Mechanical Ventilation (MV)

Presenting the Argument

10/15 jk

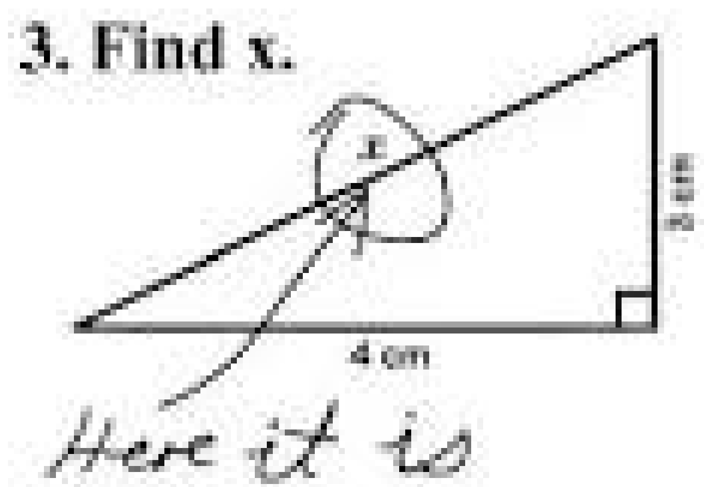
Our job is to convince people who think they know more than us to do what we want

And (if you're really good) make them think it's their idea!

Presenting a Compelling Argument

- Establish the “givens” of the arguments
  - Example “two points make a line”
- Present all responsible arguments – even ones you don’t support
- Construct a systematic approach that supports your argument.

Presenting the Givens



Ventilation – Exchanging water in the Fish Tank

The solution to pollution is dilution

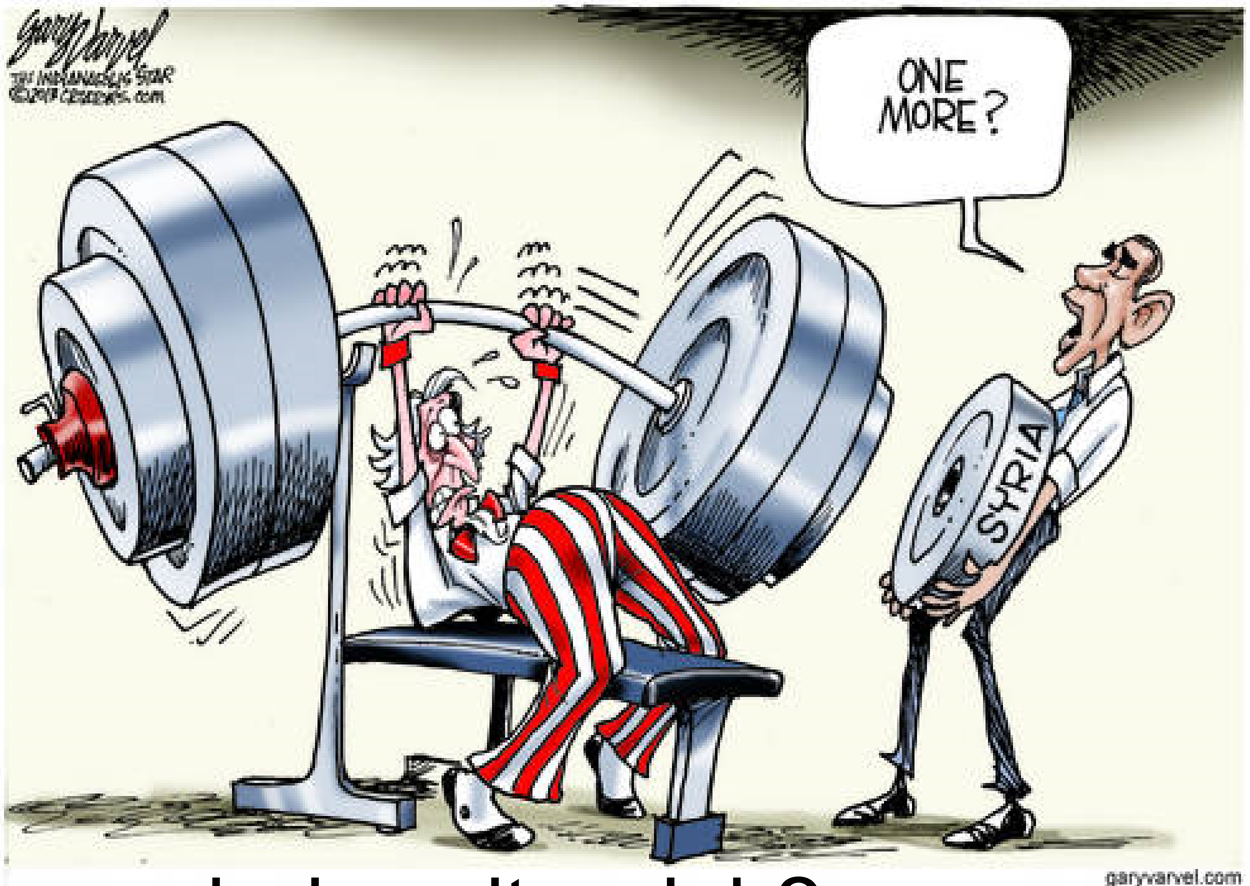
Ventilation/Volume Exchange

- The movement of gas in and out of the lungs
- Marker of effectiveness = $PaCO_2$
- Marker of efficiency = Minute Ventilation
- $VA = RR\ (V_t - V_d)$
  - VA= Alveolar ventilation – gas reaching profused alveoli
  - V_t =Tidal Volume
  - V_d = Dead Space Ventilation (part of breath that does not reach profused alveoli

Effectiveness Vs Efficiency
Driving a Tank to Chicago

Did you get there = Effectiveness
How much did it cost = Efficiency

Bench Pressing Analogy



How much does it weigh?
How strong is the lifter?
How many time to you want to lift it?

