The Basics of Ventilator Management

What are we really trying to do here

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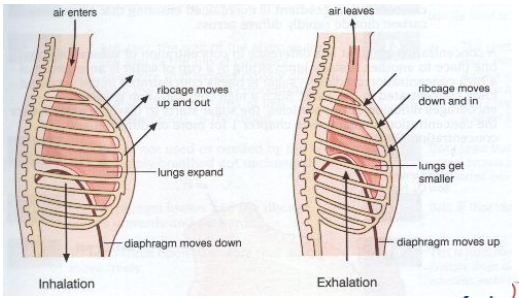
Overview

- 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



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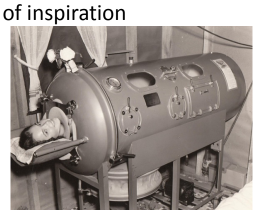
How a Mechanical Ventilator works

- 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

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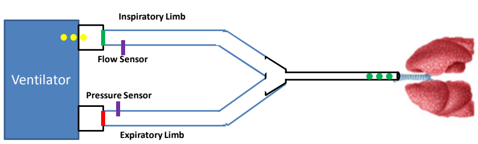
How a Mechanical Ventilator works

- The Modern Ventilator
  - How it works

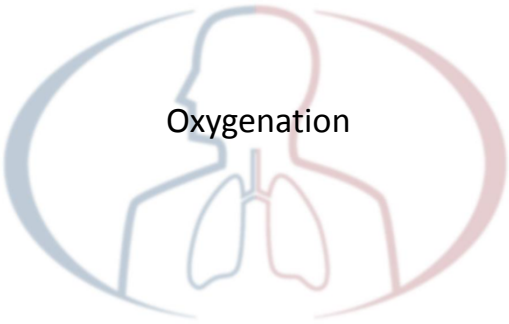


So what are the goals of Mechanical Ventilation

- 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

Lab	Oxygenation	Ventilation
Pulse Ox	Saturation >88-90%	
Arterial Blood Gas(ABG)	Po_2(75-100 mmHg)	pCO_2(40mmHg) ⬇ pH(~7.4)

Oxygenation

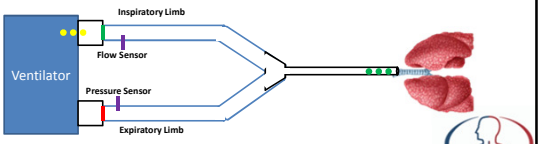


How do we effect Oxygenation

- 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.



How do we effect Oxygenation

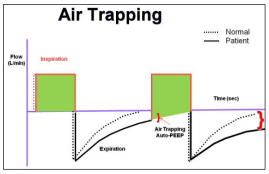
- Positive End Expiratory Pressure (PEEP)
  - Has two primary Effects
    - Increases the uptake of Oxygen into the blood stream
      - Henry's law- the solubility of a gas in a liquid is directly proportional to the pressure of that gas above the surface of the solution.
      - So the more pressure on the oxygen the more of it will pass across the alveolocapillary membrane and increase the oxygen content in the blood.

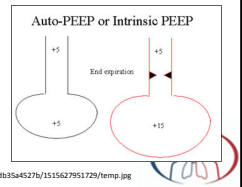
How do we effect Oxygenation

- Positive End Expiratory Pressure (PEEP)
  - Has two primary Effects
    - 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 in complete exhalation of air
      - Mainly seen in obstructive lung disease- COPD and Asthma
      - Due to collapse of the airways on exhalation





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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 in complete exhalation of air
      - 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.

Ventilation

How do we effect Ventilation

- The amount of ventilation effects the amount of CO_2 eliminated from the body
  - ➢Varies the amount of CO_2 in the blood (pCO_2)
    - ➢This varies the pH
- If the patient is:
  - Acidotic- you increase the ventilation to try and eliminate more CO_2 and buffer to normal
  - Alkalotic- you decrease the ventilation to try and retain more CO_2 to buffer to normal

How do we effect Ventilation

- The amount of ventilation is expressed as:
  - Minute Ventilation (MV or $\dot{V}_T$)
    - The amount of air cycled through the lung in 1 minute
      - Normal at rest is 5-6 L/min
    - Minute Ventilation is calculated by

Respiratory Rate	**X**	Tidal Volume (V_T)

      - Tidal Volume- the amount of air in 1 breath expressed in CCs

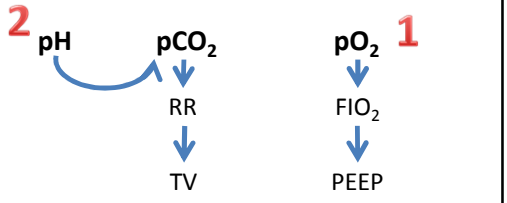
How do we effect Ventilation

- 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

Lets put these two concepts together

Oxygenation + Ventilation

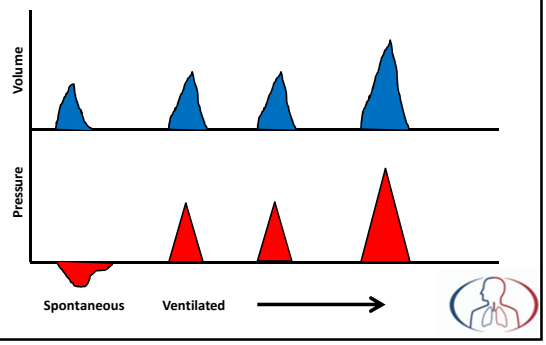
Quick approach to Vent and ABG



Ventilator Modes

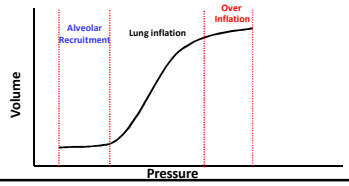
- Most Ventilator Modes are focused with how we control the MV- mainly through different ways of delivering the Tidal Volume
- Ventilator Modes can be broken down into two rough categories based on what we set as the fixed value vs what we allow to vary with each breath
  - Volume driven Modes where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



