Mechanical Ventilation

Educational Reinforcement Material

Table of Contents

Outline

Mechanical Ventilation Basics: Part 1

A. 0055 Goals of Mechanical Ventilation
    a. 0110 1) Maximize patient comfort (MV settings, sedation)
    b. 0134 2) Decrease work of breathing/ allow spontaneous breathing
        i. One of the main reasons for mechanical ventilation is when your patient is having excessive work of breathing and they are either in respiratory failure or on the verge of respiratory failure.
        ii. Optimal type of breath is spontaneous breath
    c. 0230 3) Provide adequate (not perfect) gas exchange (oxygenation and ventilation)
        i. Clearly define oxygen saturation goals
        ii. Clearly define CO_2 goals
            1. 02:53 Example: A patient with a traumatic brain injury would need a normal CO_2 goal because a high CO_2 would increase cerebral blood flow and thereby increase intracranial pressure.
    d. 0330 4) Minimize toxicity
        i. Barotrauma- overdistension
        ii. Volutrauma- high volumes
        iii. Atelectotrauma- opening and closing alveoli
        iv. O_2 toxicity- >60% (even for short periods of time)
        v. 04:15 Adverse effects on the cardiovascular system
    e. 0430 5) This is a supportive therapy to allow time for other interventions to treat the cause of respiratory failure

B. 0511 Basic Review: Respiratory Physiology
    a. 0515 Inhalation
        i. Functional Residual Capacity (FRC): Volume of gas in the lungs at end expiration, but prior to inhalation; a state of no gas exchange
            1. Natural tendency is for the lungs to want to collapse due to the natural elastic forces of the lung
            2. Natural tendency of the chest wall to want to expand outwards
        ii. 0545 Active process by diaphragmatic contraction into the abdomen and the rib cage to move outwards
            1. ↑intra-thoracic volume
            2. ↓ intra-thoracic pressure
            3. ↑ Pressure gradient between atmosphere and intra-thoracic space
    b. 06:20 Exhalation
        i. Passive process
            1. Diaphragm relax
            2. Lung recoils
            3. ↑ intra-thoracic pressure
            4. Creates a pressure gradient (alveolar pressure exceeds atmospheric pressure) and gas flow proceeds out of the lungs
        ii. Active process: obstructive physiology (example: COPD and asthma) causes it to become active

C. 06:55 Positive Pressure Ventilation
    a. Spontaneous breathing occurs via a negative pressure circuit (pulled into the lungs)
    b. Mechanical ventilation is a complete reversal of normal physiological breathing and occurs via a positive pressure system (pushed into the lungs)
    c. Air flow into lungs is now the result of a machine (ventilator) pushing or forcing air into the lungs

D. 0748 Oxygenation
    a. Diffusion: oxygen moves down the concentration gradient, down the alveoli and into the capillaries
    b. 0803 FiO_2 – first way to improve oxygenation

c. 0812 PEEP- second way to improve oxygenation (optimal PEEP)
d. 0826 Mean Airway Pressure average pressure your lung is being exposed to during mechanical ventilation- both inspiration and expiration
    i. 0844 I:E ratio (inspiration to expiration) – lungs stay in expiration twice as long as inspiration
e. 0910 Inspiratory time: can increase oxygenation, but is usually used for refractory hypoxemia; this increases the mean airway pressure -> improved oxygenation
    i. 0930 Allows air re-distribution from highly compliant alveoli to less compliant alveoli
    ii. 0944 Maintaining a larger surface area at end inspiration and allowing more time for air to diffuse across the alveoli and into the capillaries

E. 1002 Ventilation= removal of CO_2 from the body
   a. Simple diffusion + Convection- CO_2 builds up in the capillaries
   b. 1040 Minute Ventilation= Respiratory Rate x Tidal Volume
      i. 1058 Dead space ventilation-in theory people should breathe in gas that is void of CO_2; however, the CO_2 that remains in the airway mixes w/ the inhaled gas=> increased dead space ventilation with worsening respiratory distress/ decreased ventilation => decreased gradient for CO_2 to diffuse out of the capillaries
      ii. 1138: inhalation of CO_2 "void" gas allows CO_2 to diffuse out of the capillaries and into the alveoli, which is removed with exhalation; if we breathe in a larger tidal volume, this will extend the alveoli, which increases the transfer of CO_2 or breath faster by increasing the respiratory rate
      iii. 1212 Tidal volume- limit to how much can deliver, goal 4-8 ml/kg of predicted body weight
         1. If give too much-> volutrauma
      iv. 1237 Respiratory Rate
         1. 1245: Obstructive Lung Disease (e.g. COPD and Asthma)- want to decrease the respiratory rate to allow more time in exhalation because if the expiratory time is too short then the CO_2 is trapped

F. 1352 Complications of Mechanical Ventilation
   a. 1406 Barotrauma: injury to alveoli, caused by excessive pressure from the ventilator
      i. 1607 Looking at the plateau pressure, a.k.a. the pressure that the alveoli see-> this is seen by doing an inspiratory pause
      ii. 1650- limit the plateau pressure to < 30 mmHg
   b. 1413 Volutrauma: over distension of alveoli from excessive tidal volume (Vt)
      i. 1656: limit the tidal volumes to 4-8 ml/ kg of predicted body weight
   c. 1416 Atelectotrauma: damage which may occur when repetitively opening and closing lung units (a type of sheering stress to the lung)
      i. 1705: Importance of Optimal PEEP
         1. 1716 End Inspiration: well expanded and optimal to provide adequate gas exchange
         2. 1729: Expiration with inadequate PEEP: the alveoli collapse and develop atelectasis; a lot more pressure will be needed to expand the alveoli from the collapsed state to the volume at end expiratory (sheer stress)
         3. 1803: Expiration with adequate PEEP: less pressure is needed to re-expand the alveoli at end expiration (have not allowed the alveoli to close and become atelectatic)
         4. 1825: Driving Pressure- difference between the plateau pressure and the PEEP
   d. 1438 Biotrauma: lung injury resulting from inflammation mediators (precipitated by VILI) this can be caused by barotrauma, volutrauma, or atelectotrauma
   e. 1509 Oxygen Toxicity: lung injury due to O_2 induced production of free radicals
      i. Using a goal of <100% saturation allows weaning of FiO_2 and decrease risk of oxygen toxicity; goal of <60% FiO_2

