Ventilator Management 101

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Basic Ventilator settings

Affects mainly oxygen (Hypoxic failure)

Affects mainly CO_2 (Hypercarbic failure)

FiO_2

Tidal Volume

Respiratory rate

PEEP

FiO_2 (Fraction of Inspired Air)

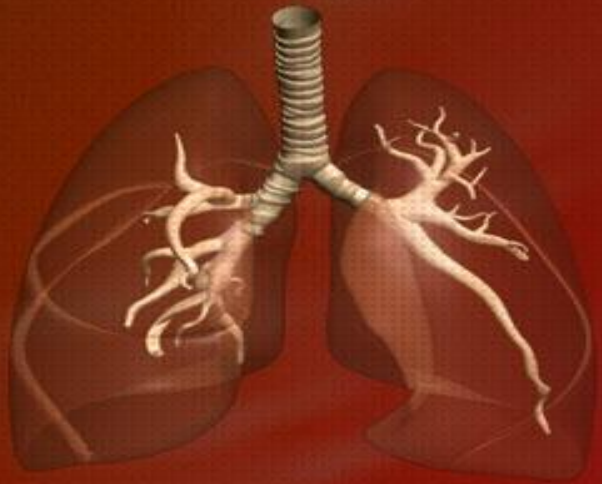
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0 %

Room air is 21%

FiO_2 (Fraction of Inspired Air)

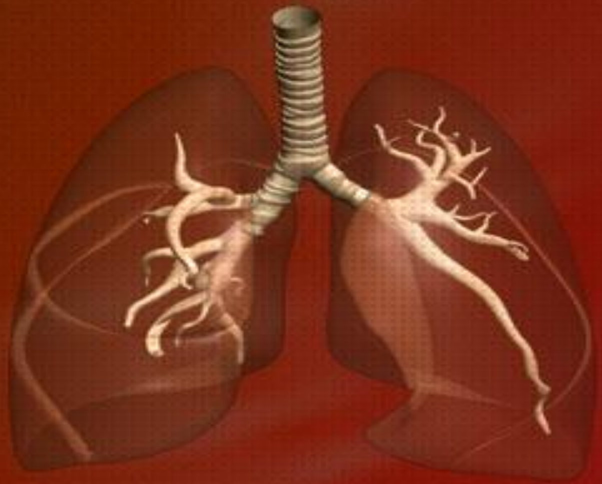
100% = 1.0
90% = 0.9
80% = 0.8
70% = 0.7
60% = 0.6
50% = 0.5
40% = 0.4
30% = 0.3
20% = 0.2
10% = 0.1
0 % = 0.0

Generally, FiO_2 is expressed as a decimal place rather than a percentage when dealing with ventilators.



FiO_2 (Fraction of Inspired Air)

Often start FiO_2 at 1.0 (100%) after intubation and titrate to an arterial oxygen saturation (SaO_2) greater than 90% and/or a PaO_2 greater than 60 mm Hg



Negative impact of FiO_2 : Oxygen Toxicity

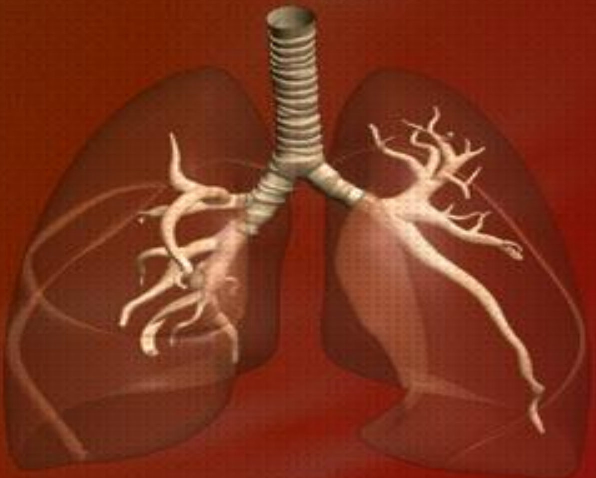
Oxygen is highly reactive, making it susceptible to one electron reductions resulting in the production of oxygen free radicals

- O_2 (superoxide)
- HO (hydroxil radical)
- 1 O_2 (singlet oxygen)
- H_2O_2 (hydrogen peroxide)

Intracellular enzymes exist which can eliminate oxygen free radicals

In hyperoxia, production of oxygen free radicals exceeds the capacity of the antioxidant enzymes to detoxify them.

Inactivates enzymes, perturbs membrane functions and damages genetic material resulting in death and lysis of oxygen sensitive cells resulting in the microvascular and alveolar cell injury

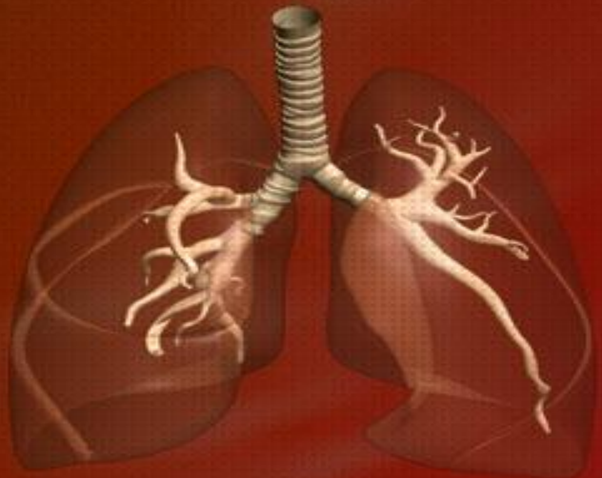


Negative impact of FiO_2: Oxygen Toxicity

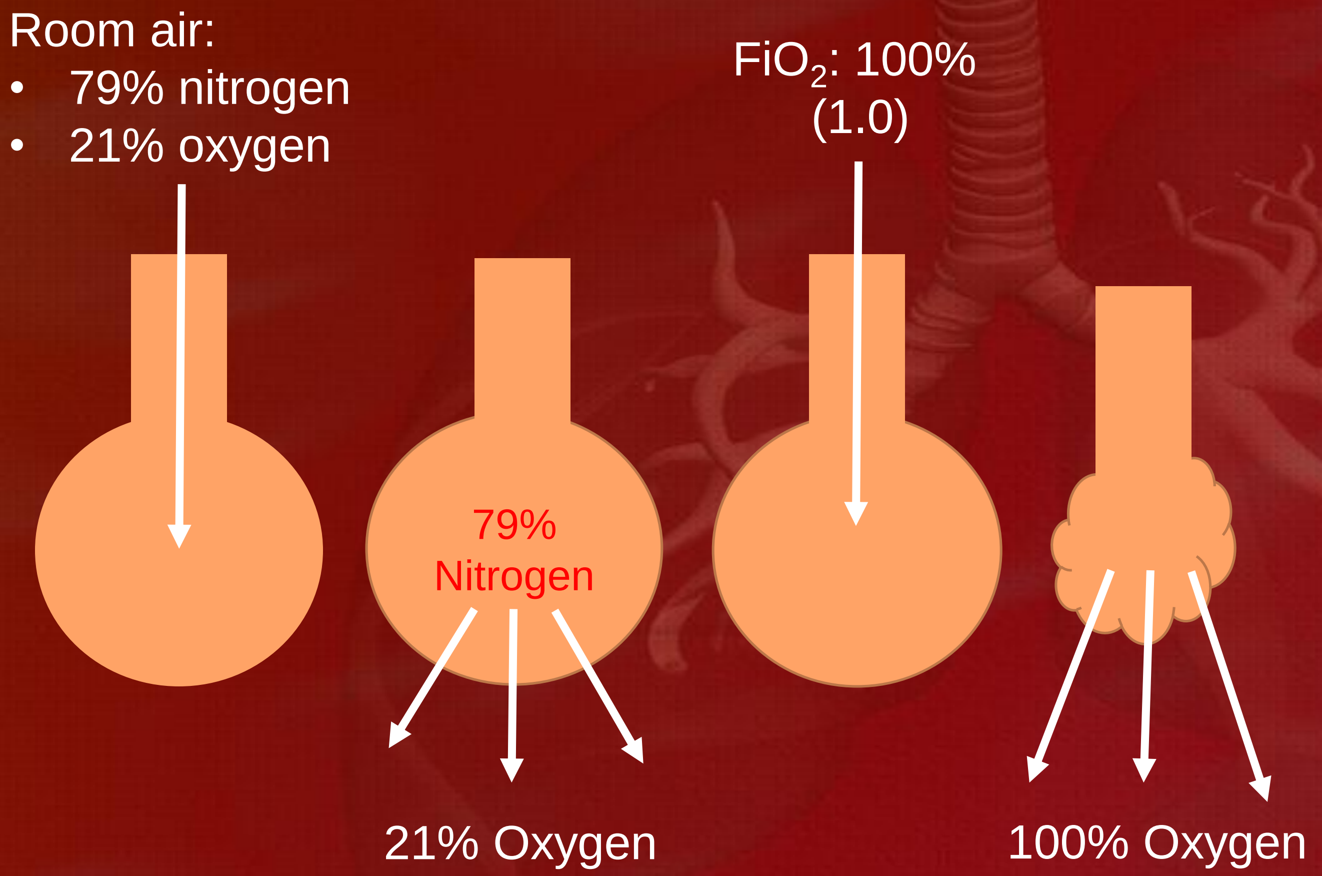
Studies indicate that the risk of oxygen toxicity exists in FiO_2 levels above 0.5, likely for longer than 24 hours.

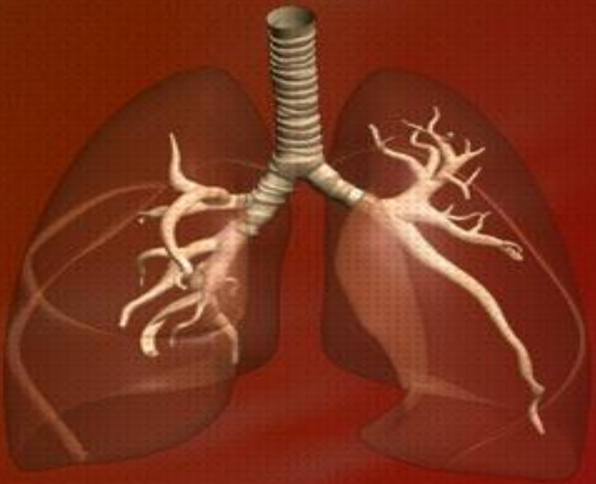
The end results of oxygen toxicity include:

- Decreases in inspiratory and expiratory lung volumes
- Decreases in flow rates
- Decreases in carbon dioxide diffusing capacity
- Decrease in lung capacity
- Increase susceptibility to mucous plugging, atelectasis and secondary infection by impairing mucociliary clearance



Negative impact of FiO_2 : Nitrogen Washout





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- Tidal Volume
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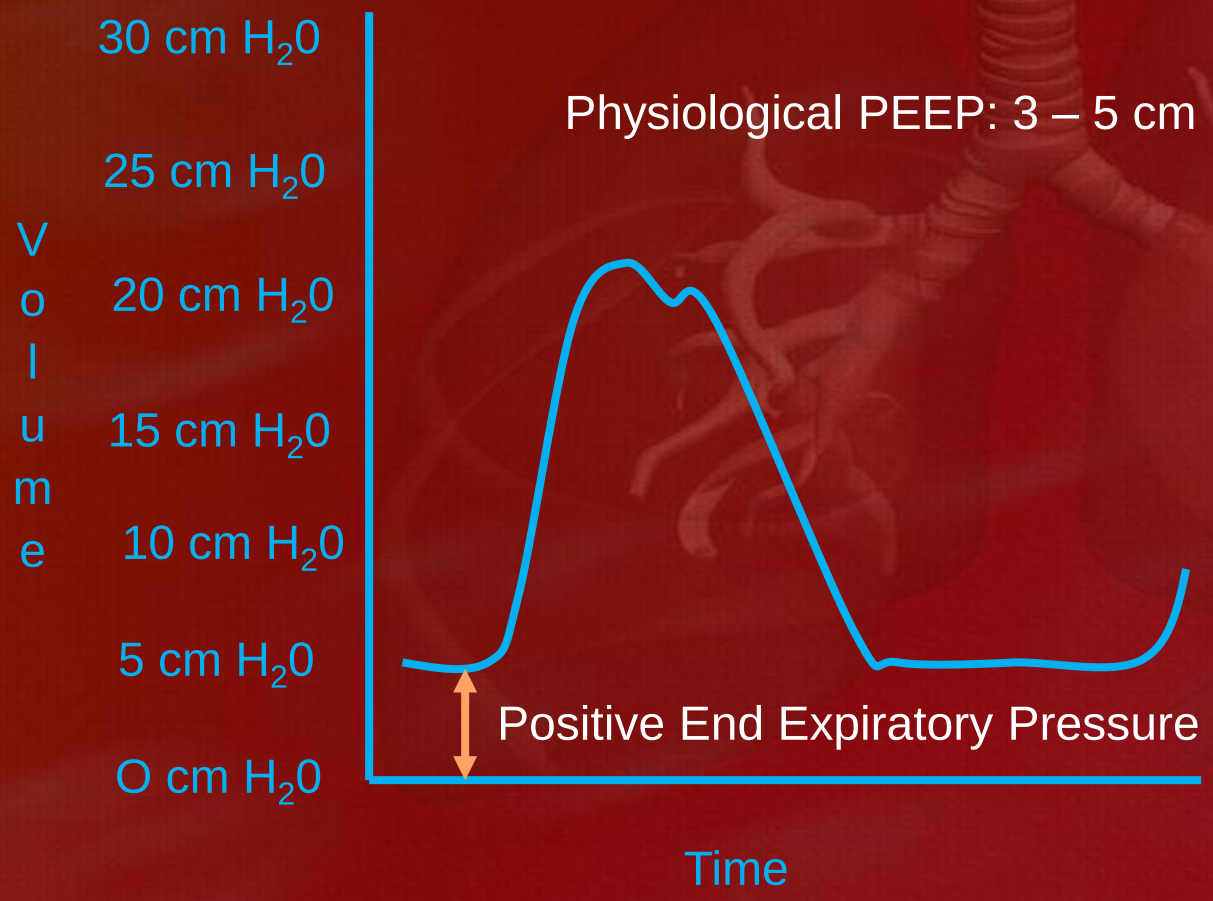
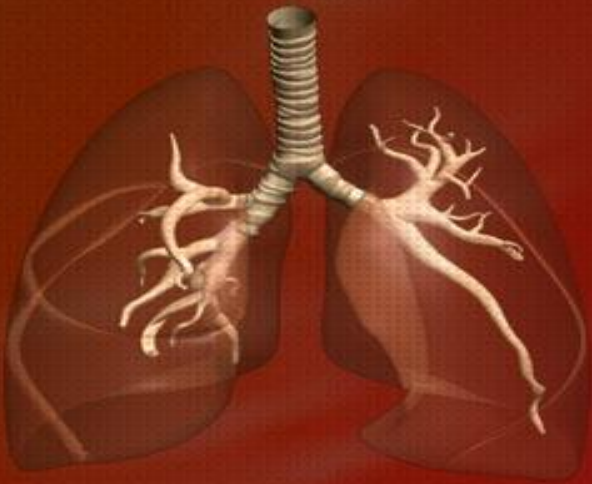
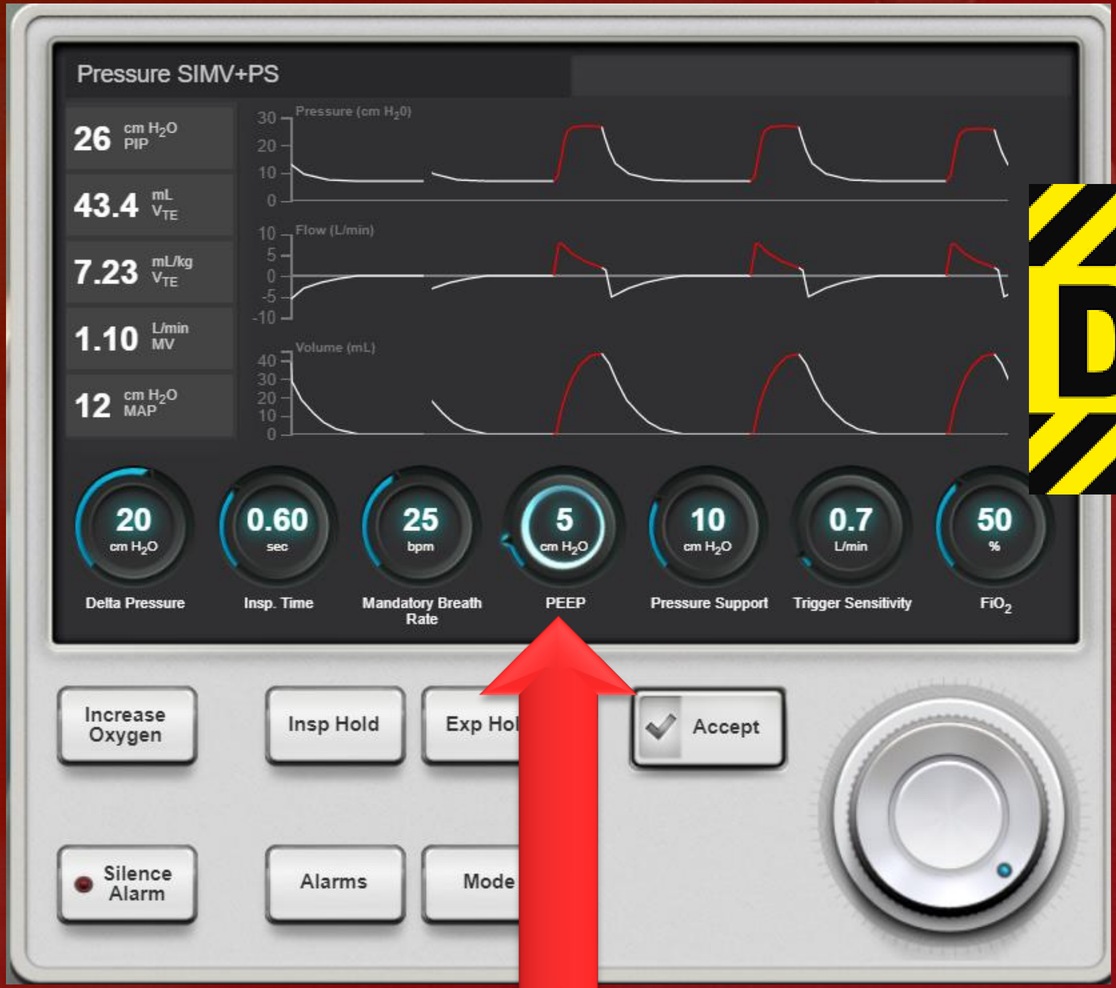
Positive End Expiratory Pressure

