Ventilation
Mechanical ventilation

- Prominent factor in development and growth of respiratory care & critical care medicine

- Expansion & increased sophistication of the mechanical ventilator
  - Negative pressure
  - Positive pressure
  - Invasive ventilation
  - Non invasive ventilation
Mechanics & physiology

Spontaneous breathing

- respiratory muscles contract
- enlarged thoracic cavity
- negative pressure created within the chest
- flow of air at atmospheric pressure into lungs

Negative pressure ventilators attempt to mimic these mechanics whilst achieving goals of adequate oxygenation & ventilation
History of Ventilation

- Polio epidemic – 1950’s.
- Medical student ‘ventilators’.
- Iron lung / cuirass ventilator.
- Negative pressure.
- ICU was born.
Positive pressure ventilation

- Uses a system for delivery of gas into the lungs during inspiration
- Expiration occurs passively
- Patients exhale to atmospheric pressure or to set level of PEEP
Indications for ventilation

- Acute respiratory failure
  - Unresponsive to conventional treatment
  - No longer provide adequate gas exchange
- Neuromuscular failure
- Prophylactic ventilation
- Raised ICP
Effects of ventilation

**Oxygenation**
- Alveolar surface area
  - Mean airway pressure
  - Inspiratory time
  - PEEP
  - FiO2
  - Pulmonary blood flow

**Elimination of CO2**
- Tidal ventilation
  - Inspiratory pressure
  - Tidal volumes
  - Expiratory time

And reduced work of breathing
Ventilatory cycle

4 basic phases
- Expiratory-inspiratory changeover
- Inspiration
- Inspiratory-expiratory changeover
- Expiration

Variables can be altered to carry out phases
- Trigger – initiates inspiration
- Limit – maximum value (pressure/volume) on inspiration
- Cycle – ends inspiration
Breath types...

- Breath types are classified by whether a patient or the ventilator triggers, limits and cycles the breath
- 4 different breath types that a patient on a ventilator may demonstrate clinically
- Machine cycled breaths
  - Mandatory or assisted
- Patient cycled breaths
  - Supported or spontaneous
Breath types

- **Control/Mandatory**: Machine triggered and machine cycled
- **Assisted**: Patient triggered but machine cycled
- **Spontaneous**: Both triggered and cycled by the patient
Ventilator settings & variables

- FiO2
- Rate
- Tidal volumes
- Airway pressures
- PEEP
- I:E ratio
- Mode
- Position
Tidal volume (Vt)

- Volume of gas moved into or out of lungs in a single normal inspiration or expiration
- Represents volume reaching alveoli plus anatomical dead space
- Averages 5-8ml/kg
- Traditionally – atelectasis undesirable, large Vt became the norm
  - Risk of ALI
- Low tidal volume ventilation strategies (6ml/kg)
Triggering/Sensitivity

- Self ventilation negative pressure = - 3 mmHg
- Normal = - 0.5 to – 2 below baseline
- Levels below cause discomfort
- Higher (0) causes autocycling
Oxygen toxicity

- High levels > 60% for > 24hrs probably harmful
  - Pulmonary capillary cell swelling
  - Damage to surfactant producing cells
  - ↓Lung compliance
  - Haemorrhagic interstitial and alveolar oedema
  - Mucociliary impairment
PEEP

- Prevents alveolar collapse & improves recruitment
- Redistributes extravascular lung water
- Improves oxygenation

- Reduces venous return – reduce cardiac output
- Gas trapping & ↑CO2
- Over distends alveoli
- Increased peak inspiratory pressure
What is best PEEP?

- Aim for acceptable PaO2
- Watch Vt!
- The best method for determining this is not yet known
Contra-indications for PEEP

• All of these are because of increased intra-thoracic pressure.

  • Hypovolemia due to cardiac effects of PEEP
  • Asthma, COPD, emphysema due to air trapping - relative
  • Unilateral lung disease – overdistention alveoli in healthy lung
  • Intra-cranial pathology – reduction of venous return, increase ICP – relative
  • Untreated pneumothorax
Ventilator induced lung injury

- Iatrogenic component to respiratory failure
- Mechanical ventilation – leads to physical trauma to lung tissue
  - Barotrauma
  - Volutrauma
  - Atelectrauma
- Release of inflammatory mediators (Interleukins, TNF)
- Lung injury
- SIRS
Volutrauma

- Lung over-inflated
- Alveoli over-stretched
Barotrauma

- High pressures
- Pneumothorax
- Interstitial emphysema
Atelectrauma

- Repetitive opening and closing of “recruitable” alveoli
- High shearing forces
- Disrupts surfactant layer
O2 transfer occurs in inspiratory and plateau

Normal lung – alveolus 95% filled in 1.8 secs

Poor compliance increases this

Therefore prolonging inspiration may be beneficial
I:E ratio cont’d...

