rodengren,[3] though typically air bubbles are rapidly re-absorbed by the eye. The desirability of a longer acting tamponade gas substance led to the investigation of the properties of denser gases which would have slower rates of diffusion and hence greater therapeutic effects. In addition, silicone oils of various chemical characteristics have also been used as tamponade material after surgery for retinal detachments and macular holes, though they require an additional surgical procedure for their subsequent removal. The range of functions provided by the vitreous and the relative merits of available tamponade materials is reviewed by Kleinberg *et al.*[4]

## Gas tamponades

One of the early gases investigated as a tamponade material was sulphur hexafluoride. In the 1970s Abrams *et al*[5] monitored the gas bubble composition as a function of time for initial injection of pure sulphur hexafluoride gas in rabbit eyes. Over a period of 96 hours the gas concentration of sulphur hexafluoride fell to around 3 per cent and with replacement by an equilibrium mixture of oxygen, nitrogen and carbon dioxide. Preferential diffusion of more mobile smaller gas molecules into the sulphur hexafluoride gas bubbles results in their initial expansion as the entrained gas pressure increases. This is an undesirable characteristic for gas tamponades where a target gas concentration is now usually set at a limit concentration to prevent bubble expansion. For sulphur hexafluoride this value is typically 14 per cent and for perfluoropropane 16 per cent. Values of gas mixture in excess of these values can result in elevated intraocular pressures.

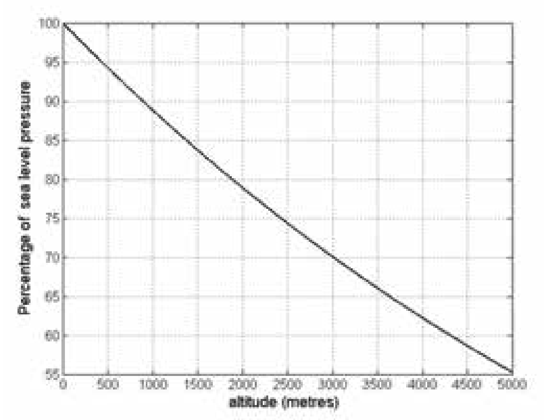


**Figure 1 Variation of percentage of sea level pressure as a function of elevation above the earth's surface**

## Hazards of gas tamponades

### Nitrous oxide

One of the hazards of gases such as sulphur hexafluoride or perfluoropropane is subsequent patient exposure to nitrous oxide as an anaesthetic. Highly mobile nitrous oxide molecules preferentially diffuse into the residual gas bubble in the eye and increase its pressure. Hart[6] describes three patients where vision was lost in two and impaired in the third as a result of exposure to nitrous oxide within a period between 10 days and one month from initial perfluoropropane administration. Observation of adverse effects involving exposure to nitrous oxide has also been observed by Lee[7] for a period of up to 37 days after use of perfluoropropane. Fu *et al*[8] report a further series of five cases with long acting gas tamponades. A more extensive set of 13 cases involving vision impairment following administration of nitrous oxide subsequent to retinal gas tamponade is described by Silvanus *et al.*[9] In this review, almost all of the cases resulted in total loss of visual function in the affected eye. This is perhaps one good reason not to undertake vitreoretinal surgery involving gas tamponade in both eyes within a time period which could render both eyes vulnerable to nitrous oxide exposure.

### Aircraft travel

While the risks of exposure to nitrous oxide may not be obvious, the hazards of flying in passenger aircraft at reduced cabin pressures are easier to anticipate. One of the terms used to describe cabin pressurisation is the 'cabin height', where typically aircraft pressurisation corresponds to an atmospheric elevation of around 2,400 metres (≈ 8,000 feet). Figure 1 indicates the reduction of pressure with height elevation above the earth's surface, so that at a height of 2,400 metres, atmospheric pressure is around 75 per cent of that at ground level.

Where a gas bubble is present during the plane ascent, the process of depressurisation will cause the bubble to expand and, although there will be some expansion of the eye volume, there is the potential for a significant increase in intraocular pressure. Sudden, more extreme, depressurisations would, in addition, result in even more radical pressure elevations.