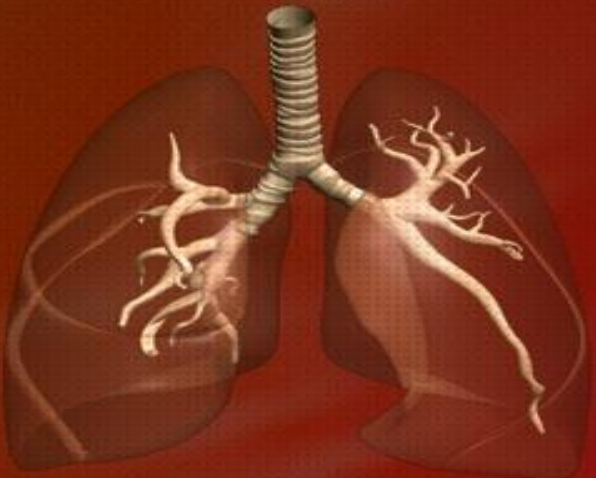




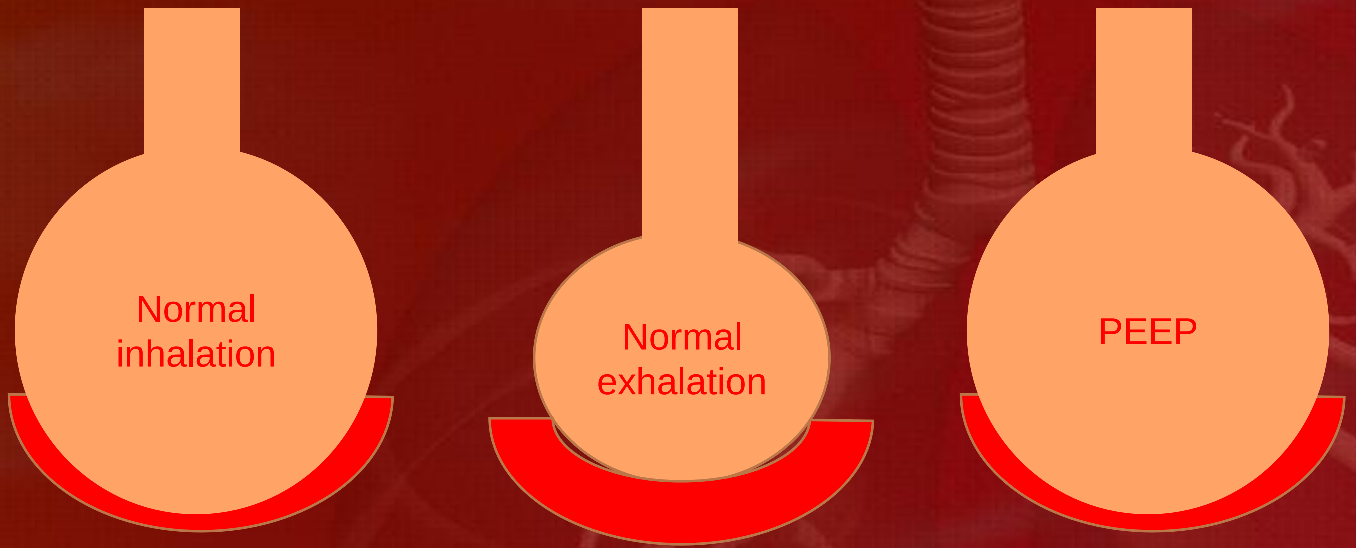
Positive End Expiratory Pressure

PEEP generally started at 5 cm $H_2$0 and increase as needed to increase PaO_2 (usually increase in increments of 2 cm $H_2$0)

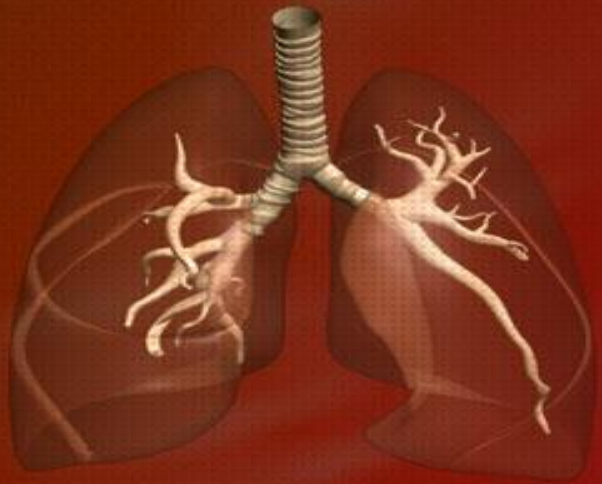




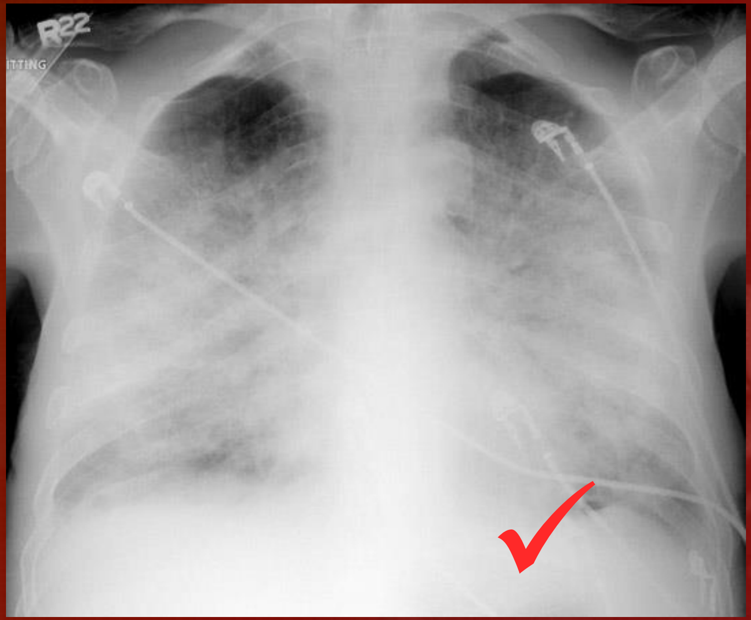
Negative impact: Positive end expiratory pressure (PEEP)



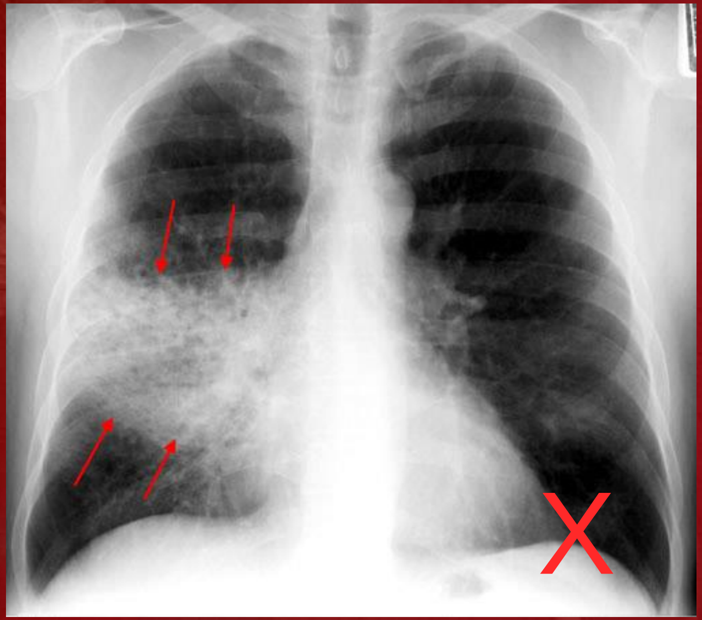
- Increased right ventricular afterload and right ventricular dysfunction
- Decreased left ventricular preload
- Hypotension (more pronounced in those with underlying hypovolemia and/or a poor ejection fraction)
- Can cause increased intracranial pressure
- High levels of PEEP can cause barotrauma



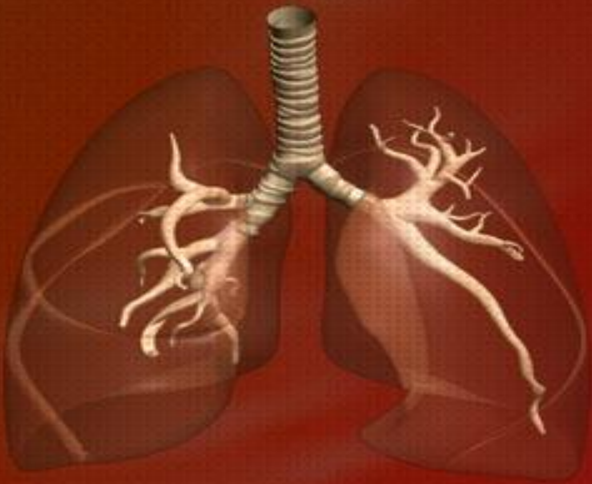
Positive end expiratory pressure (PEEP)



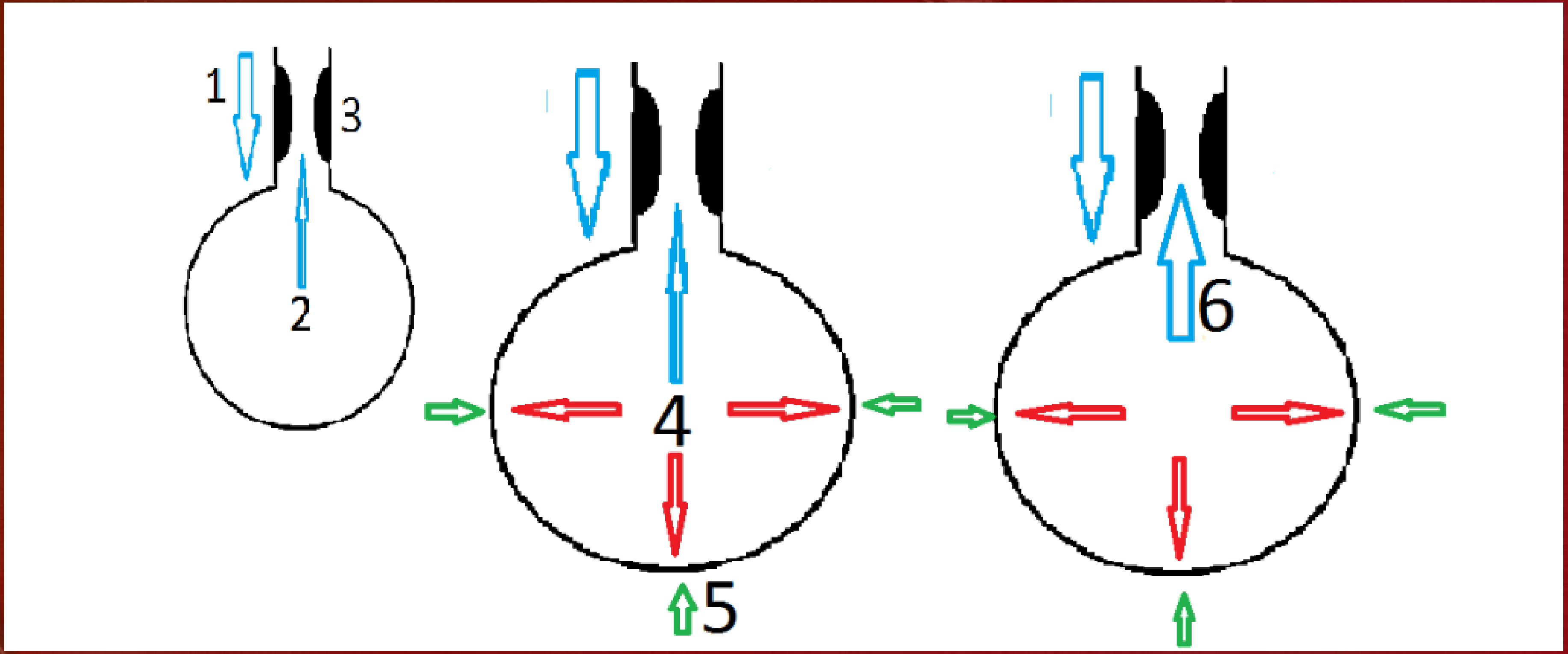
PEEP useful in diffuse conditions (e.g. ARDS, pulmonary edema, alveolar hemorrhage)



PEEP must be used cautiously in localized conditions (e.g. lobar pneumonia)



FYI – Auto-PEEP (breath-stacking)



