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CASE SERIES

High intraocular pressure in four vitrectomized eyes with intravitreal C3F8 without high altitude travel

K Brosh, I Strassman and M Seelenfreund

Abstract

Importance **It is well known that altitude ascent with intravitreal gas can cause expansion of gas and intraocular pressure (IOP) elevation. According to Boyle's law, the gas bubble will not expand unless a higher altitude than the gas insertion site has been reached. We report four cases in which intravitreal gas was injected at an altitude of 790 m (Jerusalem). All four cases developed high IOP even though they did not reach a higher altitude in their post-operative period.**
Observations **A report of four patients following vitrectomy with 12% mixture of perfluoropropane and air are presented. All four patients arrived with ocular pain following the ascent by car of 765–1100 m to Jerusalem where the vitrectomy and gas insertion was conducted. Upon examination, all four patients had high IOP (30–55 mm Hg). IOP was well controlled with IOP-lowering medications. None of the patients suffered from long-term complications.**
Conclusions and Relevance **Caution should be taken with altitude changes in patients with intravitreal gas even if there was no ascent from the altitude in which the vitrectomy was performed.**
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Department of Ophthalmology, Shaare Zedek Medical Center, Jerusalem, Israel

Correspondence:
K Brosh, Department of Ophthalmology, Shaare Zedek Medical Center, Eli Cohen 1a, Jerusalem 92347, Israel
Tel: +972 50 716 3004;
Fax: +972 2 655 5184.
E-mail: broshk@gmail.com

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Introduction

It is well known that air travel should be avoided in the post-operative period of vitrectomized eyes with intravitreal gas.[1,2] According to Boyle's law ($P_1V_1 = P_2V_2$), ascent to a higher altitude causes expansion of a intravitreal gas which can lead to increase in intraocular pressure (IOP).[3] However, minor altitudinal changes are usually tolerated by the vitrectomized eye with intravitreal gas due to compensatory mechanisms.[4] Therefore, the standard of care advised by retinal surgeons is to avoid flights and high altitude ascent as long as there is intraocular gas present. We report four patients with intravitreal gas who developed elevated IOP due to moderate altitude descent followed by equivalent altitude ascent. To the best of our knowledge, this is the first report of high IOP with intravitreal gas without any altitude ascent from the place where the gas was inserted.

Case description

In the past 10 years, we have treated four patients who had undergone intravitreal perfluoropropane injection and developed severe IOP elevation associated with altitude ascent. All four patients suffered from retinal detachment and underwent pars plana vitrectomy with suture-less sclerotomy. All the operations were performed at the Shaare Zedek Medical Center, Jerusalem, which is located 790 m above the sea level. Following pars plana vitrectomy and retinal laser photocoagulation, fluid-gas exchange with 12% mixture of perfluoropropane with air was performed. The patients were discharged to their home towns with an intravitreal gas bubble.

Cases 1 and 2

The patients lived in Jerusalem but visited a lower altitude during the early post-operative period. On their way back to Jerusalem, there is

a section with a rapid elevation of 500 m. This section rate of ascent is approximately 40 m/min by car. Following the ascent, the patients arrived to ophthalmic emergency room with ocular pain and IOP elevation.

Cases 3 and 4

Both patients lived at a lower altitude than the hospital so the patients came to each follow-up after altitude ascent. Patient 3 arrived to the emergency room with ocular pain and high IOP after the same ascent to Jerusalem as described above. The 4th patient was seen at the hospital outpatient clinic with recurrent IOP spikes on each follow-up visit. Each IOP spike was after ascent of 1100 m at a rate of approximately 35 m/min. He was under treatment with three IOP-lowering medications.

In all the patients, IOP-lowering medications were given immediately in order to help normalize the IOP. This, and the continued stay at the same altitude allowed for the return to normal IOP in all patients within approximately 1 h. Case details are shown in Table 1.

Discussion

In all four patients, the bubble of gas was inserted in a hospital located in Jerusalem (795 m), therefore according to Boyle's law, upon returning to Jerusalem after altitude changes the size of the gas bubble should be the same as before altitude changes. In all the patients, IOP was elevated after the altitude ascent implying some other mechanism may be involved. This phenomenon has been described in previous study on rabbits exposed to hyperbaric enviroment.[5] Two possible explanations are (1) larger volume of aqueous by hypotony prevention mechanism or (2) gas bubble enlargement by diffusion of particles in hyperbaric environment into the bubble. In our opinion, the former mechanism is more likely as the gas bubble did not expand in the aforementioned hyperbaric report.[5] In order to prevent ocular hypotony at lower altitude, self-regulatory mechanisms fill the eye with aqueous humor.[5] Previously Johnstone *et al*[6] showed trabecular meshwork collapse at low IOP, which increases aqueous volume in the eye. However, upon altitude ascent, the gas bubble expands to the same size as when it was at hospital discharge, but with a larger volume of aqueous, therefore the IOP rises. Furthermore, self-compensatory mechanisms which include choroidal compression, sclera expansion, and increased aqueous outflow[4] need time to fully accommodate.[3,4] Therefore, a rapid rate of ascent can overcome the compensatory mechanisms and can induce high IOP and pain.

If a moderate altitude ascent is inevitable during the post-operative period, the physician should recommend the following:

1. Prescribing prophylactic medication for IOP control before the ascent.
2. Recommending gradual ascent with multiple stops.
3. Immediate descent in case of ocular pain or vision loss.
4. Consider modifying the amount of gas placed, based on the change of the altitude that the patient will experience and the post-operative period that this changes will take place.

The decision whether to allow patients after vitrectomy with intravitreal gas to travel to a higher

Table 1 Summarized data of four patients with IOP elevation following altitude ascent

Patient	*Altitude of habitation place (m)*	*Altitude of the lowest spot on his route (m)*[a]	*Altitude ascent (m)*	*Approximate highest rate of altitude ascent (m/min)*	*Gas bubble size (%)*	*Post-operative day*	*Intraocular pressure after ascent*[b]	*Lens*
1	790[c]	20	770	40	70	13	55	Pseudo phake
2	790[c]	0	790	40	55	4	46	Phake
3	395	25	765	40	80	4	40	Pseudo phake
					60	15	27	
					40	29	18	
4	240	−310 Dead sea	1100	35	70	12	36[d]	Phake
					65	16	40[d]	
					60	19	50[d]	
					50	26	20[d]	

[a] The highest spot on the route of all patients was Jerusalem (790 m).
[b] All IOP examinations were done at Jerusalem (790 m).
[c] Lived in Jerusalem.
[d] The patient was under medications for lowering intraocular pressure.

altitude should be on a case to case basis, considering the amount of altitude change, the size of the gas bubble, the rate of altitude ascent, and glaucoma status. All patients should be informed that in case of pain or visual loss in an eye with a gas bubble, immediate ophthalmologic examination should be undertaken. As a general rule, patients should avoid as possible, rapid altitude elevation even if a similar descent was done in the post-operative period without any discomfort.

Summary

What was known before

- High altitude travel or flight of patients with intravitreal gas may cause gas expansion and high IOP.

What this study adds

- High IOP can be caused by altitude changes in patients with intravitreal gas even if there was no ascent from the altitude in which the vitrectomy was performed.

Conflict of interest

The authors declare no conflict of interest.

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