G. 1850: Hemodynamic Consequences

a. Cardiac output is determined by a pressure gradient, or high-pressure system leaving the left ventricle and returning to the heart via a low-pressure system via the right atrium
b. 1911 Spontaneous breathing is a negative pressure, which causes a lower pressure system in the thorax and less resistance of blood flow to return to the right atrium and assist in allowing adequate venous return and pre-load
c. 1932 Positive pressure ventilation leads to positive intrathoracic pressure leads to higher right atrial pressures and impede venous return
    i. 1944 The decrease in venous return is amplified when a patient has decreased intravascular volume. This can lead to a decrease in cardiac output and mean arterial pressure = need a fluid bolus to restore intravascular volume and improve preload.
d. 2010: Right Atrium: Positive pressure is delivered-> increased positive intrathoracic pressure and this pressure is transmitted to the low pressure right atrium -> increase in pressure in the right atrium -> impedance of venous return and decreased preload
    i. This is less of a problem in patients that are not intravascularly volume depleted
e. 2048- Right Ventricle- Increased intrathoracic pressure leads to increase right ventricular afterload, which is normally well tolerated, except in patients with RV failure (e.g. long standing pulmonary hypertension or acutely from a massive PE)=> RV collapse and failure with possible cardiac arrest
f. 2128: Left Ventricle- Positive intrathoracic pressure leads to a decreased pressure gradient between the ventricle and the intrathoracic space will decrease LV afterload => increased stroke volume and cardiac output
    i. 2150- Heart failure- beneficial by assisting the LV and allowing more cardiac output

Mechanical Ventilation Basics: Part 2

A. 0130 Modes
B. 0212 Terminology
    a. 0216 Breath Type: 3 types of breaths that can be delivered (1) controlled (2) assisted (3) spontaneous
    b. 0228 Breath Delivery: How much volume of gas is delivered to the patient (volume or pressure)
    c. 0235 Mode: How breath types are combined together; examples: CMV, ACV, IMV, PS
C. 0256 Mechanical Ventilator Breaths and Pull-ups: Imagine you have never heard or attempted a pull up for this analogy
    a. 0318 Controlled Breath
        i. No work (You just hang on the bar while the trainer pushes you up the bar a few times)
        ii. Ventilator does all the work; the frequency/ rate of the breaths and the amount of gas delivered is fully dependent on the ventilator
            1. 0551 Example: CMV (controlled mandatory ventilation) - ventilator determines the rate and the amount of gas
    b. 0401 Assisted Breath
        i. Start Work (You make the effort to start doing the pull-up, but the trainer knows you are not strong enough- they then do everything, once they see your effort)
        ii. Ventilator takes over the work: The patient will trigger a breath, and once that is sensed by the ventilator, the ventilator does all the work. The patient can determine the respiratory rate.
            1. 0600 Example: ACV (Assist control ventilaton) - combination of a controlled breath and assisted breath
    c. 0450 Supported Breath (also called spontaneous breath)
        i. Able to do some or most of the work (You are now much stronger to start the pull up. The trainer will only give you some support to complete the pullup. The weaker you are, the more support the trainer has to give you, and the inverse is true- the stronger you are, the less support the trainer has to give you)
        ii. Ventilator assists to finish work (i.e. pressure support). The patient starts the process of taking a breath, and only gets some support from the ventilator. However, most of the work is done by the patient.
            1. 0535 Example: pressure support will assist or augment their efforts
            2. 0608 Example: SIMV (synchronized intermittent mandatory ventilation) - Ventilator combines a controlled or assisted breath with a spontaneous breath
D. 0628 Breath Delivery
    a. 0632 Volume breath: a preset amount of gas is delivered to the patient
        i. 0650: The amount of pressure the ventilator needed to deliver this volume of gas is unknown as this depends on the patient's compliance
        ii. 0710 The lower the compliance, or the stiffer the lung, the more pressure it will take to deliver the volume
        iii. 0721 As the compliance increases, or the lung gets more stretchy, the less pressure it will take to deliver the same volume of gas
    b. 0657 Compliance= change in volume / change in pressure
        i. 0820 If you are on a volume mode, pay close attention to the pressure;
            1. if the pressure is increasing -> compliance is decreasing
            2. if the pressure is decreasing-> compliance is increasing
        ii. 0850 If you are on a pressure mode, pay close attention to the volume
            1. if the volume is increasing -> compliance is increasing
            2. if the volume is decreasing-> compliance is decreasing
    c. 0730 Pressure breath: a preset pressure will deliver the gas
        i. 0747 The amount of volume that will be delivered to the patient is unknown

ii. 0748 The lower the compliance means that less volume will be delivered to a patient at a given pressure
iii. 0802 To give a larger volume of gas, in a patient with low compliance, a higher preset pressure would need to be given
iv. 0810 As the compliance increases, or the lung gets more stretchy, the more volume will be delivered with the same amount of pressure

E. 0925 Peak inspiratory pressure (PIP)
   a. 1014- Normally should be in the teens, <20 cm of water pressure
      i. 1045 Dynamic Pressure needed to fully inflate the lung and overcome the resistive and elastic forces of the lungs
   b. 1026 Plateau Pressure (PPlat): pressure that alveoli see (inspiratory pause)- static pressure
   c. 1055 PIP > 30 cm of water pressure, need to check the plateau pressure
      i. 1106 Elevated PIP and elevated PPlat= indicate decrease compliance
         1. 1113 Lung itself = pulmonary edema, pneumonia, ARDS, or pulmonary contusion
         2. 1121 Chest wall/ thorax= pneumothorax, pleural effusion, large circumferential burns w. eschar formations
         3. 1136 Abdomen= massive ascites or abdominal compartment syndrome
   d. 1145 Elevated PIP and low PPlat= high resistance in the circuit or patient
      i. Examples: pt biting ET tube, kinked ET tube, increased secretions, mucous plugging, COPD or Asthma

F. 1236 Pressure Vs Volume
   a. 1257: Advantage of Volume delivered breath
      i. More control over the minute ventilation = tidal volume X respiratory rate
      ii. More clinicians are familiar with volume breaths
   b. 1343: Disadvantage of Volume delivered breath
      i. As compliance decreases, there will be need for higher peak. Inspiratory pressures, which can lead to barotrauma
      ii. Flow pattern is delivered, constant flow wave form, can lead to patient discomfort and there by increased peak inspiratory pressures = 1433 square breath on the ventilation
   c. 1407 Note: we breath by a decelerating inspiratory wave form
   d. 1456: Advantage of Pressure delivered breath
      i. Uses a decelerating waveform, which is physiological and can be more comfortable for the patient
      ii. Lower. Peak inspiratory pressure compared to a volume breath
      iii. Improves oxygenation due to a higher mean airway pressure compared to volume breath
   e. 1533: Disadvantages of Pressure delivered breath
      i. No direct control over minute ventilation; have to make sure the patient is getting an adequate tidal volume for the pressure
      ii. Less familiar to clinicians
      iii. Have to constantly pay attention to the pressures, since compliance is changing a lot, to get an adequate or appropriate tidal volume