Ventilation/Volume Exchange

$$\Delta P_T = (V*E) + (Q*R)$$

ΔP_T = total pressure change needed to displace a breath

Actions

V = Displaced volume

Q = Gas flow through airways

Impedance factors

E = Elastic recoil of the system

R = Resistance (Frictional forces) opposing gas flow

Ventilation/Volume Exchange

$$\Delta P_T = (V*E) + (Q*R)$$

- An ↑ in any of these factors ↑ the total pressure change needed to displace a breath
- In spontaneous breathing, ΔPT is developed by the inspiratory muscles, primarily the diaphragm
- When load (ΔP_T) is great than capacity (inspiratory muscle strength) ventilatory failure ensues

EXTERNAL RESPIRATION

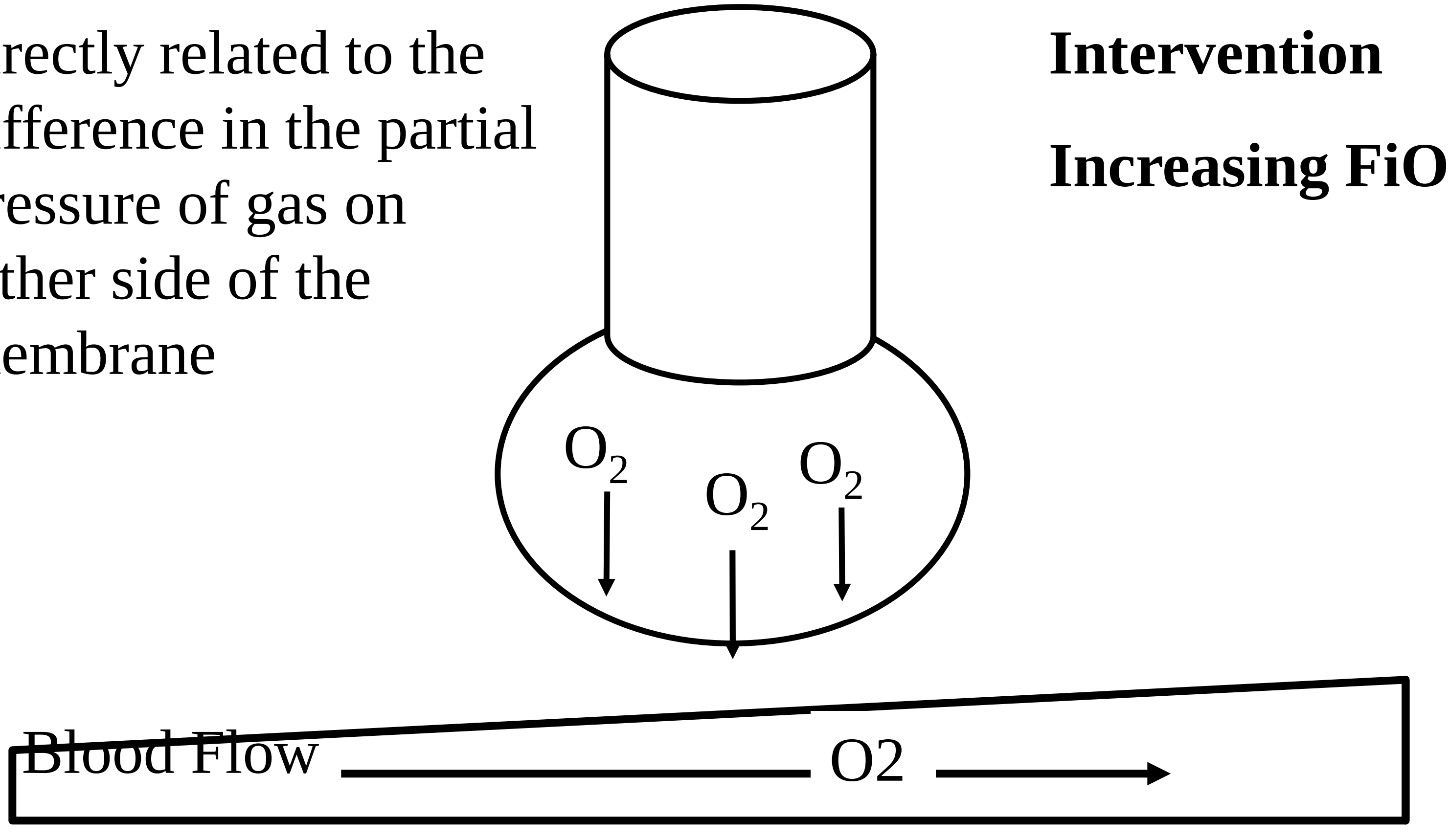
- The movement of gas across membranes
- Effectiveness measured by PaO2
- Marker of efficiency = PaO2/FiO2
  - PaO2 of more than 500 on100% O2 is normal
  - PaO2 < 300 on 100% = Acute lung injury
  - PaO2 < 200 on 100% is one criteria for ARDS

Fick's Law
Jumping a Gap Analogy

How strong are their legs?
How wide is the gap?
How big is the ledge?

