Drug Administration (FDA). The indication for postoperative analgesic infusion of remifentanil stipulates that it must be administered under the direct supervision of an anesthesia practitioner.

To measure PCO_2 in the PACU with arterial blood gases would have required a far more invasive technique than was warranted for these patients. Future investigations could include end-tidal CO_2 and a more detailed analysis of respiratory pattern.

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Predicting the Severity of Carbon Monoxide Poisoning at Varying FIO_2

To the Editor:—Frink et al.[1] showed that extremely high carboxyhemoglobin (COHb) concentrations can be produced in 25-kg pigs by the inhalation of desflurane through a breathing circuit with dried CO_2 absorbents, which produce carbon monoxide (CO) through anesthetic breakdown. These experiments were performed at 40% inspired oxygen, although in clinical practice, inspired oxygen concentrations can vary from less than 25% to nearly 100%, impacting the resultant severity of CO poisoning as measured by COHb concentrations.

We attempt to exemplify the clinical effect of various inspired oxygen concentrations during the rapidly changing CO concentrations produced by desflurane breakdown by using mathematical modeling to extrapolate the data of Frink *et al.* We interpolated parts per million CO from the graphic data presented in figures 3 and 4 of the study by Frink *et al.* and applied these data to the equation developed by Coburn *et al.*,[2] (CFK equation) to determine the COHb concentration. Good experimental fit of this equation has been documented by Peterson *et al.*[3] We used this equation to calculate the accumulation of COHb as a function of the absorption and elimination of CO through respiration using Microsoft Excel (Microsoft Corporation) for the MacIntosh (Apple Computer, Inc., Cupertino, CA). The implementation of the CFK equation required that assumptions be made to complete the respiratory profile, as shown in table 1. We used the CFK equation to calculate the COHb concentration by an iterative method using CO concentrations interpolated from the graphic data of Frink *et al.* To validate the appropriateness of using the CFK equation, we graphically show the correlation of the calculated COHb data to the measured experimental data of Frink *et al.* in figure 1. This results in an r^2 value of 0.997 for the descending data points and an overall r^2 value of 0.967. Several possible explanations exist for the slight deviation of the experimental and calculated data during the ascending phase of the curve. It is possible that physiologic parameters (*e.g.*, cardiac output) were severely compromised during this phase of the experiment, and differences reflected changes in circulation in the experimental animals from those for which the

Table 1. Assumed Values for Experimental Data

Parameter	Value
Weight	25 kg
Tidal volume	275 ml
Respiratory rate	10 min^{-1}
Dead space	68 ml
Body surface area	0.6 m^2
Hemoglobin	14.0 g/dl
Barometric pressure	750 mmHg
Blood volume	1875 ml
DL_{CO}	5.9 $ml \cdot min^{-1} \cdot mmHg^{-1}$

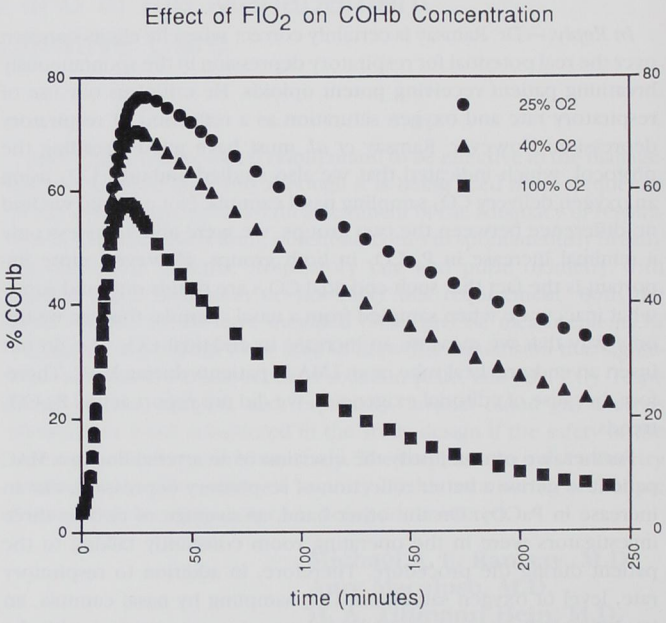

Fig. 1. Shows the concentration of CO *(open circles)* in parts per million (ppm) interpolated from the graphic data of Frink *et al.* This figure also compares COHb % calculated at 40% inspired oxygen from these data *(small triangles)* using the CFK equation for comparison with the experimental COHb % taken from the graphic data of Frink *et al.* The experimental COHb data correlate well with those predicted by the CFK equation.