Manual

Mechanical Ventilation Part 1

Learning objectives

LIST THE GOALS OF MECHANICAL VENTILATION

NAME THE FACTORS THAT CONTROL OXYGENATION AND VENTILATION

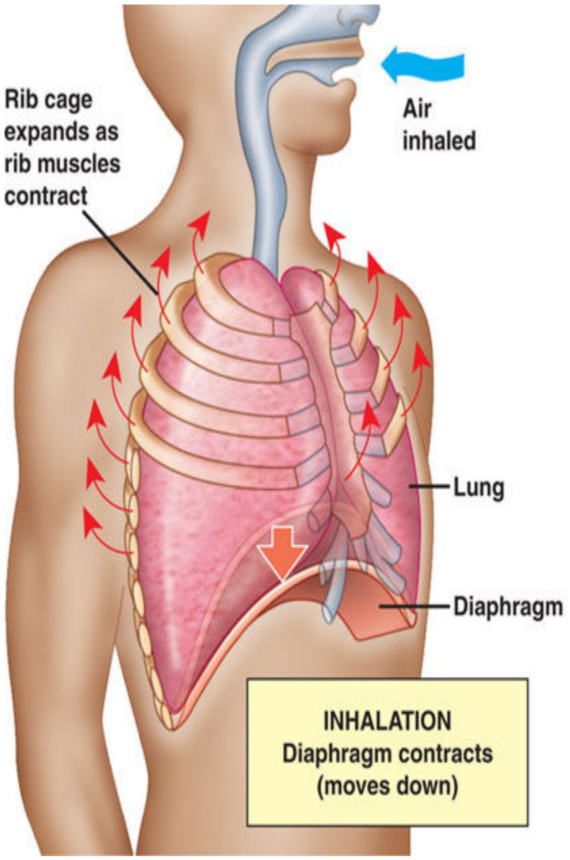
DISCUSS COMPLICATIONS THAT MAY ARISE DURING MECHANICAL VENTILATION

Goals of Mechanical Ventilation 0055

1. Maximize patient comfort (MV settings, sedation)
2. Decrease work of breathing/ allow spontaneous breathing
   - One of the main reasons for mechanical ventilation is when your patient is having excessive work of breathing and they were either in respiratory failure or on the verge of respiratory failure.
   - Optimal type of breath is spontaneous breath
3. Provide adequate (not perfect) gas exchange (oxygenation and ventilation)
   - Clearly define oxygen saturation goals
   - Clearly define CO_2 goals
     - Example: A patient with a traumatic brain injury would need a normal CO_2 goal because a high CO_2 would increase cerebral blood flow and thereby increase intracranial pressure.
4. Minimize toxicity
   - Barotrauma- overdistension
   - Volutrauma- high volumes
   - Atelectotrauma- opening and closing alveoli
   - O_2 toxicity- >60% (even for short periods of time)
   - Adverse effects on the cardiovascular system
5. This is a supportive therapy to allow time for other interventions to treat the cause of respiratory failure

Basic Review: Respiratory Physiology 0511

Inhalation



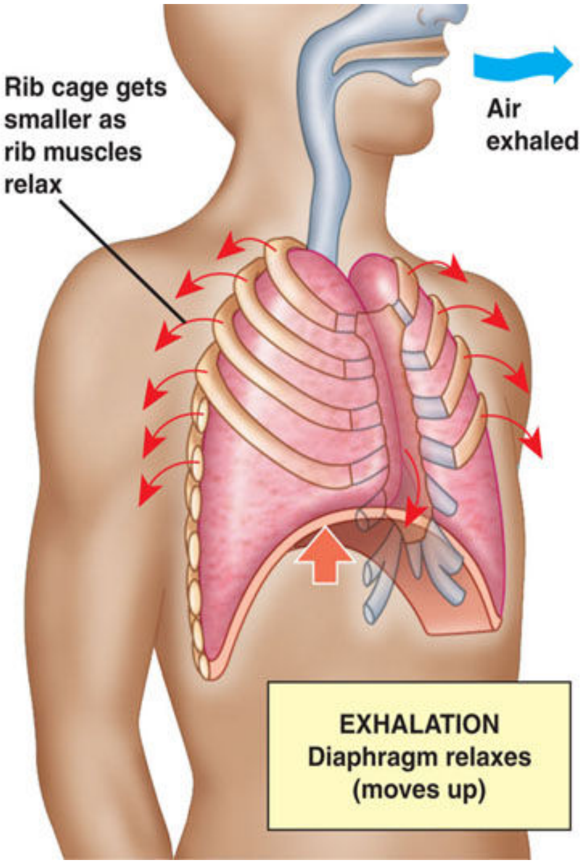
Functional Residual Capacity (FRC): Volume of gas in the lungs at end expiration, but prior to inhalation; a state of no gas exchange

Natural tendency is for the lungs to want to collapse due to the natural elastic forces of the lung

Natural tendency of the chest wall to want to expand outwards

- Active process by diaphragmatic contraction into the abdomen and the rib cage to move outwards
- ↑intra-thoracic volume
- ↓ intra-thoracic pressure
- ↑ Pressure gradient between atmosphere and intra-thoracic space

Exhalation



- Passive process = Diaphragm relax
- Lung recoils
- ↑ intra-thoracic pressure
- Creates a pressure gradient (alveolar pressure exceeds atmospheric pressure) and gas flow proceeds out of the lungs

Active process: obstructive physiology (example: COPD and asthma) causes it to become active

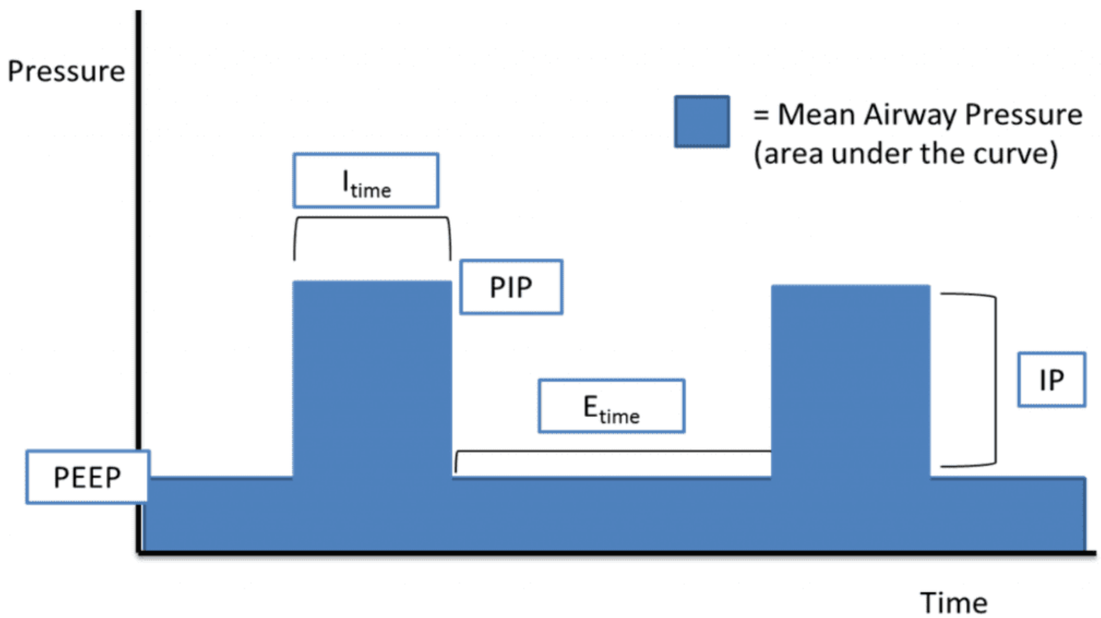
Positive Pressure Ventilation 0655

- Spontaneous breathing occurs via a negative pressure circuit (pulled into the lungs)
- Mechanical ventilation is a complete reversal of normal physiological breathing and occurs via a positive pressure system (pushed into the lungs)
- Air flow into lungs is now the result of a machine (ventilator) pushing or forcing air into the lungs

