Anesthesia Machines
“Give me to drink mandragora… That I might sleep out this great gap of time my Anthony is away.”

[excerpt from Anthony and Cleopatra]

• Mandrake (*Mandragora officinarum*) is a plant related to the potato family.
Purpose

- Anesthesia units dispense a mixture of gases and vapors and vary the proportions to control a patient’s level of consciousness and/or analgesia during surgical procedures.
Functions

• Provide oxygen (O2) to the patient.
• Blend gas mixtures that can include (besides O2) an anesthetic vapor, nitrous oxide (N2O), other medical gases, and air.
• Facilitate spontaneous, controlled, or assisted ventilation with these gas mixtures.
• Reduce, if not eliminate, anesthesia-related risks to the patient and clinical staff.
Anesthesia delivery

- The patient is anesthetized by inspiring a mixture of O2, the vapor of a volatile liquid halogenated hydrocarbon anesthetic, and, if necessary, N2O and other gases.

- Because normal breathing is routinely depressed by anesthetic agents and by muscle relaxants administered in conjunction with them, respiratory assistance — either with an automatic ventilator or by manual compression of the reservoir bag — is usually necessary to deliver the breathing gas to the patient.
Principles of operation

- An anesthesia system comprises four basic subsystems:
  - a gas supply and control circuit;
  - a breathing and ventilation circuit;
  - a scavenging system;
  - a set of system function and breathing circuit monitors (e.g., inspired O2 concentration, breathing circuit integrity).
Safe practice of anesthesia

• Anesthesia machines incorporate a number of alarms that indicate:
  – levels and variations of several physiologic variables and parameters associated with cardiopulmonary function; and/or
  – gas and agent concentrations in breathed-gas mixtures.
Safe practice of anesthesia

• Anesthesia machines must monitor:
  – O2 concentration;
  – airway pressure; and either
  – the volume of expired gas ($V_{\text{exp}}$); or
  – the concentration of expired CO2 (capnography).

• Stand-alone monitors may be used to track other essential variables:
  – electrocardiogram;
  – SpO2;
  – blood pressure (invasive / non-invasive);
  – temperature.
MAJOR COMPONENTS

- Gas Supply
- Pressure Regulators
- Flowmeters
- Vaporizers
- Safety Devices
- Breathing System
Continuous-flow anesthesia system

Gas Supply

Gas Control and Flowmeters

Vaporizer

O₂ Flush Valve

N₂O Shutoff/Low O₂ Pressure Alarm

Gas Pipelines

Reserve Cylinders

Fresh Gas Flow

Selector Valve

APL Valve

Scavenging System

Ventilator

To Atmosphere

Breathing Circuit

Reservoir Bag

Patient

Figure . Continuous-flow anesthesia system

Reproduced from Health Care Product Comparison System, ECRI. 2003 – Anesthesia Units
Breathing circuits used in continuous-flow systems

**Figure**. Examples of breathing circuits

Reproduced from Health Care Product Comparison System, ECRI. 2003 – Anesthesia Units
• Circle systems – advantages:
  – conserve a greater proportion of the anesthetic gases: ↓ cost;
  – conserve body heat and moisture from the patient.

• T-piece systems – advantages:
  – lower circuit compliance;
  – easier circuit sterilization;
  – less complex design requiring fewer valves and no CO2 absorber (although one can be used with it).

Note: T-piece systems are used most often in pediatric anesthesia.
Gas Supply

To purge the breathing circuit of anesthetic vapors.

O2 supply pressure < 25-30 psi: unit decreases or shuts off the flow of the other gases and activates an alarm.
• Lack of O2 delivered to the patient (Hypoxia):
  – can result in brain damage or death.

• Administration of O2 in a concentration of 100%, even for a short duration, may be toxic:
  – resorption atelectasis;
  – particularly acute in neonatal anesthesia; can cause retrolental fibroplasia and bronchopulmonary dysplasia.
Gas Supply

Pipeline Inlet (between 45 and 55 psig)

Pressure reduced to 50 psig
Pressure Regulators

Closed

Open

Outlet 50psig
Flowmeters

N2O and O2 flow controls are interlocked so that the proportion of O2 to N2O can never fall below a minimum value (nominal 0.25) to produce a hypoxic breathing mixture.
Vaporizers

- Inhaled anesthetic agents, with the exception of N2O, exist as liquids at room temperature and sea-level ambient pressure.
- Vaporizers add a controlled amount of anesthetic vapor to the gas mixture.
- Types of vaporizers:
  - variable bypass (conventional);
  - heated blender;
  - Measured flow;
  - draw-over.
Safety Devices
Diameter Index Safety System

Body

Bore

Nipple

Nose

Shoulder

Nut
Safety Devices
Pin Index Safety System

Gas                      Index Pins
Oxygen                   2-5
Nitrous Oxide            3-5
Air                      3-6
Cyclopropane             3-6

