Breathing Circuits and Vaporizers

KSS School of Anaesthesia Basic Science Course
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What you need to know

- **Breathing Circuits**
  - Types/Classification
  - Circle systems
  - Mapleson - ahhh
    - Spontaneous/Manual
    - CO2 elimination
    - FGF rates
  - Real circuits

- **Vaporisers**
  - Types/Classification
  - Plenum vaporisers
    - Basic principles of how they work
    - Compensatory mechanisms
  - Newer vapor delivery units
Breathing Circuits

Their purpose:
– A delivery system for the anaesthetic
– Maintain a supply of oxygen
– Remove carbon dioxide from the body

Without:
– significantly increasing the work of breathing
– significantly increasing physiological deadspace
Requirements for a breathing circuit?

- **Essential**
  - Deliver gases same conc as machine
  - Rapidly
  - Eliminate CO2
  - Minimal apparatus dead space
  - Minimal resistance

- **Desirable**
  - Economical
  - Conservation of heat
  - Humidification
  - Light weight
  - Easy to use
  - Polution
  - Adults + children
  - Efficient both spont and mech.
Dead Space

- **Anatomical**
  - The first portion contains no CO2 and comes from the upper respiratory tract where no gas exchange takes place
  - This is the anatomical dead space

- **Apparatus**
  - Volume of breathing system
  - From patient end
  - To point to and fro movement takes place
  - ↑ leads to ↑PaCO2
Rebreathing

- Expired alveolar gas (containing 5% carbon dioxide) is inspired as part of the next tidal volume.

- Anaesthetic circuits are designed to minimize this occurring as it may lead to serious elevations in blood CO₂ levels:
  - By ensuring an adequate flow of fresh gas which flushes the circuit clear of alveolar gas,
  - or in the case of a circle system by the use of sodalime which absorbs the CO₂.
Some Important Numbers

- **MINUTE VENTILATION** = TIDAL VOLUME x BREATHS/MIN.
  ~80 mls/ kg/ min

- **ALVEOLAR VENTILATION** = (TIDAL VOLUME - DEAD SPACE) x BREATHS/MIN
  ~70 mls/ kg/ min

- Fresh Gas Flow rates often set in relation to these numbers to prevent rebreathing.
Numerous classifications since anaesthesia began!!!

1. Open, semi-open, semi-closed and closed
2. Rebreathing and Non-rebreathing systems
3. Breathing systems with CO2 absorption/ without CO2 absorption
4. Unidirectional flow/ bidirectional flow systems
5. The Mapleson Classification
What we use in our practice:

- Semi-closed Systems

  Gas enters from machine
  
  Some leaves via scavenger
  Rest stays in circuit

- Two types:
  - Circle system (can be closed)
  - Mapleson Systems
Circle Systems

- Are great because:
  - Allow rebreathing of anaesthetic gases
    - lower FGF rates - save money
    - Less pollution
    - Conserves heat and moisture
  - Minimal dead space
Components of the Circle System

- Fresh gas source
- Unidirectional valves
- Inspiratory & expiratory tubing
- Y-piece connector
- APL valve
- Reservoir bag
- CO₂ absorber
- VIC/ VOC
Rules for Circle System

- Unidirectional valve must be between patient & bag on both sides
- FGF cannot enter between patient & expiratory valve
- APL cannot be located between patient & inspiratory valve
What are the disadvantages?

- Slow changes in the inspired anaesthetic concentration
  - Inadequate delivery
  - Slow respond
- VOC only
- Closed systems unstable
In 1954


Classified Semiclosed systems A-E depending on order of:

- FGF entry, APL valve, Reservoir bag

Adequate CO2 Removal depends on:

- Circuit
- FGF
- Spontaneous/ Manual
Mapleson

Layout simple
What happens to CO2 very complex
The expiratory valve close to the patient to reduce the dead space.

- Afferent reservoir system

- Spont Ventilation
  FGF = Minute Volume
  ~6 l min⁻¹
  Good

- Manual Ventilation
  FGF = 2.5 x Minute Volume
  Bad
  ~15 l min⁻¹

- Magill
- Lack
Real Circuits Lack
Mapleson B and C

- Not commonly used in anaesthetic practice
- Mapleson C used in ITU
- ‘Waters circuit’
- Need high FGF
Mapleson D

- FGF delivered to the patient end
- APL valves + breathing bag at the expiratory end of the circuit
- *Efferent reservoir system*

- Spontaneous ventilation
  - FGF = 2.5 x Minute Volume
  - Bad ~15l min⁻¹

- Manual Vent
  - FGF = Minute Volume
  - Good

- Inner tube leak dangerous

Mechanical Ventilation
Fresh Gas fills distal part of corrugated tube
The Bain Circuit

- Bain system
Mapleson E and “F”

- Used in Paediatrics
- Performs in a similar way to the Mapleson D
- No valves = little resistance to breathing

- Introduced in 1937 by P Ayre and is known as the Ayre's T-piece
- Jackson-Rees modification which has an open bag attached to the expiratory limb

- Spont Vent FGF = 3 x Minute Volume
- Manual Vent FGF = 1000 + 100 mls/kg
Humphrey ADE

- Not really just A, D, E combined
- More efficient ~ 50mls/kg/min
- Use on paediatrics
Humphrey ADE
Vaporisers
Eagle Bill`s Vaporizing Pipe

Customer reviews of this product

"Like no other vaporiser you've ever used!!..."
Tom W, 2008-09-06 19:30:15
DEFINITIONS

