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Education

EDUCATION

Using screen-based simulation of inhaled anaesthetic delivery to improve patient care

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Abstract

Screen-based simulation can improve patient care by giving novices and experienced clinicians insight into drug behaviour. Gas Man® is a screen-based simulation program that depicts pictorially and graphically the anaesthetic gas and vapour tension from the vaporizer to the site of action, namely the brain and spinal cord. The gases and vapours depicted are desflurane, enflurane, ether, halothane, isoflurane, nitrogen, nitrous oxide, sevoflurane, and xenon. Multiple agents can be administered simultaneously or individually and the results shown on an overlay graph. Practice exercises provide in-depth knowledge of the subject matter. Experienced clinicians can simulate anaesthesia occurrences and practices for application to their clinical practice, and publish the results to benefit others to improve patient care. Published studies using this screen-based simulation have led to a number of findings, as follows: changing from isoflurane to desflurane toward the end of anaesthesia does not accelerate recovery in humans; vital capacity induction can produce loss of consciousness in 45 s; simulated context-sensitive decrement times explain recovery profiles; hyperventilation does not dramatically speed emergence; high fresh gas flow is wasteful; fresh gas flow and not the vaporizer setting should be reduced during intubation; re-anaesthetization can occur with severe hypoventilation after extubation; and in re-anaesthetization, the anaesthetic redistributes from skeletal muscle. Researchers using screen-based simulations can study fewer subjects to reach valid conclusions that impact clinical care.

Key words: anaesthesia, general; anaesthetics, gases; anaesthetics, volatile atmospheric pollution; anaesthetic techniques, inhalation

Editor's key points

- Computerized simulations are useful in predicting the pharmacokinetic behaviour of anaesthetic drugs.
- A number of clinically important scenarios have been modeled using the simulation program Gas Man® to predict inhaled anaesthetic gas tensions from inspired gas to effect site.
- Knowledge of inhaled anaesthetic gas pharmacokinetics is critical to optimizing the use of this unique drug class.

The path of inhaled anaesthetic agent movement through body compartments was initially described by Kety in 1950.[1 2] Eger[3 4] developed this model further in research and education. Inhaled anaesthetics traverse the path from vaporizer to breathing circuit, lungs, arterial blood, and to tissues, most notably the brain and spinal cord (Fig. 1). Brain and spinal cord, the site of anaesthetic action, belong to the vessel-rich tissue group (VRG), which also includes kidney, liver, heart, and lung. Venous blood from all tissues returns as mixed venous blood carrying anaesthetic back to the pulmonary arteries and then to the alveoli of the lungs.

Body tissues are commonly grouped according to their perfusion time constants (τ) as fast (composed of the VRG), medium [composed of muscle (MUS)], and slow [composed of fat (FAT)]. For the common inhaled agents, these time constants are

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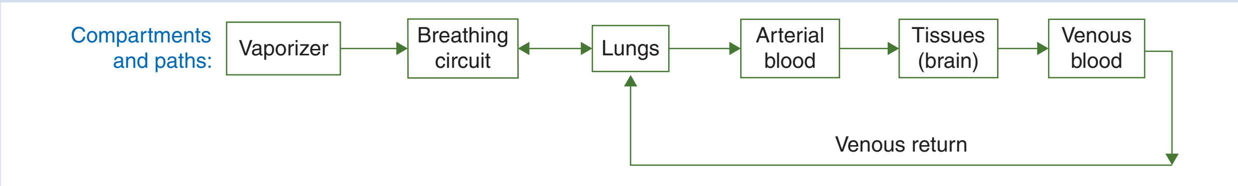

Fig 1 Path of anaesthetic from vaporizer to brain. Inhaled anaesthetics traverse the path from vaporizer to breathing circuit, lungs, arterial blood, and to tissues, most notably the brain and spinal cord, which are important members of the vessel-rich tissue group. Anaesthetic returns to the lungs (alveoli) in mixed venous blood that returns from all tissue groups.

