Anesthesia Breathing Systems, Unidirectional Valves, Gas Supply

Source: Unknown
2016
Classification of Breathing Systems

**Functional**
- Rebreathing – no CO$_2$ absorber
- Non rebreathing – has CO$_2$ absorber

**Structural**
- Open system
- Semi open system
- Semi closed system
- Closed system

<table>
<thead>
<tr>
<th>Mode</th>
<th>Reservoir (Breathing Bag)</th>
<th>Rebreathing</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>No</td>
<td>No</td>
<td>Open drop</td>
</tr>
<tr>
<td>Semi-open</td>
<td>Yes</td>
<td>No</td>
<td>Non-rebreathing circuit or Circle system at high FGF</td>
</tr>
<tr>
<td>Semi-closed</td>
<td>Yes</td>
<td>Yes, partial</td>
<td>Circle system at low FGF</td>
</tr>
<tr>
<td>Closed</td>
<td>Yes</td>
<td>Yes, complete</td>
<td>Circle system, with APL (pop-off) valve closed</td>
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</tbody>
</table>
Open System

- Patient’s airway remains open to room air
- Insufflation – blowing anesthetic gases across a patient’s face (pediatric inductions, eye surgery)
- Open drop – highly volatile anesthetic dripped onto a gauze covered mask applied to patient’s face (Schimmelbusch mask)
Open System

- **Advantages**
  - No added resistance to patient’s breathing

- **Disadvantages**
  - Poor control of concentration and depth of anesthesia
  - Inability to assist or control ventilation
  - No conservation of heat or humidity
  - Difficult airway management during head and neck surgery
  - Pollution of operating room
Mapleson’s Semi-open Systems

- No CO$_2$ absorption
- High fresh gas flows (FGF) required to prevent rebreathing by flushing out CO$_2$
Bain Circuit

Advantages
• Lightweight
• Easily sterilized
• Scavenging facilitated
• Warming of inspired gases

Hazards
• Unrecognized disconnection of inner tube
• Kinking of inner tube
Relative Efficiency of Mapleson’s Systems

- Prevention of rebreathing of exhaled CO$_2$
- Spontaneous ventilation
Circle System – Principles

- Sufficient oxygen to supply the body’s basal needs and absorption of CO$_2$ means the same mixture of gases can be rebreathed repeatedly

*System may be completely closed or may have a leak when used with larger gas flows*

- At higher flows (6L/min), the system becomes semi-closed and soda-lime is unnecessary

- With basal flows (0.3–0.5L/min), rebreathing is total and expired CO$_2$ is removed by soda-lime (or baralyme)
Circle System

**Closed** - total rebreathing - expired CO₂ is removed by CO₂ absorber (soda-lime or baralyme)

- FGF matches exactly that consumed by patient (0.3-0.5L/min)
- Pop-off valve closed
- Venting is excluded

**Semi-closed** system – has a leak when used with larger (higher) gas flows (≥ 6L/min) - soda-lime usually becomes unnecessary
Advantages of Circle System

- Economical – permits low fresh gas flows
- Reduces OR pollution
- Conservation of heat and humidity
- Relative constancy of inspired concentration
Disadvantages of Circle System

- Multiple components - can malfunction, disconnect, leak, or be arranged incorrectly
- Inspired gas concentrations difficult to predict
- Concentration and depth cannot be rapidly changed
- Bulky - less convenience and portability
- Increased resistance to breathing
- Alkaline dust may pass to patient

- Adsorption of volatile agents to soda-lime - lowers initial concentration and “hangs over” to subsequent patients
- Production of toxic compounds by anesthetic reaction with soda-lime
- Stuck unidirectional valves can cause CO₂ rebreathing (open position) or total circuit occlusion (closed position)
Breathing Systems

What are the disadvantages of a Mapleson D vs. a circle system?

- No carbon dioxide absorption
- Higher fresh gas flows – wasteful, pollution, not economical
- More difficult to scavenge
- Loss of heat and humidity
Carbon Dioxide Absorber
(Soda Lime and Baralyme)

- Air space in the charged canister should equal the patient’s tidal volume
- Nearly half the volume in a properly packed canister is intergranular space
- Granule size is 4-8 mesh size – (will pass through a strainer having 4 to 8 wires per inch)
- Canister vertical position prevents “channeling” - preferential passage of exhaled gases through the canister via pathways of least resistance
Indicators

- pH sensitive
- Ethyl violet
  - most frequently used indicator
  - changes to purple as absorption proceeds
  - may be deactivated by fluorescent lighting
Rebreathing

A patient is on a circle system. You notice that he is rebreathing CO$_2$ and FiCO$_2$ is rising. Where is the malfunction?