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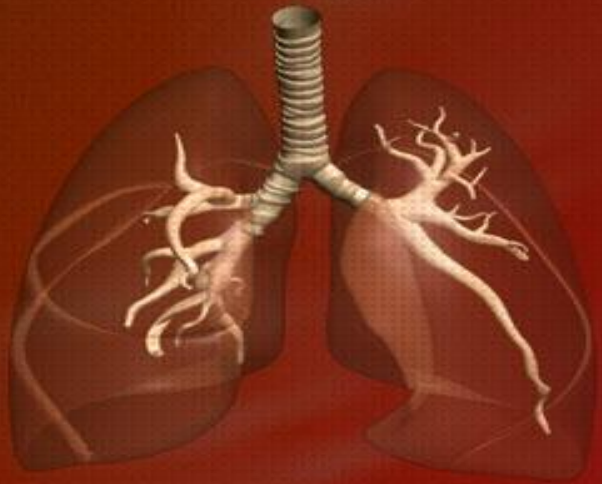
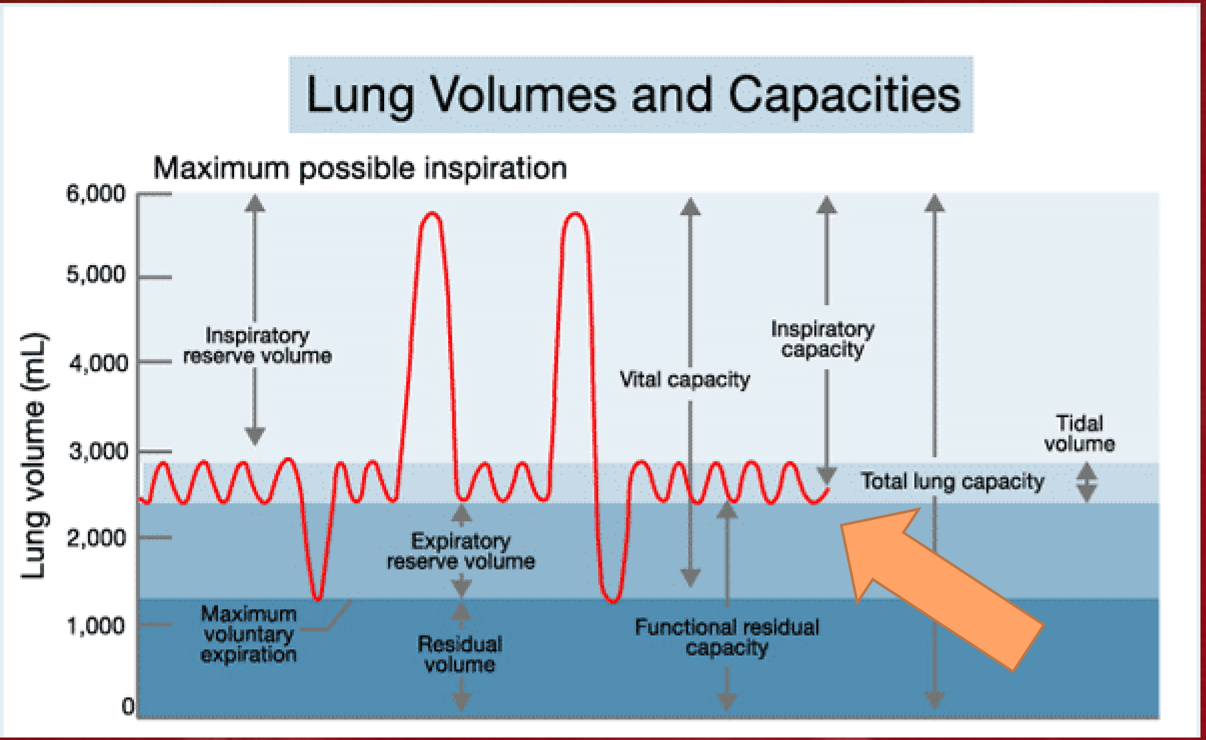
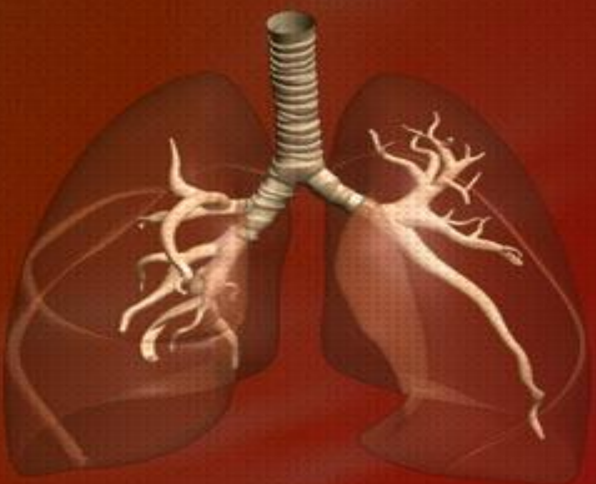
- Respiratory rate



Tidal volume (Vt)





Decreased Vt (e.g. 3 – 6 mL/kg of ideal body weight) for non-compliant lungs (e.g. ARDS or asthma)

↔

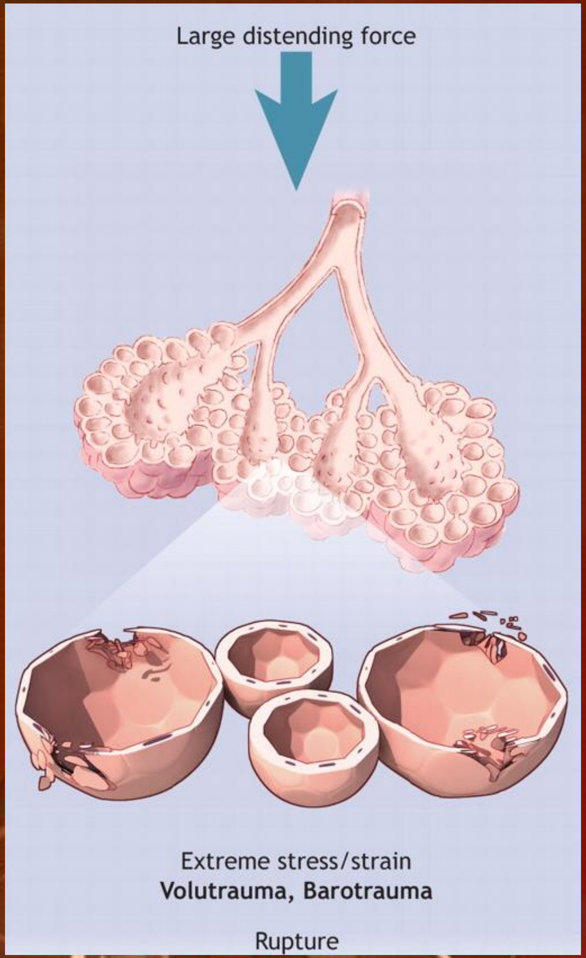
Normal Vt is 5 – 8 mL/kg of ideal body weight (often start at 8 mL/kg, generally not above 10 mL/kg)

↔

Increased Vt (> 8 mL/kg) may be considered to improve blood gases if lungs are compliant (usually not above 10 mL/kg)

Tidal volume and the ventilator

Tidal volume and the ventilator



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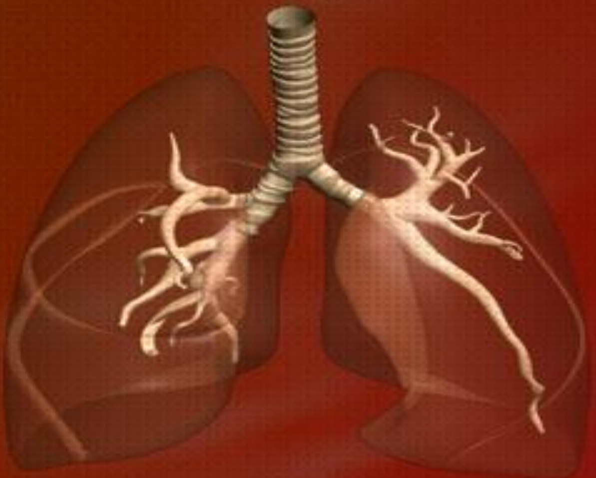


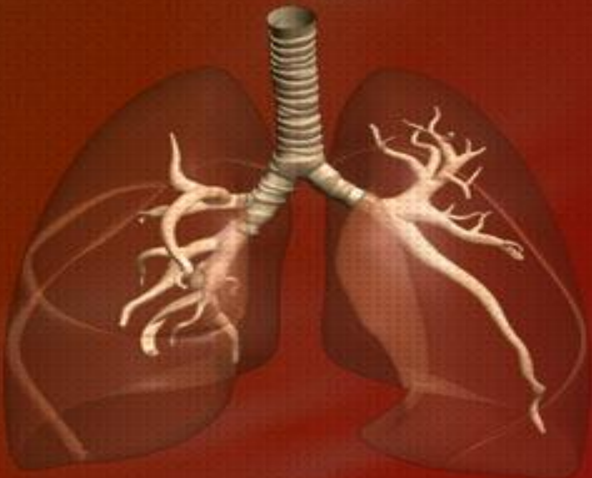
Respiratory rate (RR)

Lower RR will retain CO_2; useful for conditions such as alkalosis and asthma

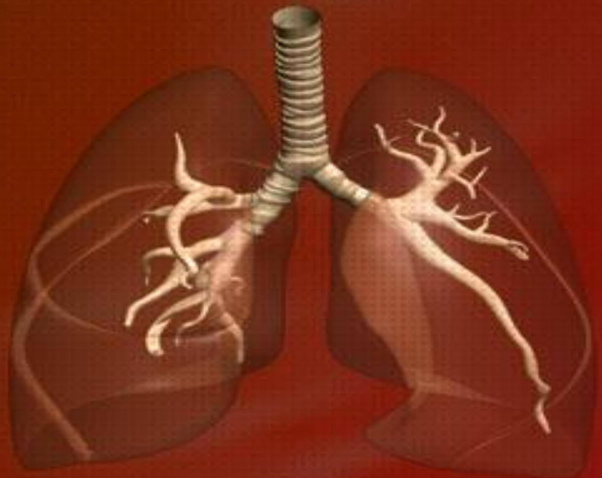
Normal RR is 8 – 12 breaths per minute

Higher rates will blow off CO_2; useful for conditions like metabolic acidosis, sepsis, ARDS and intracranial injury

Generally, the initial RR on a ventilator should be set to 2/3 the pre-intubation RR.



Respiratory rate



Negative Impact: Respiratory rate

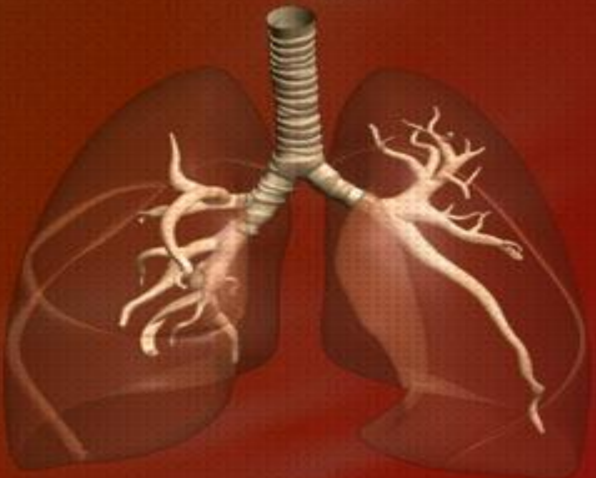
- Too high:
  - Respiratory alkalosis
  - Auto-PEEP
- Too low:
  - Inadequate oxygenation
  - Acidosis

Minute ventilation

- Definition – volume of gas exchanged in a minute
- Multiply Vt by RR

Vt x RR = minute volume

480 mL X 10 BPM = 4800 mL or 5 L/min



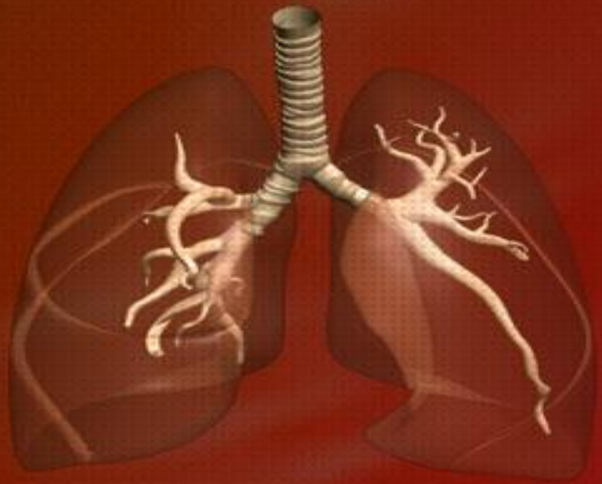
Lower minute volume is used to increase $PaCO_2$ (may also be necessary for non-compliant lungs) ⟷ **Target minute volume is usually 5 – 8 L/minute.** ⟷ **Higher minute volume is used to reduce $PaCO_2$**

Minute ventilation

Vt x RR = minute volume

Increasing tidal volume has slight advantages over increasing respiratory rate because increasing respiratory rate does not alter dead space but increasing tidal volume decreases dead space and improves ventilation

Ventilator Management – The Ventilatory Cycle

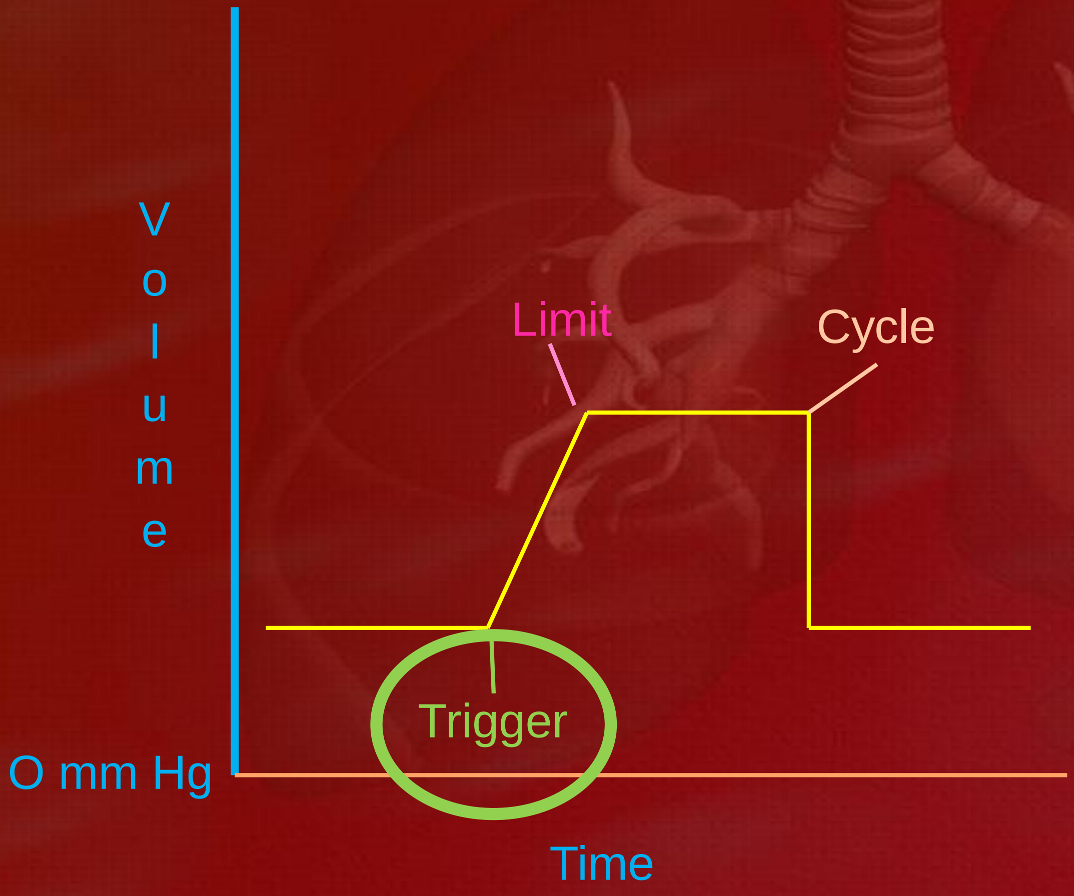


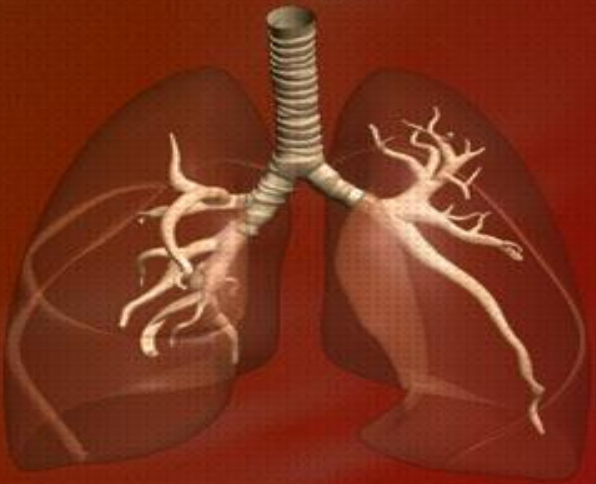
The ventilatory cycle

Initiation of inspiration is known as the “trigger”