Houston *et al*[10] described varying advice to passengers from airlines regarding the safety of flying after gas injection. There would appear, however, to be a consensus to delay air travel by around two weeks after sulphur hexafluoride injection and six weeks after injection of perfluoropropane. This is based on the varying rates at which gas bubbles of different composition reduce in size.

Lincoff *et al*[11] anticipated that in patients with a residual gas volume of up to 0.6ml (typically 10 per cent of eye volume), the eye can probably compensate for the usual reduction in cabin pressure as the aircraft ascends to its 'cabin pressure'. Gandorfer and Kampik[12] described cases of central retinal artery occlusion where patients had flown with intraocular gas bubbles of bubble sizes between 30 per cent and 50 per cent of their original size.

Mills *et al*[13] reported observations of a group of 10 patients exposed to a simulated aircraft pressurisation protocol of an equivalent 598mm Hg cabin pressure. Bubble sizes were in the range 10 per cent to 20 per cent of initial size. Within this group, eight patients tolerated the regime satisfactorily with pressures not rising above 30mm Hg and one patient sustained pressures above 30mm Hg. Unsustainably high pressures were, however, developed by one patient who was released from the test chamber. There is the anticipation that the compensating factor of filtration rate of aqueous humour with raised intraocular pressure varies between patients and that this equivalent rate could be as high as 0.02ml/minute based on observations of the time to reduce intraocular pressure after injection of 0.1ml ranibizumab.

## Gas mixture preparation

While there is some degree of awareness of the goal of use of target concentrations of sulphur hexafluoride and perfluoropropane, there is evidence that, in practice, gas concentrations may vary significantly. This may explain reported cases of elevated intraocular pressure following establishment of gas tamponade. A method of determination of gas mixture concentration[14] has recently been reported where a precision analytical weighing balance is used to validate the gas concentrations drawn up in disposable syringes and in filled test eyes of volume 6.1ml. Preliminary measurements indicate that consideration requires to be given to the dead space of components such as particle filters within the gas fill circuit. This is indicated in Figure 2 where in the 'flush' technique perfluoropropane gas in the filter increases the level of prepared gas concentration from a target value of 16 per cent to an actual value of around 17.5 per cent. In the non-flush technique, air is drawn into the syringe and compensates for additional gas present in the particle filter, so that the mean value of determinations is closer to the target value of 16 per cent. The flush technique is, however, expected to deliver more consistent and accurate concentrations if the additional gas in the particle filter is diluted with a compensating volume of air.

**TABLE 1**

**Summary of precautions with gas tamponades**

| Tamponade gas | Nitrous oxide administration | Aircraft travel |
|---|---|---|
| Sulphur hexafluoride | Avoid nitrous oxide exposure if gas bubble is still present | Delay by at least two weeks for cabin pressure of 75 per cent of sea level pressure |
| Perfluoropropane | Avoid nitrous oxide exposure if gas bubble is still present | Delay by at least six weeks for cabin pressure of 75 per cent of sea level pressure |

## Discussion

Table 1 summarises some precautions relating to use of gas tamponades. It is identified, however, that further work requires to be undertaken to identify 'best practice' procedures for preparation and injection of gas tamponades such as sulphur hexafluoride and perfluoropropane based on determination of gas concentrations using gas weighing and other available techniques.

