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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 (SF₆) was substituted for vitreous. When the ventilating gas was changed to nitrous oxide (N₂O) 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, N₂O should be avoided in patients during and following intravitreal injection of SF₆ for up to 10 days. (Key words: Anesthesia: ophthalmologic. Anesthetics, gases: nitrous oxide. Eye: intraocular pressure. Gases, non-anesthetic: sulfur hexafluoride.)

INTRAVITREAL SULFUR HEXAFLUORIDE (SF₆) 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 (N₂O) exchange into SF₆ 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 (O₂) to maintain end-tidal carbon dioxide (CO₂) 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.

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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 pH 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 SF₆ 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% O₂ to 66% N₂O in O₂, and IOP was observed. Changes in IOP that resulted from introducing N₂O were allowed to stabilize; thereafter the ventilating gas was changed back to 100% O₂ to observe recovery.

Results

The IOP changes and the time required for the change to occur following the change of ventilating gas from O₂ to N₂O:O₂ and back to O₂ (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 N₂O:O₂ was 1.8 ± 1.0 mmHg (SEM). When the gas was changed back to O₂, the mean decrease in IOP was 0.3 ± 0.9 mmHg.

Discussion

In 1920, Rist and Stohl¹ determined the dynamics of gas absorption from air-containing pockets during air breathing. Transfer of N₂O into air-containing spaces was reported first by Hunter in 1955.²

Tenney *et al.*,³ studying the dynamics of gas exchange in intraperitoneal SF₆ pockets during air breathing, demonstrated nitrogen (N₂) entry prior to absorption. Nitrogen entry into intravitreal SF₆ was demonstrated by Norton.⁴ Intravitreal injection of SF₆ has been advocated

TABLE 1. Intraocular Pressure (IOP) Change

	100% O ₂ → N ₂ O:O ₂	N ₂ O: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 O₂ and N₂ have similar solubilities and diffusion coefficients (table 2), the effect of N₂O following O₂ ventilation should be somewhat similar to that of N₂O following air ventilation. Oxygen breathing resulted in no IOP change during our study. In test eyes, changing the ventilating mixture to N₂O:O₂ 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 O₂, IOP decreased 17.1 ± 3.7 mmHg in 18.1 ± 1.8 min.

The solubility of N₂O is 34 times the solubility of nitrogen (table 2). The diffusion coefficients are approximately equal. Accordingly, N₂O enters air-filled spaces more rapidly than N₂ leaves. This accounts for the observed increase in volume and/or pressure during N₂O:O₂ 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% N₂O was added to the breathing mixture. When N₂O was discontinued, IOP decreased in 27 min.

TABLE 2*. Physical Properties of Selected Gases

Gas	O ₂	N ₂	N ₂ O	SF ₆
Blood/gas partition coefficients	0.0223 ⁵	0.0147 ⁶	0.468 ⁷	0.004 ⁸
Diffusion coefficient in H ₂ O at 25°C (cm ² ·s ⁻¹ × 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 N₂O is 117 times greater than SF₆ and has a diffusion coefficient twice as great (table 2). When SF₆ is injected intravitreally instead of air, the effect of N₂O:O₂ anesthesia on intraocular volume and/or pressure is more rapid.

Therefore, in the clinical setting, N₂O should be avoided in patients in whom intravitreal injection of gas is planned. Additionally, N₂O 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 SF₆.

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