Factors Affecting the Rate of Gas Movement Across the A/C Membrane

The rate of diffusion is directly related to the difference in the partial pressure of gas on either side of the membrane

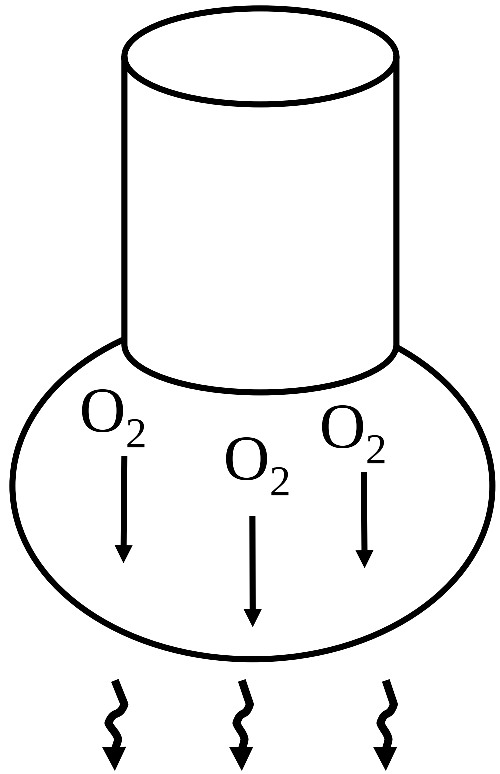


Clinical Intervention

Increasing FiO2

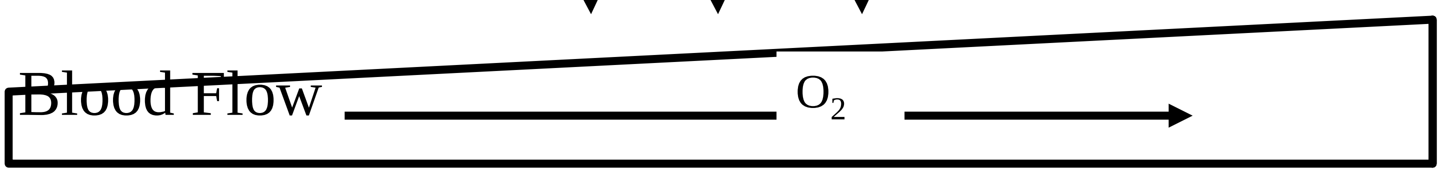
Factors Affecting the Rate of Gas Movement Across the A/C Membrane

The rate of diffusion is directly related to the membrane’s permeability characteristics for the gas