- Unidirectional valves
- CO$_2$ absorber
Unidirectional Valves

- Two in circle system (inspiratory and expiratory)
- Part of absorber assembly
- Incompetence of either valve $\Rightarrow$ bidirectional gas flow $\Rightarrow$ CO$_2$ rebreathing
Unidirectional Valve Check

- Disconnect breathing tubes from machine
- Close APL valve
- Turn off all gas flow
* Blow air against valve direction to check competence

Inhalation valve test
- Connect breathing tube to inhalation outlet
- Occlude exhalation outlet
- Blow air into breathing tube
- Bag fills up if inspiratory valve incompetent

Exhalation valve test
- Connect breathing tube to usual breathing bag site
- Connect breathing bag to exhalation outlet
- Cover inhalation outlet
- Blow air into breathing tube
- Bag fills up if expiratory valve is incompetent
Gas Delivery

- Signs of wall oxygen failure
- What happens if the wall oxygen fails with the E-cylinder at 1500 psi in the open position?
Gas Supply Sources

1. Bulk pipeline supply
   - Liquid oxygen
   - Bank of H-cylinders (gaseous state)

- Diameter Index Safety System (DISS) minimizes risk of wall misconnection
Gas Supply Sources

2. **Cylinder (back-up) supply**
   - Storage of compressed gases
   - Designated according to letters A to H (A is smallest)
   - Color coded
   - Hanger yoke uses Pin Index Safety System (PISS) to discourage incorrect cylinder attachments
   - Prevents accidental cylinder interchanging
   - Can be defeated using multiple seals ("washers")

*E-cylinders most common on anesthesia machines*
**Important!**

- **Do NOT leave cylinders open while machine is being supplied from the pipeline**

- The machine preferentially uses gas from the higher pressure pipeline source

- **Depressing O₂ flush valve or high peak ventilator flows can also transiently drop the pipeline pressure below 45psig**

**Transient fluctuations in pipeline source below 45psig cause gas to be used from the cylinder – and may eventually become depleted**
Gas Delivery

• Signs of wall oxygen failure
• What happens if the wall oxygen fails with the E-cylinder at 1500 psi in the open position?
Wall Oxygen Failure

Safety devices that alert the anesthesiologist include:

- **Pressure sensor shut-off** (“fail-safe”) valve – shuts off or proportionately decreases the supply of non-oxygen gases
- **Oxygen supply failure alarm** is activated once the oxygen pressure falls below a predetermined level
Wall Oxygen Failure

Plan of action

• Open emergency oxygen supply

• Disconnect wall supply – in case of accidental crossover or contamination with impurities

For bellows type ventilators

• Change to low flow anesthesia

• Change to manual ventilation
Calculation of Vaporizer Output

- In the vaporizing chamber, anesthetic vapor at its SVP constitutes a mandatory fractional volume of the atmosphere, e.g., 32% for halothane.
- If 100 mL of carrier gas enters the vaporizing chamber, it represents 68% of the atmosphere in the chamber – the remainder is 32% halothane vapor.
- For halothane: \( y = 100 \text{ ml/min} \), therefore which \( x \) can be calculated to be 47 mL.
- Larger volume of gas leaves the vaporizing chamber than enters it. The additional volume is anesthetic vapor at its saturated vapor concentration.
Ventilation Disconnection

- **Bellows nomenclature is determined by direction of bellows movement during the expiratory phase**
  - **Ascending (standing) bellows** – ascend during expiratory phase - safer – it does not refill if a total disconnection occurs
  - **Descending (hanging) bellows** – descend during expiratory phase – continues its upward and downward movement during a disconnection because room air is entrained by gravity into the breathing system at site of disconnection
An anesthetized and paralyzed patient is mechanically ventilated. The unidirectional valve on the inspiratory limb of the circle system is found to be incompetent, and a replacement is not immediately available. The most appropriate management is to increase the

A. Fresh gas flow rate
B. I:E ratio
C. Inspired oxygen concentration
D. Respiratory rate