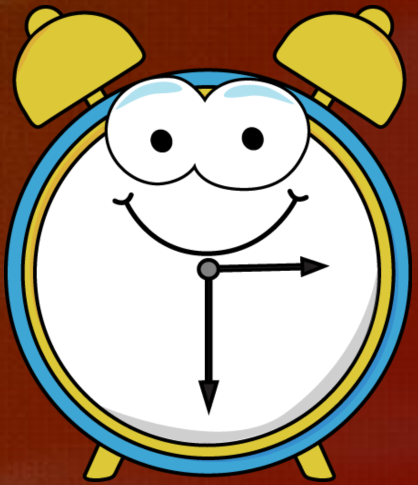
There are three triggers:

1. Time
2. Pressure
3. Flow

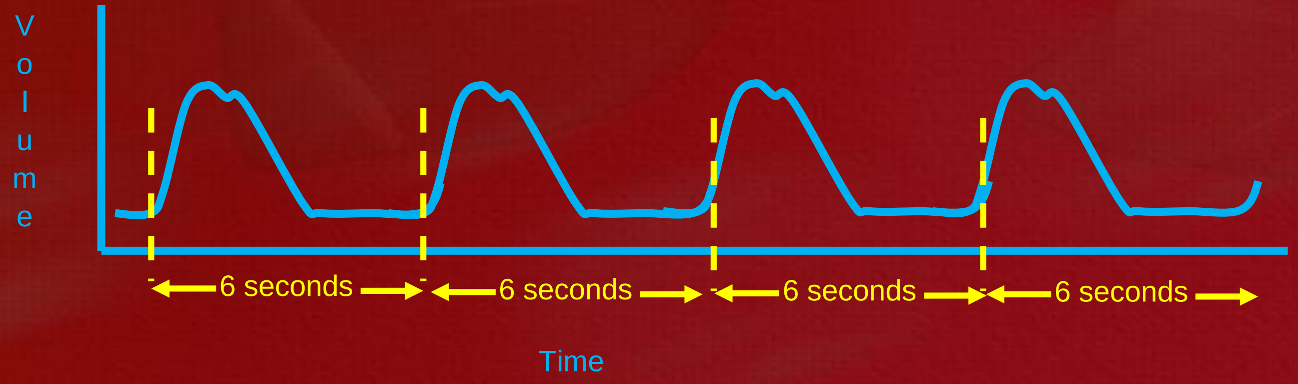




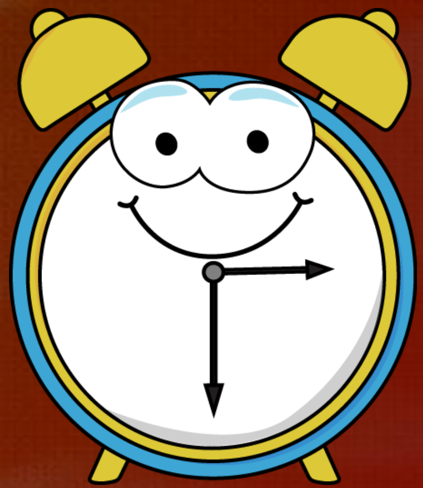
Triggers

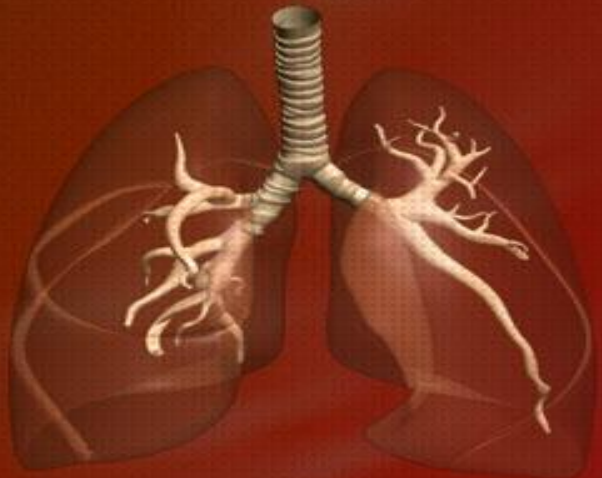


- **Time trigger**
  - Machine controlled
  - Breaths are delivered at a rate set on the ventilator
  - For example, if the rate is set to 10 breaths per minute, a breath will be delivered every six seconds regardless of patient effort.



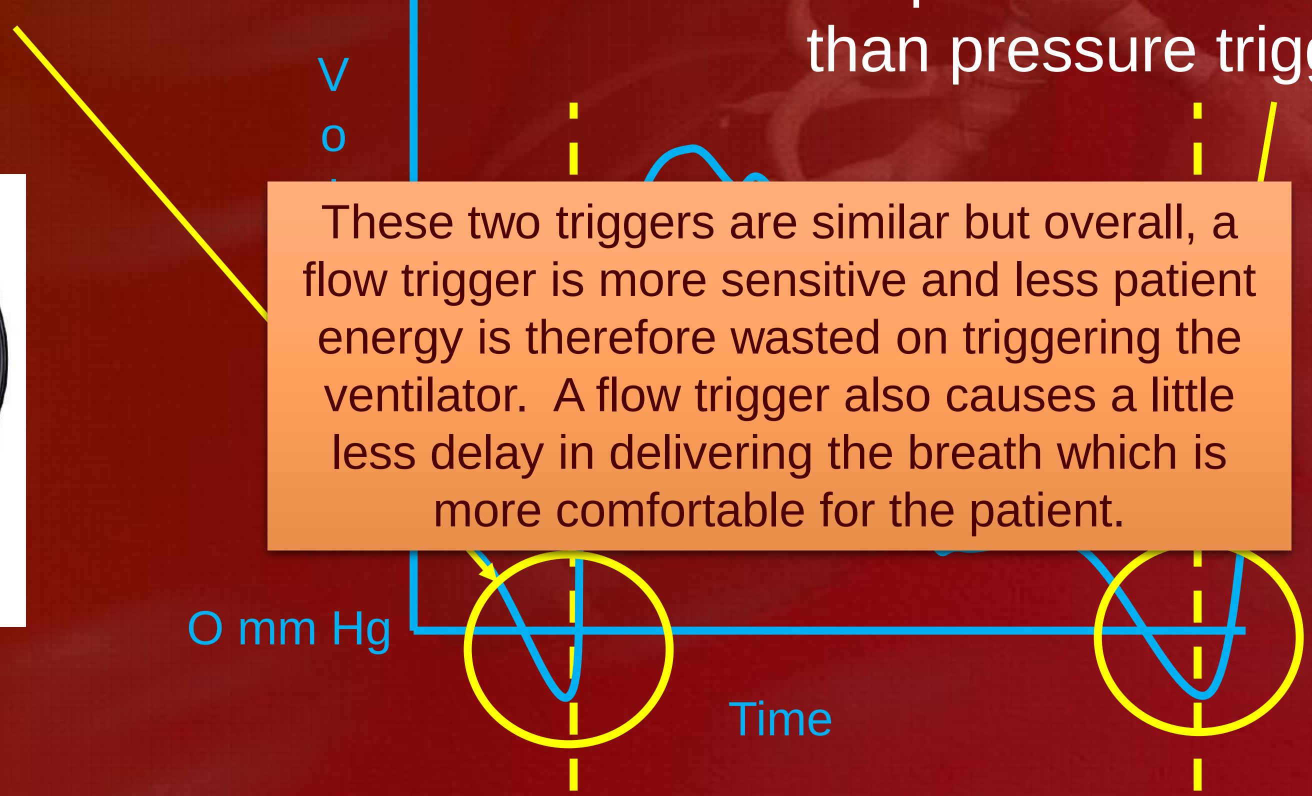
Time trigger





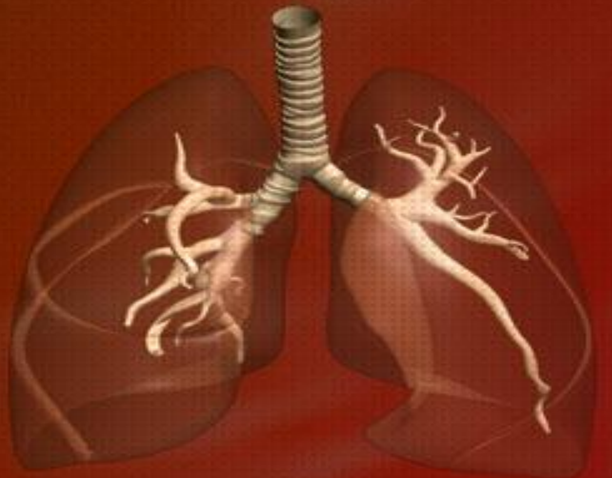
- **Pressure trigger**
  - Patient triggered
  - The patient triggers the breath by inspiratory effort. Once the negative pressure is sensed by the ventilator, it delivers a breath.

- **Flow Trigger**
  - Patient triggered
  - The breath is triggered by a change in flow direction within the ventilator tubing initiated by patient breath.
  - Requires less work by the patient than pressure triggered ventilation

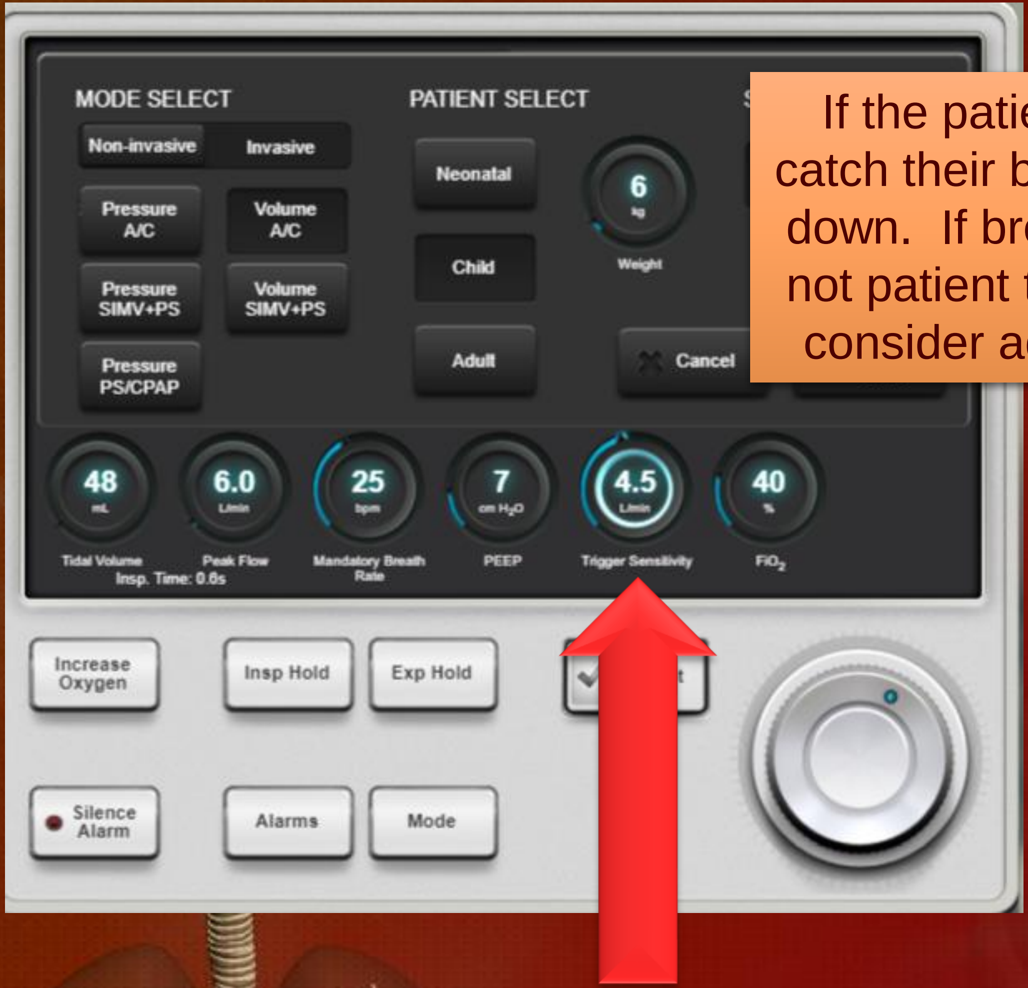


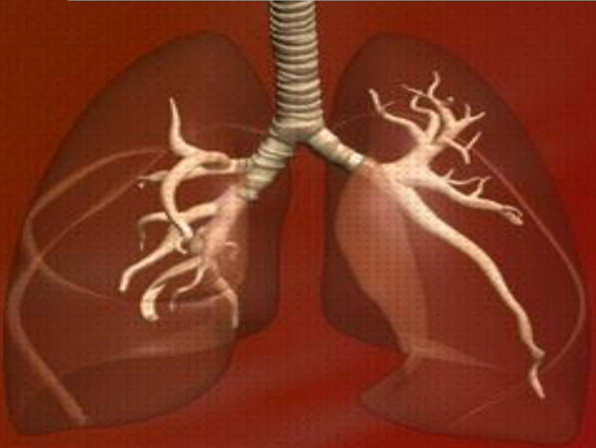
These two triggers are similar but overall, a flow trigger is more sensitive and less patient energy is therefore wasted on triggering the ventilator. A flow trigger also causes a little less delay in delivering the breath which is more comfortable for the patient.

- Flow trigger
  - Set as a positive number in L/minute
  - Normal is 0.8 - 3.0 L/minute
- Pressure trigger
  - Set as a negative number in cm H_20
  - Normal is -2 cm H_20

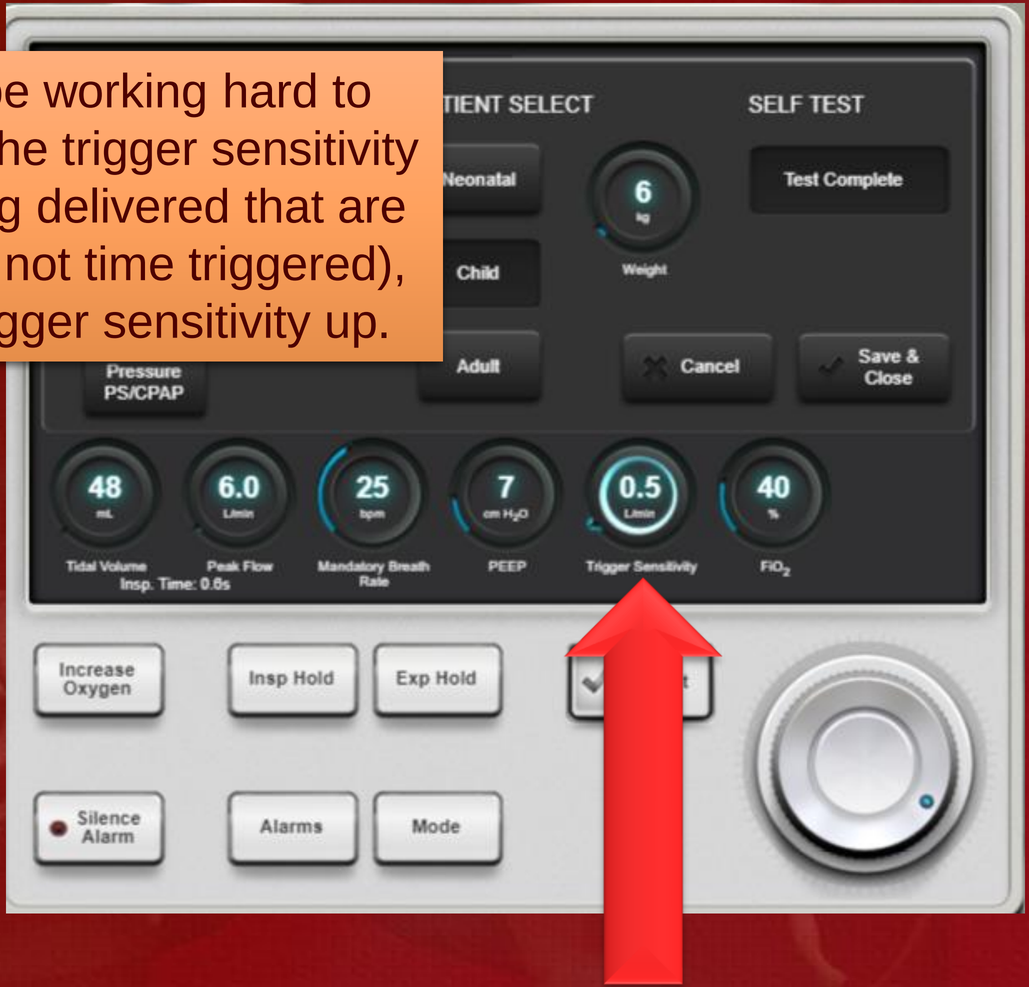


If the patient seems to be working hard to catch their breath, adjust the trigger sensitivity down. If breaths are being delivered that are not patient triggered (and not time triggered), consider adjusting the trigger sensitivity up.