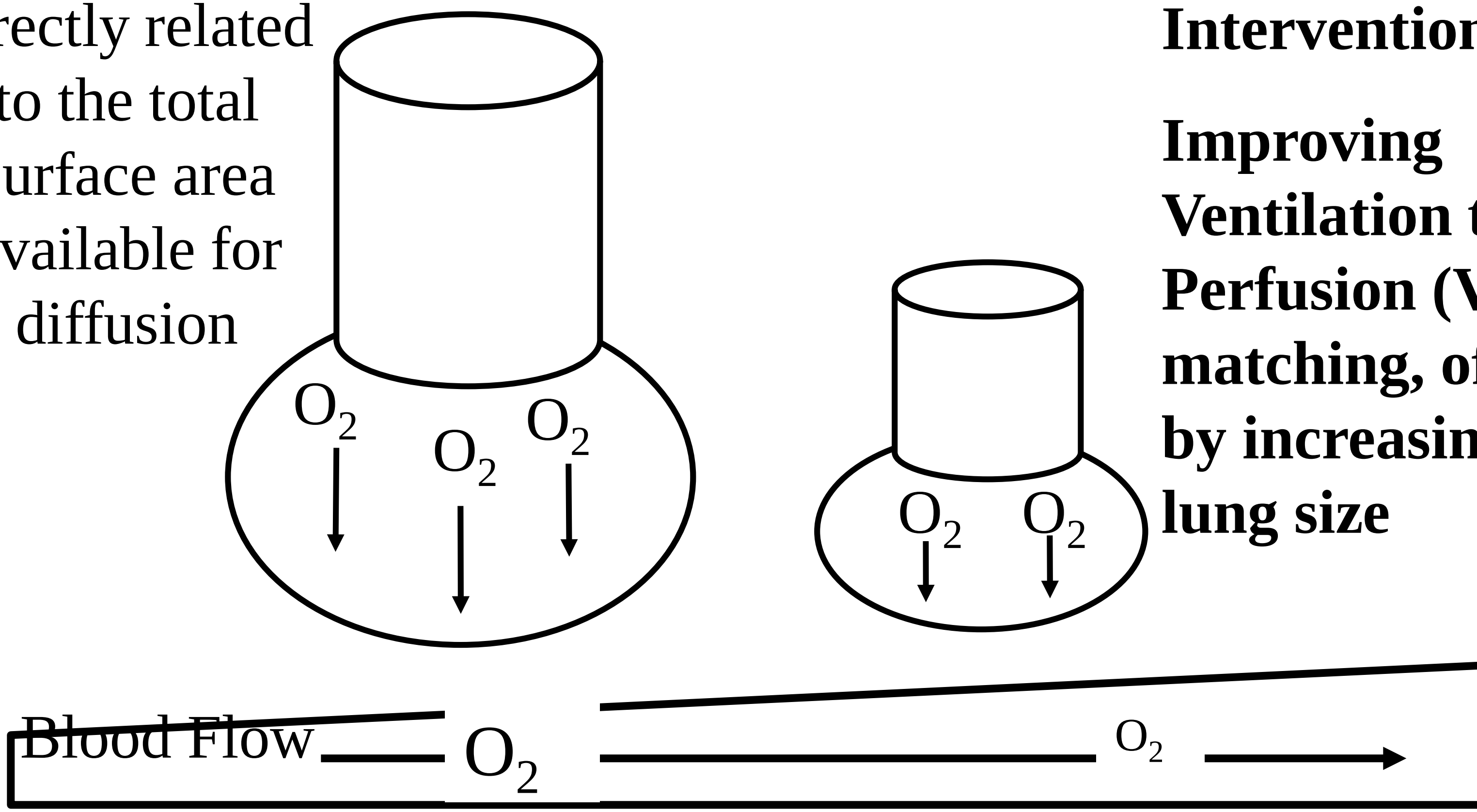
Clinical Intervention

Thinning A/C Membrane



Factors Affecting the Rate of Gas Movement Across the A/C Membrane

The rate of diffusion is directly related to the total surface area available for diffusion



Clinical Intervention

Improving Ventilation to Perfusion (V/Q) matching, often by increasing lung size

V/Q Mismatch in Mechanical Ventilation

Classic Sources of V/Q Mismatch

- Restrictive processes:
  - ↓lung size creating airway instability
    - Loss of airway patency
    - Alveolar collapse
  - ↓ O_2's ability to reach perfused alveolar/capillary membranes
- Disruption in blood distribution in the lung
- Results in V/Q mismatch and ↓ SaO_2, which is non-responsive to ↑ O_2 dose (refractory hypoxemia)

Improving O2 diffusion

Beyond ↑ oxygen dose, ↑ V/Q matching is most often used:

- Traditionally through lung distention via PEEP/CPAP
- Distention therapy is best reflected in mean airway pressure (MAP).
- Additional options include
  - Proning/positioning
  - Unilateral lung ventilation
  - Inverse I:E ventilation
  - Spontaneous, non positive pressure assisted, ventilation

The Collapsed House Analogy

An alveolus, like a house is never more stable than when its collapsed into its own basement

Does the Chest Move the Lung, or Does the Lung Move the Chest?

Ventilation Distribution in Positive Pressure (PPB) vs. Spontaneous, Non-pressure Assisted Breathing (SB)

The chest is moving the lung

- During SB, pleural pressure drop favors high perfusion regions, promoting ↑V/Q matching

The lung is moving the chest

- During PPB, there is no pleural pressure drop, so ventilation go to the areas of least resistance, often, the areas of lowest perfusion, promoting ↓V/Q matching

Indications for Positive Pressure Therapy (Lung Distention)

- **Respiratory failure (Type 1)** - Hypoxemia (↓PaO_2) refractory to oxygen therapy

Indication for Mechanical Ventilation

- **Ventilatory failure (Type 2 Respiratory Failure) -** Impending or frank Hypercapnia (↑$PaCO_2$) with or without hypoxemia

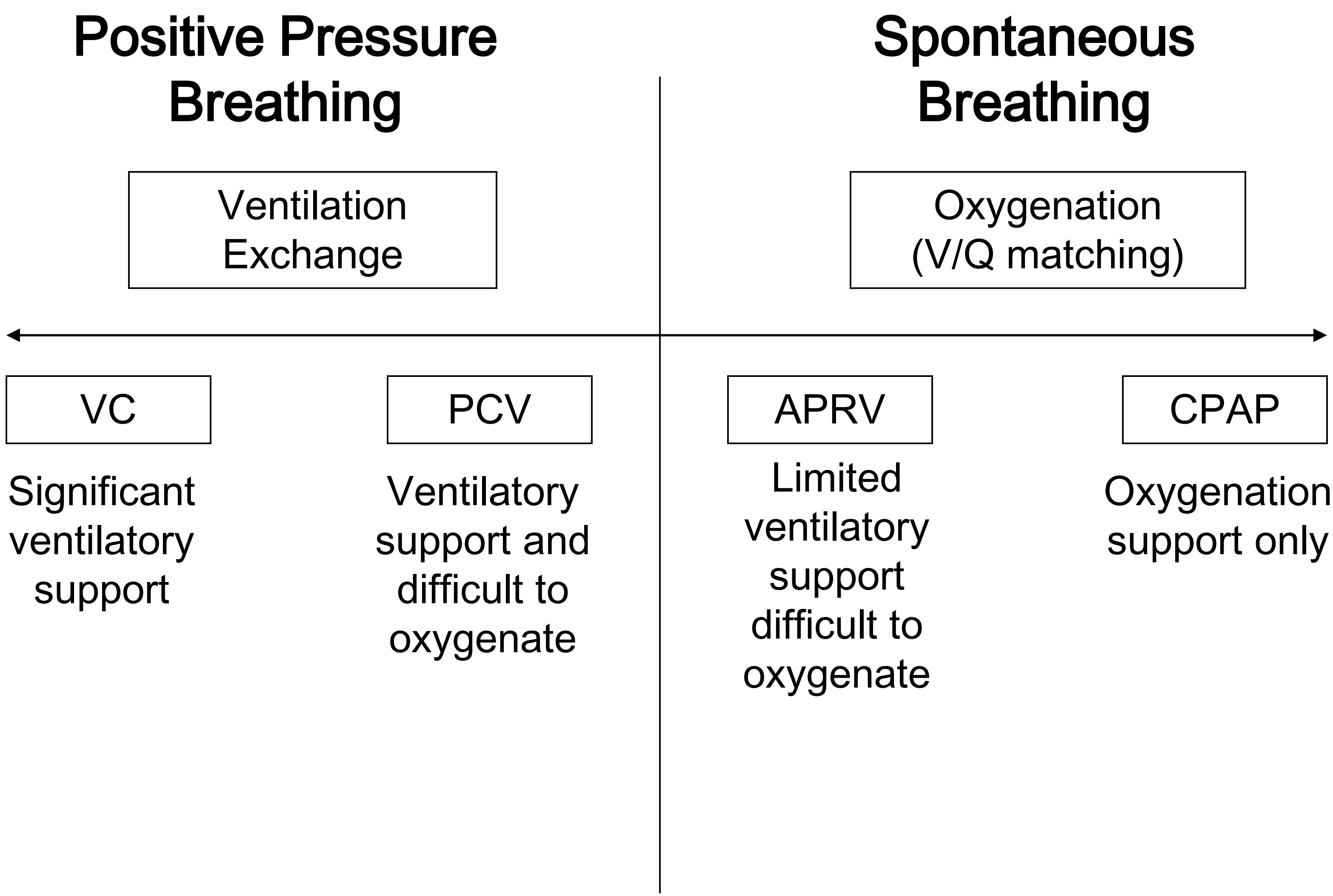
General Goals of Mechanical Ventilation/Positive Pressure Therapy

