Anaesthetic Equipment

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Summary

• Anesthesia workstation

• Breathing systems

• Gas analyzers

• Safety in the OR: Electrical safety, fire in the OR
Anesthesia workstation
High pressure gas delivery

Receives gas from the cylinders

Gas cylinder and attachments
Non return valves
Pressure gauges
Primary pressure regulator

Reduces cylinder pressure
4000-1444 kPa -> 310-420 kPa

To protect the patient, the apparatus and maintain constant pressure

- Cylinders are not usually used, but it is a necessary safety feature
- Color coded and specific pin index safety system connection
Medical gas cylinders

- Made of chrome-molybdenum steel or carbon steel
- Sizes defined by water capacity (L)
- Gases stored in a compressed gaseous form
  - Gas content = water capacity (L) x pressure (bar)
- N2O and CO2 are liquefied gasses under pressure
  - Pressure remains constant until cylinder is empty
Intermediate pressure systems
Receives gas from hospital pipelines 300-400 kPa

- Consists of:
  - Pipeline secure inlet connections
  - Pipeline pressure gauges and indicators
  - Master switch
  - Oxygen pressure failure devices
  - Oxygen flush
  - Additional or secondary regulators
  - Flow control valves
Safety devices to secure $O_2$ delivery

1. Oxygen pressure failure system (fail-save valve)

- Anesthesia workstation standards require that when oxygen supply pressure is reduced, the delivered oxygen concentration at the common gas outlet does not fall below 21%
- Mechanical, pneumatical or electronic cut off devices
- They detect failure based on pressure and not flow, hence they do not protect against hypoxic gas delivery
Safety devices to secure $O_2$ delivery

2. Anti-hypoxia devices

- Additional regulator upstream of the flow meters
- Flow is constant even if fluctuations in the pipeline pressure
- These reduce the $O_2$ pressure to 14 psig and 26 psig for $N_2O$

3. Oxygen flush

- Delivers 35l/min/$O_2$ directly from pipeline or cylinder
- May cause barotrauma and dilutes inhaled anesthetic
Low pressure systems

Delivers gas from the flowmeters via vaporizers to the patient

- Flowmeters
- Vaporizers and their mounting devices
- Unidirectional and pressure relief valves: set at 35kPa
- Common gas outlet: receives all the gasses and vapors and delivers the mixture to the breathing system
- Breathing system: traditionally not part of the machine, but newer ones may have a built in circle system
Flowmeters

1. Mechanical (rotameters)

- Constant pressure variable orifice flowmeters
- Each calibrated for a particular gas
- Bobbin rotation indicates proper working conditions
- Accurate within 10% of indicated flow
Flowmeters

2. Transitional or hybrid flowmeters

- Works with a needle valve. Flow can be generated without electric power, but the measurement and display is electronic.

3. Electronic flowmeters

- Gas flow set, measured and displayed electronically.
- No manual valve.
- Backed up with a basic O2 delivery system in case of power or machine failure.
Flowmeter safety

• Only one flow control be provided for each gas at a time

• A protective barrier around the control minimizes accidental changes in settings.

• Tubes are made leak-proof with neoprene washers (O-rings) at both ends of the flow meter assembly.

• The bobbin is visible throughout the length of the tube

• The tubes have an antistatic coating
Vaporizers

• Volatile anesthetics must be vaporized before being delivered to the patient
• Located between the flowmeters and the common gas outlet

• **Physics of vaporization:**
  • The molecules of volatile anesthetic in a closed container are distributed between the liquid and gaseous phases
  • Vapor pressure depends on the agent’s characteristics and the temperature
  • Vaporization requires energy (latent heat of vaporization), which results in a loss of heat from the liquid
  • The t° of the remaining liquid decreases unless heat enters the system
  • A liquid’s boiling point is the t° at which its vapor pressure is equal to the atmospheric pressure
  • At higher altitudes the boiling point decreases
Variable bypass vaporizers