Oxygenation 0748

Diffusion: oxygen moves down the concentration gradient, down the alveoli and into the capillaries

1. FiO_2 – first way to improve oxygenation
2. PEEP (positive end- expiratory pressure)- second way to improve oxygenation (optimal PEEP)
   a. Mean Airway pressure: average pressure your lung is being exposed to during mechanical ventilation- both inspiration and expiration
   b. I:E ratio (inspiration to expiration) – lungs stay in expiration twice as long as inspiration
3. Inspiratory time: can increase oxygenation, but is usually used for refractory hypoxemia
   a. Increases the mean airway pressure -> improved oxygenation
   b. Allows air re-distribution from highly compliant alveoli to less compliant alveoli
   c. Maintaining a larger surface area at end inspiration and allowing more time for air to diffuse across the alveoli and into the capillaries



Ventilation= removal of CO_2 from the body

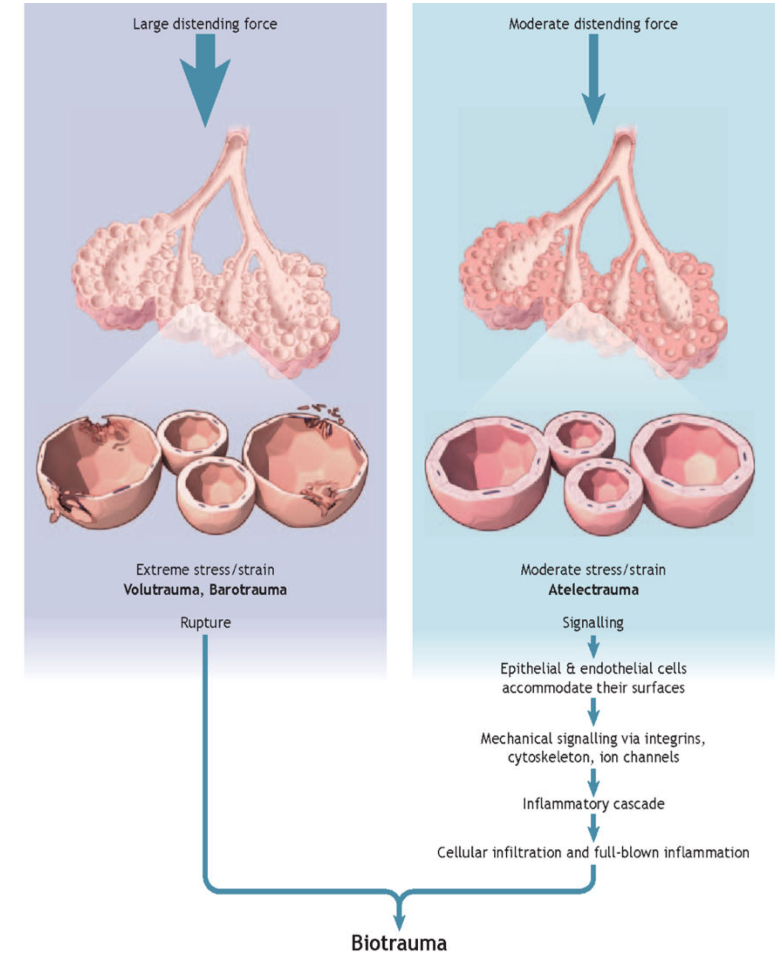
Simple diffusion + Convection- CO_2 builds up in the capillaries

Minute Ventilation= Respiratory Rate x Tidal Volume

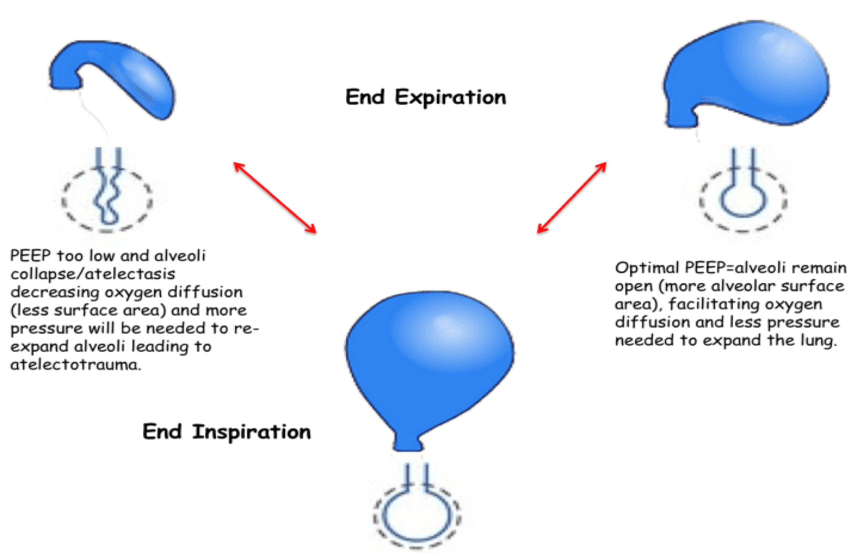
1. Respiratory Rate
2. Tidal Volume
    - Dead space ventilation-in theory people should breathe in gas that is void of CO_2; however, the CO_2 that remains in the airway mixes w/ the inhaled gas=> increased dead space ventilation with worsening respiratory distress/ decreased ventilation => decreased gradient for CO_2 to diffuse out of the capillaries
    - Inhalation of CO_2 "void" gas allows CO_2 to diffuse out of the capillaries and into the alveoli, which is removed with exhalation; if we breathe in a larger tidal volume, this will extend the alveoli, which increases the transfer of CO_2 or breath faster by increasing the respiratory rate
    - Tidal volume- limit to how much can deliver, goal 4-8 ml/kg of predicted body weight
        - If give too much-> volutrauma
3. Expiratory Time
    - Obstructive Lung Disease (e.g. COPD and Asthma)- want to decrease the respiratory rate to allow more time in exhalation because if the expiratory time is too short then the CO_2 is trapped

Complications of Mechanical Ventilation 1352

Ventilator Associated Lung Injury (VILI)



1. Barotrauma: injury to alveoli, caused by excessive pressure from the ventilator
   - Plateau pressure, aka the pressure that the alveoli see-> this is seen by doing an inspiratory pause
   - limit the plateau pressure to < 30 mmHg
2. Volutrauma: over distension of alveoli from excessive tidal volume (Vt)
   - Limit the tidal volumes to 4-8 ml/ kg of predicted body weight
3. Atelectotrauma: damage which may occur when repetitively opening and closing lung units (a type of sheering stress to the lung)
   - Importance of Optimal PEEP
   - End Inspiration: well expanded and optimal to provide adequate gas exchange
   - Expiration with inadequate PEEP: the alveoli collapse and develop atelectasis; a lot more pressure will be needed to expand the alveoli from the collapsed state to the volume at end expiratory-> sheer stress
   - Expiration with adequate PEEP: less pressure is needed to re-expand the alveoli at end expiration-> have not allowed the alveoli to close and become atelectatic