- CO2 Clearance (Exchange)
  - Volume Exchange
- Oxygenation
  - Surface area manipulations **(Distention)**
  - FiO2 (Adjusted if other approaches ineffective)

The 3 Big Questions

- How much Distention (oxygenation)?
- How much exchange (ventilation)?
- How much is the patient able to participate in ventilation (Can the chest move the lung, or must the lung move the chest)?

When to use which Method of MV



Non-Invasive Approach

It's a Facial Tissue Not a Kleenex Analogy

NIPPV Vs BiPAP

Distention Therapy - CPAP

- CPAP: Continuous Positive Airway Pressure
  - Does not directly assist with inspiration, therefore is not technically a form of mechanical ventilation.
  - Pressure setting directly impact resting lung size and airway stability – improving V/Q matching

Exchange Techniques – NIPPV (BiPAP)

- NIPPV Non-invasive positive pressure ventilation
- CPAP with additional pressure applied during inspiration
  - Is therefore a form of mechanical ventilation

Don’t wait to intubate

Take-Home Points

- NIPPV is ***not*** a replacement for ETI and CMV
  - COPD and Auto-immune process may be exceptions
- Can be very effective on an Acute and Chronic basis
- Proper Interface is paramount to success
- Patient education and flexibility will improve compliance

Invasive Mechanical Ventilation

Method of MV

Often based on need

- Oxygen delivery (via distention and V/Q matching)
  - Often used in ARDS or Acute Lung Injury
- CO_2 clearance (via exchange)
  - Most common during post-op recovery

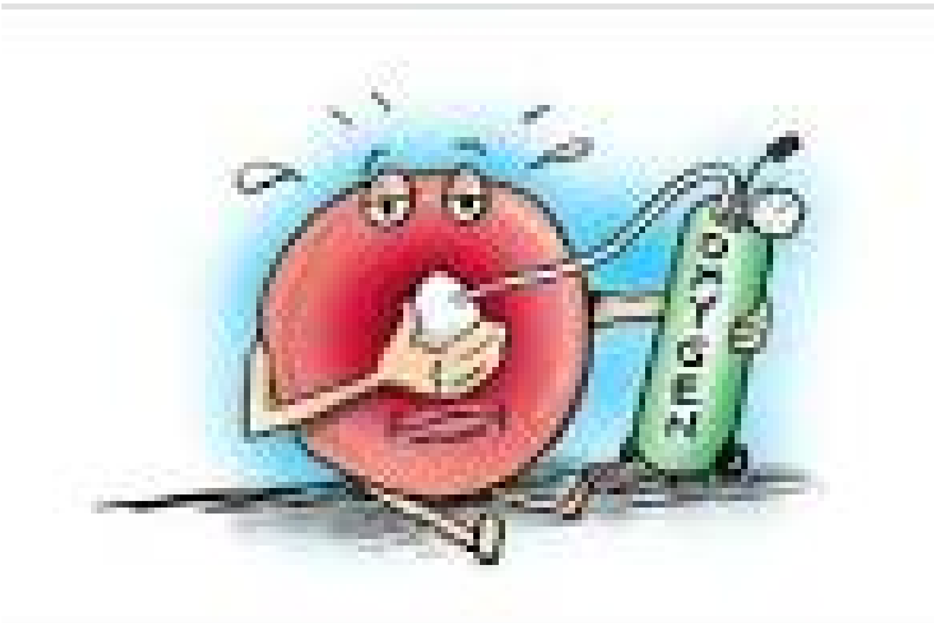
Goals of MV in ARDS/Acute Lung Injury

Deliver enough oxygen to tissues to met aerobic needs (lactic acid)