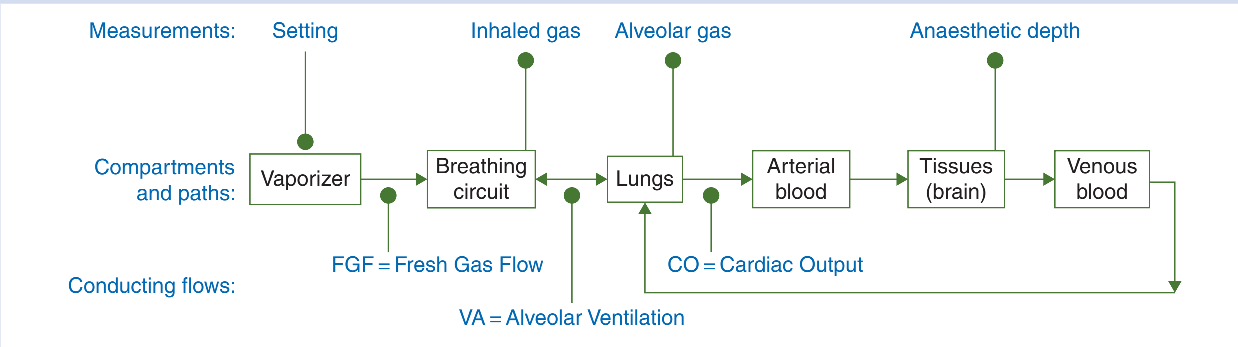

Fig 2 Connecting flows and measurements along the path of anaesthetic. Flows are fresh gas flow (FGF), alveolar ventilation (VA), and cardiac output (CO). Measurements are delivered (Set) concentration, inhaled concentration, alveolar concentration, and tissue concentration expressed as partial pressure, tension, or fraction so that tissue concentration equals arterial concentration at equilibrium.

τ_{VRG}=1.5–3 min, τ_{MUS}=80–150 min, and τ_{FAT}=25–50 h. Figure 2 shows the names of the connecting flows and measured anaesthetic levels along the path of inhaled anaesthetic movement during uptake, distribution, and elimination. Flows are fresh gas flow (FGF), alveolar ventilation (VA), and cardiac output (CO). The measure of anaesthetic level in a compartment is the partial pressure or tension, expressed as a percentage of atmospheric pressure at sea level.[1] Equilibrium is achieved when anaesthetic tensions in connected compartments are equal. The program does not correct for intertissue diffusion of anaesthetics, aneasthetic metabolism, or pulmonary shunt. Gas Man® depicts alveolar tension and alveolar ventilation and does not show end-tidal anaesthetic tension that would be affected by alveolar dead space. Gas Man® uses Euler integration to represent breath-by-breath kinetics, with a minor adaptation to stabilize the behaviour of the model in extreme conditions of FGF, VA, and CO that might be imposed by a user to probe beyond physiological possibilities. The user can change all parameters of the patient from within the simulation and can add new drugs or change existing drug parameters by editing the .ini file.

Screen-based simulator

The student edition of Gas Man® and accompanying workbook may be downloaded free from www.medmansimulations.org or gasmanweb.com. The student edition allows the user to perform all of the simulations described in the 52 lessons and to create and perform any simulations the user desires. This allows the user to explore hypotheses such as the ones published in the cited literature and any others that the user wants to create to test the safety and effectiveness of clinical care protocols. The free student edition allows the user to play back simulations created and saved by others. Some simulation files are available on the Gas Man® website under 'Educational Tools'. Saving and distributing simulations requires the purchase of a single-user or site license.

Gas Man® is a screen-based computer simulation that depicts gas and vapour tension pictorially and graphically in the locations that Kety described.[5–7] The picture (Fig. 3) shows the compartment locations, their connections, and the degree to which each is filled. Compartment filling continues to change as the simulation progresses. The graph panel (Fig. 4) shows the time course of the user adjustments and the resulting anaesthetic tensions in the modeled locations. The overlay panel allows comparisons (Fig. 5, panel 5). Five simulations of different drugs or the same drugs administered in different ways can be viewed. For each simulation, tension, minimum alveolar concentration fraction (MAC), or cost can be represented graphically. Ratios of anaesthetic tensions in different compartments can also be viewed.

The gases and vapours modeled are desflurane, enflurane, ether, halothane, isoflurane, nitrogen, nitrous oxide, sevoflurane, and xenon. Multiple agents can be administered simultaneously. The effects of breathing circuit, venous return, anaesthetic uptake, and liquid vaporization can be removed or added to clarify concepts. Figure 5 shows the development of the alveolar tension curve by simulation of alveolar wash-in and then addition of cardiac output and venous return in successive exercises. Body weight can be changed to compare children with adults and different animals of mass between 50 g and 1500 kg.

Learning environment: screen-based simulation and workbook

The Gas Man® learning environment includes a workbook with exercises that guide the user through the full curriculum of