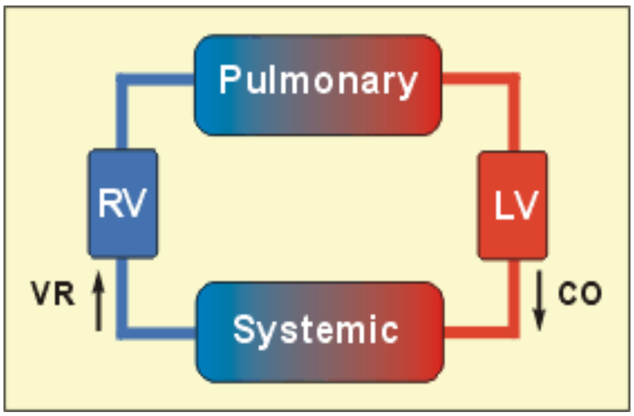


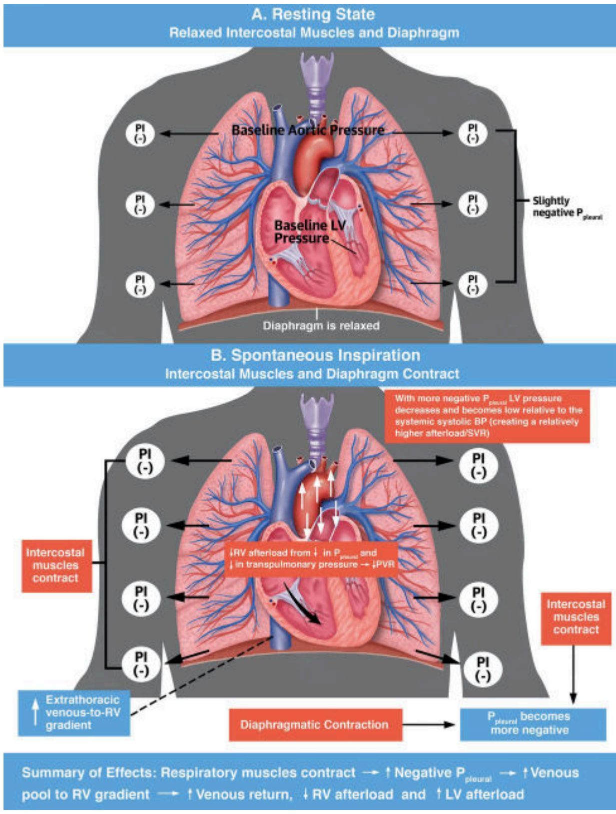
  - Driving Pressure- difference between the plateau pressure and the PEEP
4. Biotrauma: lung injury resulting from inflammation mediators (precipitated by VILI) this can be caused by barotrauma, volutrauma, or atelectotrauma
5. Oxygen Toxicity: lung injury due to O_2 induced production of free radicals
   - Using a goal of <100% saturation allows weaning of FiO2 and decrease risk of oxygen toxicity; goal of <60% FiO_2

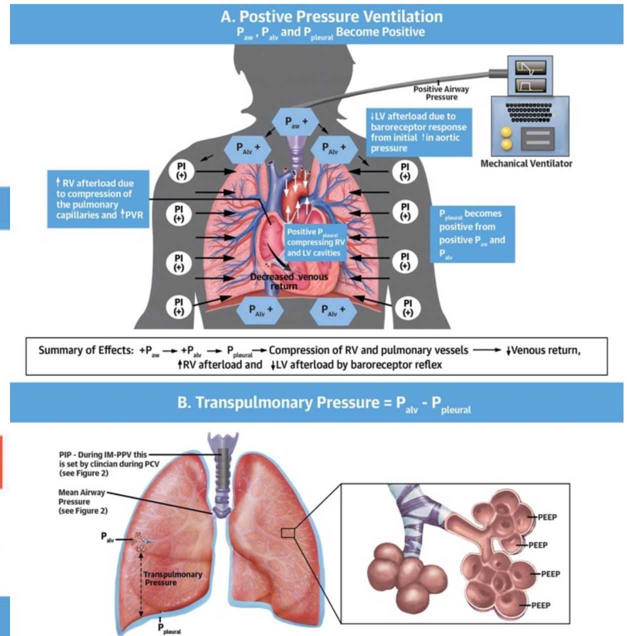
Hemodynamic Consequences 1850

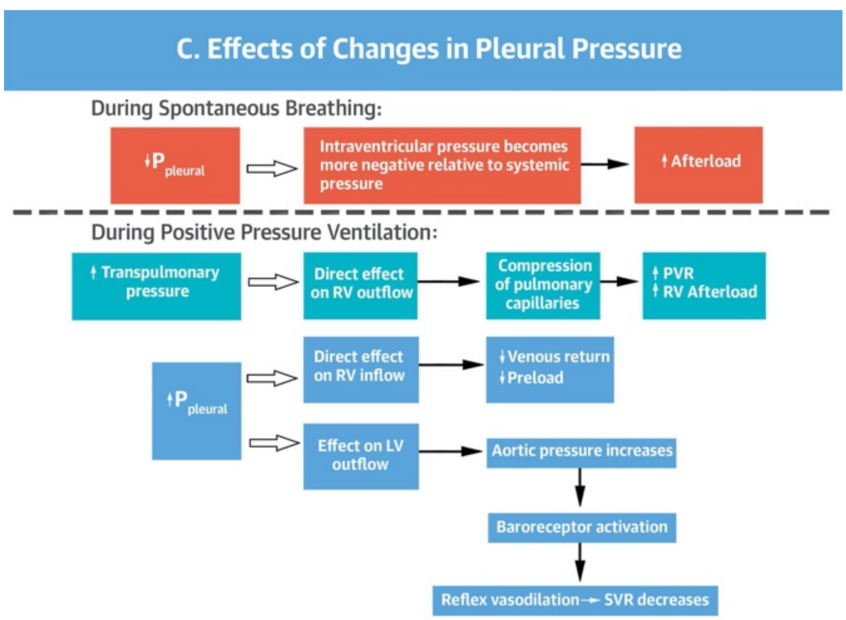
Cardiac output is determined by a pressure gradient, or high-pressure system leaving the left ventricle and returning to the heart via a low-pressure system via the right atrium

Spontaneous breathing is a negative pressure, which causes a lower pressure system in the thorax and less resistance of blood flow to return to the right atrium and assists in allowing adequate venous return and pre-load