- Clear enough CO2 to maintain life
- Avoid lung stress

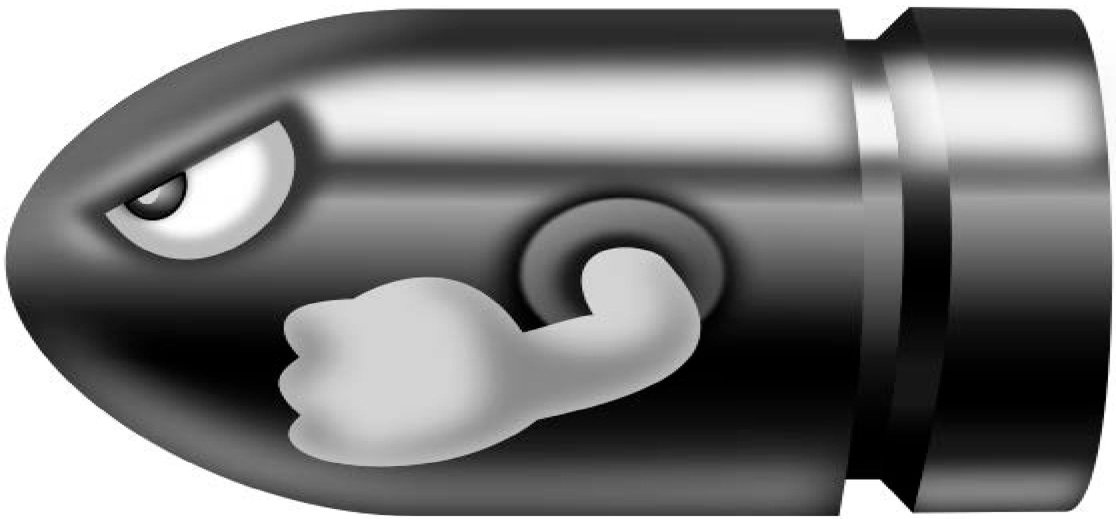
More than this is not helpful

Why do We care about oxygen anyway?



They say “I’d feel better if the patient’s Pa02 was 80 instead of 55
and You say
“I understand, but I’m not here to make you feel better, I’m here to what’s best for the patient

The Bullet Analogy



Its not the energy in the bullet when it leaves the gun that's the problem, it the energy in the bullet when it hits your chest that hurts!

Avoiding Lung Stress

Peak Airway Pressure (PIP)

Total force required to deliver breath (ΔPt)

- Pressure required to flow gas through airways ($\dot{V}$*R),
  - Is not transmitted to alveolar wall
  - Does not in itself indicate ↑risk of barotrauma
- Pressure required to distend lung (V*E)

Avoiding Lung Stress

Plateau Pressure (P_{plat})

- Force required to distend lung
- Measured in static conditions
- In ARDS, static pressures <30 cmH2O, when associated with Vt of 6 ml/Kg IBW were associated with better outcomes
- Values >35 cmH2O, regardless of Vt size, were associated with poorer outcomes

Therefore lower PIP but decreasing flow components will not lower lung stress

To reduce lung stress, lower plateau

Volume Exchange (Ventilation) Orientated Techniques

Volume Cycled Ventilation

Advantage

- Reproducible volumes ↑likelihood of constant ventilation (CO_2 exchange)

Disadvantage

- Lack of volume adjustments with changing lung mechanics may ↑ risk of barotrauma.
- Difficult to control mean airway pressure. (Distention)
- Positive pressure breathing increases V/Q mismatch (lung is moving chest)

Pressure Support

Advantage

- Seems to be more effective at reducing work of breathing and promoting muscle coordination than IMV.
- Self adjusting flows able to respond to pt's breathing pattern.

Disadvantages

- No guaranteed volume or frequency
- Difficult to control mean airway pressure. (Distention)
- May increase V/Q mismatch (lung is moving chest)

Distending Techniques

Give Them the Image

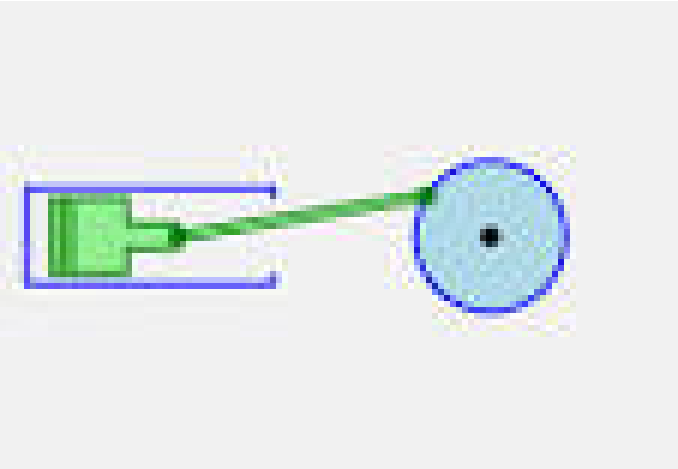
Distending Techniques

- Focuses on improving gas membrane transfer by ↑ average lung surface area – blood contact area
- ↑ Mean Airway Pressure (P_{ma}) (and therefore average lung volume) by:
  - Increasing resting lung size via PEEP/CPAP
  - Increasing inspiratory time (breath holding)
  - Increasing delivered volume (not popular at this time)

PEEP vs. Inspiratory Time (T_i)

Affects on MAP

Why We have PEEP
Old Days Remembered



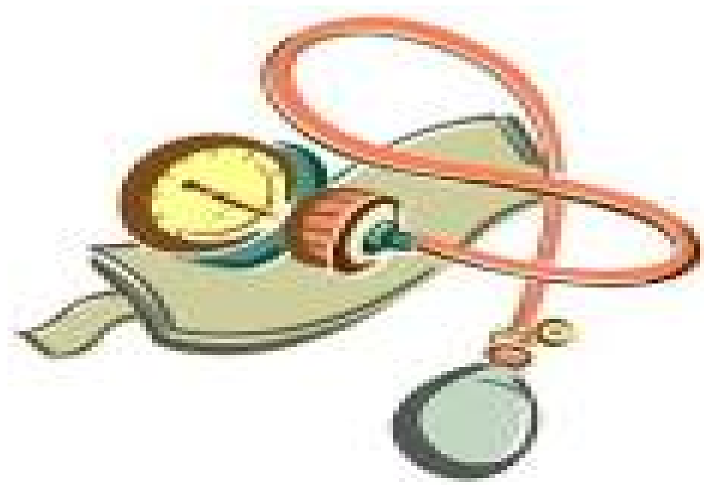
Does the Lung Respond to Distention? Recruitment Maneuvers

