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Nitrous Oxide Increases Intraocular Pressure after Intravitreal Sulfur Hexafluoride Injection

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In anesthetized cats ventilated with oxygen, 0.5 ml of the inert gas sulfur hexafluoride (SF_6) was substituted for vitreous. When the ventilating gas was changed to nitrous oxide (N_2O) 66%, balance oxygen, intraocular pressure increased from 14.4 to 30.3 mmHg in 19.5 min. When the ventilating gas was changed back to oxygen, intraocular pressure decreased from 29.1 to 12.0 mmHg in 18.1 min. This intraocular pressure change secondary to gas volume alteration may adversely affect therapeutic outcome of ophthalmic surgery. Accordingly, N_2O should be avoided in patients during and following intravitreal injection of SF_6 for up to 10 days. (Key words: Anesthesia: ophthalmologic. Anesthetics, gases: nitrous oxide. Eye: intraocular pressure. Gases, non-anesthetic: sulfur hexafluoride.)

INTRAVITREAL SULFUR HEXAFLUORIDE (SF_6) is advocated for the surgical treatment of giant retinal tears, during which patients often receive inhalation anesthesia. Available information indicates that gas transfer may occur during the surgical procedure, possibly altering therapeutic outcome because of changes in intravitreal gas bubble volume and/or intraocular pressure (IOP).

On reviewing the literature, we found no direct information on the dynamics of nitrous oxide (N_2O) exchange into SF_6 pockets in either experimental animals or humans. We felt it appropriate to study the time course and magnitude of this anticipated change.

Method

Eleven mongrel cats weighing 3.5–5.0 kg were anesthetized with intraperitoneal pentobarbital (20 mg/kg), intubated, and ventilated with 100% oxygen (O_2) to maintain end-tidal carbon dioxide (CO_2) between 3.5% and 5.0%. A front limb intravenous catheter was used to administer 5% dextrose in water, additional pentobarbital, and pancuronium sufficient to maintain paralysis. A rectal thermistor probe was inserted for continuous temperature monitoring and temperature was controlled with a heating pad. A femoral cutdown enabled venous and arterial cannulation for continuous recording of venous and arterial pressures. Venous and arterial blood was sampled intermittently for blood gas analysis, and sodium bicarbonate was administered to maintain an arterial *p*H of 7.2–7.35.

In test eyes, conjunctival incision and dissection were carried out to expose the sclera at the superior lateral quadrant. A 22-gauge needle was inserted through the pars-plana, 0.25 to 0.5 ml of vitreous fluid was aspirated, 0.5 ml of SF_6 was injected, and the needle removed. A 25-gauge butterfly needle was placed into the anterior chamber of both test and control eyes, and IOP was recorded continuously.

Baseline values were observed for stability for at least 30 min. The ventilating gas then was changed abruptly from 100% O_2 to 66% N_2O in O_2, and IOP was observed. Changes in IOP that resulted from introducing N_2O were allowed to stabilize; thereafter the ventilating gas was changed back to 100% O_2 to observe recovery.

Results

The IOP changes and the time required for the change to occur following the change of ventilating gas from O_2 to N_2O:O_2 and back to O_2 (eleven eyes) are listed in table 1.

Intraocular pressure also was measured in six control eyes. The mean increase in IOP when the ventilating gas was changed to N_2O:O_2 was 1.8 ± 1.0 mmHg (SEM). When the gas was changed back to O_2, the mean decrease in IOP was 0.3 ± 0.9 mmHg.

Discussion

In 1920, Rist and Stohl[1] determined the dynamics of gas absorption from air-containing pockets during air breathing. Transfer of N_2O into air-containing spaces was reported first by Hunter in 1955.[2]

Tenney *et al.*,[3] studying the dynamics of gas exchange in intraperitoneal SF_6 pockets during air breathing, demonstrated nitrogen (N_2) entry prior to absorption. Nitrogen entry into intravitreal SF_6 was demonstrated by Norton.[4] Intravitreal injection of SF_6 has been advocated

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TABLE 1. Intraocular Pressure (IOP) Change

	100% O_2 → N_2O:O_2	N_2O:O_2 → 100% O_2
Change in IOP (mmHg)	+15.91 ± 2.8	−17.14 ± 3.65
Time to stable pressure (min)	19.5 ± 2.1	18.1 ± 1.75

because of slower absorption of the gas (approximately 10 days) compared with air (approximately 5 days).

Since O_2 and N_2 have similar solubilities and diffusion coefficients (table 2), the effect of N_2O following O_2 ventilation should be somewhat similar to that of N_2O following air ventilation. Oxygen breathing resulted in no IOP change during our study. In test eyes, changing the ventilating mixture to N_2O:O_2 resulted in a mean IOP increase of 15.9 ± 2.8 mmHg (SEM) in 19.5 ± 2.1 min. On changing the ventilating mixture back to O_2, IOP decreased 17.1 ± 3.7 mmHg in 18.1 ± 1.8 min.

The solubility of N_2O is 34 times the solubility of nitrogen (table 2). The diffusion coefficients are approximately equal. Accordingly, N_2O enters air-filled spaces more rapidly than N_2 leaves. This accounts for the observed increase in volume and/or pressure during N_2O:O_2 anesthesia in such spaces. Smith *et al.*[9] demonstrated this effect in monkey eyes. Air was injected intravitreally and IOP increased in 24 min when 75% N_2O was added to the breathing mixture. When N_2O was discontinued, IOP decreased in 27 min.

TABLE 2*. Physical Properties of Selected Gases

Gas	O_2	N_2	N_2O	SF_6
Blood/gas partition coefficients	0.0223[5]	0.0147[6]	0.468[7]	0.004[8]
Diffusion coefficient in H_2O at 25°C ($cm^2 \cdot s^{-1} \times 10^5$)	2.2[8]	2.01[8]	2.6[8]	1.16[8]

* Superscripts refer to references cited, in all but left column.

The solubility of N_2O is 117 times greater than SF_6 and has a diffusion coefficient twice as great (table 2). When SF_6 is injected intravitreally instead of air, the effect of N_2O:O_2 anesthesia on intraocular volume and/or pressure is more rapid.

Therefore, in the clinical setting, N_2O should be avoided in patients in whom intravitreal injection of gas is planned. Additionally, N_2O should be avoided for up to 5 days in patients who have received intravitreal air and for up to 10 days in patients who have received intravitreal SF_6.

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