- Incomplete expiration causes ↑CO2
- Bronchospasm reduces expiratory flow and longer expiratory time
- Normal ratio 1:2
- Reverse I:E ratio (2:1)
- Risk of auto-peep, it is uncomfortable, increased sedation
Types of Ventilation

- Non-invasive - CPAP
- BIPAP
- Invasive - CPAP
- BIPAP / APRV
- CMV
- SIMV
- ASV / PSV
- Other - HFV
- HFJV
- HFOV
Types of Ventilator
In pairs / groups...

- What modes of ventilation are you familiar with?

- How do they work?

- How do we minimise the risk of ventilator associated lung injury / ALI?
**CMV**

*Continuous mandatory ventilation*

- volume-controlled
- time cycled
- machine-triggered

- In this volume-controlled ventilation mode, the patient receives the set tidal volume (VT) with every mandatory breath.

- The number of mandatory breath is defined by the frequency (RR). This means that the minute volume (MV) remains constant over time.
SIMV

*Synchronised Intermittent Mandatory Ventilation*

- Pressure or volume limited.
- Combination of mandatory and spontaneous breathing.
- Spontaneous breath within breath cycle sensed by a pressure or flow sensor and supported.
- Preset ‘backup’ rate always delivered but spontaneous supported breaths in between.
- Mandatory breath synchronised if spontaneous breath during trigger window.
- Decrease support by turning down rate so patient takes additional spontaneous breaths.
Pressure Support (ASB)

- Insufficient spontaneous breathing.
- Spontaneous breath triggers ventilator to deliver gas until preset pressure is reached.
- Preset inspiratory support pressure above PEEP triggered by spontaneous breathing.
- Good weaning mode, comfortable.
- Flow cycled mode of ventilation
**ASV**

- Adaptive supportive ventilation. ‘Intelligent ventilation’. Closed-loop control.
- Minute ventilation only parameter set.
- Ventilator “thinks” and continually changes frequency and tidal volume based on lung mechanics and spontaneous respiratory effort.
- Minimises the work rate of breathing.
- Encourages spontaneous ventilation and weaning.
- Every breath synchronised with spontaneous effort or full mechanical ventilation provided.
APRV

- Airway Pressure Release Ventilation.
- Mid-1990’s USA.
- Release of airway pressure from elevated baseline to simulate expiration.
- Elevated baseline facilitates oxygenation, releases allow CO2 removal.
- Maximise alveolar recruitment by keeping lung inflated for extended time with high CPAP.
APRV cont’d

- CO2 removal not limited to release phase as spontaneous ventilation allowed through respiratory cycle

- Weaning – reduce P high and T high lengthened – drop & stretch

- Lower airway pressures, less CVS effects, spontaneous breathing possible, comfortable – less sedation.
A diagram illustrating spontaneous breath with pressure (cmH2O) on the y-axis and time (sec) on the x-axis. The diagram shows transitions between high and low pressures (P high and P low) with corresponding time changes (T high and T low).
BiPAP

- Biphasic / Bilevel positive airway pressure
- Cycles between two levels of CPAP.
- Pressure-controlled, time-cycled.
- Allows assisted spontaneous breathing at all times.
- Triggered synchronised with spontaneous effort.
- Set inspiratory time and frequency rather than I:E ratio.
- Bilevel with prolonged I:E ratio = APRV
- Wean by reducing P insp and frequency
High Frequency Ventilation

- Rates as high as 300 – 900 per minute.
- HFOV – provides pressure lower than ambient pressure during expiratory phase producing ‘active’ expiration.
- Helps protect alveoli from volutrauma.
- Alveoli kept at relatively constant volume.
- Larger amplitudes and lower frequencies of ‘wave’ remove more CO2
Protective ventilation strategies

- Smaller tidal volumes
- ARDS network study
  - 12,800 patients
  - Study arms – 12ml/kg (high) or 6ml/kg (low)
  - Better oxygenation first 3 days in high group
  - But significant reduction in mortality in low group at 28 days (31% vs. 39.8%)
- Permissive hypercapnia
- Different ventilation strategies
- PEEP
- ? Faster weaning
Prone position

• Improves oxygenation in 2/3 of patients
• ? Why
• Perfusion – gravity
• Ventilation – reduced compression of lung tissue by the heart
• 1x multi-centre trial concluded no outcome benefit
• Possible benefit in severely hypoxaemic patients
Ventilator Care Bundle

- Gastric ulcer prophylaxis
- DVT prophylaxis
- Daily interruption of sedation
- Head up 30%
- Early mobilisation
Summary

- Ventilation is commenced for many reasons, not just respiratory.
- Many side effects of ventilation, especially if prolonged.
- Multiple modes, many do the same thing.
- Keep the patient oxygenated and safe without doing iatrogenic harm.
- If volume controlled, watch airway pressure, if pressure controlled, watch tidal volume.
Any questions?
References & acknowledgements...


- Jennifer Cuthill (Consultant Anaesthetist)