Ventilators

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KSS Basic Science Course
Objectives

• Discuss Classification/ terminology
• Look at Modes of ventilation
• How some specific ventilators work
• Questions
What is a mechanical ventilator?

- A machine that generates a controlled flow of gas into a patient’s airways

- Most commonly gas flows along a pressure gradient between the upper airway and the alveoli. (Positive Pressure Ventilation)

- The magnitude, rate and duration of flow are determined by the operator.
How are mechanical ventilators classified?

- Lots of different classifications
- Many historical
- Depends which textbook
- Can be confusing
- Often same words used for different meanings
Negative v Positive

• Negative-pressure ventilators ("iron lungs")
  – Used extensively during polio outbreaks in 1940s – 1950s

• Positive-pressure ventilators
  – Now the modern standard of mechanical ventilation
  – Uses pressures above atmospheric pressure to push air into lungs
  – Requires use of artificial airway
Classification continued

• Mechanism of Action (historical)
  – Mechanical thumbs,
  – Minute volume dividers,
  – Bag squeezers,
  – Intermittent blowers

• Mapleson
  – Constant Flow generators: High pressure/ constant flow
  – Constant Pressure generators: Low pressure/ variable flow

• Cycling (from I to E)
  – Pressure, Volume, Time or Flow
Volume v Pressure

- Flow can be either volume targeted or pressure targeted

- Volume:
  - Most widely used system
  - Terminates inspiration at preset volume
  - Delivers volume at whatever pressure is required up to specified peak pressure
  - May produce dangerously high intrathoracic pressures
Volume v Pressure

- Flow can be either volume targeted or pressure targeted

- Pressure:
  - Terminates inspiration at preset pressure
  - Avoid barotrauma
  - Ventilation volume can vary with changes in airway resistance, pulmonary compliance
Terminology

- “Control”
- “Cycling”
- “Triggering”
- “Mode”
Control

- Two meanings
- *How the ventilator knows how much flow to deliver*
  - Volume - flow generated according to preset volume
    “Volume Controlled Ventilation”
  - Pressure - flow generated according to preset pressure
    “Pressure Controlled Ventilation”

- *Pt receives a set number of breaths and cannot breathe between ventilator breaths*
  - As in Control Mode/ Controlled Mandatory Ventilation
Cycling

- How the ventilator switches from *inspiration* to *expiration*.
- Pressure Cycled - older simpler ventilators
  - Manley
- Volume Cycled - commonest system
- Time Cycled - when setting inspiratory pauses etc
- Flow cycled - used in Pressure Support
Triggering

• *How the ventilator cycles from* expiration *to inspiration.*

• **Time triggered**
  – the ventilator cycles at a set frequency as determined by the controlled rate.
  – Typical theatre ventilator doing CMV

• **Pressure triggered**
  – the ventilator senses the patient's inspiratory effort by way of a decrease in the baseline pressure
  – PS mode

• **Flow triggered**
  – the ventilator senses the patient's inspiratory effort by change in flow
  – Less effort, constant flow generated, modern ITU ventilators
  – PS mode
Terminology

Mode

- Describes the pattern of breaths delivered

- CMV, Assist Control, (S)IMV, PS, PCV

- CMV - Controlled Mandatory Ventilation
  - No allowances for spontaneous breathing.
  - Many anaesthesia ventilators operate in this way.

- AC - Assist Control
  - Pt triggers breaths
  - assisted breaths are facsimiles of controlled breaths.
  - Old mode
IMV and SIMV

• IMV
  – Developed to facilitate liberation from mechanical ventilation
  – Demand valve placed in the breathing system
  – Gas for spont breath diverted to avoid usual ventilator circuit (high resistance)
  – Gas derived from reservoir bag
  – Mandatory breaths reduced until pt breathing on CPAP only
• Problems with IMV
  – Stacking - spont breath and machine breath occur together.
  – Work - spont breaths not supported
Terminology - **Mode**

**SIMV**

- Similar to IMV
- Microprocessor technology
- Mandatory breaths synchronised to avoid stacking by:
  - Machine breaths initiated by patient breath (Flow/pressure triggered)
  - Machine breaths timed to delay ventilations until end of spontaneous patient breaths
- Spontaneous breaths above mandatory rate supported by Pressure Support. - less work
Pressure Support