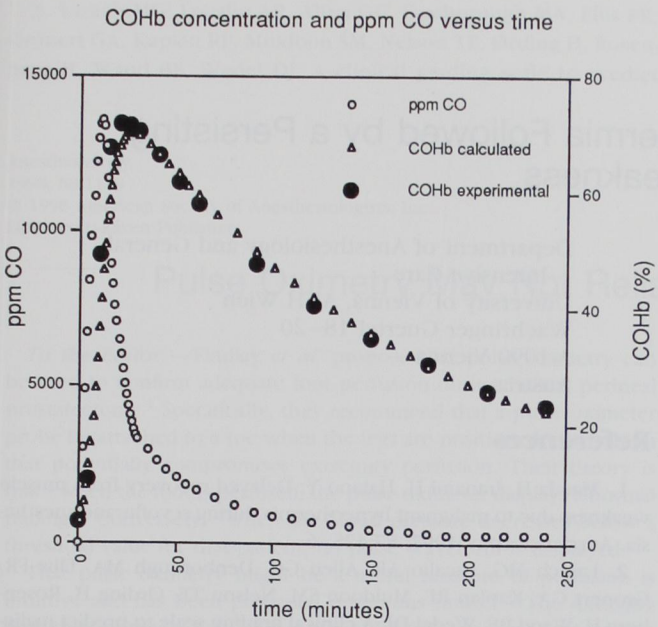

Fig. 2. Shows the predicted concentration of COHb in % resulting from the use of the CFK equation as a function of time at different inspired oxygen concentrations. The data at 40% O_2 are identical to those in figure 1.

CFK equation was developed. Despite these limitations, the CFK equation provides excellent predictions under these extreme conditions.

In figure 2, we show the results of mathematical modeling using the CFK equation to extrapolate the CO concentration data to different inspired oxygen concentrations (FiO_2). These COHb concentrations would be predicted to result from exposure to the CO concentrations interpolated from the data of Frink *et al.* and also at 100% and 25% oxygen. Predicted results at 100% oxygen yielded smaller COHb concentrations, possibly accounting for the low incidence of CO poisoning detected by clinical signs. Conversely, the predicted results at 25% oxygen suggest that CO toxicity would be enhanced under these conditions. The routine use of an increased FiO_2 may reduce CO poisoning during anesthesia because of the competitive binding of CO and oxygen, but CO poisoning occurring with low FiO_2 may be more severe.

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In Reply:—We appreciate the additional calculations of Drs. Woehlck and Dunning to our published data regarding calculated carboxyhemoglobin concentrations from CO exposure with desflurane and dry CO_2 absorbent. From our CO data, the calculated data by Woehlck and Dunning closely approximates our observed carboxyhemoglobin concentrations with 40% O_2 in pigs, which is encouraging. Their calculation involves several assumptions concerning ventilatory values, as shown in their table 1. Although these values for individual animals are not exact, the values closely approximate those of the mean for our study animals, and hence their calculated values parallel our experimental results. Their calculations for carboxyhemoglobin with 25% and 100% O_2 concentrations are useful additions—particularly the data regarding results in 100% O_2, as this oxygen concentration would often be used by practitioners during the first few minutes of anesthesia when the greatest CO exposure is occurring. Several other variables will likely alter the CO exposure and resultant carboxyhemoglobin concentrations. These include the use of a higher fresh gas flow rate and lower anesthetic concentration, both of which might reduce the degree of CO exposure that occurs. These several factors, along with our inability to readily detect CO exposure, likely produce the low incidence of reports regarding this phenomenon.

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