- Temporary lung hyperinflation to determine if it is possible to recruit lung units
- Common approach – 40 cmH2O of CPAP for 40 seconds.
- Can cause drop in blood pressure and heart rate.
- Saturations often fall during the maneuver
- SpO2 ↑= consider distention therapy

PEEP AND CPAP
Adjusting Resting Lung Volumes

- Restrictive processes reduce lung surface area and creates airway instability
  - reduces O2's ability to reach alveolar/capillary membrane
  - results in decreased blood oxygen levels.
- Traditional method of counter-acting:
  - continuous lung pressurization > atmospheric pressure, even during exhalation, to ↑resting lung size (FRC).

Mean Airway Pressure is like Mean Blood Pressure



Just a diastolic BP contributes to systolic, so PEEP contributes to plateau. Therefore, the higher the PEEP, the less Δp until critical plateau pressure is reached.

Time Cycled Ventilation Pressure Control

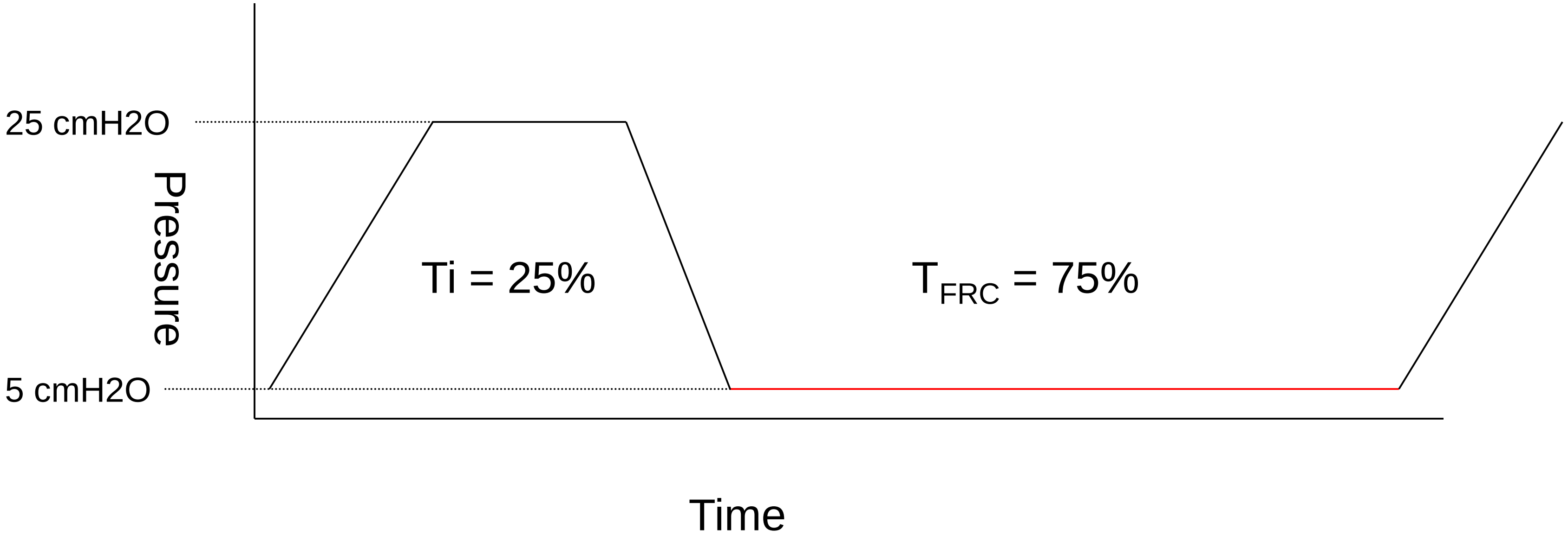
- Historically was not a common method, due to technical limitations.
- Now used in patients with very “stiff” lungs in ↑ average lung surface area without ↑absolute lung volume.
- Time cycled, pressure limited

Keeping Money in the Bank Analogy

Its not just how much you put in, but how long you keep it there!

Mean Airway Pressure

- $MAP = \dfrac{P_i * T_i\% + P_{FRC} * T_{FRC}\%}{100}$



Mean Airway Pressure

Example

P_i = 25 cmH2O T_i% = 25%
P_{FRC} = 5 cmH2O T_{FRC}= 75% **Driving Pressure = 20 cmH2O**

