The Basics of Ventilator Management

What are we really trying to do here

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Overview

• Approach to the physiology of the lung and physiological goals of mechanical Ventilation
• Different Modes of Mechanical Ventilation and when they are indicated
• Ventilator complications
• Ventilator Weaning
• Some basic trouble shooting

How we breath

http://people.eku.edu/ritchisong/301notes6.htm
How a Mechanical Ventilator works

• The First Ventilator - the Iron Lung
  – Worked by creating negative atmospheric pressure around the lung, simulating the negative pressure of inspiration

How a Mechanical Ventilator works

• The Modern Ventilator
  – The invention of the demand oxygen valve for WWII pilots if the basis for the modern ventilator

How a Mechanical Ventilator works

• The Modern Ventilator
  – How it works

Flow Sensor
Pressure Sensor
Inspiratory Limb
Expiratory Limb
Ventilator
Capillary Limb
So what are the goals of Mechanical Ventilation

• What are we trying to control
  – Oxygenation
    • Amount of oxygen we are getting into the blood
  – Ventilation
    • The movement of air into and out of the lungs, mainly effects the pH and level of CO\(_2\) in the blood stream

<table>
<thead>
<tr>
<th>Lab</th>
<th>Oxygenation</th>
<th>Ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Ox</td>
<td>Saturation &gt;88-90%</td>
<td>pCO(_2) (40mmHg)</td>
</tr>
<tr>
<td>Arterial Blood Gas(ABG)</td>
<td>(P_O_2) (75-100 mmHg)</td>
<td>pH (~7.4)</td>
</tr>
</tbody>
</table>

Oxygenation

How do we effect Oxygenation

• Fraction of Inspired Oxygen (FiO\(_2\))
  – Percentage of the gas mixture given to the patient that is Oxygen
    • Room air is 21%
    • On the vent ranges from 30-100%

• So if the patient’s blood oxygen levels are low, we can just increase the amount of oxygen we give them
How do we effect Oxygenation

• Positive End Expiratory Pressure (PEEP)
  – positive pressure that will remains in the airways at the end of the respiratory cycle (end of exhalation) that is greater than the atmospheric pressure in mechanically ventilated patients.

– Has two primary Effects
  • Increases the uptake of Oxygen into the blood stream
    – Henry's law: the solubility of a gas in a liquid is directly proportional to the pressure of that gas above the surface of the solution.
    – So the more pressure on the oxygen the more of it will pass across the alveolocapillary membrane and increase the oxygen content in the blood.
  • Helps splint collapsed or partially consolidated airways open recruiting more alveoli for gas exchange
    – Reduces atelectasis
    – Main effect is on Oxygenation but does have a minimal effect on ventilation but should not be used for this purpose
How do we effect Oxygenation

• Positive End Expiratory Pressure (PEEP)
  – Extrinsic PEEP vs Intrinsic PEEP (Auto-PEEP)
  • Intrinsic PEEP is increasing intrathoracic pressure due to incomplete exhalation of air
    – Mainly seen in obstructive lung disease: COPD and Asthma
    – Due to collapse of the airways on exhalation

Result is a build up of pressure that decreases Cardiac Blood Return that then results in hypotension

PEEP from the Vent is not the same as and does not result in AutoPEEP

– Actually reduces it by preventing airway collapse

Quick test: detach the ET tube from the vent tube for 30-45 secs, reattach and immediately repeat the BP. If auto PEEP should see an immediate improvement.
How do we effect Ventilation

• The amount of ventilation effects the amount of CO₂ eliminated from the body
  ➢ Varies the amount of CO₂ in the blood (pCO₂)
  ➢ This varies the pH
• If the patient is:
  — Acidotic- you increase the ventilation to try and eliminate more CO₂ and buffer to normal
  — Alkalotic- you decrease the ventilation to try and retain more CO₂ to buffer to normal

How do we effect Ventilation

• The amount of ventilation is expressed as:
  — Minute Ventilation (MV or V₅₀)
    • The amount of air cycled through the lung in 1 minute
      — Normal at rest is 5-6 l/min
    • Minute Ventilation is calculated by
      \[ \text{Respiratory Rate} \times \text{Tidal Volume (V₅₀)} \]
      — Tidal Volume- the amount of air in 1 breath expressed in CCs

How do we effect Ventilation

• Respiratory Rate
  — Increasing it will blow off more CO₂ and raise the pH
  — Decreasing it will hold onto to CO₂ and drop the pH
• Tidal Volume
  — Increasing the size will blow off more CO₂ and raise the pH
  — Decreasing the size will hold onto to CO₂ and drop the pH
Let's put these two concepts together
Oxygenation + Ventilation

