Hyperventilation and rehypnotization: a GasMan simulation. II: risk of rehypnotization.

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Introduction:

- normocapnic hyperventilation decreases recovery time after prolonged anesthesia
- theoretically this effect is small with less soluble agents
- hyperventilation may result in less wash-out of the agent from the muscle group (MG)
- subsequent hypoventilation after initial recovery
  - could redistribute agent to the vessel rich group (VRG)
  - could result in rehypnotization (= F_{VRG} > MACawake)
- we used GasMan® (MedManSimulations, Inc., Chestnut Hill, MA) to determine
  - what degree of hypoventilation results in rehypnotization
  - whether agent solubility affects rehypnotization

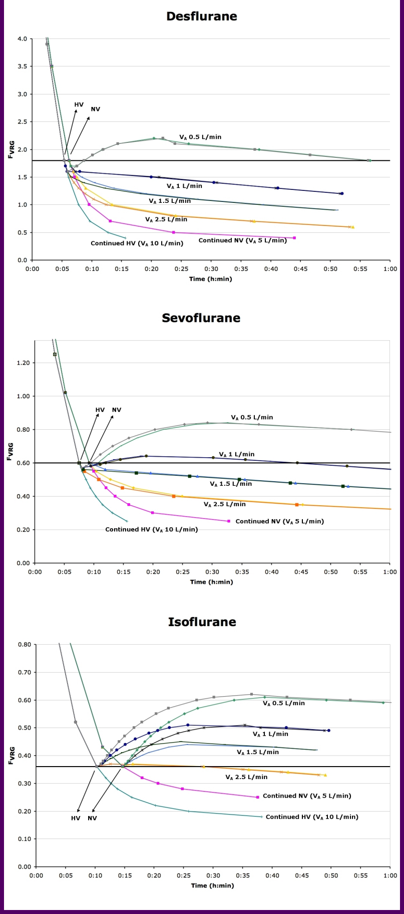
Methods:

- GasMan® simulation
- 1 MAC of isoflurane, sevoflurane, and desflurane for 8 h
- normoventilation (5 L/min)
- after 8 h, agent administration is stopped
  - fresh gas flow to 10 L/min to avoid rebreathing
  - normoventilation (V_A 5 L/min) and hyperventilation (V_A 10 L/min)
- once F_{VRG} = 0.3 MAC (MACawake) hypoventilation is started
  - alveolar minute ventilation (V_A) of 2.5, 1.5, 1, and 0.5 L/min
  - "control group" with normoventilation (5 L/min)
- observation of F_{VRG}: F_{VRG} > 0.3 MAC = rehypnotization

Results:

- with desflurane, only V_A of 0.5 L/min results in rehypnotization
- with sevoflurane, V_A of 1 and 0.5 L/min results in rehypnotization
- with isoflurane, V_A of 2.5, 1 and 0.5 L/min results in rehypnotization
- with isoflurane, initial hyperventilation slightly increased the rise in F_{VRG} during hypoventilation for each degree of hypoventilation

Figure 1.



Discussion:

- emergence is faster with agents with lower solubility[1]
- normocapnic hyperventilation can hasten emergence, especially with higher soluble agents[1]
- hypoventilation after initial recovery can result in rehypnotization
  - less so for poorly soluble agents
  - occurs faster with more severe hypoventilation
  - is slightly worse with initial hyperventilation (only for isoflurane)
  - has not been described before

Conclusions:

- desflurane: the low solubility still allows sufficient clearance by the lungs even in the presence of mild-moderate hypoventilation
- isoflurane: even mild hypoventilation results in rehypnotization
- although normocapnic hyerventilation speed up recovery from isoflurane, it could increase the risk of rehypnotization when subsequent hypoventilation occurs; therefore this practice cannot be recommended
- clinical studies are required to confirm these findings

Reference:

1. Eger E et al. Anesth Analg 2005;100:1020-33.

Appendix: What determines emergence?

$F_{CNS} \leq$ MAC awake (0.3 MAC)

3. Intuitive explanation of emergence: clearance

- Clearance = $\frac{1}{1+\frac{\lambda_{B/G} \times Q}{V_A}}$ [1]
- clearance increases when $\lambda_{B/G}$ or Q are low and when V_A is high
- changes in Q and V_A are less when $\lambda_{B/G}$ is low

Figure 2.

Q	5	5	5	2.5	10
V_A	5	2.5	10	5	5
Clearance desflurane	0.7	0.54	0.83	0.83	0.54
Clearance change (%)		77%	117%	117%	77%
Clearance sevoflurane	0.61	0.43	0.75	0.75	0.43
Clearance change (%)		72%	125%	125%	72%
Clearance isoflurane	0.43	0.28	0.61	0.61	0.28
Clearance change (%)		64%	139%	139%	64%

- this clearance formula assumes that F_{ven} is constant
- therefore this formula is only valid in the very early stages of recovery

4. Rehypnotization caused by hypoventilation

- more agent is transferred from the tissues to the alveoli than is removed form the alveoli

$$Q \times \lambda_{B/G} \times (F_{ven} - F_A) > V_A \times F_A$$

- if less agent is transferred from the tissues to the alveoli, then rehypnotization is less likely to occur for a certain degree of hypoventilation
- amount of agent transferred with venous blood to alveoli at time 0: $Q \times \lambda_{B/G} \times F_{ven}$
  - $F_{ven\ des}$: 5.7%; $F_{ven\ sevo}$: 1.89%; $F_{ven\ iso}$: 1.13%
  - desflurane: 80 FRC units
  - sevoflurane: 123 FRC units
  - isoflurane: 245 FRC units
- washout of agent from tissues is an exponential process, determined by each tissue's τ

5. How much agent has been removed from the body at the moment F_A = MACawake?

- at 8 h, total amount of agent in the body is:
  desflurane: capacity VRG*100% + capacity MG*100% + capacity FG*26.7% = 33.84 FRC units
  sevoflurane: capacity VRG*100% + capacity MG*100% + capacity FG*17% = 68.09 FRC units
  isoflurane: capacity VRG*100% + capacity MG*97% + capacity FG*17% = 130.45 FRC units
- at time F_A = MAC awake, total amount of agent in the body is:
  desflurane: capacity VRG*30% + capacity MG*95% + capacity FG*26.7% = 32.31 FRC units
  sevoflurane: capacity VRG*30% + capacity MG*93% + capacity FG*17% = 63.85 FRC units
  isoflurane: capacity VRG*30% + capacity MG*95% + capacity FG*17% = 125.61 FRC units
- amount of agent removed from the body: desflurane: 4.5%; sevoflurane: 6.2%; isoflurane: 3.7%