What might happen if the sensitivity is set too high?



What might happen if the sensitivity is set too low?

Combination triggers

Notice that this ventilator is flow triggered (2.0 cm H_20)

Also note that the mandatory breath rate is set to 10 breaths per minute.

Therefore, if the patient does not trigger a breath every 6 seconds, the ventilator will deliver a breath to ensure a minimum of 10 breaths per minute

The ventilatory cycle

The amount of volume delivered is known as the "limit"

The limit may be defined by:

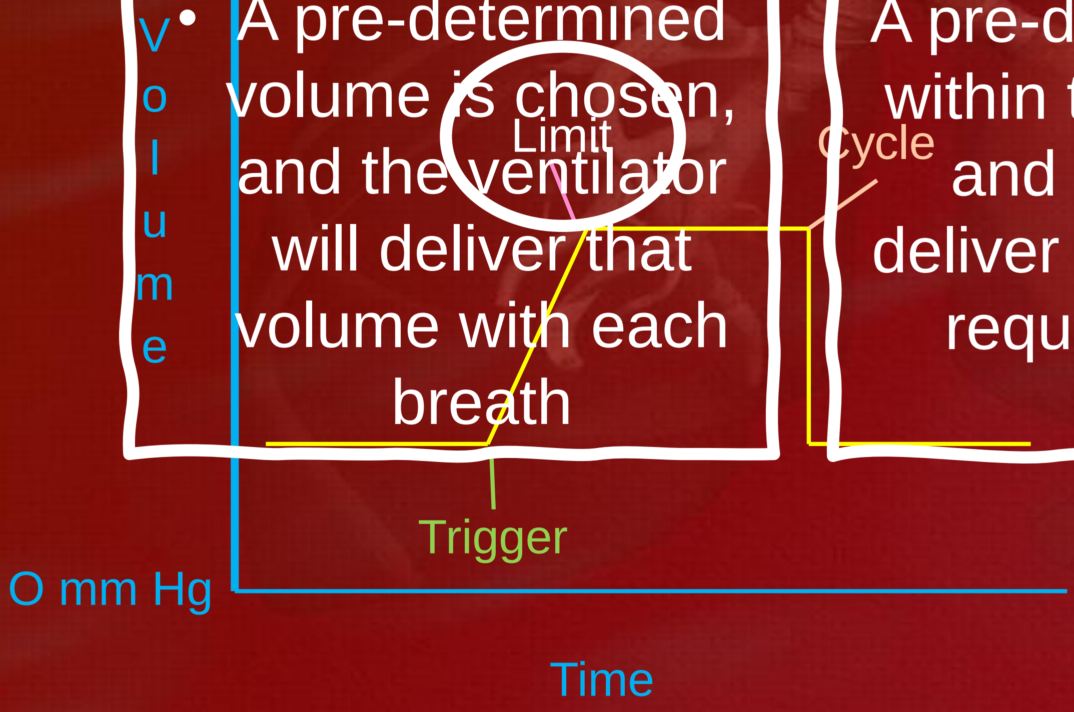
1. Volume
2. Pressure
3. Flow

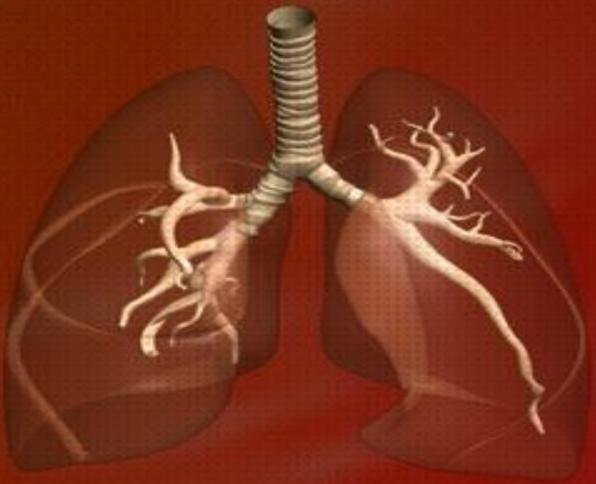
Volume controlled ventilation (VCV)

- A pre-determined volume is chosen, and the ventilator will deliver that volume with each breath

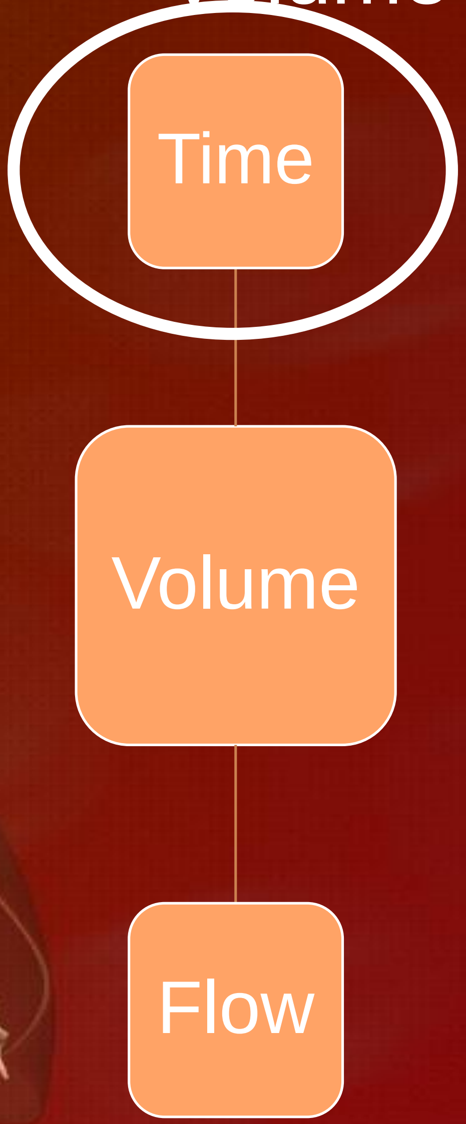
Pressure controlled ventilation (VCV)

A pre-determined pressure within the chest is chosen and the ventilator will deliver whatever volume is required to reach that pressure.





Volume Control Ventilation (VCV)



The volume is established based on the patient's ideal body weight and the desired minute volume.

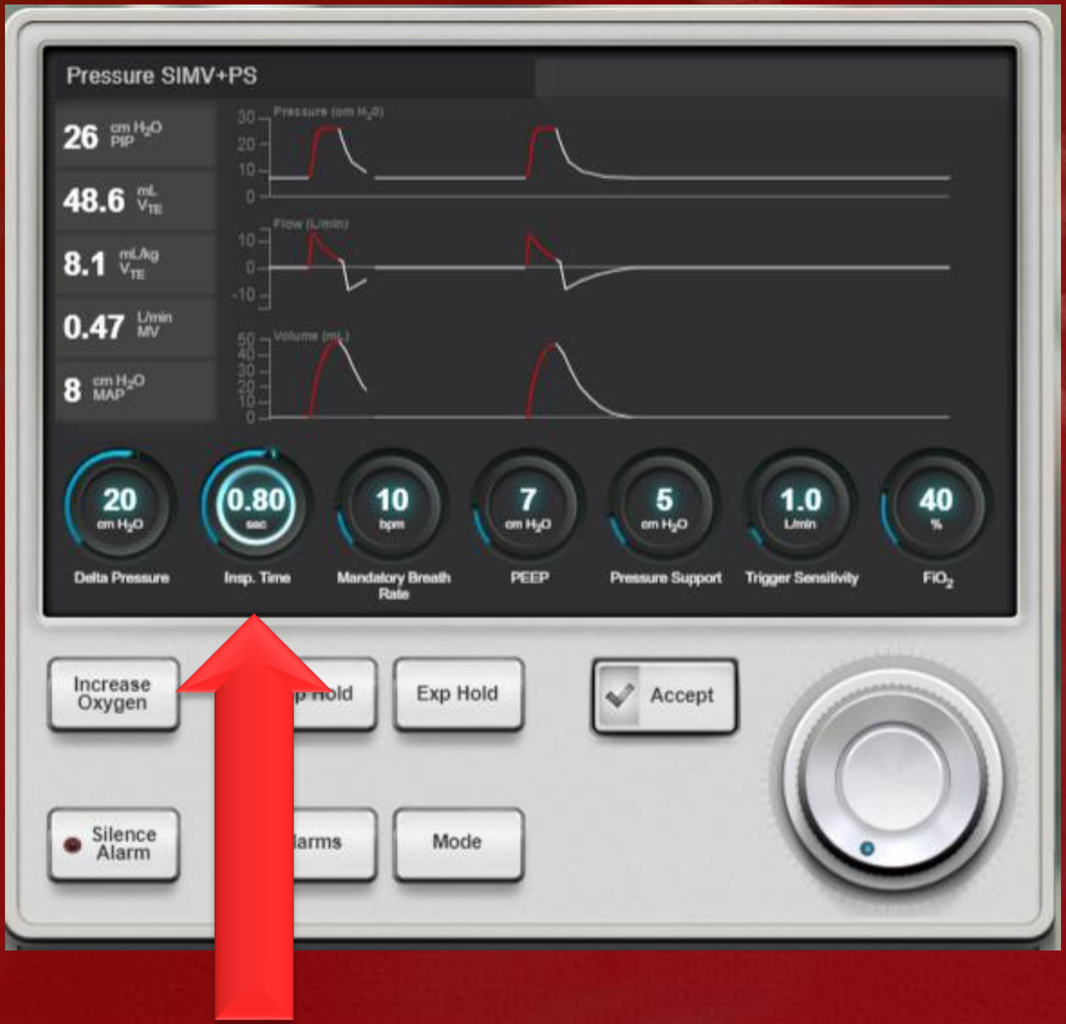
Once volume is established, then a second variable must be set (either time or flow). The ventilator will determine the remaining variable.

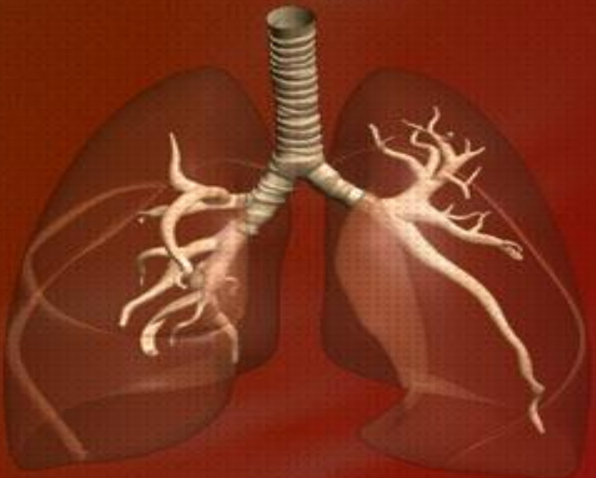
- VCV is chosen
- The patient's ideal body weight is 80 kg and a tidal volume of 6 mL/kg is chosen (480 mL)
- The ventilator is set to deliver 480 mL of volume.

VCV - Tidal volume

The second variable we choose to set is time. This is telling the ventilator over what time frame we want the total volume delivered (0.80 seconds in this example)

VCV- Inspiratory time





Setting inspiratory time in VCV

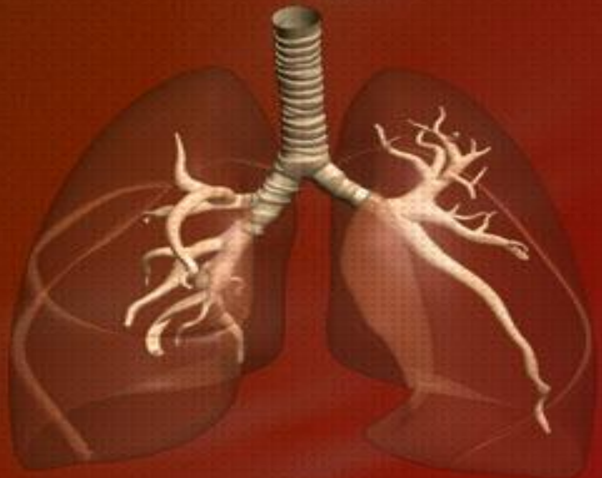
May be shortened in obstructive disease (asthma, COPD) to allow more time for exhalation

⟷

Normal inspiratory time is 0.8 – 1.4 seconds

⟷

May be lengthened in conditions like ARDS to improve alveolar recruitment



Volume Control Ventilation (VCV)

Time

Volume

Flow

A second alternative is to set flow rate instead of time. Flow is the speed that the total volume is delivered through the tubing into the lungs.

VCV – Peak Inspiratory Flow

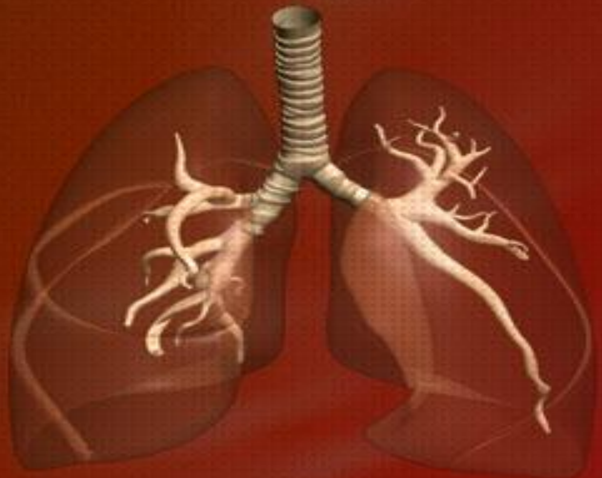
Lower Inspiratory flow can result in increased work of breathing by the patient.

↔

Speed that air is delivered during inspiration. Normal is 60 L/minute

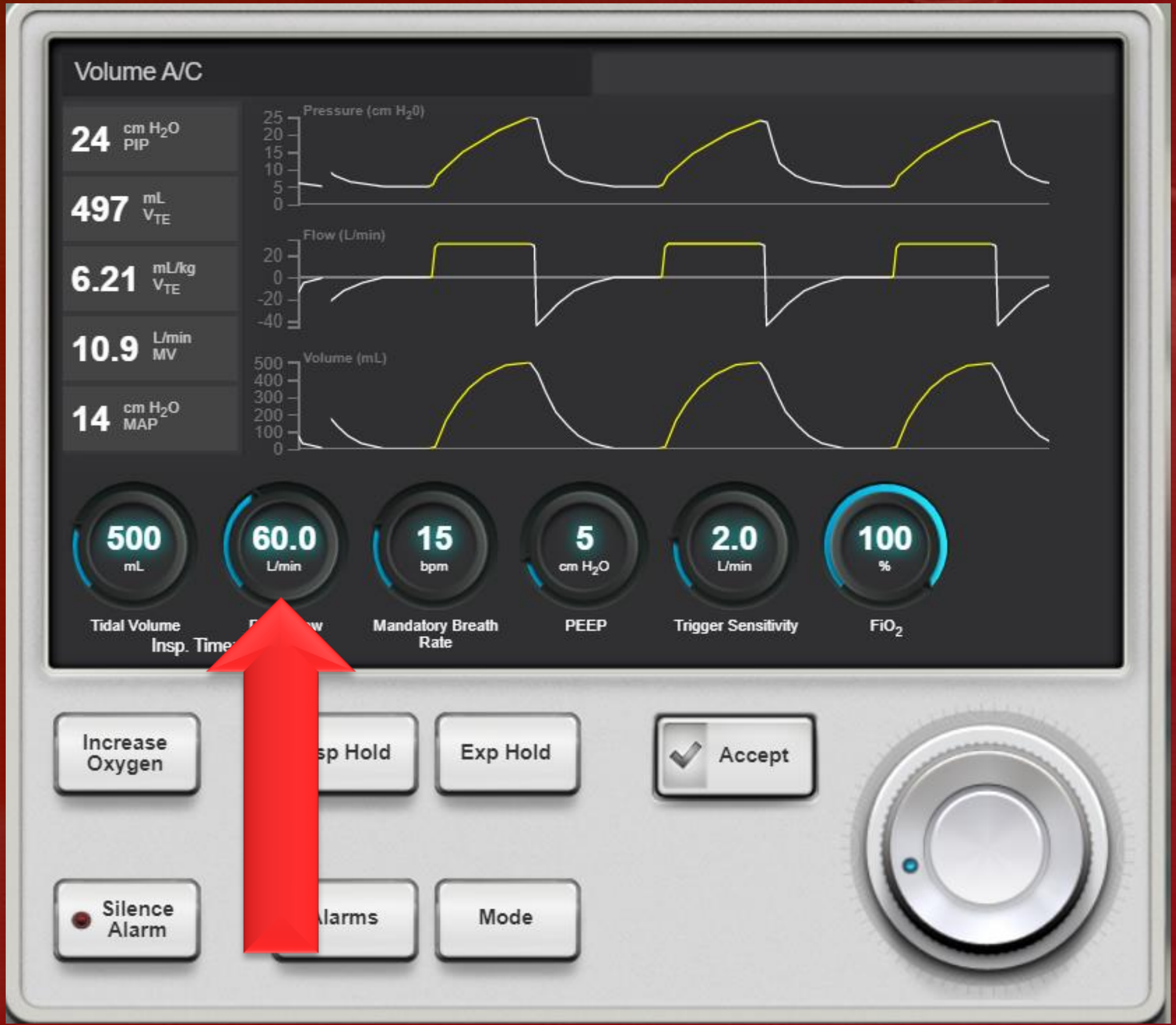
↔

May be increased in patients with asthma (rapid inspiration allowing longer exhalation) or for signs of air hunger



VCV - Peak Inspiratory Flow

In this example, the ventilator is set to deliver 500 mL of volume at a flow rate of 60 L/minute.