Quick approach to Vent and ABG

Ventilator Modes

- Most Ventilator Modes are focused with how we control the MV - mainly through different ways of delivering the Tidal Volume
- Ventilator Modes can be broken down into two rough categories based on what we set as the fixed value vs what we allow to vary with each breath
  - Volume driven Modes where we set the volume of each breath
  - Pressure driven Modes where we set how much pressure we use to give each breath
The Relationship Between Volume and Pressure

Pulmonary Compliance

- The measure of the lungs ability to stretch and expand
- On vent this is exhibited by the relationship between Volume and Pressure
  - Compliance = $\Delta V / \Delta P$

Pressure also Influence by Airway Resistance

- Resistance in the Airways increases the amount of pressure needed to deliver a full breath
- Resistance is mainly driven by the Radii of the airways
### Ventilator Modes

<table>
<thead>
<tr>
<th>Volume Driven</th>
<th>TV</th>
<th>Driving pressure</th>
<th>Peep</th>
<th>Peak Pressure</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Mechanical Ventilation (CMV)</td>
<td>Set</td>
<td>Fixed</td>
<td>Varies</td>
<td>Varies</td>
<td>Oldest form, rarely seen today, rate is totally fixed, patient can not get additional breaths, mainly only used in OR anesthesia machines.</td>
</tr>
<tr>
<td>Assist Control Ventilation (AC)</td>
<td>Set</td>
<td>Set</td>
<td>Varies</td>
<td>Set</td>
<td>Rate and TV will give additional breaths if patient attempts them.</td>
</tr>
<tr>
<td>Pressure Driven</td>
<td>Varies</td>
<td>Set</td>
<td>Set</td>
<td>Set</td>
<td>Used to try to minimize high airway pressures that can result in Barotrauma, vent will give additional breaths over set rate if patient attempts them.</td>
</tr>
<tr>
<td>Pressure Support (PS)</td>
<td>Varies</td>
<td>Varies</td>
<td>Set</td>
<td>Set</td>
<td>Patient fully drives rate, mainly used as a weaning mode.</td>
</tr>
</tbody>
</table>

- **Hybrid Modes**
  - Synchronized Intermittent Mandatory Ventilation (SIMV)
    - Hybrid between AC and PS
    - You set a: Baseline Rate, TV, PS, FIO2 and PEEP
    - Pt gets whatever amount of breaths you set (like CMV), if they wish to breath more then that, then those breaths are done with the PS
Ventilator Modes

• Hybrid Modes
  – Airway Pressure Release Ventilation (APRV)
    • Has been shown to decrease peak airway pressures, improve alveolar recruitment, increase ventilation of dependent lung zones
    • Actually better for oxygenation and ventilation
    • Useful in patients with poor pulmonary compliance
      – Ex chest trauma or super morbid obesity

![Pressure-time curve for APRV](https://www.researchgate.net/profile/Ehab_Daoud2/publication/227860541/figure/fig1/AS:648610702176256@1531652250374/Pressure-time-curve-for-APRV-P-high-is-the-high-CPAP-P-low-is-the-low-CPAP-T.png)

Ventilator Modes

• Hybrid Modes
  – Neutrally Adjusted Ventilatory Assist

![Neutrally Adjusted Ventilatory Assist](https://www.maquet.com/contentassets/c5fd3e44458046d384a04c75a98c5ebf/ventilator-asynchrony.png)

![Neutrally Adjusted Ventilatory Assist](https://thoracickey.com/wp-content/uploads/2016/06/B9781455707928000325_f032-009a-9781455707928.jpg)
Ventilator Modes

- Vent Vs Noninvasive Ventilation (Bipap)
  - NIV Insp Pressure = Pressure Support
  - NIV Exp Pressure = PEEP
  - Only practical difference is how the device is attached to the patient

Specific Disease States:
Acute Respiratory Distress Syndrome (ARDS)

- Respiratory Failure characterized by the acute onset of bilateral alveolar infiltrates and hypoxemia
- Settings
  - Set initial TV at 6 ml/kg PBW
  - Goal of plateau pressure ≤30 cm H₂O
  - Adjust RR to get a pH of 7.25-7.35
  - Permissive Hypercapnia used to lower airway pressures
  - Adjust FiO₂ and PEEP to get a goal PaO₂ 55-80 mmHg or SpO₂ 88-95%

Specific Disease States: COPD/Asthma

- Due to collapse of the airways and respiratory muscle disadvantage from hyperinflation, patient’s are prone to auto-PEEP and worsening air trapping
- Pt may have hypercarbia at baseline, so a high CO₂ may be normal for them, let the pH guide you
- Settings
  - Set initial TV at 6 ml/kg PBW
  - Goal of plateau pressure ≤30 cm H₂O
  - Set rate for and I:E ratio of 1:2-3
  - May need to use higher flows to accomplish this
  - Permissive Hypercapnia is acceptable here
  - May need to increase PEEP to help counter balance auto-PEEP
  - Adjust FiO₂ and PEEP to get a goal PaO₂ 55-80 mmHg or SpO₂ 88-95%
  - May also need to adjust the flow trigger, as some severe COPD patients have trouble producing a enough flow to trigger the vent
Complications of Mechanical Ventilation