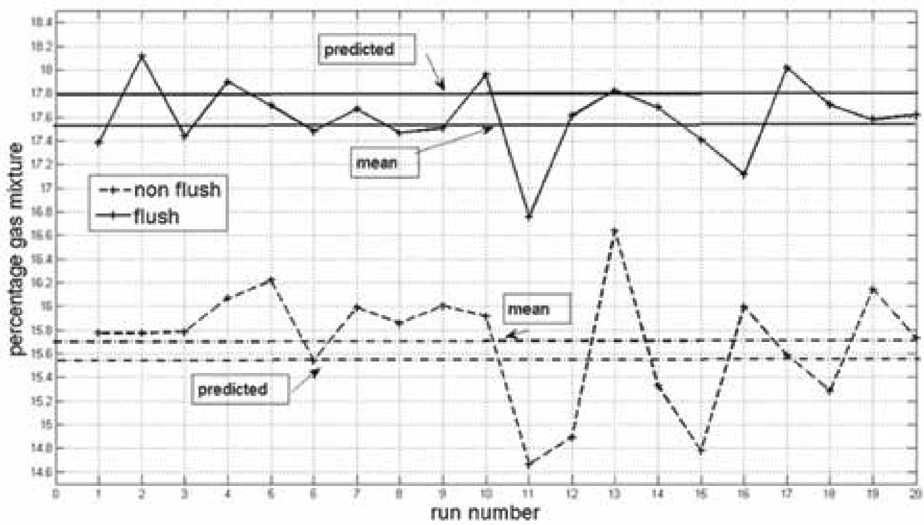


**Figure 2 Gas fill by different techniques - 'flush' and 'non-flush' for a sequence of separate fill procedures**

### References

**1** Sigler EJ, Randolph JC, Charles S, Calzada JI. Intravitreal fluorinated gas preference and occurrence of rare ischemic postoperative complications after pars plana vitrectomy: a survey of the american society of retina specialists. *J Ophthalmol*, 2012; 230596.
**2** Ohm J. Uber die behandlung der netzhautablosung durch operative entleerung der subretinalen flussigkeit und einspritzung von luft in den glaskorper, *Albrecht von Græfe's Archiv fur Ophthalmologie*, 1911; 79(3): 442-450.
**3** Rosengran B. Results of detachment of the retina with diathermy and injection of air into the vitreous, *Acta Ophthalmologica*, 1938 16: 573-579.
**4** Kleinberg TT, Tzekov RT, Stein L, Ravi N, Kaushal S. Vitreous substitutes: a comprehensive review. *Surv Ophthalmol*, 2011; 56(4):300-23.
**5** Abrams GW, Edelhauser HF, Aaberg TM, Hamilton LH. Dynamics of intravitreal sulfur hexafluoride gas. *Invest Ophthalmol*, 1994; 13(11):863-8.
**6** Hart RH, Vote BJ, Borthwick JH, McGeorge AJ, Worsley DR Loss of vision caused by expansion of intraocular perfluoropropane (C3F8) gas during nitrous oxide anesthesia. *Am J Ophthalmol*, 2002; 134(5):761-3.
**7** Lee EJK. Use of nitrous oxide causing severe visual loss 37 days after retinal surgery *Br J Anaesth*, 2004; 93 (3): 464-466.
**8** Fu AD, McDonald HR, Eliott D, Fuller DG, Halperin LS, Ramsay RC, Johnson RN, Ai E. Complications of general anesthesia using nitrous oxide in eyes with preexisting gas bubbles. *Retina*, 2002; 22(5): 569-74.
**9** Silvanus MT, Moldzio P, Bornfeld N, Peters J. Visual loss following intraocular gas injection. *Dtsch Arztebl Int*, 2008 105(6): 108-12.
**10** Houston S, Graf J, Sharkey J. Commercial air travel after intraocular gas injection. *Aviat Space Environ Med*, 2012 83(8): 809-10.
**11** Lincoff H, Weinberger D, Reppucci V, Lincoff A. Air travel with intraocular gas. The mechanisms for compensation. *Arch Ophthalmol*, 1989; 107:902-906.
**12** Gandorfer A, Kampik A. Expansion of intraocular gas due to reduced atmospheric pressure. Case report and review of the literature]. *Ophthalmologe*, 2000; 97:367-370.
**13** Mills MD, Devenyi RG, Lam WC, Berger AR, Beijer CD, Lam SR. An assessment of intraocular pressure rise in patients with gas-filled eyes during simulated air flight. *Ophthalmology*, 2001; 108: 40-44.
**14** Clarkson, DM, Manna A and Hero M. Preliminary measurements of gas concentrations of perflropropane using an analytical weighing balance, *Medical Engineering and Physics*, 2013; pii: S1350-4533(13)00171-9.

● **Dr Douglas Clarkson** is development and quality manager at the department of clinical physics and bio-engineering, Coventry and Warwickshire University Hospital Trust