

## Correspondence

### A Mathematical Approach to Gas Distribution during Respiration

*To the Editor:*—Kitahata, Taub, and Conte (ANESTHESIOLOGY 35: 607–611, 1971) observed that the administration of nitrous oxide to cats previously ventilated with N<sub>2</sub>O-free gas resulted in a rapid increase in F<sub>ACO<sub>2</sub></sub> to above control, with a subsequent decline toward control values. This observation documents what had been predicted by Rackow, Salanitre, and Frumin.<sup>1</sup> The explanation offered by Kitahata *et al.* was that of the “concentrating effect,” proposed by Stoelting and Eger,<sup>2</sup> and readily described in mathematical terms.

The fundamental law of conservation of mass is applicable to respired gases. For any gas, C, in a mixture of gases, the quantity of C, Q<sub>C</sub>, is equal to the product of the fractional concentration (F<sub>C</sub>) and the total volume (V) of the mixture:

$$F_G \times V = Q_G$$

The net pulmonary uptake of G, U<sub>G</sub>, is equal to the difference between the quantity of G inhaled and the quantity exhaled:

$$U_G = (F_{IG} \times V_I) - (F_{EG} \times V_E) \quad (1)$$

where subscripts I and E refer to inhaled and exhaled, respectively. Of course, a negative net uptake is interpreted as net excretion.

Now let us consider the gas CO<sub>2</sub>. If there is no inhaled CO<sub>2</sub>, *i.e.*, F<sub>ICO<sub>2</sub></sub> = 0, equation 1 reduces to:

$$U_{CO_2} = - (F_{ACO_2} \times V_E), \quad (2)$$

where A means alveolar. (The substitution of A for E is valid because all gas exchange occurs at the alveolus.) If the net excretion of CO<sub>2</sub> is a constant, then F<sub>ACO<sub>2</sub></sub> × V<sub>E</sub> = constant. Any effect which reduces V<sub>E</sub> must result in an increase in F<sub>ACO<sub>2</sub></sub> such that the product remains constant. When N<sub>2</sub>O is added to

the inspired gas mixture, pulmonary uptake of this gas reduces the total volume of gas available for expiration; V<sub>E</sub> decreases. The decrease in V<sub>E</sub> effected by N<sub>2</sub>O uptake is responsible for the increase in F<sub>ACO<sub>2</sub></sub> which was observed by Kitahata *et al.* The reverse situation, *i.e.*, net pulmonary excretion of N<sub>2</sub>O, as during emergence from N<sub>2</sub>O anesthesia, increases V<sub>E</sub>. This results in a decreased F<sub>ACO<sub>2</sub></sub>.

It should be emphasized that changes in F<sub>ACO<sub>2</sub></sub> will cause physiologic responses in the organism. Especially important are the changes in ventilatory effort, which will have profound effects on the composition of alveolar gas. This mathematical approach may facilitate understanding of the phenomenon observed and can be extended to other phenomena such as the “second-gas effect,”<sup>3</sup> “diffusion anoxia,”<sup>4</sup> and “apneic oxygenation.”<sup>5</sup>

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