- **High Pressures**
  - Barotrauma - stretch injury to the lung
    - Caused by large tidal volumes and high lung pressures
    - Worsens outcomes in ARDS
    - Can lead to Pneumothorax
  - Causes:
    - High Airways Resistance
      - Bronchospasm or ET tube obstruction (mucous plugging vs biting tube)
    - Decreased lung compliance
      - worsening disease (ARDS/CHF), Pneumothorax, mainstem intubation
  - To fix determine underlying problem and fix that

- **High FIO2**
  - High levels of O2 are toxic to the lungs
    - Exact level that is safe has not been determined
    - Goal is ≤50%
      - As long as SpO2 is >90% or pO2 > 60 mmHg
  - To fix
    - Consider increasing PEEP
    - Prone Positioning
    - If available, Inhaled Nitric Oxide
  - **Auto-PEEP**
    - Due to inadequate exhalation time
    - To fix – increase exhalation time

- **Patient-Ventilator Dysynchrony**
  - Causes:
    - Patient discomfort and anxiety
    - Impaired oxygenation/Ventilation
  - Fix:
    - Improve sedation
    - Adjust ventilator mode
    - Paralysis may be considered
Complications of Mechanical Ventilation

- Ventilator Associate Pneumonia
  - Due to interruption of Upper Airway Defenses
    - Impair cough, gag, and Mucous Clearance
    - Colonization of upper airway or GI track
  - Fix:
    - No fool proof method
    - Head of bed at 30-45 deg
    - Minimize time on ventilator
    - Oral Care
    - HiLow suction ET tubes
    - Minimize breaks in vent circuit tubing
    - Drain ventilator circuit condensate

Ventilator Weaning

- Settings should be minimized daily to increase patient’s share of ventilatory effort
  - Minimize amount of FIO₂ (goal 30-40%) and PEEP (goal 5)
  - Decreasing mandatory rate
  - Weaning amount of Pressure support

Ventilator Weaning

- When is the patient ready to wean
  - When the underlying problem has improved
    - FIO₂ ≤40%
  - Minute Ventilation ≤ 10L
  - Mental Status allows patient to follow commands or at least protect airway
Ventilator Weaning

• Spontaneous Breathing Trials (SBTs)
  – Many protocols call for short daily trails 5-10 mins followed by a formal trial for 30min to 2 hrs
  – No vent support- T piece or low level of PEEP(5) or PS(7 mmHg) only
  – Clinical signs of trial failure- Heart rate > 140 BPM, RR >35, SBP >180 or <90, SpO₂ <90, pH <7.32, PaO₂ < 50 mmHg, diaphoresis, agitation

Ventilator Weaning

• Spontaneous Breathing Trials (SBTs)
  – Rapid Shallow Breathing Index (RSBI)
    • RSBI is MV/RR
    • RSBI < 105 shows a small increase in probability of success weaning, however a RSBI >105 shows a significant probability of failing to wean
    – Better negative predictor

Ventilator Troubleshooting

• When you call the Physician don’t just know the settings but know the variable parameters
  – Respiratory rate- the set rate and if and how much patient is over breathing the vent
  – AC- what are the peak pressures and plateau pressures
  – PC or PS- what are the tidal volumes
  – SIMV- peak pressures on the assisted breaths, TV of the pressure supported breaths
Ventilator Troubleshooting

• Respiratory Deterioration with patient on Assist Control

[Diagram showing pressure waveform with labels for PIP, Pplat, compliance, auto-PEEP, and PEEP]

Ventilator Troubleshooting

• Respiratory Deterioration with patient on Assist Control

[Diagram showing changes in PE, PE, and Pplat with labels for Air Leak, Hyperventilation, Increased, and No change]

Major Take Aways

• How to approach the ABG and the Vent
  1. First look at Oxygenation
     • Fix with FiO2 or PEEP
  2. Then look at pH and pCO2
     • Adjust by changing RR or TV
• The different ventilator modes mainly aim at providing ventilation
• Know what mode the vent is in and if it is primarily volume or pressure controlled so you can make understand any changes in the patient
**Major Take Aways**

- Constantly work to minimize ventilator settings to minimize complication and encourage weaning of the patient.
- When you call the Physician don’t just know the settings but know the variable parameters:
  - Respiratory rate: the set rate and if and how much patient is over breathing the vent.
  - AC: what are the peak pressures and plateau pressures.
  - PC or PS: what are the tidal volumes.
  - SIMV: peak pressures on the assisted breaths, TV of the pressure supported breaths.
- If the vent is on AC, then knowing how the peak and plateau pressures have changed can give you hints to what may be wrong.

**References**