Breathing Systems

Professor Khalid Bashir
Introduction

- The devices that connect and deliver anaesthetic gases from anaesthetic machine to patient
- Spontaneous respiration / IPPV
- Ports for gas sampling, airway pressure, flow and volume monitoring
Classification of breathing systems

- Open
- Semi-open
- Semi-closed
- Closed

**Open** is the old fashioned method of dropping ether or chloroform over a gauze
Semi-open

- Is usually a single limb system.
- High fresh gas flows (equivalent to or more than patients minute volume) are required with these systems to stop rebreathing of expired carbon dioxide. *e.g. mapleson Systems*
Closed system (Circle systems)

- **Semi Closed**
  - expired gases pass through a CO$_2$ absorbent
  - carbon dioxide removed, expired gases rebreathed.

- **Closed circuits**
  - fresh gas flows equivalent to the metabolic uptake
  - minimal flows are required to prevent rebreathing.
Components of breathing systems

- Fresh Gas connection.
- Patient connection.
- Adjustable Pressure Limiting (APL) Valve
- Reservoir bag & tubing
- Waste gas connection.
- Carbon dioxide absorbers (circle system only)
- Unidirectional valve (Circle system only)
The Ideal Breathing System:

• Simple and safe to use.
• Delivers the right gas mixture.
• Allows all methods of ventilation in all age groups.
• Efficient.
• Adjustable Pressure relief.
• Small and light.
• Allows easy removal of waste gases.
• Easy to maintain with low running costs
Mapleson Systems

• In 1954 Professor W.W. Mapleson, University of Wales
• Different arrangements of components of breathing system, i.e., fresh gas flow, breathing tube, mask, reservoir bag, and expiratory valve.
Mapleson system

Mapleson A

Mapleson B

Mapleson C

Mapleson D

Mapleson E

"Mapleson F"

FG = Fresh gas  P = Patient
Mapleson A System (Magills circuit)

- APL valve close to the patient
- Fresh gas inlet near the reservoir bag away from the patient.
- The corrugated tube is usually 110 cm long
- Capacity equal to tidal volume
Mapleson A (Magills circuit)
Functioning of Mapleson A
APL valve kept fully open
Advantages of Mapleson A

- Best circuit for spontaneous respiration as no rebreathing occurs with adequate flows.
- Less fresh gas flow is required during spontaneous respiration.
- FGF = Minute ventilation (70 ml/kg)
Disadvantages of Mapleson A

• Theatre pollution is increased
• High fresh gas flow requirements during mechanical ventilation.
• APL valve close to patient: dragging effect
Modification of Mapelson A system:

Lack’s System

Allows waste gas scavenging
Mapleson B and C systems:

- They are not commonly used in anaesthetic practice.
- C system may be used for emergency resuscitation.
- High flow gases to prevent rebreathing of CO$_2$.
- Theatre pollution is maximum.
Mapleson D
Mapleson D modification:
Advantages of Bain System:

• Light weight, Low resistance.
• FGF tube near pt. end
• Minimal drag on ETT as compared to Magill’s circuit.
• Outer tube transparent
• It is easy to detect any kinking or disconnection of the inner fresh gas flow tube.
Advantages of Bain System:

- Usual length 180 cm
- Can be increased as for MRI
- Easy for scavenging of gases as scavenging valve is at machine end of the circuit.
- There is some warming of the inspired fresh gas by the exhaled gas present in outer tubing.
- Spontaneous and IPPR
Disadvantages of Bain System:

• Due to multiple connections in the circuit there is a risk of disconnections
• There can be kinking of the fresh gas supply inner tube blocking the fresh gas supply leading to hypoxia.
• There can be crack in the inner tube causing leakage.
• Hypoxemia/hypercapnia
Checking the Bain Circuit:

• **Pethick’s test** – To check the integrity of the inner tube, activate the oxygen flush and observe the bag. Due to venturi effect the high flow from the inner tube at the patient end will create a negative pressure in the outer exhalation tubing and this will suck gas from the bag and bag will deflate. If the inner tube is not intact, this maneuver will cause the bag to inflate slightly.
• **Bobbin test** For checking integrity of inner tube of Bains system, a test is performed by setting a low flow on the oxygen flowmeter and occluding the inner tube with a finger or barrel of a small syringe at the patient end while observing the flow meter indicator. If the inner tube is intact and correctly connected, the bobbon will fall.
Mapleson E & F System
Mapleson E system
(Ayre’s T-piece)

• Valve less breathing system, no resistance
• Children up to 25 to 30 kg
• T shaped connector, corrugated tube
• Length/volume of tubing: rebreathing/entrainment
Mapleson F System
(Jackson Rees Modification)
Advantages of Mapleson E & F

• Easy assembly
• Inexpensive.
• Low resistance system due to the absence of valves.
• Offers CPAP
• Spontaneous and IPPR
• Used in ICU for weaning
Disadvantages of Mapleson E&F

