Vents 101

Dan Holena, MD
Assistant Professor
Division of Traumatology and Surgical Critical Care
Department of Surgery
University of Pennsylvania School of Medicine
Purpose

• To provide a working knowledge of ventilators to students coming into clinical rotations
Origins of mechanical ventilation

- **Negative-pressure ventilators**
  - "iron lungs"
    - Non-invasive ventilation first used in Boston Children’s Hospital in 1928
    - Used extensively during polio outbreaks in 1940s – 1950s

- **Positive-pressure ventilators**
  - Invasive ventilation first used at Massachusetts General Hospital in 1955
  - Now the modern standard of mechanical ventilation
Outline

• Common Ventilator Modes
• Ventilator Settings – reporting them
The goal of ventilation is to facilitate CO₂ release and maintain normal $P_aCO_2$

- **Minute ventilation** ($V_E$)
  - Total amount of gas exhaled/min.
  - $V_E = (RR) \times (T_V)$
  - $V_E$ comprised of 2 factors
    - $V_A = \text{alveolar ventilation}$
    - $V_D = \text{dead space ventilation}$
  - $V_D/V_T = 0.33$
  - $V_E$ regulated by brain stem, responding to pH and $P_aCO_2$
The primary goal of oxygenation is to maximize O₂ delivery to blood (P_aO₂)

- Alveolar-arterial O₂ gradient (P_AO₂ – P_aO₂)
  - Equilibrium between oxygen in blood and oxygen in alveoli
  - A-a gradient measures efficiency of oxygenation
  - P_aO₂ partially depends on ventilation but more on V/Q matching

Oxygenation

The primary goal of oxygenation is to maximize $O_2$ delivery to blood ($P_{aO_2}$)

- Oxygenation in context of ICU
  - V/Q mismatching
    - Patient position (supine)
    - Airway pressure
    - Pulmonary parenchymal disease
  - Small-airway disease

V/Q Matching. **Zone 1** demonstrates dead-space ventilation (ventilation without perfusion). **Zone 2** demonstrates normal perfusion. **Zone 3** demonstrates shunting (perfusion without ventilation).
It’s all about pressure and volume
The two basic kinds of positive Pressure Ventilation

• Volume cycled
• Pressure cycled
Pressure cycled ventilation

- Target airway pressure is the constant variable
- Tidal volume is dependent on in part on compliance of the lung and inspiratory time
Pressure Control Ventilation (PCV)

Ventilator determines inspiratory time - no patient participation

- Triggered by time
- Limited by pressure
- Affects inspiration only
Pressure Control Ventilation (PCV)

Ventilator determines inspiratory time - no patient participation

- **Disadvantages**
  - Requires frequent adjustments to maintain adequate $V_E$
    - Pt with noncompliant lungs may require alterations in inspiratory times to achieve adequate $T_V$
Volume cycled ventilation

- Tidal Volume is the constant variable
- Airway pressure is dependent on in part on compliance of the lung
Volume-cycled ventilation

- AC
  Assist mode
  Control mode
  AC (Assist control)
- IMV
- SIMV
Control Mode

- Ventilator delivers a specified respiratory rate and tidal volume
- No breathing in between
Assist Mode

• Delivers a set tidal volume every time the ventilator is triggered
• Patient controls rate
Assist Control

- Delivers a set tidal volume every time the ventilator is triggered
- Patient controls rate
Two other modes of Volume cycled ventilation:

- Intermittent Mechanical Ventilation (IMV)
- Synchronized Intermittent Mechanical Ventilation (SIMV)
Pressure SUPPORT Ventilation

• CPAP
• BIPAP
Pressure Support Ventilation (PSV)

Patient determines RR, $V_e$, inspiratory time - a purely spontaneous mode

- Triggered by pt’s own breath
- Limited by pressure
- Affects inspiration only
Pressure Support Ventilation (PSV)

Patient determines RR, $V_e$, inspiratory time - a purely spontaneous mode

- Stand alone method
  - Augments inflation volumes during spontaneous breaths
- Complement volume-cycled modes (i.e., SIMV)
- BiPAP (CPAP plus PS)
Intermittent Mandatory Ventilation
Ventilator delivers a fixed volume

- Patient receives a set number of ventilator breaths
- Different from Control: pt can initiate own (spontaneous) breaths
- Different from Assist: spontaneous breaths are not supported by machine with fixed TV
- Ventilator always delivers breath, even if pt exhaling
Synchronized Intermittent Mandatory Ventilation

- Spontaneous breaths and mandatory breaths
- If pt has respiratory drive, the mandatory breaths are synchronized with the patient’s inspiratory effort
For all practical purposes...

