Inhalational Anesthesia

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Inhalational Anesthesia

- Gases or volatile liquids
- Administration and Elimination is by the lungs
- Metabolism is slow
- Equilibrate with tissues.
- Interaction with tissues and liquids is by non specific physical interactions with membrane components
  - Some work on GABA or NMDA receptors or through potassium channels activation.
MAC = Minimum Alveolar Concentration

- A measure of anesthetic potency.
- Alveolar tension required to produce surgical anesthesia (skin incision) in 50% of patients.
MAC = Minimal Alveolar Concentration
<table>
<thead>
<tr>
<th>Anesthetic Gas</th>
<th>Minimum Alveolar Concentration in Oxygen (MAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrous oxide</td>
<td>&gt;100.00</td>
</tr>
<tr>
<td>Desflurane</td>
<td>6.00</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>2.05</td>
</tr>
<tr>
<td>Enflurane</td>
<td>1.68</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>1.15</td>
</tr>
<tr>
<td>Halothane</td>
<td>0.75</td>
</tr>
<tr>
<td>Methoxyflurane</td>
<td>0.16</td>
</tr>
</tbody>
</table>

*a Expressed as the percent of lung gases that are anesthetic gas at 1 atm.
*b MAC value greater than 100 indicates that hyperbaric conditions are required to produce anesthesia.

Anesthesia Cycle

- Delivering System
- Alveoli
- Blood -------- CNS
- Tissues
Anesthesia Machine
Excess gas is vented out through the pop-off (APL) valve to the scavenging system.

6. ...through the expiratory limb one-way valve...

5. ...from the patient through the expiratory breathing tube...

7. ...in & out of the reservoir bag...

8. ...through the absorbent canister where CO₂ is removed...

9. ...and then back towards the patient.

1. Fresh gas enters the circle from the common gas outlet of the anesthetic machine...

2. ...flows through the inspiratory limb one-way valve...

3. ...then flows through the inspiratory breathing tube...
Inhalational Anesthesia

Alveolar Tension \textit{corresponds to} Brain Tension

Rate of Rise in Alveolar Tension Depends on:

- Inspired tension.
- Pulmonary ventilation
- Transfer from alveoli to Blood:
  a. Pulmonary BF
  b. Solubility \textit{in} blood.
- Loss from blood to tissues
**Figure 25.2**
Alveolar tension of a hypothetical anesthetic gas of low solubility after 10 breathing cycles. Alveolar tension approaches inspired tension.
Induction of anesthesia is slower with more soluble anesthetic gases

- Solubility in blood is represented by the relative size of the blood compartment (the more soluble, the larger the compartment).

- Relative partial pressures of the agents in the compartments are indicated by the degree of filling of each compartment.

- For a given concentration or partial pressure of the two anesthetic gases in the inspired air, it will take much longer for the blood partial pressure of the more soluble gas (halothane) to rise to the same partial pressure as in the alveoli.

- Since the concentration of the anesthetic agent in the brain can rise no faster than the concentration in the blood, the onset of anesthesia will be slower with halothane than with nitrous oxide.
The alveolar anesthetic concentration approaches the inspired anesthetic concentration fastest for the least soluble agents.
A Ventilation Effects

- Nitrous oxide
- Halothane
- Diethyl ether

63% equilibration

$P_{alv}/P_i$

Minutes

2 L/min ventilation  8 L/min ventilation
Cardiac Output Effects

- Nitrous oxide
- Halothane
- Diethyl ether

$P_{alv}/P_i$

Minutes

2 L/min cardiac output $= 18$ L/min cardiac output
Nitrous oxide

\[
\begin{align*}
\text{O} & \\
\text{N} & = \text{N}
\end{align*}
\]

Halothane

\[
\begin{align*}
\text{F} & - \text{Br} \\
\text{F} & - \text{C} - \text{C} - \text{H} \\
\text{F} & - \text{Cl}
\end{align*}
\]

Enflurane

\[
\begin{align*}
\text{F} & - \text{F} - \text{F} \\
\text{H} & - \text{C} - \text{C} - \text{O} - \text{C} - \text{H} \\
\text{Cl} & - \text{F} - \text{F}
\end{align*}
\]

Xenon

\[
\begin{align*}
\text{Xe}
\end{align*}
\]

Isoflurane

\[
\begin{align*}
\text{F} & - \text{H} - \text{F} \\
\text{F} & - \text{C} - \text{C} - \text{O} - \text{C} - \text{H} \\
\text{F} & - \text{Cl} - \text{F}
\end{align*}
\]

Desflurane

\[
\begin{align*}
\text{F} & - \text{H} - \text{H} \\
\text{F} & - \text{C} - \text{C} - \text{O} - \text{C} - \text{F}
\end{align*}
\]

Sevoflurane

\[
\begin{align*}
\text{F} & - \text{C} - \text{F} \\
\text{F} & - \text{H} - \text{H} \\
\text{F} & - \text{C} - \text{F}
\end{align*}
\]