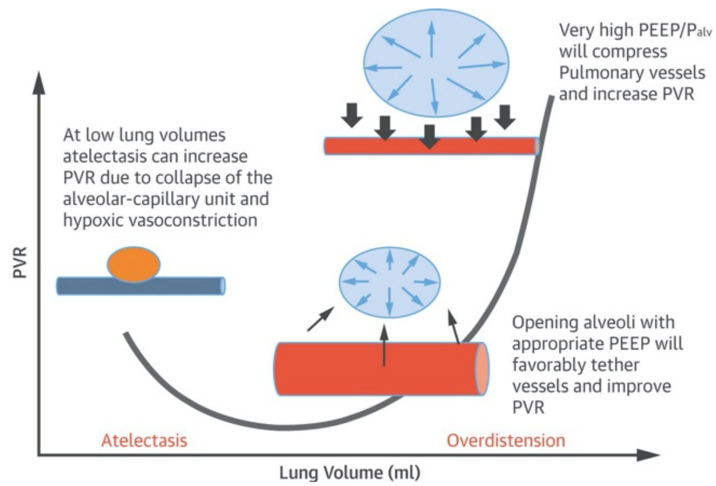


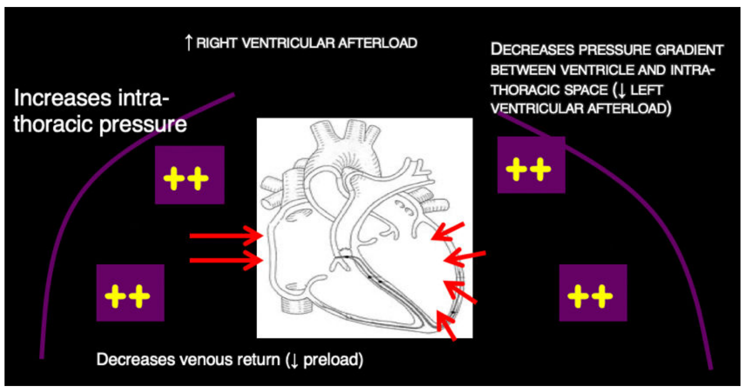




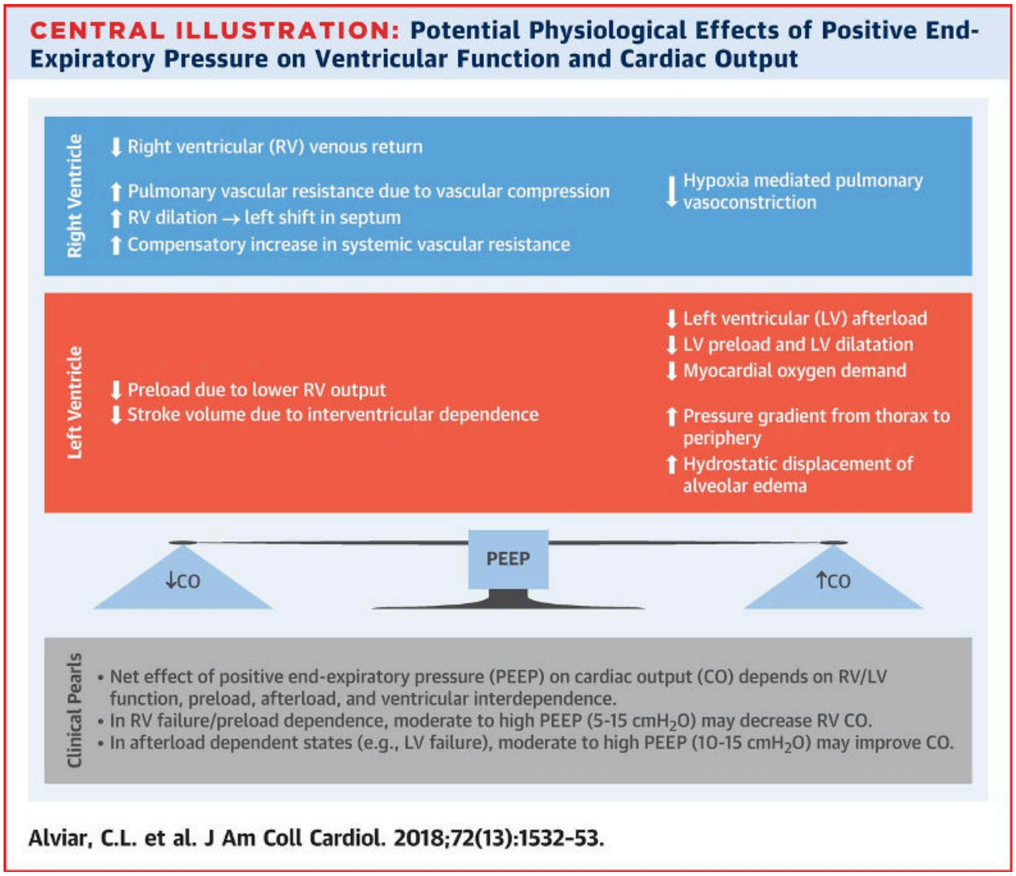
Positive pressure ventilation leads to positive intrathoracic pressure leads to higher right atrial pressures and impede venous return

The decrease in venous return is amplified when a patient has decreased intravascular volume. This can lead to decrease in cardiac output and mean arterial pressure = need a fluid bolus to restore intravascular volume and improve preload.





- Right Atrium-
  - Positive pressure is delivered-> increased positive intrathoracic pressure and this pressure is transmitted to the low pressure right atrium -> increase in pressure in the right atrium -> impedance of venous return and decrease preload
  - This is less of a problem in patients that are not intravascularly volume depleted
- Right Ventricle-
  - Increased intrathoracic pressure leads to increase right ventricular afterload, which is normally well tolerated, except in patients with RV failure (e.g. long standing pulmonary hypertension or acutely from a massive PE)=> RV collapse and failure with possible cardiac arrest
- Left Ventricle-
  - Positive intrathoracic pressure leads to a decreased pressure gradient between the ventricle and the intrathoracic space will decrease LV afterload => increased stroke volume and cardiac output
- Heart failure-
  - beneficial by assisting the LV and allowing more cardiac output


CENTRAL ILLUSTRATION: Potential Physiological Effects of Positive End-Expiratory Pressure on Ventricular Function and Cardiac Output
Right Ventricle
↓ Right ventricular (RV) venous return
↑ Pulmonary vascular resistance due to vascular compression
↑ RV dilation → left shift in septum
↑ Compensatory increase in systemic vascular resistance
↓ Hypoxia mediated pulmonary vasoconstriction
Left Ventricle
↓ Preload due to lower RV output
↓ Stroke volume due to interventricular dependence
↓ Left ventricular (LV) afterload
↓ LV preload and LV dilatation
↓ Myocardial oxygen demand
↑ Pressure gradient from thorax to periphery
↑ Hydrostatic displacement of alveolar edema
↓CO
PEEP
↑CO
Clinical Pearls
• Net effect of positive end-expiratory pressure (PEEP) on cardiac output (CO) depends on RV/LV function, preload, afterload, and ventricular interdependence.
• In RV failure/preload dependence, moderate to high PEEP (5-15 cmH$_2$O) may decrease RV CO.
• In afterload dependent states (e.g., LV failure), moderate to high PEEP (10-15 cmH$_2$O) may improve CO.
Alviar, C.L. et al. J Am Coll Cardiol. 2018;72(13):1532-53.

