VENTILATOR STRATEGIES

Patrick Cullinan, DO FCCM, FACOI, FACOEP
San Antonio, TX
DISCUSSION OBJECTIVES

1. How Positive Pressure Ventilation (PPV) helps
   • Reduce work of breathing (WOB)
   • Restore adequate gas exchange
2. The essentials in PPV
   • Variables Involved
   • Modes of Ventilation
3. Clinical Considerations
   • Volume/Pressure Relationship (Time, Flow, Trigger)
4. Ventilator Liberation
WHY VENTILATE

• Unprotected and unstable airways (e.g., coma)
  • Intubation and IPPV allows to
    • Airway maintenance
    • Minimize risk of aspiration
    • Maintain adequate alveolar ventilation

• Hypercapnic respiratory acidosis
  • IPPV and NIPPV
    • \( \mu \) WOB and prevent respiratory muscle fatigue (speeds recovery when fatigue is already present)
    • Maintain adequate alveolar ventilation (prevent or limit respiratory acidosis as needed)

• Hypoxic respiratory failure
  • Alveoli collapse or fluid filled alveoli
  • IPPV and NIPPV help correct hypoxemia as it allows to
    • Deliver a high FiO\(_2\) (100% if needed during IPPV)
    • Reduce shunt by keeping alveoli open
PPV CONSIDERATIONS

- Positive and negative effects associated with PPV
  - Circulation
    - Reduced venous return and afterload
    - Hypotension
    - Cardiac output effect
  - Lungs
    - Increased thoracic pressure
    - Barotrauma
    - Ventilator-induced lung injury (VILI)
  - Gas exchange
    - Compression of capillaries - PEEP
    - May increase dead space $V_D$ (compression of capillaries)
    - Shunt – peep manuever
PPV INITIATED BY FOUR VARIABLES

- Trigger
  Initiates the breath
- Control
  Controls delivery
- Limit
  Terminates the breath
- Cycle
  Initiates the frequency

- Mandatory
  • A/C, SIMV
- Pressure
  • PC (Pressure Control, Time Cycled)
- Dual Control
  • PRVC (A/C, SIMV)
  • APRV
- Spontaneous
  • CPAP
  • Pressure Support
How the work of breathing partitions between the patient and the ventilator depends on:

1. Mode of ventilation (e.g., in A/C majority of work done by the ventilator)
2. Patient effort and synchrony with the mode of ventilation
3. Specific settings of a given mode (e.g., level of pressure in PS and set rate in SIMV)
Mandatory Ventilation
ASSIST CONTROL (A/C)

- A/C - Tidal volume ($V_T$) of each delivered breath is the same, regardless of whether it was triggered by the patient or the ventilator. At the start of a cycle, the ventilator senses a patient's attempt at inhalation by detecting negative airway pressure or inspiratory flow.
SYNCHRONIZED INTERMITTENT MANDATORY VENTILATION (SIMV)

SIMV - Delivers a minimum number of fully assisted breaths per minute, synchronized with patient respiratory effort. Breaths are patient- or time-triggered, flow-limited, and volume-cycled. However, any breaths taken between volume-cycled breaths are not assisted; the volumes of these breaths are determined by the patient's strength, effort, and lung mechanics.
CLINICAL CONSIDERATIONS

- Volume Control Modes (A/C, SIMV)
  - Guaranteed $V_T$ regardless of compliance
  - In non-variable flow modes (A/C, SIMV) PIFR demands may not be met
  - Can cause increased Paw leading to barotrauma, volutrauma and adverse hemodynamic effects
- Ventilation Asynchrony $\uparrow$ WOB
PRESSURE CONTROL
PRESSURE – TIME CYCLED

• Pressure
  • PC - ventilator delivers a flow to maintain the preset pressure at a preset respiratory rate over a preset inspiratory time (IT)

• Clinical Considerations
  • Ability to manage Paw
  • Variable $V_T$ as pulmonary mechanics (compliance) change
  • Potential for excessive $V_T$ as compliance improves
DUAL CONTROL MODES
PRESSURE REGULATED VOLUME CONTROL (PRVC/VC+)

- **PRVC** - Pressure modulates (up or down) to achieve a preset tidal volume. Breaths are controlled by pressure (inspiratory + PEEP) and volume, limited by pressure (inspiratory + PEEP) and cycled by time.
CLINICAL CONSIDERATIONS - PRVC

• Advantage of both V and P control – maintains minimum Paw to provide constant $V_T$
• Manages ventilation breath-to-breath ($P \uparrow$ or $\downarrow$ to maintain $V_T$ based on $V_T$ of previous breath)
• The pressure limit fluctuates between 0 cm H$_2$O above the PEEP level to 5 cm H$_2$O below the High-pressure alarm
• Improved patient-ventilator synchrony
• Variable PIFR
• If patient demand $\uparrow$’s pressure level may $\downarrow$ when support is most necessary resulting in $\downarrow$ Pmean leading to hypoxemia
AIRWAY PRESSURE RELEASE VENTILATION (APRV)

- APRV - Time cycled pressure mode that cycles between two different baseline pressures (Hi/Lo) based on time that can be synchronized with patient effort. Controlled ventilation can be maintained by time cycling and occurs when pressures changes from high to low. PS can be added. Inverse Ratio.
CLINICAL CONSIDERATIONS - APRV

- Mandatory breaths occur when P changes from High to Low
- Variable Flow
- Preservation of spontaneous breathing at high CPAP
- ↓ WOB, ↓ barotrauma, ↓ circulatory compromise, ↓ sedation
- $V_T$ changes with alteration in compliance
SPONTANEOUS

• Continuous positive airway pressure/Pressure Support ventilation (CPAP/PSV) – Flow Cycled
  • CPAP – demand breaths with the pressure level during inspiration equal to the preset-PS + PEEP and cycled by time or flow.