- Used as a partial or full support mode
- Patient triggers the ventilator (pressure/flow triggered)
- The ventilator delivers a flow up to a preset pressure limit
- Patient controls duration of breath
- Flow cycled
- Flow cycles off when flow declines to a certain percentage of peak inspiratory flow
  - (5 - 25% depending on type of ventilator)
Pressure Controlled Ventilation (PCV)

- Flow generated according to preset pressure
- Peak Pressure
- Many different modes can be pressure controlled eg CMV, SIMV or AC
- Flow waveform is always **decelerating**
  - Flow slows as it reaches the pressure limit.
- Improve the distribution of ventilation in a lung with heterogeneous mechanical properties (as in acute lung injury)
- “Gas distribution in pressure control is like dropping a glass of water on the floor: the water trickles into every nook and cranny”

Pressure Control Ventilation
Advanced Modes

- Developed for treatment of ARDS
- Frequently ARDS pt require inverse ratio ventilation.
- With traditional pressure control CMV or SIMV uncomfortable for pt
- Often require heavy sedation/ paralysis
- Leads to resp muscle and diaphragmatic weakness.
APRV (Airway Pressure Release Ventilation)

- Advanced Pressure Control Mode
- Ventilator cycles between two different levels of CPAP
- Base line pressure is pHigh
- Cycles to pLow to facilitate CO2 removal
- pHHigh time > pLow time (inverse ratio)
- Pt can breath spontaneously on top of this more comfortably
Terminology - Mode

“BIPAP” or “DUOPAP”

- Advanced Pressure Control Mode
- Bi-level CPAP correct term
- *BIPAP correct term used for mode of Non-invasive ventilation*
- Advance on APRV allows easier breathing on top of two levels of CPAP
- Allows Pressure Support of spont breaths
- Advantage better tolerated and less sedation other modes of pressure control.
What is the Plateau Pressure?

- VCV only (PCV: pHHigh/ limit = plateau pressure)
- True reflection of alveolar pressure
What is the difference between PEEP and CPAP?

• Used interchangeably
• Both are a form of expiratory support
• Elevate baseline airway pressure
• CPAP
  – Continuous Positive Airway Pressure
  – Use term when no additional inspiratory support
• PEEP
  – Positive End Expiratory Support
  – Use term when providing inspiratory support
How Some Specific Ventilators work

Theatre Ventilators
Generally these are volume-controlled ventilators.

- Bag in bottle type ventilators
- Bag Squeezers
- Volume Cycled, Time Triggered, CMV mode.
- Modern ventilators allow Pressure Control, SIMV and PEEP
- Main advantage is guaranteed minute ventilation.
- Good in theatre where lung compliance affected by surgery
Bag in Bottle

• Expandable bag is enclosed in an airtight “bottle”.
• Injection or extraction of air in the bottle causes expansion and contraction of the bag
• Injection electronically controlled
• **Electronic solenoid valves**
  – electromechanical valve for use with liquid or gas
  – shut off, release, dose, distribute or mix fluids
Manley Ventilator

- Historical Interest
- 1952, Roger Manley, Westminster Hospital
- Most popular model used in Europe for 4 decades
- Gas driven, no electrical power, no explosion hazard
- Minute Volume divider
- Gas flow from anaesthetic machine used to lift a weighted bellows
- Falls under gravity, forcing gas into lungs.
- Inflation pressure varied by sliding movable weight on top of the bellows.
- The volume of gas delivered adjusted on curved slider restricts bellows excursion
- You can only set Vt and FGF (not RR)
  - RR = FGF/ Vt
Penlon Nuffield Anaesthetic Ventilator

- Compressed gas
- Require high pressure
- Intermittent blower
- Uses “Fluid Logic” (coanda effect)
- Control unit with spool valve
- Patient valve - connects to circuit
- Newton Valve for paediatrics
- Pneupac child ventilators
Transport Ventilators

• Generally Volume Control Ventilators:
  – Guaranteed Minute ventilation
  – Good in transit if patient’s tidal volumes are not being continuously monitored

• Volume Cycled, Time Triggered, CMV mode.
• Modern ventilators allow Pressure Control, SIMV and PEEP
• Small, Compact and Rugged
• Battery power supply
• Pneumatic supply (compressed gas)
• Intermittent blowers
• Earlier models fluidic logic controls
• Newer models electronic logic controls
ITU Ventilators

- High pressure generators
- Sophisticated multi-modal ventilators
- Microprocessor control
- Feedback mechanisms
  - Pressure and flow transducers
  - Record and regulated flows/volumes delivered
- Electronic solenoid valves
Questions