Front View

Side View

Cylinder
Safety Devices

Oxygen Pressure Failure Devices

- Inlet Controlling Gas (O2)
- Vent to Atmosphere
- Outlet to Flowmeter
- Inlet Anesthetic Gas
Safety Devices

Vaporizer Interlock
Bain System – a common configuration of the T-piece system
Inhalation-Assisted Manual Ventilation

To Patient

Fresh Gas

To Scavenger

To Ventilator

ORBIS
saving sight worldwide
Exhalation-Assisted Manual Ventilation

From Patient

Fresh Gas

To Scavenger

To Ventilator

ORBIS
saving sight worldwide
Inhalation-Ventilator Controlled Ventilation

To Patient

Fresh Gas

From Ventilator

To Scavenger
Exhalation-Ventilator Controlled Ventilation

From Patient

To Scavenger

Fresh Gas

To Ventilator
CO2 Absorbers

• soda lime

• barium hydroxide lime
O2 Monitor

• An O2 monitor located on the inspiratory side of the breathing circuit analyzes gas sampled from the Y-piece of the patient’s breathing circuit and displays O2 concentration in volume percent.

• O2 monitors sound an alarm if the O2 concentration falls below the preset limit.
Adjustable Pressure Limiter (APL) Valve

- Pressure imposed on the patient’s lungs can cause serious lung damage.
- Either an APL valve or a valve in the ventilator allows excess gas to escape when a preset pressure is exceeded.
- Types:
  - spring-loaded;
  - needle.
- Many APL valves do not have calibrated markings: The anesthetist must adjust them empirically to give a desired peak inspired pressure.
- Circle systems and T-piece systems also include a pressure gauge for monitoring circuit pressure and setting the APL valve.
Adjustable Pressure Limiter (APL) Valve

- Adjusting Knob
- Needle Valve
- Check Valve
- To Scavenger
Scavenging System - Rationale

- Captures and exhausts waste gases to minimize the exposure of the operating room staff to occupational risks.

- Exposure to trace levels of anesthetic gases continually present in the operating room can cause adverse health effects in operating room personnel:
  - increased incidence of spontaneous abortion;
  - congenital anomalies in babies.

- Trace gas levels in the air may have a slight anesthetizing effect on the anesthetist and surgeon.
Scavenging System

• Scavenging systems remove gas by a vacuum, a passive exhaust system, or both.

• Note: Inadequate evacuation of some scavenging systems can cause pressure to build up in the breathing circuit, with the potential for pneumothorax (air in the pleural cavity).
Vacuum (active):

- Vacuum scavengers use the suction from an operating room vacuum wall outlet or a dedicated vacuum system.

- To prevent positive or negative pressure in the vacuum system from affecting the pressure in the patient circuit, manifold-type vacuum scavengers use one or more positive or negative pressure-relief valves in an interface with the anesthesia system.

- Open-type vacuum scavengers have vacuum ports that are open to the atmosphere through some type of reservoir; such units do not require valves for pressure relief.
Scavenging System

Passive exhaust system:

– Passive-exhaust scavengers can vent into a hospital ventilation system (if the system is the non-recirculating type) or, preferably, into a dedicated exhaust system.

– The slight pressure of the waste-gas discharge from the anesthesia machine forces gas through large bore tubing and into the disposal system or directly into the atmosphere.
Scavenging System

- Adjustable Pressure Limiter Valve
- Positive Pressure Relief Valve
- Negative Pressure Relief Valve
- Flow Controller
- Expired Gas from Patient
- Waste Gas
Preventive Maintenance

- Test apparatus and supplies:
  - Lung simulator with adjustable compliance or ventilator tester
  - Pressure gauge or meter with 2 cm H2O resolution, from -20 to +120 cm H2O
  - Various breathing circuit adapters
  - Leakage current meter or electrical safety analyzer
  - Ground resistance ohmmeter
  - Additional items as required for specific manufacturers’ procedures
Preventive Maintenance

• Qualitative tests:
  – Chassis/Housing
  – Mount/Fasteners
  – Casters/Brakes
  – AC Plug
  – Line Cord
  – Strain Reliefs
  – Circuit Breaker/
  – Tubes/Hoses
  – Cables
  – Fittings/Connectors
  – Filters
  – Controls/Switches
  – Fan
  – Battery/Charger
  – Indicators/Displays
  – Alarms/Interlocks
  – Labeling
  – Accessories
  – Bellows
Preventive Maintenance

• Quantitative tests:
  – Grounding resistance [≤0.5 Ω]
  – Leakage current [≤300 μA chassis]
  – Modes and settings [±10% accuracy]
  – Monitors and Alarms [±10% accuracy]
  – Alarms tested:
    • Airway pressure
    • Tidal volume
    • FIO2
    • Others
Preventive Maintenance

• Others:
  
  – Gas Supply
  – Pneumatic lines (including air filters)
  – Gas cylinders (and gauges and regulators, if so equipped)

  – Patient Circuit
  – Breathing circuit (including filters)
  – Humidifiers
  – Pressure-relief mechanism
  – Absorber
IEC Standards

ISO Standards