- **Vapour**
  - Matter in the gaseous form below its critical temperature

- **Latent heat of vaporisation**
  - Amount of heat required to vaporise a particular liquid

- **Vapour Pressure**
  - Pressure exerted by molecules escaping from the surface of the liquid to enter gaseous state
DEFINITIONS

- **Saturated Vapour Pressure**
  - Equilibrium point at which no. of molecules leaving liquid state is equal to no. entering

- **Boiling Point**
  - Temperature at which vapour pressure is equal to atmospheric pressure
## Properties of commonly used agents

<table>
<thead>
<tr>
<th>Volatile agent</th>
<th>SVP (kPa) at 20°C</th>
<th>BP (°C) at 100kPa</th>
<th>MAC</th>
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<tbody>
<tr>
<td>Halothane</td>
<td>31.9</td>
<td>51</td>
<td>0.76</td>
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<tr>
<td>Enflurane</td>
<td>23.1</td>
<td>56</td>
<td>1.68</td>
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<tr>
<td>Isoflurane</td>
<td>31.5</td>
<td>48</td>
<td>1.15</td>
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<tr>
<td>Sevoflurane</td>
<td>21.3</td>
<td>58</td>
<td>2</td>
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<tr>
<td>Desflurane</td>
<td>88.5</td>
<td>23</td>
<td>6</td>
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</tbody>
</table>
FUNCTIONS OF VAPORISERS

- Produce vaporisation of volatile agent
- Mix vapour with fresh gas flow
- Control the mixture despite variables

i.e.,

to deliver safe and accurate concentrations of inhalational anaesthetic agents to the patient
Classification of Vaporisers

- Simple
- Variable Bypass
  - Draw Over
  - Plenum
- Measured Flow Vaporisers
- Aladin Cassettes
Simple

- vaporising chamber - metal/glass bowl or bottle
- containing liquid anaesthetic
- tap controlling the proportion of gas flowing through it
- Fresh gas flow split into two streams by a flow splitting valve
- One stream bypasses the vaporising chamber, other passes through and becomes saturated
- Streams then re-join
- Final concentration determined by use of flow splitting valve
- 2 main types – Plenum and Draw over
DRAW OVER VAPORISERS

- Gas is drawn into the vaporising chamber by patient’s inspired effort
- Low resistance
- Used within circuit
  - a circle absorber system
  - non-rebreathing draw-over apparatus
- Don't require pressurised source of gases
- Useful for field hospitals
  - Battle fields and bush
- Poor accuracy of concentrations
Examples include
- Epstein Mackintosh Oxford (EMO),
- Oxford Miniature Vaporiser (OMV)
- Tri-service apparatus
PLENUM VAPORISERS

- Most commonly used in modern hospital practice
- Precision Vaporisers
- Gas passes through vaporiser under pressure at the back bar of the machine
- High resistance
- Examples include Ohmeda TEC 3/4/5,
Why are they precision?

- **FACTORS AFFECTING PRECISION**

  - **Fresh gas flow** – as flow rate increases, increasing amount of vapour is required to saturate the carrier gas

  - **Anaesthetic potency** – More potent volatile agents require greater dilution of the vapour and the greater the splitting ratio

  - **SVP** – Agents with a higher SVP are easier to vaporise and require higher ratios

  - **Pumping effect** – Effect produced by repetitive changes in circuit resistance at common gas outlet. Can lead to surges of volatile agent in circuit
FACTORS AFFECTING PRECISION

- Temperature
  - Increasing environmental temperature causes an increase in SVP.
  - Temperature tends to fall in chamber due to latent heat of vaporisation, which is more marked at higher flows.
Why are they precision?

- BECAUSE OF COMPENSATORY MECHANISMS
  - Plenum vaporisers are incredibly efficient
COMPENSATORY MECHANISMS

1. Use of wicks and bubble mechanisms to increase surface area

The wicks improve vaporisation.

Bubbling through sintered material
2. Bimetallic strip
varies flow through bypass chamber with temperature change

3. Heat sinks
metal or water at base of vaporiser to smooth out temperature fluctuations
MEASURED FLOW VAPORISER

- Used for Desflurane (TEC 6)
- Boiling point of Desflurane is 23.6°C
- Chamber in which volatile agent is heated by electrical element to 39°C
  - Need plugging in and warm up
- Produces pure vapour under pressure
- Controls addition of the pressurised vapour to the fresh gas flow using pressure compensated controlled valve
Datex-Ohmeda Aladin vaporizer

- Cassettes containing volatile liquid anesthetic
- Inserted into a port containing the central electronic control mechanism
- This dispenses agent into the stream of fresh gas flow.
- Controlled by a throttle valve steered by the central processing unit (CPU).
- Cassette is only a liquid sump without control mechanisms
- They can be tipped in any orientation without danger
- Maintenance free
How do you use a vaporiser at altitude?

- Atmospheric pressure decreases
- But SVP pressure stays the same
- Should you turn down your vaporiser?
  - No
- Vaporisers aren’t calibrated for atm pressure
Because it’s the partial pressure that matters not the concentration dialed up

Imagine gas X has MAC of 10%
This actually means you need Partial pressure of 10kpa in alveolus
at atmospheric pressure (100kpa)
SVP is 20%
Splitting ratio of 1:1

Go to 6000m - SVP stays the same (related to temperature) but atm pressure halves
Splitting ratio same
This will double the concentration given by vaporiser 20%
But this delivers the same partial pressure of (20% of 50 kpa = )10kpa
Questions?