- The FGF to the patient is split in 2 by a splitting valve
- One bypasses the vaporizing chamber and is free from volatile agent
- The other passes through the vaporizer chamber and becomes saturated
- The final vapor concentration is controlled by using a flow splitting valve
**Variable bypass vaporizers**

1. **Draw over**
   - Gases are at ATM pressure and are drawn through the vaporized chamber by the inspiratory efforts of the patient.
   - Low resistance vaporizer
   - Poor accuracy since flow rated vary: at low flow rated the resistance will become significant and gases will bypass the chamber, at high flows there will be increased dilution of the vapor and concentration will also decrease
Variable bypass vaporizers

2. Plenum

- The inspired gases are at higher than ATM pressure and pressurize the vapor chamber
- High resistance vaporized
- Accurate in wide range of flows
- Accurate in a wide range of temperatures due to built in temperature compensation
- Can be used in altitude because partial pressure of the volatile agent remains constant
Measured flow vaporizers

TEC 6 Desflurane vaporizer

- Desflurane boiling point = 23.5°C
- Desflurane is heated up to 39°C under a pressure of 194 kPA or 1500mmHg
- A continuous flow of desflurane vapor from the chamber is added to the FGF via the concentration control valve
- Shut-off valve activated by tilting the vaporizer
Safety features of vaporizers

Transport setting to prevent spillage of the liquid agent into the bypass channel

Interlock mechanism to prevent using two agents simultaneously

Pin safety system to prevent filling up with wrong agent
Breathing systems

- A breathing system may consist of all or some of:
  
  - Face mask
  
  - Gas hoses and connectors
  
  - Reservoir bag
  
  - CO2 absorber
  
  - Adjustable pressure limiting (APL) valve
  
  - A valve to switch between controlled (CV) and spontaneous ventilation (SV)
  
  - One-way valve to prevent rebreathing

<table>
<thead>
<tr>
<th></th>
<th>Insufflation and Open Drop</th>
<th>Mapleson</th>
<th>Circle</th>
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<tbody>
<tr>
<td>Complexity</td>
<td>Very simple</td>
<td>Simple</td>
<td>Complex</td>
</tr>
<tr>
<td>Control of anesthetic depth</td>
<td>Poor</td>
<td>Variable</td>
<td>Good</td>
</tr>
<tr>
<td>Ability to scavenge</td>
<td>Very poor</td>
<td>Variable</td>
<td>Good</td>
</tr>
<tr>
<td>Conservation of heat and humidity</td>
<td>No</td>
<td>No</td>
<td>Yes¹</td>
</tr>
<tr>
<td>Rebreathing of exhaled gases</td>
<td>No</td>
<td>No¹</td>
<td>Yes¹</td>
</tr>
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</table>

¹These properties depend on the rate of fresh gas flow.
<table>
<thead>
<tr>
<th>Mapleson Class</th>
<th>Other Names</th>
<th>Configuration</th>
<th>Required Fresh Gas Flows</th>
<th>Comments</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spontaneous</td>
<td>Controlled</td>
</tr>
<tr>
<td>A</td>
<td>Magill attachment</td>
<td>[Image]</td>
<td>Equal to minute ventilation (≈80 mL/kg/min)</td>
<td>Very high and difficult to predict</td>
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<tr>
<td>B</td>
<td>Waters' to-and-fro</td>
<td>[Image]</td>
<td>2 × minute ventilation</td>
<td>2–2½ × minute ventilation</td>
</tr>
<tr>
<td>C</td>
<td>Bain circuit</td>
<td>[Image]</td>
<td>2 × minute ventilation</td>
<td>2–2½ × minute ventilation</td>
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<tr>
<td>D</td>
<td>Ayre's T-piece</td>
<td>[Image]</td>
<td>2–3 × minute ventilation</td>
<td>1–2 × minute ventilation</td>
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<tr>
<td>E</td>
<td>Jackson-Rees' modification</td>
<td>[Image]</td>
<td>2–3 × minute ventilation</td>
<td>3 × minute ventilation (I:E 1:2)</td>
</tr>
</tbody>
</table>