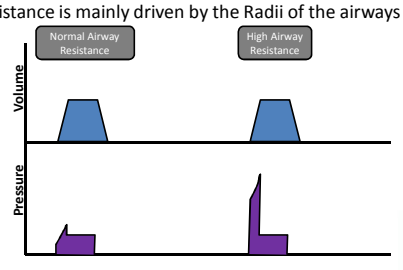
Pulmonary Compliance

- The measure of the lungs ability to stretch and expand
- On vent this is exhibited by the relationship between Volume and Pressure
  - Compliance = ΔV/ Δ 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

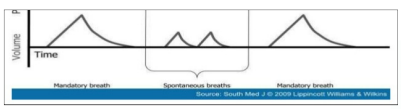
	TV	Driving pressure	Peep	Peak Pressure (Driving Pressure + Peep)	FIO2
Volume Driven	**Set**	**Varies**	Set	**Varies**	Set
Pressure Driven	**Varies**	**Set**	Set	**Set**	Set

Ventilator Modes

	Tidal Volume	Rate	Pressure	Notes
Volume Driven				
Continuous Mechanical Ventilation (CMV)	Set	Fixed	Varies	Oldest form, Rarely seen today, Rate is totally Fixed, patient can not get additional breaths, mainly only used in OR anesthesia machines
Assist Control Ventilation (AC)	Set	Set	Varies	Set rate and TV but vent will give additional breaths if patient attempts them
Pressure Driven				
Pressure Control (PC)	Varies	Set	Set	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
Pressure Support (PS)	Varies	Varies	Set	Patient fully drives rate, mainly used as a weaning mode

Ventilator Modes

- 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

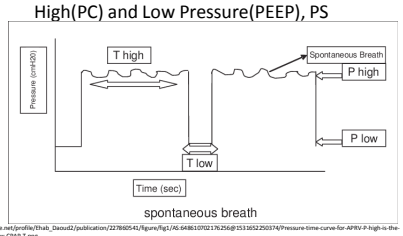


Ventilator Modes

- 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

Ventilator Modes

- Hybrid Modes
  - Airway Pressure Release Ventilation (APRV)
    - You set: RR(usually b/w 6-8 breaths a minute)(T high), a High(PC) and Low Pressure(PEEP), PS



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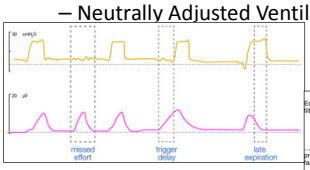
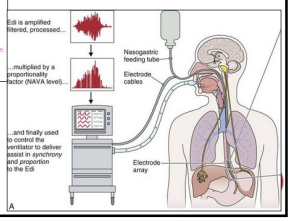
Ventilator Modes

- Hybrid Modes
  - Neutrally Adjusted Ventilatory Assist





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Ventilator Modes

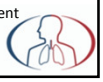
- Vent Vs Noninvasive Ventilation(Bipap)
  - NIV Insp Pressure = Pressure Support
  - NIV Exp Pressure = PEEP
  - Only practical difference is how the device is attached to the patient

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 H_20
  - Adjust RR to get a pH of 7.25-7.35
    - Permissive Hypercapnia used to lower airway pressures
  - Adjust FIO_2 and PEEP to get a goal PaO_2 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 H_20
  - 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

Complications of Mechanical Ventilation

- 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

Complications of Mechanical Ventilation

- 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 FIO_2(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, SpO_2 <90, pH <7.32, PaO_2 < 50 mmHg, diaphoresis, agitation

Ventilator Weaning

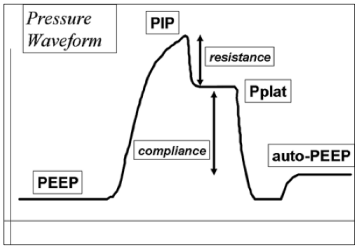
- Spontaneous Breathing Trials(SBTs)
  - Rapid Shallow Breathing Index (RSBI)
    - RSBI is MV/RR
    - RSBI < 105 shows a small increase in probability of success weaning, however a RSBI >105 shows a significant probability of failing to wean
      - Better negative predictor

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



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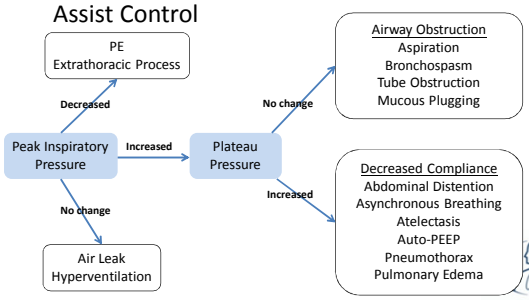
Ventilator Troubleshooting

- Respiratory Deterioration with patient on Assist Control



Major Take Aways

- How to approach the ABG and the Vent
  1. First look at Oxygenation
     - Fix with FIO_2 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

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