• Non-Invasive Positive Pressure Ventilation (NIPPV)
  • BiPAP - is a continuous positive airway pressure (CPAP) mode used during noninvasive positive pressure ventilation. It delivers a preset inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). Rate can be set to guarantee bursts of IPAP.
• Pressure Support
  • Always use in SIMV – preset RR
  • Patient generated breaths must overcome resistance - \( \uparrow \) WOB
VENTILATOR-INDUCED LUNG INJURY

• Two primary mechanistic factors:
  • Overdistension of alveoli by high transpulmonary pressures: volutrauma (↑ VT)
  • Shear-stress forces (Atelectrauma) produced by repetitive alveolar recruitment and derecruitment: collapse
  • Biotrauma (inflammatory mechanisms) and Barotrauma (ambient pressure changes)

• The degree of overinflation is dependent on:
  • VT
  • Paw
  • Duration of mechanical ventilation
ADDITIONAL CONSIDERATIONS

- Arterial Blood Gas
  - Assess pH (Acidotic, Alkalotic) (7.35 – 7.45)
  - Determine Respiratory Involvement (PaCO2) (35 – 45)
  - Determine Metabolic Involvement (HCO₃⁻, BE) (22 – 26)
  - Assess for compensation (pH↑PaCO2 ↓HCO₃⁻)
  - Metabolic Considerations (Anion Gap, Lactate)

  *Normal ABG is not normal in Critically Ill patient*

- Lactate (Prognostic Value)
- Hemodynamics
- Ventilation dysynchrony
OXYHEMOGLOBIN DISSOCIATION CURVE

- Describes the non-linear tendency for oxygen to bind to hemoglobin: below a SaO2 of 90%, small differences in hemoglobin saturation reflect large changes in PaO2.
LUNG PROTECTIVE STRATEGIES

Ventilate at Ideal Body Weight (IBW)
Males (kg): 50 kg + 2.3 kg for each inch over 5 ft
(lb): 105 lbs + 6 lbs for each inch over 5ft.
Females (kg): 45.5 kg + 2.3 kg for each inch over 5 ft
(lb): 100 lbs + 5 lbs for each inch over 5ft.

Lungs of dogs ventilated for a few hours with $V_T$ demonstrates extensive hemorrhagic injury.

ARDS 2012 NETWORK

- Oxygenation Goal: PaO$_2$ 55-80 mmHg or SpO$_2$ 88-95%
  - PEEP-FIO$_2$ Combination
  - Permissive Hypercapnia
  - O$_2$ Index = FIO$_2$ x MAP
    \[ \text{PaO}_2 \]
- P$_{plat}$ Goal: ≤ 30 cm H$_2$O
  - Check P$_{plat}$ (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or V$_T$
- pH GOAL: 7.30-7.45
- I: E Ratio Goal: Recommend that duration of inspiration be ≤ duration of expiration
IMPORTANT PRINCIPLES

Intrinsic PEEP

↑ WOB and can be offset by applying
external PEEP

↑ Expiratory resistance

↑ Respiratory rate

Δ in Pmean

Measure of the pressure applied across the
lung and chest wall

Arterial oxygenation
Cardiac output

V/Q

V without Q – Dead space
Q without V – Shunt
VENTILATOR LIBERATION

• Spontaneous Breathing Trial (SBT)
  • FiO₂ ≤ 40% and PEEP ≤ 8 OR FiO₂ < 50% and PEEP < 5
  • PEEP and FiO₂ ≤ values of previous day
  • Systolic BP ≥ 90 mmHg without vasopressor support
  • No neuromuscular blocking agents

• Mechanics
  • RSBI (f/Vₜ) < 105/min/L
  • Monitor Compliance (ΔV/ΔP, Cstat, Cdyn)
    • Cstat = Vₜ / Pplat – PEEP (inspiratory pause)
    • Cdyn = Vₜ / PIP– PEEP (active inspiration)
QUESTION #1

1) Which of the following is NOT a ventilator goal during management of ARDS

a) PaO2 55-80
b) pH < 7.2
c) Plateau pressure < 30
d) Vt 6 ml/kg of ideal body weight
QUESTION #2

2) Which of the following is a potentially deleterious effect of mechanical ventilation
   a) Respiratory muscle hypertrophy
   b) Increased mucociliary motility
   c) Decreased intracranial pressure
   d) Reduced cardiac output
The respiratory system can be thought of as a mechanical system consisting of

- resistive (airways + ETT)
- elastic (lungs and chest wall) elements in series
1. At the beginning of the inspiratory cycle, ventilator has to generate a pressure $P_{res}$ to overcome the airway resistance.

2. Next pressure rises in a linearly to reach $P_{peak}$.

3. At end inspiration, air flow is zero and the pressure drops by an amount equal to $P_{res}$ to reach $P_{plat}$. Pressure returns to baseline during passive expiration.

Pressure-time waveform is a reflection of the pressures generated within the airways during each phase of the ventilatory cycle.