<table>
<thead>
<tr>
<th>Anesthetic</th>
<th>Blood:Gas Partition Coefficient(^1)</th>
<th>Brain:Blood Partition Coefficient(^1)</th>
<th>Minimal Alveolar Concentration (MAC) (%(^2))</th>
<th>Metabolism</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrous oxide</td>
<td>0.47</td>
<td>1.1</td>
<td>&gt; 100</td>
<td>None</td>
<td>Incomplete anesthetic; rapid onset and recovery</td>
</tr>
<tr>
<td>Desflurane</td>
<td>0.42</td>
<td>1.3</td>
<td>6–7</td>
<td>&lt; 0.05%</td>
<td>Low volatility; poor induction agent (pungent); rapid recovery</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>0.69</td>
<td>1.7</td>
<td>2.0</td>
<td>2–5% (fluoride)</td>
<td>Rapid onset and recovery; unstable in soda-lime</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>1.40</td>
<td>2.6</td>
<td>1.40</td>
<td>&lt; 2%</td>
<td>Medium rate of onset and recovery</td>
</tr>
<tr>
<td>Enflurane</td>
<td>1.80</td>
<td>1.4</td>
<td>1.7</td>
<td>8%</td>
<td>Medium rate of onset and recovery</td>
</tr>
<tr>
<td>Halothane</td>
<td>2.30</td>
<td>2.9</td>
<td>0.75</td>
<td>&gt; 40%</td>
<td>Medium rate of onset and recovery</td>
</tr>
</tbody>
</table>

\(^1\) Partition coefficients (at 37°C) are from multiple literature sources.

\(^2\) MAC is the anesthetic concentration that produces immobility in 50% of patients exposed to a noxious stimulus.
<table>
<thead>
<tr>
<th>Anesthesia</th>
<th>Analgesia</th>
<th>Blood pressure</th>
<th>Respiration</th>
<th>Muscle relaxation</th>
<th>Prominent adverse effects</th>
<th>MAC</th>
<th>Blood-gas partition coefficient at 37°C</th>
<th>Vapor pressure at 20°C (torr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ether</td>
<td>4+</td>
<td>↑</td>
<td>↑</td>
<td>3+</td>
<td>Flammable; slow action</td>
<td>1.9</td>
<td>12</td>
<td>425</td>
</tr>
<tr>
<td>Halothane</td>
<td>2+</td>
<td>↓</td>
<td>↓↓↓</td>
<td>+</td>
<td>Myocardial depression; hepatotoxicity?</td>
<td>0.77</td>
<td>2.3</td>
<td>243</td>
</tr>
<tr>
<td>Methoxyflurane</td>
<td>3+</td>
<td>↓</td>
<td>↓↓↓</td>
<td>+</td>
<td>Renal toxicity</td>
<td>0.16</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>Enflurane</td>
<td>2+</td>
<td>↓</td>
<td>↓↓↓</td>
<td>2+</td>
<td>Respiratory and cardiovascular depression</td>
<td>1.68</td>
<td>1.8</td>
<td>175</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>2+</td>
<td>↓</td>
<td>↓↓↓</td>
<td>2+</td>
<td>Respiratory and cardiovascular depression</td>
<td>1.15</td>
<td>1.4</td>
<td>239</td>
</tr>
<tr>
<td>Chloroform</td>
<td>2+</td>
<td>↓</td>
<td>↓↓↓</td>
<td>+</td>
<td>Hepatotoxicity; narrow margin of safety</td>
<td>0.77</td>
<td>In dogs</td>
<td>160</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>4+</td>
<td>Little change</td>
<td>Little change</td>
<td>None</td>
<td>Weak anesthetic—need other agents as well</td>
<td>105%</td>
<td>0.47</td>
<td>Gas</td>
</tr>
<tr>
<td>Cyclopropane</td>
<td>2+</td>
<td>↑</td>
<td>↓</td>
<td>2+</td>
<td>Flammable; expensive</td>
<td>9.2%</td>
<td>0.4</td>
<td>Gas</td>
</tr>
</tbody>
</table>
Halogenated Anesthetics

Halothane

First practical anesthetist, Widely used

- Non flammable, Non toxic, Sweet odor.
- Complete anesthetist only in high doses.
- Cardiorespiratory depressant, Sensitizes the heart to NE.
Halothane

Hepatic Necrosis (1/35,000).
Hypersensitivity: ABs detected.
Abortion: In animals.

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Enflurane

- More N.M. Blockade
- Rapid Induction & emergence
- Sensitizes heart to catecholamines.
- EEG Changes------ seizures.
- Releases fluoride ions, so nephrotoxic.
Isoflurane

- Similar but: maintains C.O
- Less metabolized i.e. less heptotoxicity
- Less nephrotoxicity
- Most popular
Desflurane

- Low solubility
- Rapid Induction & Emergence
- Outpatient procedures.
- Irritating
Methoxyflurane

- Sweet smelling
- Slow induction & emergence due to high solubility.
- Profound analgesia.
- BP is maintained.
- Renal toxicity.

Sevoflurane
Nonhalogenated Anesthetics

Nitrous Oxide:

- Cardiac depressant but stimulates the sympathetic system.
- Lowers tidal volume but increases respiratory rate.
- Very weak, MAC = 105%.
- Very easy to use.
- Almost insoluble in blood so very rapid in onset.
- Analgesic (25% of Morphine)
- Used in dentistry and Labor
- Used in combination and for induction.
Ether

- Historical (1846).
- Irritant, Flammable, Explosive.
- Complete anesthetic.
- Safe except for postoperative nausea, vomiting and bad odor.

Cyclopropane.

Chloroform.

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