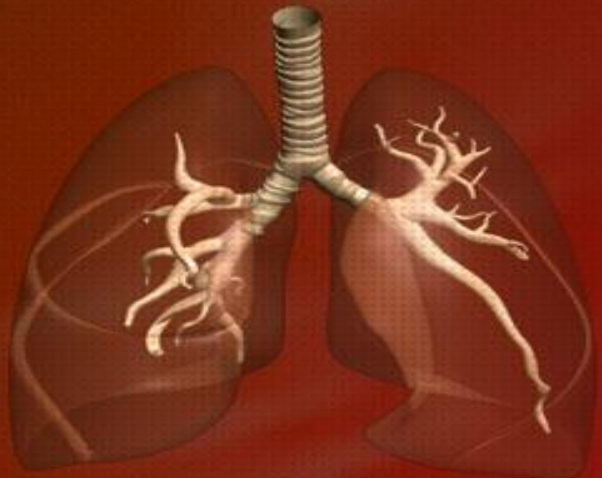
Volume Control Ventilation (VCV)

<u>Step One:</u> Set the desired volume

<u>Step Two:</u> Decide which variable to deliver that volume:

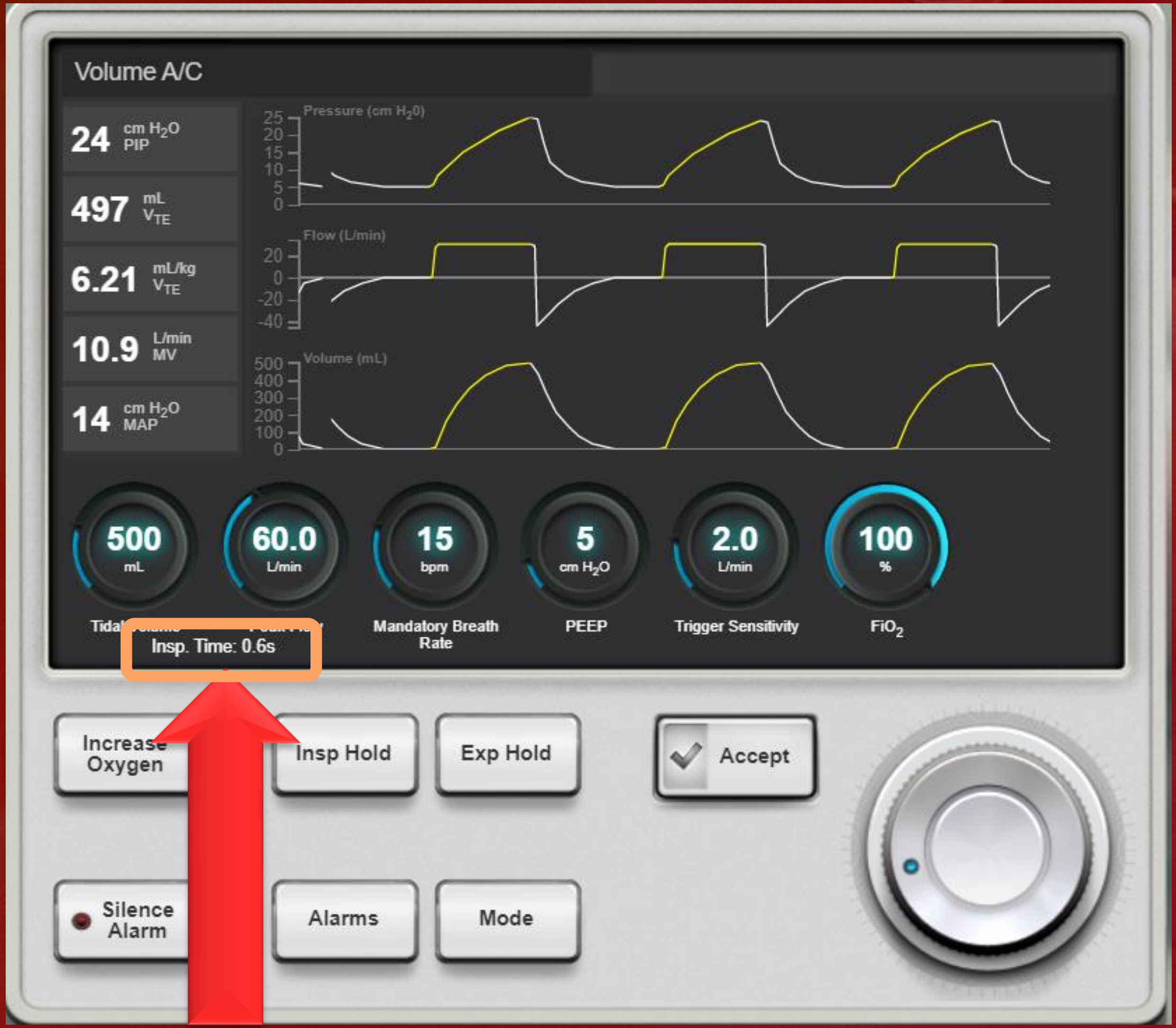
Time or Flow

[**<u>Note</u>** that the ventilator will establish the remaining variable. So, if volume and time is set, the ventilator will determine what flow. If volume and flow is set, the ventilator will determine what time that volume will need to be delivered.



VCV – Inspiratory time

In this example, the volume is set to 500 mL and the flow is set to 60 L/minute. Note that the ventilator determines (and displays) the time it will take to deliver that volume at that flow rate.

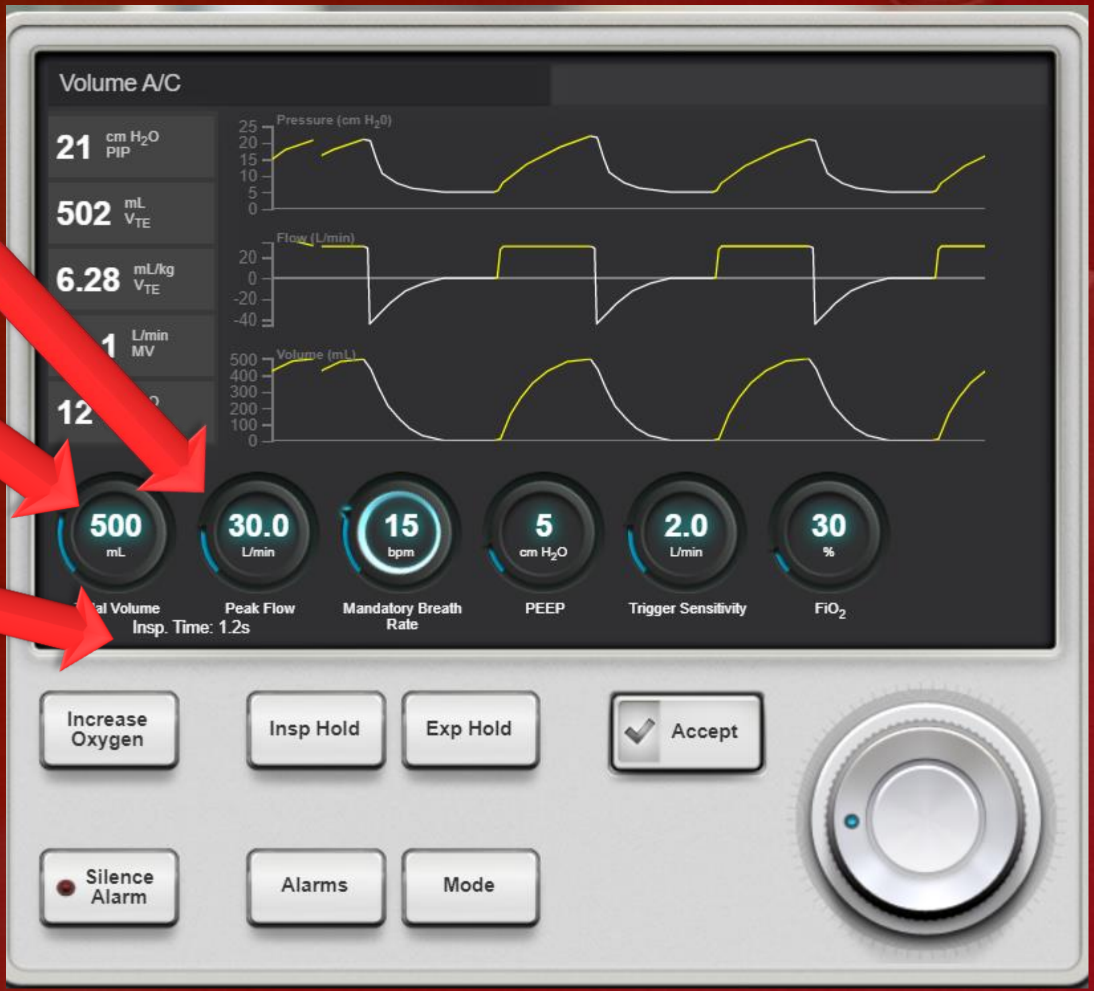


VCV – Inspiratory time

Let's cut the peak flow in half to 30 L/min

The tidal volume is still 500 mL

Inspiratory time becomes 1.2 seconds



Notice that the inspiratory time doubles when the peak flow is cut in half.

The ventilatory cycle

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The limit may be defined by:

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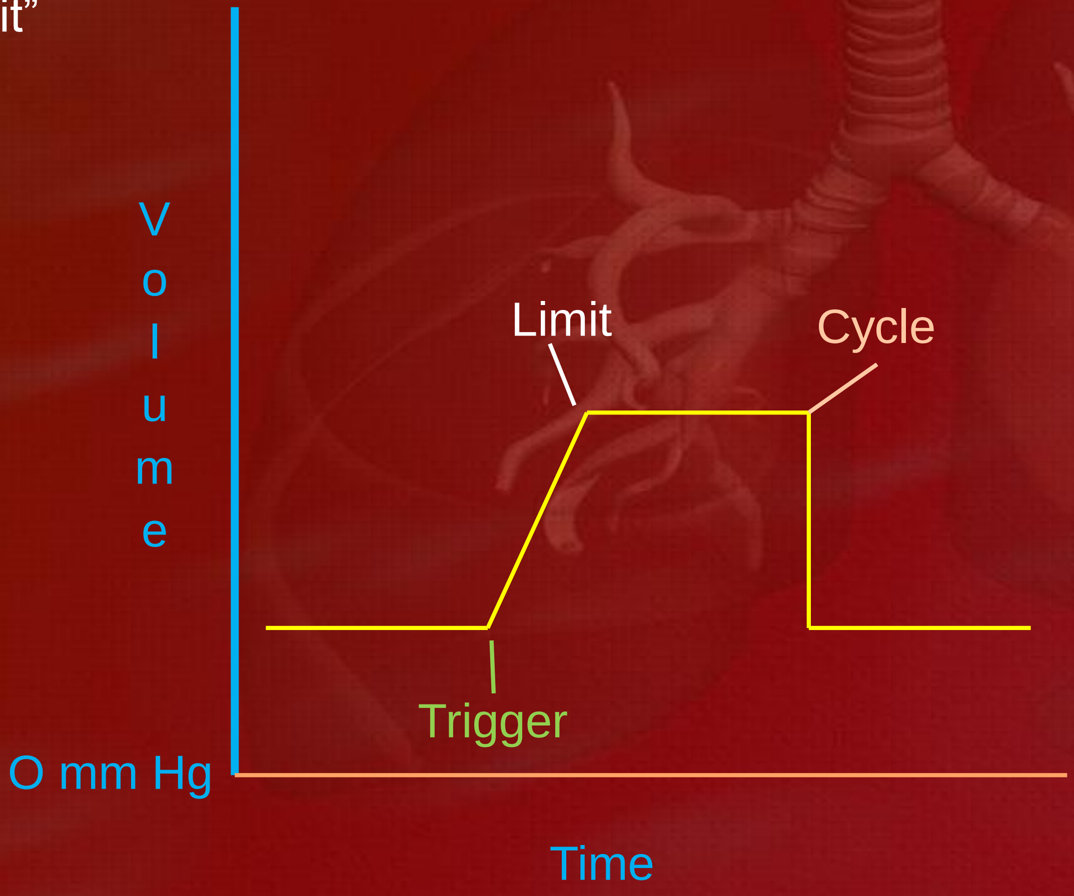
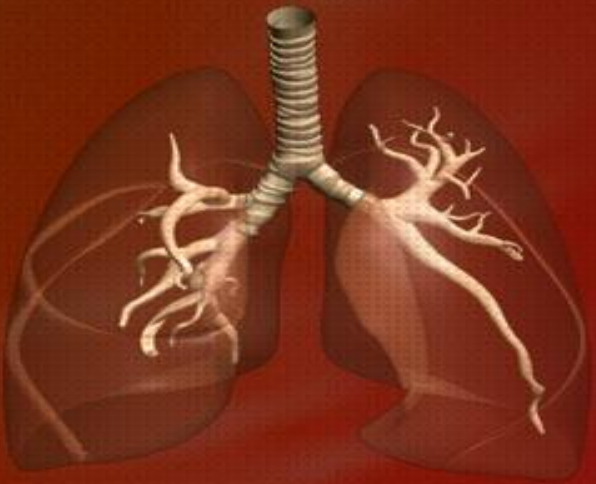
2. Pressure
3. Flow



