Title: A MECHANICAL MODEL TO SIMULATE UPTAKE AND ELIMINATION OF INHALATION ANESTHETICS

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Introduction: A mechanical model was developed to simulate the uptake and non-metabolic elimination of volatile anesthetics (e.g. halothane, enflurane, isoflurane). The model uses oil to simulate body tissues and a mixing chamber to simulate the lung volume. The model responds properly to changes in CO (cardiac output) and VA (alveolar ventilation). Unlike computer simulations of anesthetic uptake, this model can be used with actual breathing circuits and monitoring equipment. As such, the model bridges the gap between computer simulation and clinical reality, and could potentially reduce the number of animal (and clinical) experiments necessary to demonstrate clinical techniques or develop and evaluate instrumentation.

Methods: Figure 1 illustrates the concept of the model. The model consists of three tissue groups, the LG (lung group), the VRG (vessel-rich-group), and the MG (muscle group); tissues are grouped according to anesthetic solubility and blood perfusion [1]. Fatty and vessel-poor tissues are not included as these do not significantly contribute to anesthetic uptake during the first hour of anesthesia [1].

The VRG and MG are modeled using olive oil. The oil volumes (Voil) are calculated from tissue volumes (Vt) and partition coefficients ($L_{t/oil}$) according to Equation (1).

$$V_{oil} = V_t * L_{t/oil} \quad (1)$$

Equation (1) yields an "equivalent" oil volume such that, at equilibrium, the volume of anesthetic in the saturated oil equals the volume of anesthetic in the saturated tissue. The LG was modeled with an "equivalent" air volume. Gas flows (Ft) to each chamber were adjusted to model tissue blood flow (Q_t) according to Equation (2),

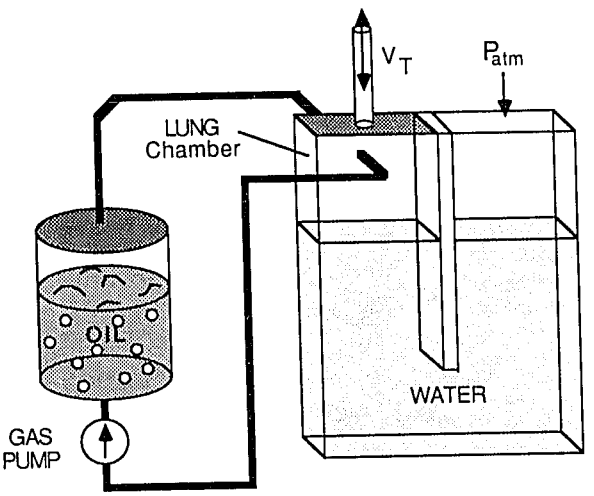
$$F_t = Q_t * L_{b/g} * K \quad (2)$$

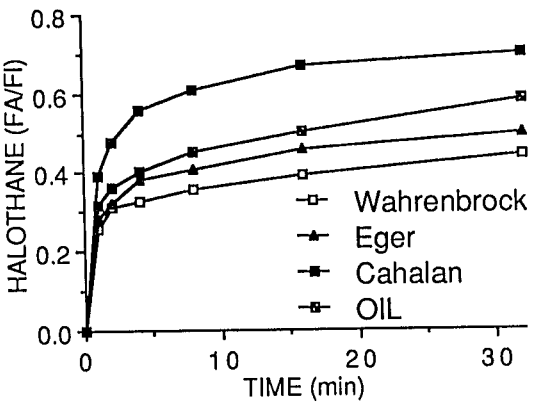
where K (1.6 for halothane) compensated for diffusion inefficiencies in the oil chambers; $L_{b/g}$ is the blood-to-gas partition coefficient.

Halothane uptake and washout were measured for 32 minutes each, with simulated COs of 2.5, 5.0, and 7.5 l/min and VAs of 2.1, 4.2, and 8.4 l/min. Inspired halothane was 1.0 vol%. Inspired and end-tidal measurements were made with an in-line infrared analyzer (Draeger, W. Germany).

Results: Figure 2 shows halothane fraction vs time for the mechanical model and patient data [1-3]. The mechanical model alveolar concentration remained within 0.07 vol% of a computer simulation [4] throughout uptake and washout. Increasing VA four-fold increased FA/FI from .43 to .57 (at 16 min), and increasing CO three-fold decreased FA/FI from .56 to .45 (at 16 min). During washout, the effects of changes in VA and CO were not as pronounced.

Discussion: The mechanical model simulation of halothane uptake and elimination is consistent with patient data and computer simulation. The observed effects of VA and CO on uptake and washout agree with theory, patient data, and computer simulation. The model may be very useful in developing and testing controllers for end-tidal anesthetics; comparing vaporizers, sensors and anesthetic analyzers; and in training anesthesia personnel in the administration of inhalation anesthetics and the effects of VA and CO on uptake, all without the need for animal experiments or human volunteers.





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