$$MAP = \frac{(25cmH2O*25) + (5\ cmH2O*75)}{100}$$

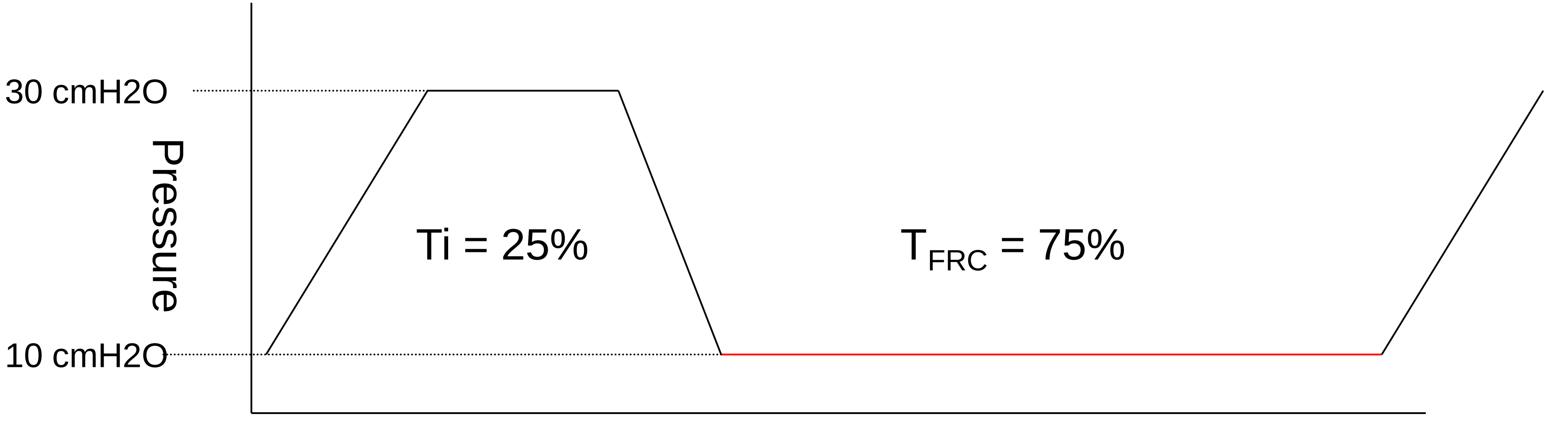
$$MAP = \frac{625+375}{100}$$

Notice P_i has a greater influence on MAP even though P_{FRC} lasts 3 times as long

MAP = 10 cmH2O

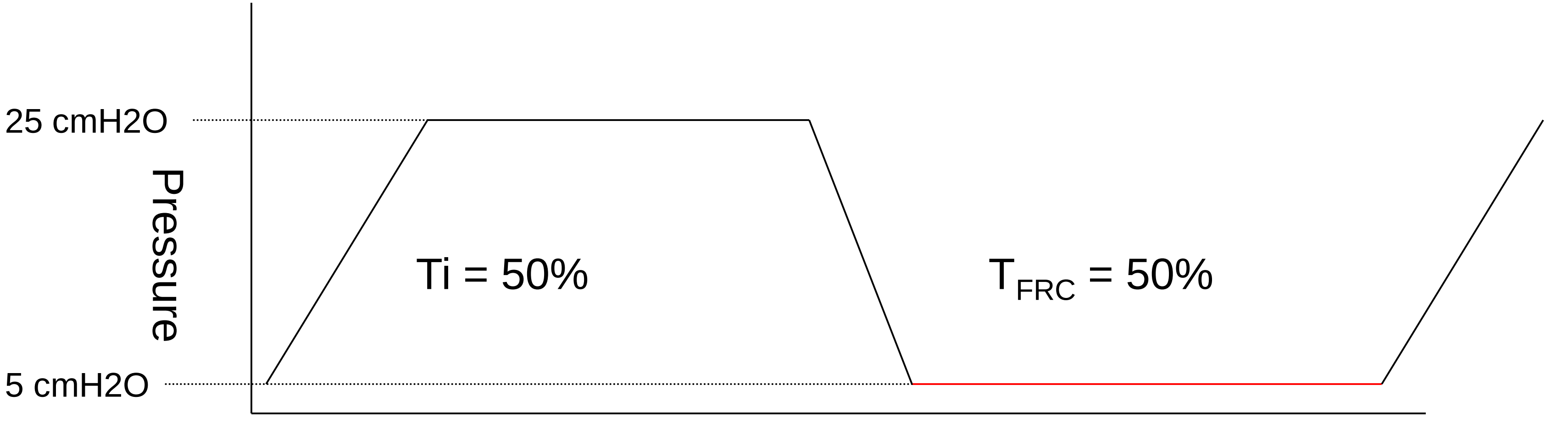
Mean Airway Pressure

Example ↑ PEEP



Mean Airway Pressure

Example ↑ Ti



Mean Airway Pressure

Example ↑ Ti

P_i = 25 cmH2O T_i% = 50%
P_{FRC} = 5 cmH2O T_{FRC}= 50%

Driving Pressure = 20 cmH2O

$$MAP = \frac{(25\ cmH2O*50) + (5\ cmH2O*50)}{100}$$

$$MAP = \frac{1250+250}{100}$$

MAP = 15 cmH2O

MAP is ↑ without ↑ lung stress due to ↑ P_{Plat}

Permissive Hypercapnia
Who Cares about CO2?

- ↑ inspiratory time often leads to a decrease in total ventilation, resulting in ↓ CO2 clearance
- Absolute PaCO2 is not as important as pH.
- Acidosis is safer than an alkalosis and ↑ O2 unloading at cellular level.
- Hypercapnia it tolerated as long as pH is generally above 7.2
- Consider metabolic interventions for extreme acidosis

Predicting Fatigue with RSBI The Sack of Potatoes Analogy

Weaning Parameters

Rapid Shallow Breathing Index (RSBI)

- RR/Vt (in L)
- >105 suggests the patient will not be able to tolerate weaning
- Better predictor of failure than success.