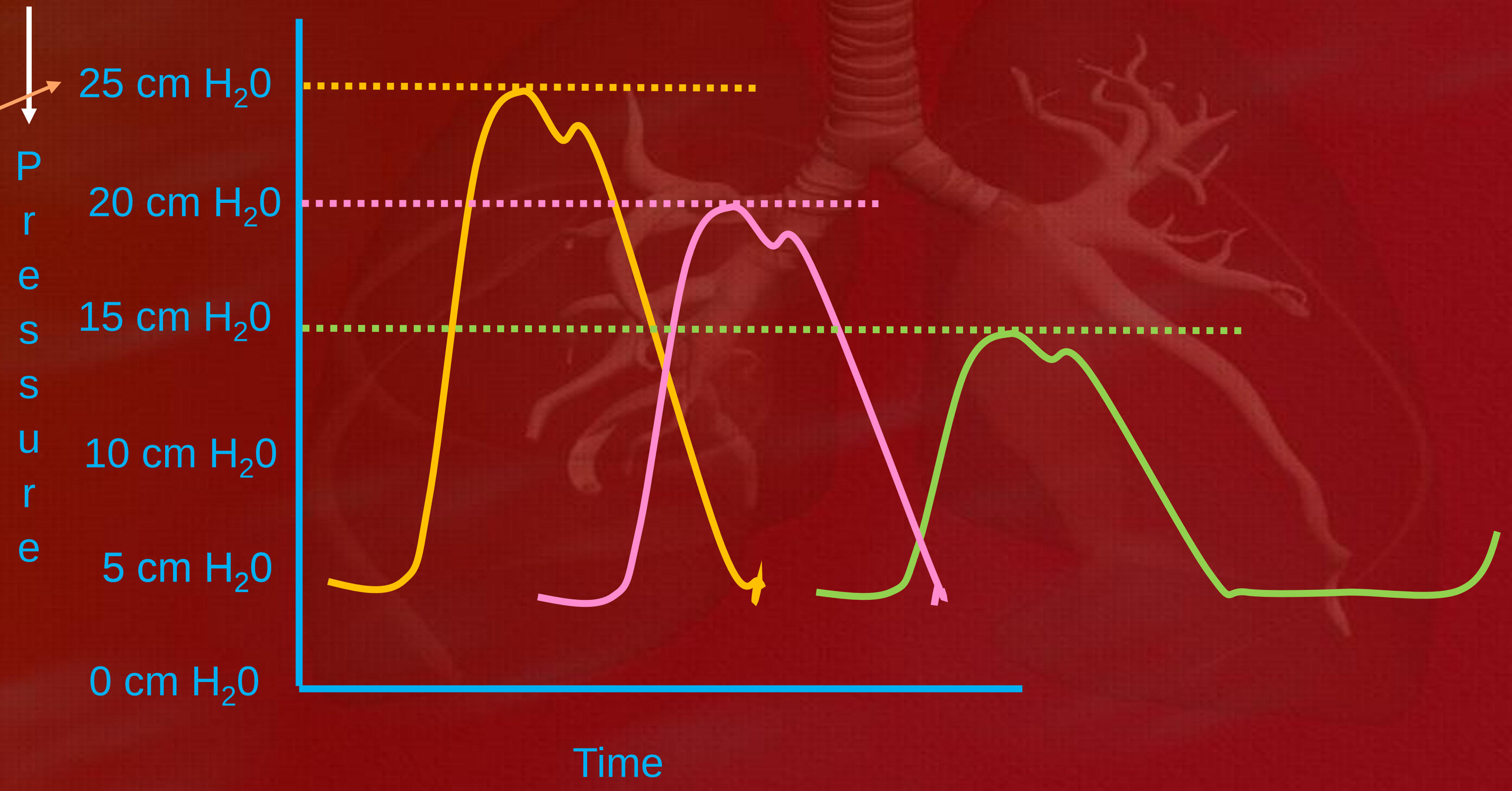
The limit can also be determined using pressures in the chest (pressure control ventilation - PCV)

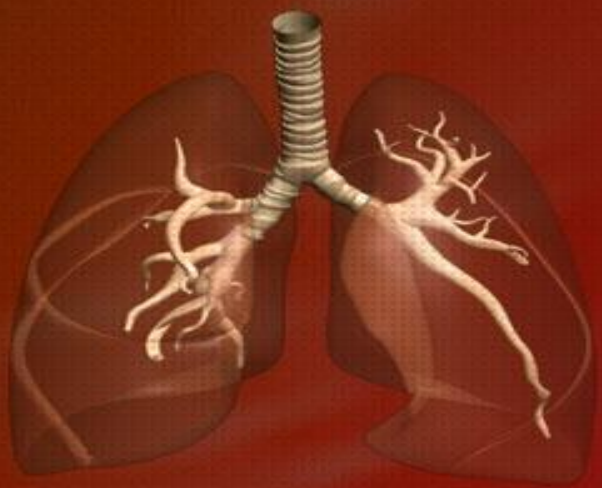


Pressure Control Ventilation (PCV)

A preset pressure (peak inspiratory pressure or PIP) is attained and maintained during inspiration. (AKA pressure-targeted ventilation, pressure-cycle ventilation, pressure-assist ventilation, pressure-control ventilation, pressure limit ventilation)

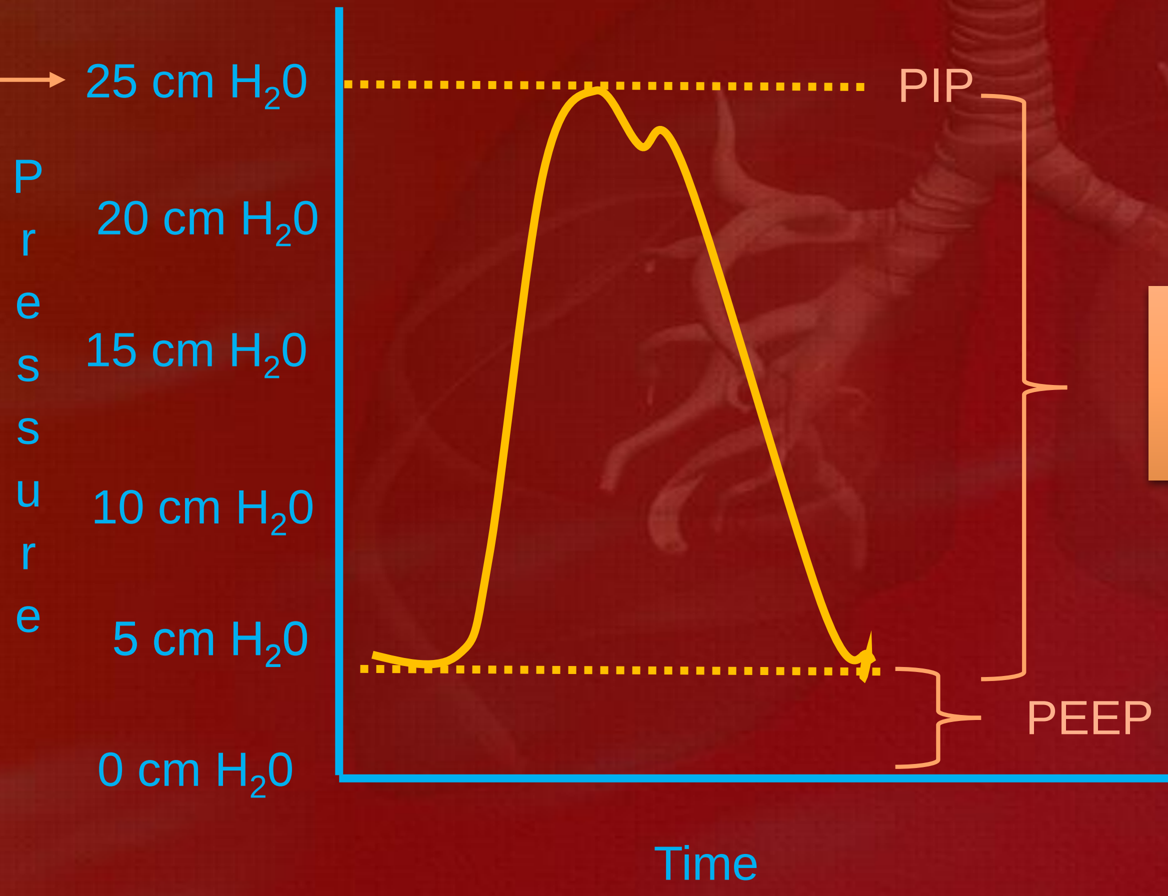
The ventilator can be set to deliver enough volume to obtain a PIP of 25 cm H_20.



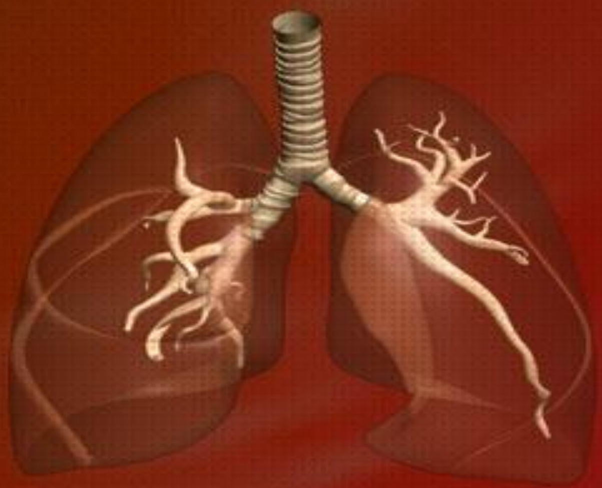


Pressure limit

If a PIP of 25 cm H_20 of pressure is desired, what pressure should be chosen on the ventilator?



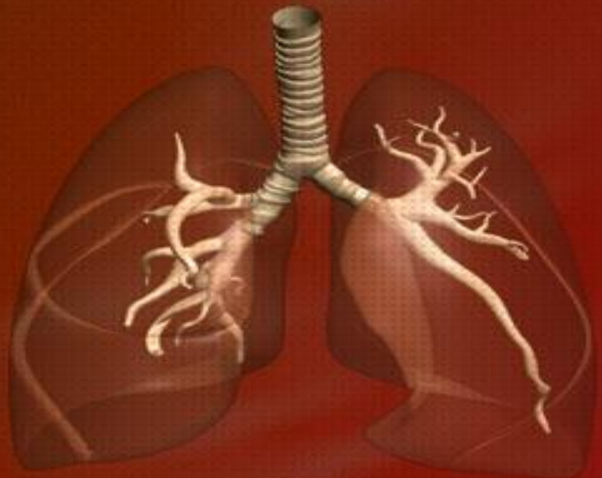
The difference between the PIP and PEEP is the Delta pressure.



Pressure Control Ventilation – Delta Pressure

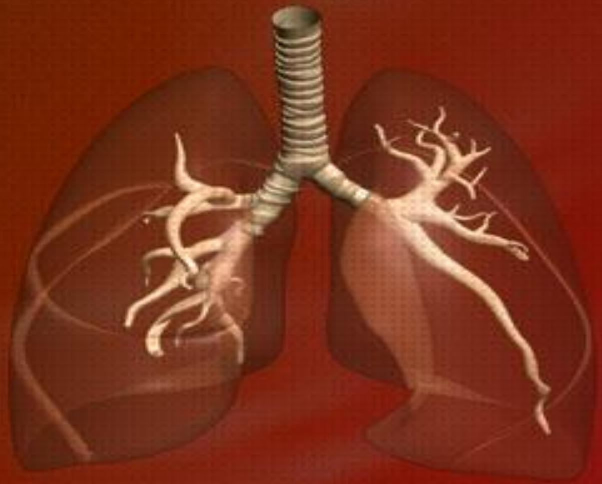
The delta pressure has been set to 20 cm H_20. What volume of air is being delivered?

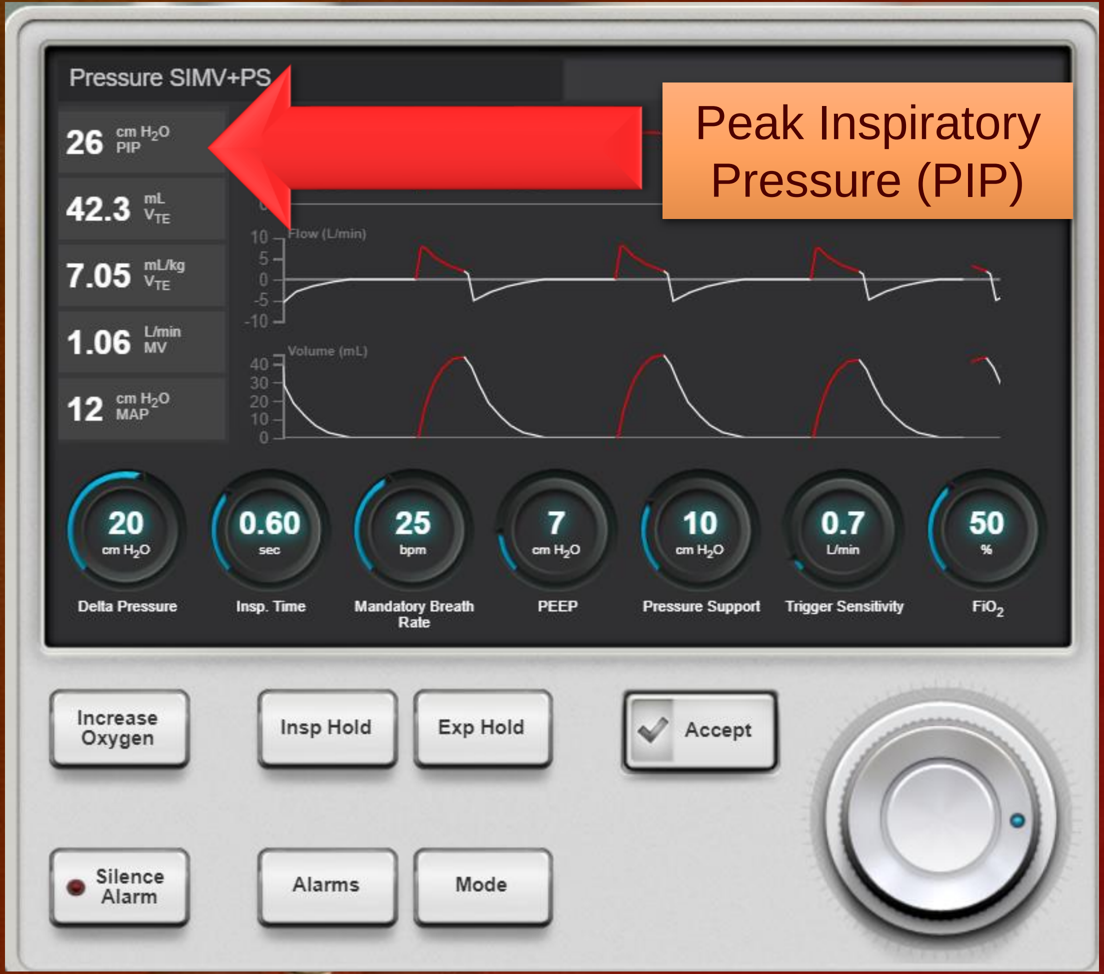
PIP (Delta pressure) is initially set based on how much pressure it takes to visibly move the chest during manual ventilation. PIP is then adjusted to achieve the desired tidal volume.



Volume Controlled Ventilation

What is a risk associated with volume-controlled ventilation?