- Assist control (AC)
- Synchronized Intermittent Mechanical Ventilation (SIMV)
- PSV (Pressure support)
Reporting Ventilator Settings

- Mode
- Rate
- Tidal Volume
- Fi02
- PEEP
- Pressure support (where applicable)
Pop Quiz

• What’s the minute ventilation of a patient on:
  • AC
  • Set Rate 12
  • TV 500cc
  • Actual rate 20
Answer

- 500cc x 20 breaths = 10L
Pop Quiz

• What’s the minute ventilation of a patient on:
  • SIMV
  • Set Rate 12
  • TV 500cc
  • Actual rate 20
Answer

• 500cc x 12 breaths + (Tvspont x 8 breaths) = ???
Pop Quiz

• What is the minute ventilation of a paralyzed patient on pressure support ventilation?
Answer

- Zero.
- That’s why paralyzed patients get put on AC or SIMV.
7.40/40/150

- pH/PCO2/Pa02
- How do I get my patients ABG to look like that?
- Ventilation (PCO2)
  
  Increasing the Minute Ventilation decreases the PCO2
7.40/40/150

- Ventilation (PCO2)
  - Increasing the Minute Ventilation decreases the PCO2
    - Respiratory Rate
    - Tidal Volume
      - Increase volume
      - Increase pressure
7.40/40/150

- Oxygenation (Pa02)
  - Increasing the Minute Ventilation decreases the PCO2
    - Increase the Mean Airway Pressure
      - PEEP
      - APRV
    - Increase the Inspired Oxygen
      - FI02
PEEP

- Enables maintenance of adequate \( P_aO_2 \) at a safe \( FiO_2 \) level
- Disadvantages
  - Increases intrathoracic pressure
  - May lead to decreased CO
  - May contribute to barotrauma
  - Rupture: PTX, pulmonary edema
PEEP

- Increases FRC
  - Prevents progressive atelectasis and intrapulmonary shunting
  - Prevents repetitive opening/closing (injury)
- Recruits collapsed alveoli and improves V/Q matching
  - Resolves intrapulmonary shunting
  - Improves compliance
“Rescue” modes of ventilation

• Inverse Ratio Ventilation (IRV)
• APRV
• Prone positioning
Assist Control

- Delivers a set tidal volume every time the ventilator is triggered
- Patient controls rate
“Rescue” modes of ventilation

- Inverse Ratio Ventilation (IRV)
  - Prolonged inspiratory time (3:1) leads to better gas distribution with lower PIP
  - Elevated pressure improves alveolar recruitment
  - No advantage over PEEP
Alternative Ventilator Settings

APRV

- Spontaneous breath
- CPAP phase
- Release phase
- Volume (ml)
- Flow (l/min)
- Time
“Rescue” modes of ventilation

• Prone positioning
  • Improved recruitment and FRC, relief of diaphragmatic pressure from abdominal viscera, improved drainage of secretions
  • Potential dangerous
  • No mortality benefit demonstrated
Indications for intubation

• Criteria
  • Clinical deterioration
  • Tachypnea: RR >35
  • Hypoxia: pO2 < 60mm Hg
  • Hypercarbia: pCO2 > 55mm Hg
  • Acidosis
  • GCS < 8
  • Need for emergent operation/anesthesia
  • Need for control
Main Indication for intubation:

- THINKING ABOUT INTUBATING THE PATIENT!
Initial Vent Settings

- Assist Control or other mandatory rate setting initially
- FiO2 100% (rapidly titrate down)
- PEEP 5
- Rate 12-15
- Tidal Volume 8cc/kg (titrate to 6cc/kg)
Tracheostomy

Prolonged intubation may injure airway and cause airway edema

• Advantages
  • Issue of airway stability can be separated from issue of readiness for extubation
    • May quicken decision to wean
  • Decreased work of breathing
  • Avoid continued vocal cord injury
  • Improved bronchopulmonary hygiene
  • Improved pt communication
Tracheostomy

Prolonged intubation may injure airway and cause airway edema

• Disadvantages
  • Long term risk of tracheal stenosis
  • Procedure-related complication rate (4% - 36%)
Remember:

- It’s not too soon to start thinking about where you are going to do your trauma surgery fellowship.....
Questions?