Mechanical Ventilation Basics: Part 2

Learning objectives

NAME THE 3 TYPES OF BREATHS

LIST THE 2 WAYS BREATHS CAN BE DELIVERED

Modes 0130

Terminology

Breath Type: 3 types of breaths that can be delivered

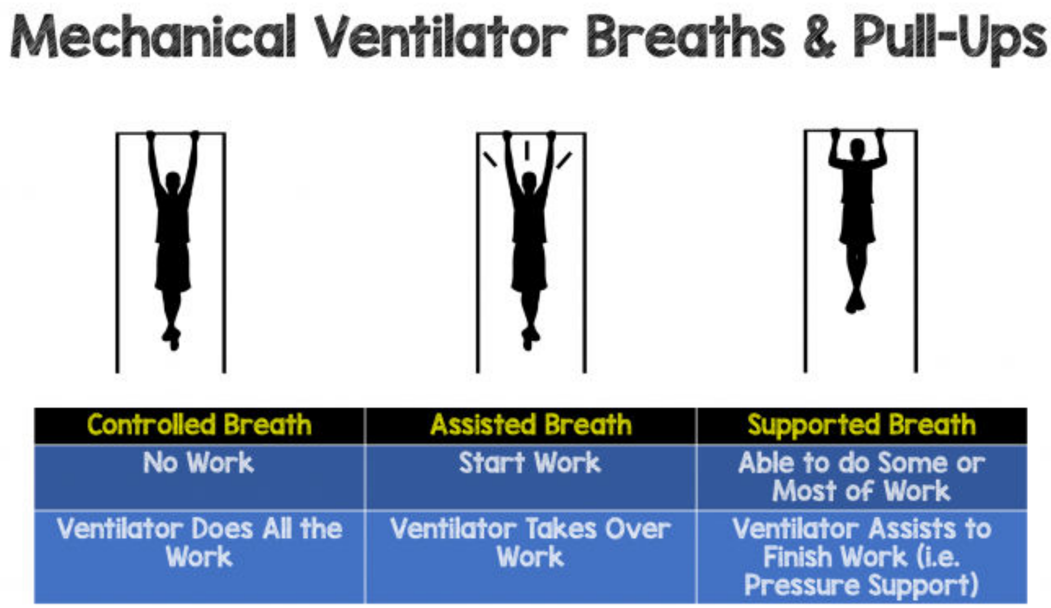
1. controlled
2. assisted
3. spontaneous

Breath Delivery: How much volume of gas is delivered to the patient

- Volume
- Pressure

Mode: How breath types are combined together; examples: CMV, ACV, IMV, PS

Mechanical Ventilator Breaths and Pull-ups 0256



Imagine you have never heard or attempted a pull up for this analogy

1. Controlled Breath
   - No work (You just hang on the bar while the trainer pushes you up the bar a few times)
   - Ventilator does all the work; the frequency/ rate of the breaths and the amount of gas delivered is fully dependent on the ventilator
     - Example: CMV (controlled mandatory ventilation)- ventilator determines the rate and the amount of gas
2. Assisted Breath
   - Start Work (You make the effort to start doing the pull-up, but the trainer knows you are not strong enough. Then they then do everything, once they see your effort.
   - Ventilator takes over the work: The patient will trigger a breath, and once that is sensed by the ventilator- the ventilator does all the work. The patient can determine the respiratory rate.
     - Example: ACV (Assist control ventilation)- combination of a controlled breath and assisted breath
3. Supported Breath (also called spontaneous breath)
   - Able to do some or most of the work (You are now much stronger start the pull up. The trainer will only give you some support to complete the pullup. The weaker you are, the more support the trainer has to give you, and the inverse is true- the stronger you are, the less support the trainer has to give you.)
   - Ventilator assists to finish work (i.e. pressure support). The patient starts the process of taking a breath, and only gets some support from the ventilator. However, most of the work is done by the patient.
     - Example: pressure support will assist or augment their efforts
     - Example: SIMV (synchronized intermittent mandatory ventilation)- Ventilator combines a controlled or assisted breath and combine with a spontaneous breath

Breath Delivery 0628

Volume breath: a preset amount of gas is delivered to the patient

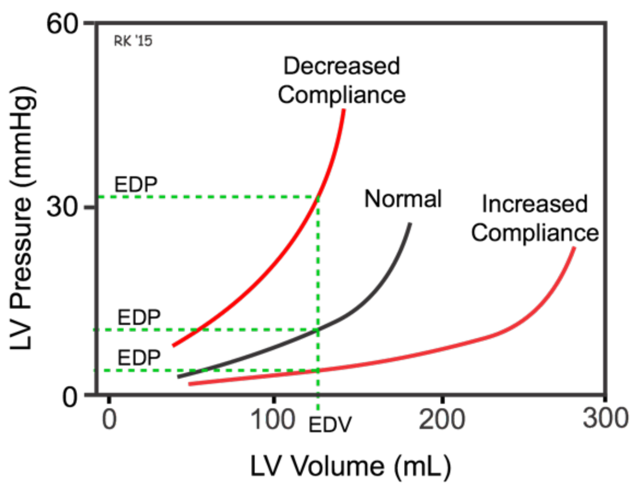
- The amount of pressure the ventilator needed to deliver this volume of gas is unknown, as this depends on the patient's compliance
- The lower the compliance, or the stiffer the lung, the more pressure it will take to deliver the volume
- As the compliance increases, or the lung gets more stretchy, the less pressure it will take to deliver the same volume of gas

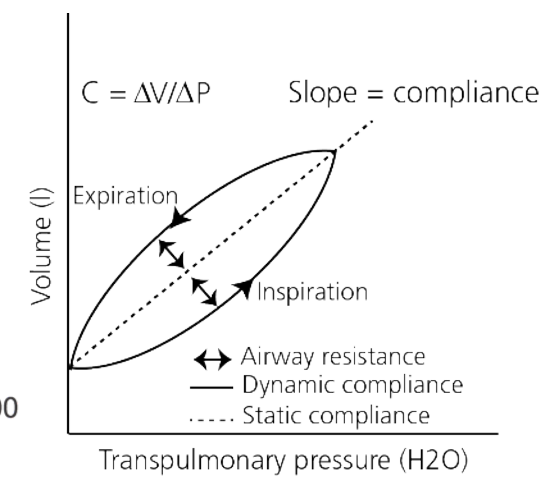
Pressure breath: a preset pressure will deliver the gas