1FGI, fresh gas inlet; APL, adjustable pressure-limiting valve.
Absorption systems

- Rebreathing alveolar gas conserves heat and humidity
- CO2 in exhaled gas must be eliminated to prevent hypercapnia

**Soda lime** is the most common absorbent and is capable of absorbing up to 23L of CO2 per 100g of absorbent. It’s main component is calcium hydroxide (80%)

- Reaction en products: heat, water and calcium carbonate
- Barium hydroxide is not longer used due to fire risk
Anesthetic Gas Analysis

- Mass spectrometry and Raman spectroscopy are of historical interest.
- Most anesthetic gases are measured by infrared absorption analysis.
- Based on the Beer-Lambert law: the absorption of infrared light passing through a solvent (gas) is proportional to the amount of the unknown gas.
- $\text{O}_2$ and $\text{N}_2$ do not absorb infrared light.
O₂ Analysis

1. Galvanic Cell (fuel cel)
   - Contains a lead anode and gold cathode bathed in potassium chloride. At the gold terminal hydroxyl ions are formed that react with the lead, gradually consuming it. These are the O₂ monitors used on many anesthesia machines in the inspiratory limb.

2. Paramagnetic Analysis
   - O₂ is nonpolar but paramagnetic, and when in a magnetic field, the gas will expand, contracting when the magnet is turned off. By switching the field on and off and comparing the result to a known standard, the amount of O₂ can be measured. Requires a water trap.

3. Polarographic Electrode
   - Has a gold or platinum cathode and a silver anode bathed separated by a semipermeable membrane. This works only if a small voltage is applied to the electrodes. The amount of current that flows between the anode and cathode is proportional to the amount of O₂ present.
Electrical Safety

The risk of electrocution

• Body contact with two conductive materials at different voltage potential may complete a circuit and result in electrical shock.

• Leakage current is present in all electrical equipment as a result of capacitive coupling, induction between internal electrical components, or defective insulation.

• The leaks are usually imperceptible to touch (<1mA) and well bellow the fibrillation threshold (100mA).

• If the current bypasses the high resistance offered by the skin or is applied directly to the heart (microshock), 100 μA may be fatal.

• The maximum leakage allowed in OR equipment is 10 μA.
Electrical Safety

Protection from electrical shock

- Most electrocutions are caused by current from the live conductor of a grounded circuit through the body and back to the ground.

- Complete patient isolation is not feasible, instead, the OR power supply can be isolated from grounds by an isolation transformer and a line isolation monitor measures the current flow from the power supply to the ground.
Electrical Safety

Surgical Diathermy

- Electrosurgical units generate an ultra-high-frequency electrical current that passes from a small active electrode (cautery tip) through the patient and exits by way of a plate electrode (dispersal pad).

- Ventricular fibrillation is prevented by using ultrahigh frequencies (0.1-3MHz), compared with line power (50-60Hz)

- Malfunction of the dispersal pad may result from disconnection, inadequate patient contact of insufficient conductive gel. The current will find another place to exit, which may result in a burn

- Precautions include: proper electrode placement, avoid prostheses and bony protuberances and elimination of patient-ground contacts
Fires and Thermal Injuries

The risk of electrocution

- Incidence of surgical fires is rare (1:87,000 cases)

- The most common risk factor related to open delivery of oxygen

- The fire triad: fuel, oxidizer and ignition source

- When the surgical site is above the xiphoid and the patient needs >30% O₂, the airway should be secured

- The most important action in case of airway fire is the fast removal of the endotracheal tube and the gas flow. The tube should be examined for missing pieces

- If the patient is on fire, the oxidizing gases should be stopped, surgical drapes removed and fire extinguished by water. If it is not immediately extinguished, then a CO₂ extinguished may be used.
References

- Fundamentals of Anaesthesia 3rd edition

- Morgan and Mikhail's Clinical Anesthesiology 5th Edition