• High fresh gas flows are required.
• Scavenging is difficult
Gas Flow Requirements Of Mapelson System

<table>
<thead>
<tr>
<th>Mapelson</th>
<th>Systems</th>
<th>Uses</th>
<th>FGF SV</th>
<th>FGF IPPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Megill Lack</td>
<td>Spontaneous Gen Anaesthesia</td>
<td>70-100 ml/kg/min</td>
<td>Min 3 x MV</td>
</tr>
<tr>
<td>B</td>
<td>Very uncommon, not in use today</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Bain</td>
<td>Resuscitation Bagging</td>
<td>Min 15 lpm</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Spontaneous IPPV, Gen. Anaes</td>
<td>150-200 ml/kg/min</td>
<td>70-100 ml/kg/min</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Ayres T Piece</td>
<td>Very uncommon, not in use today</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Jackson Rees</td>
<td>Pediatric &lt;25 Kg</td>
<td>2.5 – 3 x MV Min 4 lpm</td>
<td></td>
</tr>
</tbody>
</table>
Mapleson system
relative efficiency

- **Spontaneous**
- $A > DFE > CB$
- $A > D > C > B$: All Dogs Can Bite

- **Controlled ventilation**
- $DEF > BC > A$
- $D > B > C > A$: Dead Bodies Can’t Argue
Circle Systems

- Components of the circle systems:
  - A fresh gas inflow source.
  - Inspiratory and expiratory unidirectional valves.
  - Inspiratory and expiratory corrugated tubes.
  - Y-piece connector.
  - An overflow / pop-off valve / APL valve
  - A reservoir bag
  - Canister containing carbon dioxide absorbent
Carbon Dioxide Absorber

- The absorber canister about 1-2 kg capacity
- **Carbon dioxide absorbents:**
  - Soda lime: most common
  - Baralyme (a mixture of calcium hydroxide and barium hydroxide)
Soda lime

• Composition
  ➢ 94% Calcium hydroxide
  ➢ 5% Sodium hydroxide
  ➢ 1% Potassium hydroxide
  ➢ Silica

• Colour change: Ethyl violet

• Granule size: 4-8 mesh

• Absorbing capacity: 120 L CO₂ by 1 kg soda lime
Soda lime chemical Reaction

- \( \text{CO}_2 + \text{H}_2\text{O} \Leftrightarrow \text{H}_2\text{CO}_3 \)
- \( \text{H}_2\text{CO}_3 + 2\text{NaOH} \Leftrightarrow \text{Na}_2\text{CO}_3 + 2\text{H}_2\text{O} + \text{Heat} \)
- \( \text{Na}_2\text{CO}_3 + \text{Ca(OH)}_2 \Leftrightarrow \text{CaCO}_3 + 2\text{NaOH} \)
Advantages of circle systems:

- Maintain relatively stable inspired gas concentration
- Conservation of respiratory moisture and heat
- Prevention of operating room pollution.
- The circle system can be used as a semiclosed system or as a closed system with very low fresh gas flows.
- Spontaneous and controlled ventilation
Disadvantages of Circle systems:

• Prone to misconnections, disconnections, obstructions, and leaks.
• Malfunction of unidirectional valves.
• Resistance
• Channeling in soda lime
• Soda lime exhaustion
Thanks
Breathing circuits MCQ

Prof Khalid Bashir
Q 1. The essential component in close system is:

A) Corrugated tubes
B) unidirectional valve
C) APL valve
D) Breathing bag
E) Endtidal CO₂ port
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Q 2. The mapleson system that is also used in ICU is:

A) Lack system
B) Bain system
C) Mapleson F
D) Mapleson B
E) Mapleson A
Q 2. The mapleson system which is also used in ICU is:

A) Lack system
B) Bain system
C) **Mapleson F**
D) Mapleson B
E) Mapleson A
Q 3. Regarding Mapleson A system:

A) Gases are vented out during expiration
B) Gases are vented out during pause between inspiration and expiration
C) APL valve is kept partially open during ventilation
D) Fresh gas flow should be 2 times minute ventilation
E) Efficiency for spontaneous respiration is comparable to Bain system
Q 3. Regarding Mapleson A system:

A) **Gases are vented out during expiration**
B) Gases are vented out during pause between inspiration and expiration
C) APL valve is kept partially open during ventilation
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E) Efficiency for spontaneous respiration is comparable to Bain system
Q 4. In close circuit APL valve is located:

A) Between Soda lime and fresh gas inlet
B) In the inspiratory corrugated tube
C) Between expiratory valve and Y connection
D) Between expiratory valve and soda lime
E) In the expiratory corrugated tube
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B) In the inspiratory corrugated tube
C) Between expiratory valve and Y connection
D) **Between expiratory valve and soda lime**
E) In the expiratory corrugated tube
Q 5. The first chemical reaction occurring in soda lime is:

A) \( \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \)
B) \( \text{H}_2\text{CO}_3 + 2\text{NaOH} \)
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