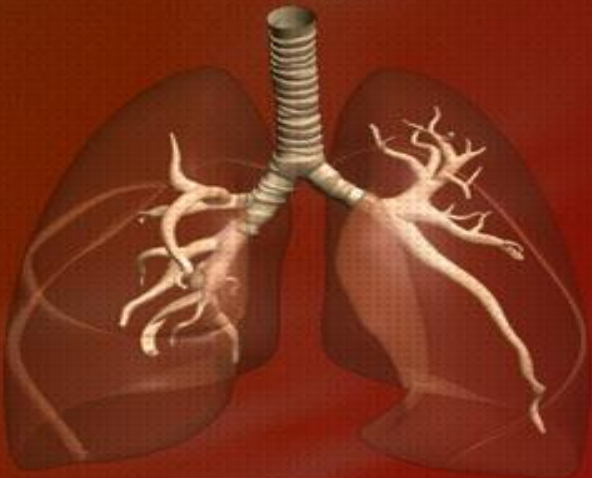


- Target PIP is generally <35 cm H_20
- Low PIP results in hypoventilation
- High PIP may cause lung damage

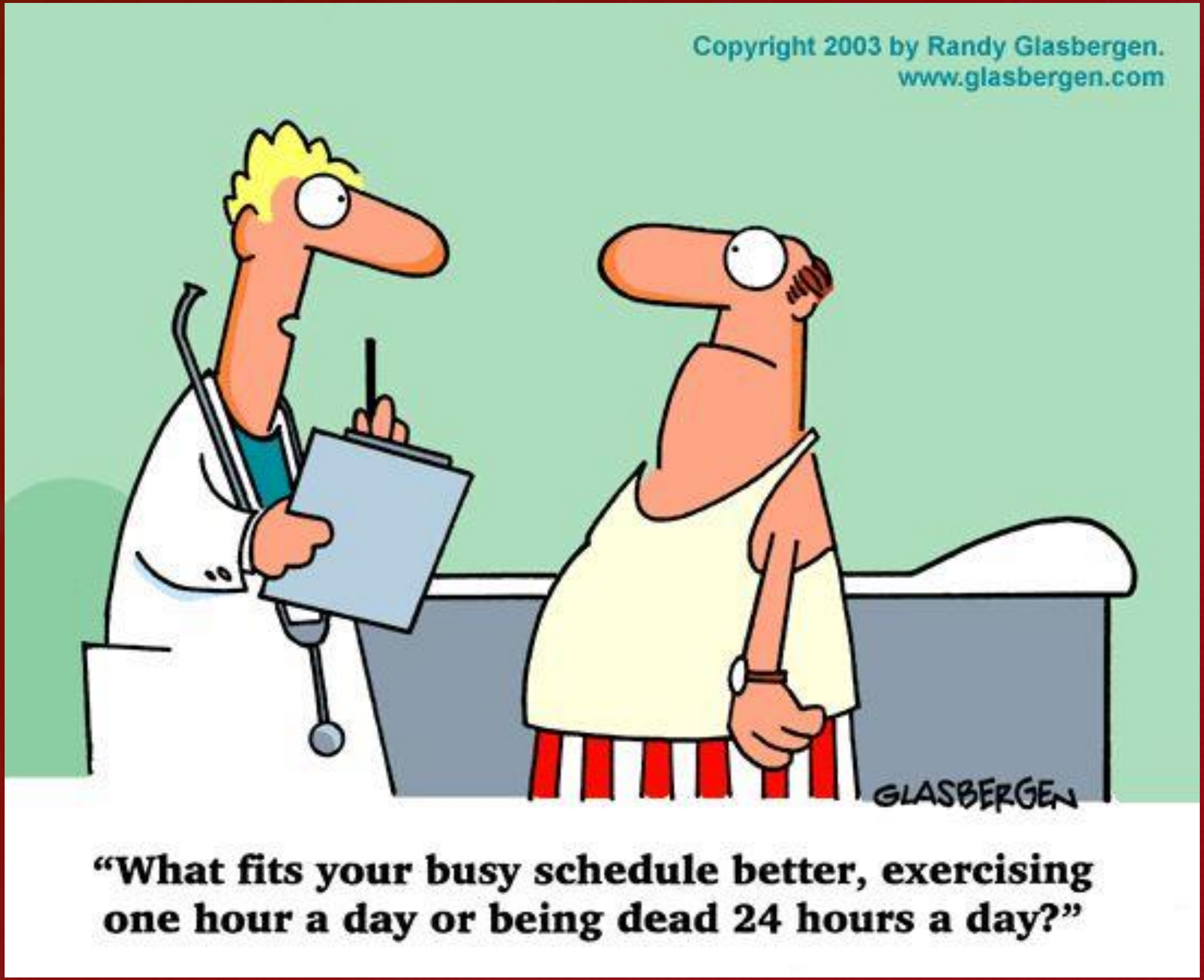
Pressure Controlled Ventilation

- Variable volumes will be delivered with each breath.
- If the following occurs:
  - Auto-PEEP…
  - Space occupying substances (pulmonary edema, pus, blood) in the lung…
  - Stiffening (fibrosis) of lung tissue…
- …it will take less volume to obtain desired PIP leading to inadequate oxygenation and ventilation.

What is a risk associated with pressure-controlled ventilation?



Let's compare VCV to PCV



Advantages of VCV/PCV

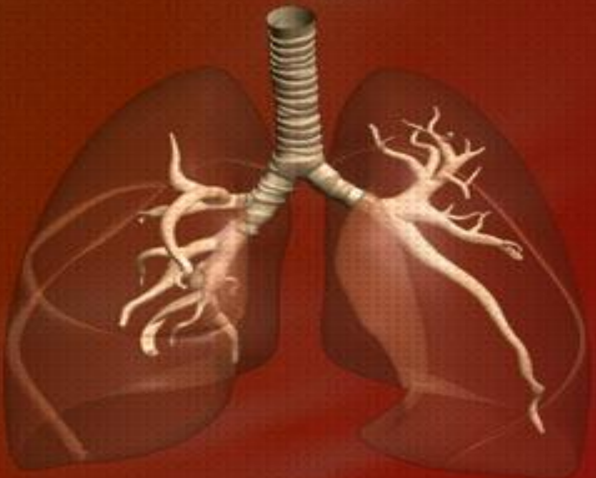
VCV (favors control of ventilation)

- Guaranteed tidal volumes produces more stable minute volume
- Initial flow rate is lower than PCV, avoids high resistance-related early pressure peak

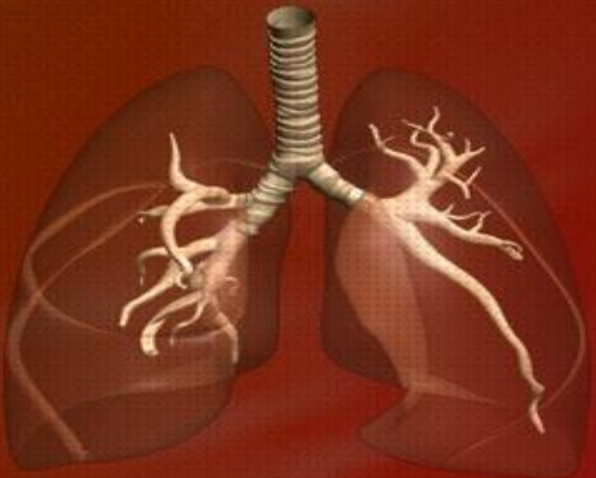
VS

PCV (favors control of oxygenation)

- Increased mean airway pressure
- Increased duration of alveolar recruitment
- Protective against barotrauma
- Patient comfort may be improved



Disadvantages of VCV/PCV



VCV (favors control of ventilation)

- **DISADVANTAGES:**
- Mean airway pressure is lower
- Recruitment poorer in lung units with poor compliance
- Insufficient flow may give rise to patient-ventilator desynchrony

VS

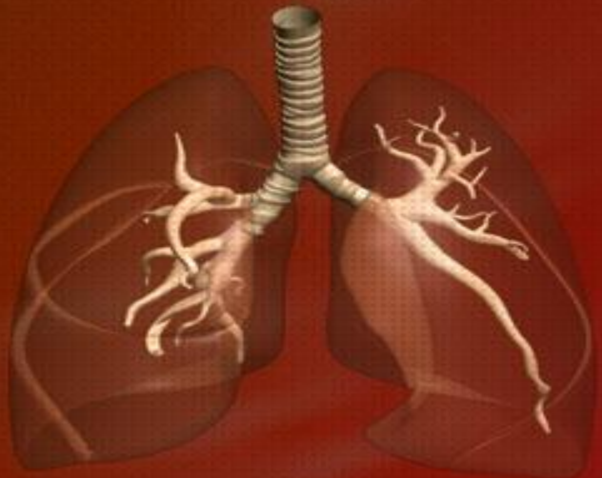
PCV (favors control of oxygenation)

- **DISADVANTAGES:**
- Tidal volume is variable and dependent on respiratory compliance
- Uncontrolled volume may result in volutrauma
- High early inspiratory flow may breach pressure limit

Dual control ventilation

- Also known as:
  - Pressure-regulated volume-control (PCRV)
  - Adaptive pressure ventilation
  - Auto-flow
  - Volume control plus
  - Variable-pressure control ventilation

Volume targeted (guaranteed) and pressure limited.

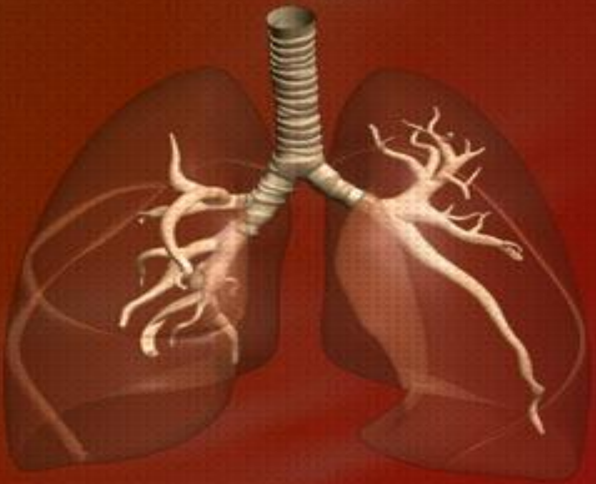


The ventilatory cycle

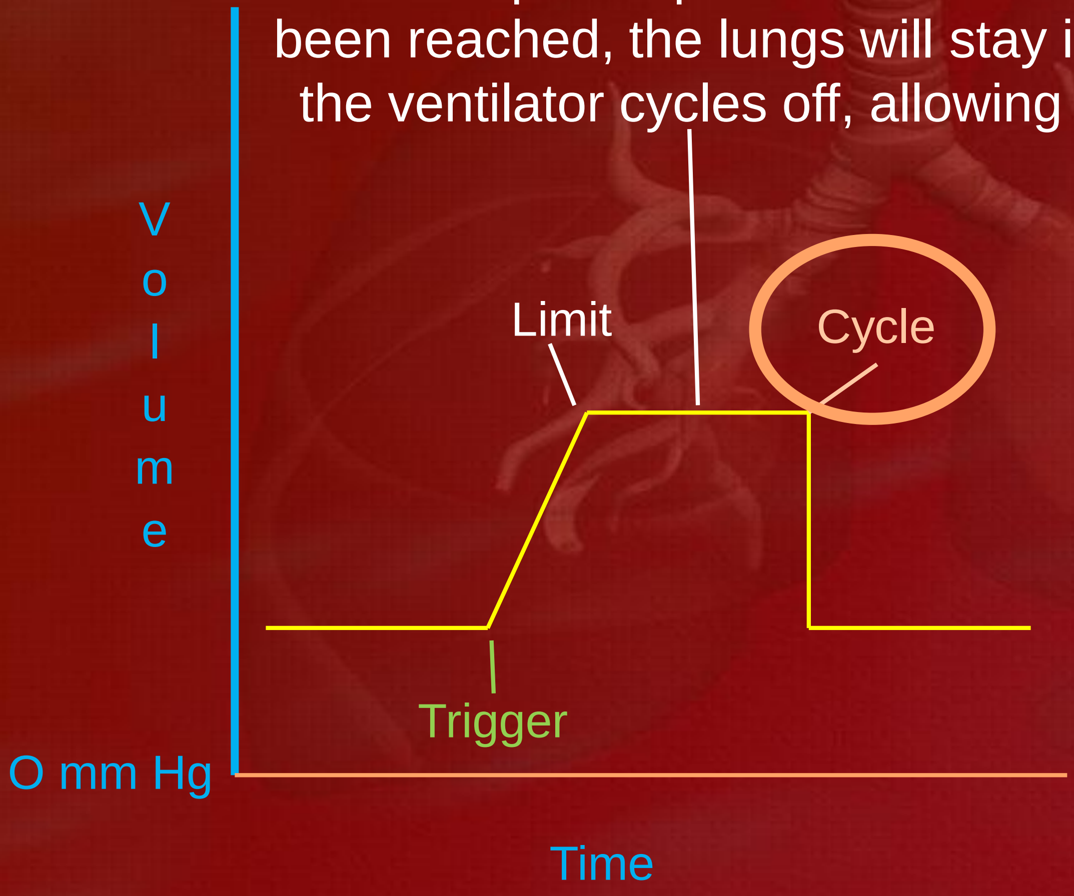
The change from inspiration to expiration is known as the “cycle”

The expiratory cycle may be initiated by:

- Time
- Volume
- Pressure
- Flow

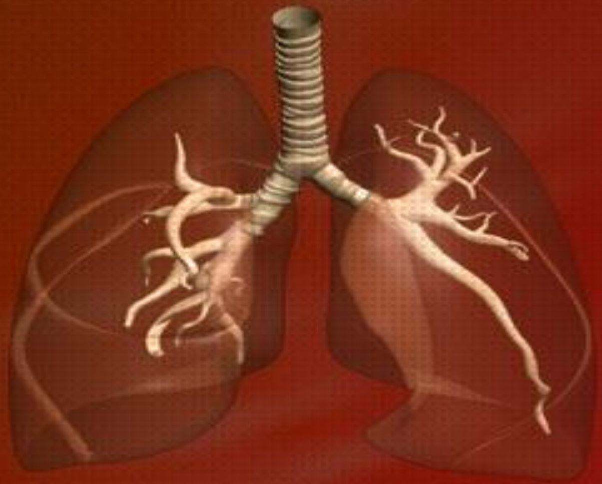


Once the preset pressure or volume limit has been reached, the lungs will stay inflated until the ventilator cycles off, allowing exhalation



Cycle

- **Time:** Terminates inspiration when the set inspiratory time is achieved. (regardless of patient effort)
- **Volume:** Terminates inspiration when the set target volume is achieved.
- **Pressure:** Terminates the breath when a set pressure is achieved. (NB – pressure cycling can be the primary cycle variable or a "backup" cycle variable with other cycling mechanism to prevent over-pressurization)
- **Flow:** Terminates inspiration when the flow has fallen to a set level (e.g. 25% of peak inspiratory flow)



Time Cycle

Inspiratory time (Ti) can be set on the ventilator for time cycles.

I:E ratio

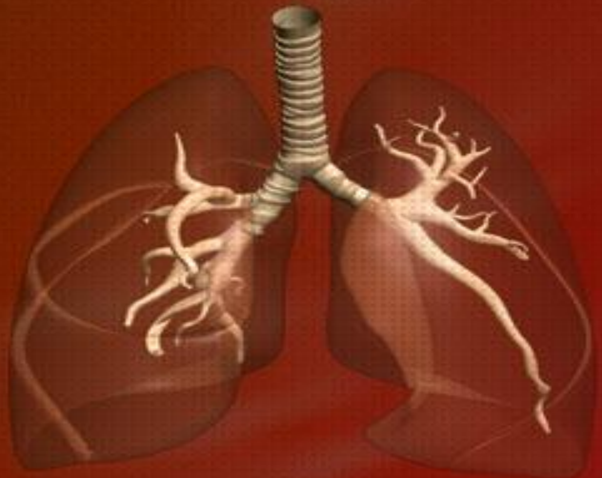
- Ti:Te is known as the I:E ratio (Inspiratory:Expiratory ratio)
- Ti = 1 second
- Te = 4 seconds
- I:E ratio is 1:4
- Normal I:E ratio is 1:2

- CONSIDER THIS:
- A patient’s respiratory rate is set at 10 breaths per minute
- Ti should be set to ____________ to result in a 1:2 I:E ratio.

I:E ratio

- Ti:Te is known as the I:E ratio (Inspiratory:Expiratory ratio)
- Ti = 1 second
- Te = 4 seconds
- I:E ratio is 1:4
- Normal I:E ratio is 1:2

- CONSIDER THIS:
- A patient's respiratory rate is set at 10 breaths per minute
- Ti should be set to 2 seconds to result in a 1:2 I:E ratio.



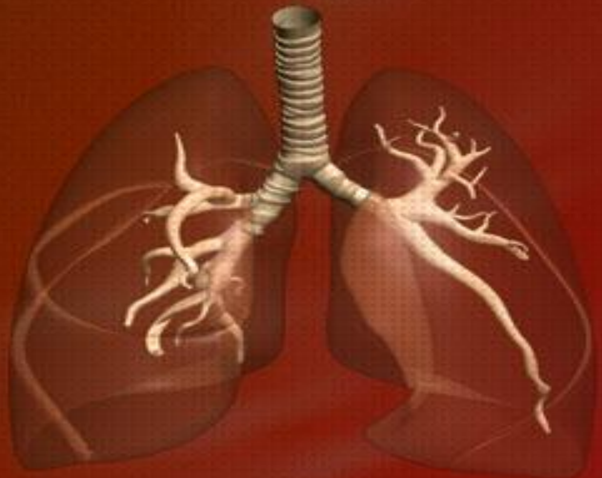
I:E ratio

Abnormal I:E ratio are uncomfortable and require deep sedation

More inspiratory time (e.g. 1:1.5 or 1:1) increases mean airway pressure (may reduce pulmonary blood flow), favors better oxygenation and reduces CO_2 clearance

↔

More expiratory time (e.g. 1:4 or higher) increases CO_2 clearance and improves ventilation but may increase atelectatisis



Questions?