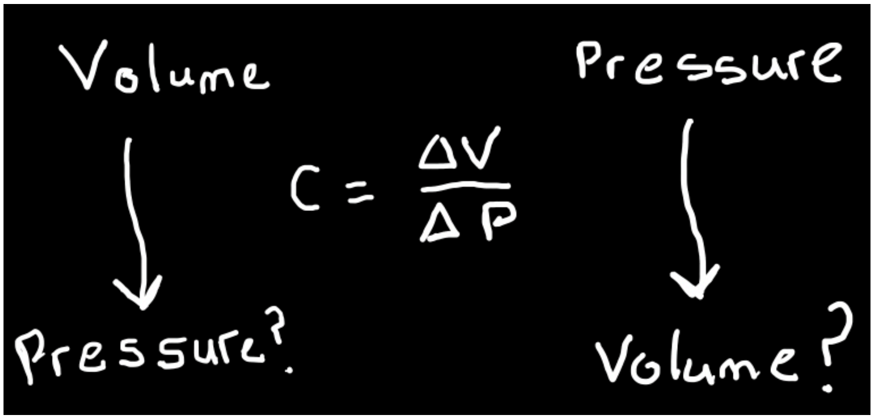
- The amount of volume that will be delivered to the patient is unknown, as this depends on the patient's compliance
- The lower the compliance means that less volume will be delivered to a patient at a given pressure
- To give a larger volume of gas, in a patient with low compliance, a higher preset pressure would need to be given
- As the compliance increases, or the lung gets more stretchy, the more volume will be delivered with the same amount of pressure

Compliance= change in volume / change in pressure

- If you are on a volume mode, pay close attention to the pressure
  - ↑ pressure = ↓ compliance
  - ↓ pressure= ↑ compliance
- If you are on a pressure mode, pay close attention to the volume
  - ↑volume = ↑ compliance
  - ↓ volume= ↓ compliance







Peak inspiratory pressure (PIP)

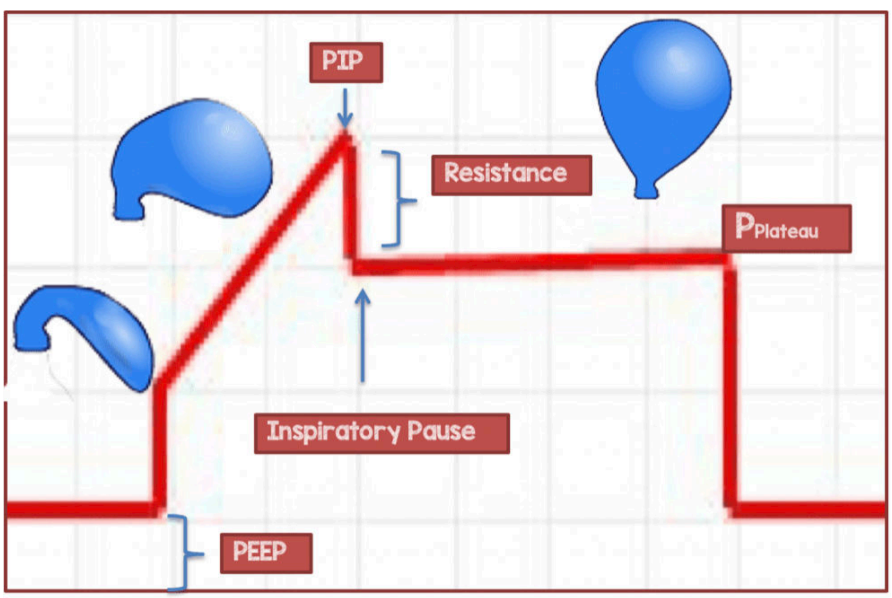
- Normally should be in the teens, <20 cm of water pressure
- Dynamic Pressure needed to fully inflate the lung and overcome the resistive and elastic forces of the lungs

Plateau Pressure (PPlat):

- pressure that alveoli see (inspiratory pause)
- static pressure since there is no air movement
- PIP > 30 cm of water pressure, need to check the plateau pressure

Airway Resistance:

- PIP – Plateau Pressure
- Normally <5cmH20 unless excessive airway resistance



Increased PIP & PPlat	Increased PIP & Unchanged PPlat
Acute Respiratory Distress Syndrome (ARDS) Pulmonary Contusion Pulmonary Edema Pleural Effusion (Large) Tension Pneumothorax Circumferential Chest Wall Burn Massive Ascites Abdominal Compartment Syndrome (Or Abdominal Packing) Pneumonia	ETT Occlusion (Kink, Biting) Secretions/Mucous Plugging Bronchospasm

Elevated PIP and elevated PPlat= indicate decrease compliance (↑ PIP + ↑ PPlat = ↓ compliance)

Lung itself= pulmonary edema, pneumonia, ARDS, or pulmonary contusion

Chest wall/ thorax= pneumothorax, pleural effusion, large circumferential burns w. eschar formations

Abdomen= massive ascites or abdominal compartment syndrome

Elevated PIP and low PPlat= high resistance in the circuit or patient

Examples: patient biting ET tube, kinked ET tube, increased secretions, mucous plugging, COPD or Asthma

Pressure Vs Volume 1236

	Advantage	Disadvantage
Volume Delivered	Minute Ventilation = RR x V_t	↑ PIP 
Pressure Delivered	 ↑ MAP	Ø direct control over MV Δ Pressure based on $C = \frac{\Delta V}{\Delta P}$

Advantage of Volume delivered breath

- More control over the minute ventilation = tidal volume X respiratory rate
- More clinicians are familiar with volume breaths

Disadvantage of Volume delivered breath

- As compliance decreases there will be need for higher peak inspiratory pressures, which can lead to barotrauma
- Flow pattern is delivered, constant flow wave form, can lead to patient discomfort and there by increased peak inspiratory pressures = square breath on the ventilation
- Note: we breath by a decelerating inspiratory wave form

Advantage of Pressure delivered breath

- Uses a decelerating waveform, which is physiological and can be more comfortable for the patient
- Lower. Peak inspiratory pressure compared to a volume breath
- Improves oxygenation due to a higher mean airway pressure compared to volume breath

Disadvantages of Pressure delivered breath

- No direct control over minute ventilation; have to make sure the patient is getting an adequate tidal volume for the pressure
- Less familiar to clinicians
- Have to constantly pay attention to the pressures, since compliance is changing a lot, to get an adequate or appropriate tidal volume

Modes of Mechanical Ventilation	Types of Breaths	Independent Variable	Dependent Variable	Notes
Volume Assist/Control	Assisted or Controlled	Preset Tidal Volume	PIP & Plateau Pressures	Control tidal volume (lung protective) Control of minute ventilation (RR & Vt)
Pressure Assist/Control	Assisted or Controlled	Preset Pressure	Adequate Tidal Volumes (not too high or low)	Patient comfort (decelerating flow), Control over delivered pressures (avoid barotrauma)
Pressure Support (PS)	Supported	Preset Pressure	Adequate Tidal Volumes (not too high or low)	Patient comfort Allows patient to maintain respiratory work effort
Synchronized Intermittent Mandatory Ventilation (SIMV) + PS	Assisted, Controlled or Supported	PC-SIMV=Preset Pressure VC-SIMV=Preset Tidal Volume	PC-SIMV=Adequate Tidal Volumes (not too high or low) VC-SIMV=PIP & Plateau Pressures	Can get benefits of supported breaths (PS), but still ensure minimum number of mandatory breaths (controlled or assisted)
Pressure Regulated Volume Control (PRVC)	Assisted or Controlled	Preset Tidal Volume	PIP & Plateau Pressures	Control Minute Ventilation Control Vt, Patient comfort (decelerating flow), Can limit high pressures (avoid barotrauma)