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BRIEF COMMUNICATION

Perfluorocarbon syndrome—a possible, overlooked source of fatal gas embolism following uveal-melanoma endoresection

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Endoresection of uveal melanoma involves vitrectomy, excision of tumour, retinal-laser under pefluorocarbon liquid (PFCL), PFCL-silicone oil (SO) exchange and cryotherapy to the sclerotomies. Intraoperative pressurised air is avoided as it can enter the bloodstream through vortex veins with potentially fatal pulmonary air embolism [1]. Perfluorodecalin (PFD) has been reported to enter the circulation during endoresection [2], with no systemic complications reported.

We describe a case of fatal gas embolism a few hours after endoresection using intraoperative perfluoro-n-octane (PFO) and discuss whether egress of PFO could be causal.

CASE REPORT

A 59-year-old man had choroidal melanoma endoresection under general anaesthesia. Intraocular pressurised air was not used. Surgery and anaesthetic were uneventful. The retina was stabilised with PFO with a possible egress of 8cc into the pulmonary circulation. After monitoring, he recovered uneventfully and was discharged the same day without apparent discomfort or difficulty. He began to feel unwell on his way home, became acutely short of breath 4.5–5 h after the operation and was taken by ambulance to hospital. On arrival, he became seriously unwell and was transferred to intensive care, where he sustained a hypoxic cardiac arrest. The CT angiogram (aorta and pulmonary arteries) indicated that 'air embolus is likely'. The patient died ~18 h after surgery. A post-mortem examination concluded the cause of death was by air embolism.

DISCUSSION

We report fatal gas embolism with PFO but without the use of intraoperative gas or air. The patient became unwell hours after surgery, unlike classical air embolism with intraoperative death. Recently, two other cases of gas embolism were reported, lethal in one, a few hours after endoresection [3] where PFO, but no intraocular gas or air, was used. After the first patient's death, extensive intraoperative monitoring (cardiac ultrasound and central venous catheterization) was used and excluded gas in the second patient's circulatory system. In both cases, gas embolism developed hours after surgery.

We hypothesise that delayed postoperative gas embolism is associated with the high vapour pressure (VP) of PFO and its entry into the bloodstream [4]. Due to immiscibility in blood, PFCLs form droplets that obstruct pulmonary capillaries causing pulmonary hypertension and hypoxia. The PFCL droplets warm to body temperature, and their VP increases. As the alveolar-capillary membrane is much less permeable to PFCL than air, and PFCL is absent in inspired air, gas bubbles (containing PFCL, O_2, CO_2, and N_2) form in the pulmonary circulation [4].

In support of this mechanism, intravenous injection of 1 mL of FC 80 causes lethal gas embolism in dogs breathing room air, but not when breathing oxygenated FC 80 liquid fluorocarbon because, in the latter, total blood gas tension does not exceed the absolute alveolar gas tension [4]. Furthermore, intravenous injection of pure PFCLs have been associated with the development of lethal gas embolism in humans with the formation of gas bubbles in the pulmonary capillaries, even in small doses [5, 6].

Importantly, the higher the VP of PFCL, the greater the risk of gas embolism. Injection of 0.1 mL/kg of PFCLs, with a VP of at least 55 mmHg at 37 °C, causes lethal gas embolism in dogs, but not PFCLs with a VP of less than 55 mmHg at 37 °C [4]. All three cases we reported used PFO, whereas no serious adverse event was associated with egress of PFD [2]. The VP of PFO is 50–55 mmHg at 37 °C, while PFD is 13.6 mmHg at 37 °C [7]. Thus, small amounts of intravenous PFO could be fatal, whereas PFD is likely to be safer.

Vitreoretinal surgeons should be aware of the potentially fatal consequences of intravenous PFO. Further work is needed to investigate this association, but we would advise surgeons to avoid PFO in cases where it may access the venous bloodstream.

REFERENCES

1. Rice JC, Liebenberg L, Scholtz RP, Torr G. Fatal air embolism during endoresection of choroidal melanoma. Retin Cases Brief Rep.2014;8:127–9. https://doi.org/10.1097/ICB.0000000000000021.
2. Joussen AM, Wong D. Egress of large quantities of heavy liquids from exposed choroid: a route for possible tumor dissemination via vortex veins in endoresection of choroidal melanoma. Graefes Arch Clin Exp Ophthalmol. 2015;253:177–8. https://doi.org/10.1007/s00417-014-2911-0.

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3. Rojanaporn D, Tipsuriyaporn B, Chulalaksiriboon P, Virankabutra T, Morakul S, Damato B. Fatal Air Embolism after Choroidal Melanoma Endoresection without Air Infusion: A Case Report. Ocul Oncol Pathol. 2021;7:321–5. https://doi.org/10.1159/000518976.
4. Sass DJ, Van Dyke RA, Wood EH, Johnson SA, Didisheim P. Gas embolism due to intravenous FC 80 liquid fluorocarbon. J Appl Physiol. 1976;40:745–51. https://doi.org/10.1152/jappl.1976.40.5.745.
5. Lanaro R, De Capitani EM, Costa JL, Bucaretchi F, Togni L, Linden R, et al. Sudden deaths due to accidental intravenous injection of perfluorocarbon during MRI cranial examinations. Forensic Toxicol. 2014;32:323–30. https://doi.org/10.1007/s11419-014-0231-z.
6. Gasparović V, Ostojić R. Unexpected hemodialysis-related deaths in Croatia. J Nephrol. 2002;15:194–7.
7. Dias AMA, Caço AI, Coutinho JAP, Santos LMNBF, Piñeiro MM, Vega LF, et al. Thermodynamic properties of perfluoro-n-octane. Fluid Phase Equilib. 2004;225:39–47.

AUTHOR CONTRIBUTIONS

HR, MRR, GKL, BED, LDC: conception, research, drafting, integrity check, final approval. MF, LW: drafting, revision, integrity check.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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