RESPIRATORY FAILURE AND INTERVENTIONS

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MAYO CLINIC

http://www.healthcare.philips.com/pwc_hc/main/shared/Assets/Images/HospitalRespiratory/BiPAPFocus_275x250.jpg

OBJECTIVES

Define	Define respiratory failure and identify the need for non-invasive positive pressure ventilation
Understand	Understand the physical principles of positive pressure ventilation and ventilatory assistance
Manage	Manage a patient on non-invasive positive pressure ventilation
Understand	Understand cardiopulmonary interaction and physiologic consequences of positive pressure ventilation
Review	Review basic mechanical ventilation principles

James Walker
Age 72
MRN 361-440-57

ARTERIAL SAMPLE
09/25/2013 11:18
System Name RC4
System ID 0405-10484
Acc No [redacted]
Patient ID
[redacted]

Operator 32112

ACID/BASE

pH	7.35	
pCO_2	55	mmHg
pO_2	55	mmHg
HCO_3^-act	29	mmol/L
BE(B)	2.9	mmol/L

CO-OXIMETRY

Hct	36	%
tHb	12.4	g/dL
sO_2	96.4	%
FO_2Hb	95.5	%
FCOHb	0.7	%
FMetHb	0.2	%
FHHb	3.6	%

CORRECTED 37.0 °C

pO_2(A-a)(T)	92.1	mmHg
pO_2(a/A)(T)	0.50	

Temperature	37.0	°C
F_IO_2	36.0	%
pAtm	740	mmHg

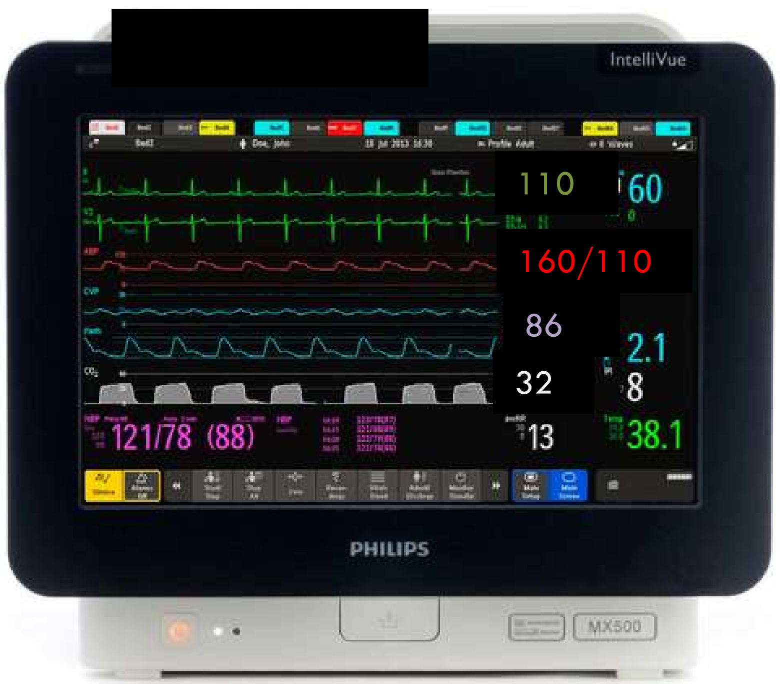
PATIENT RANGES

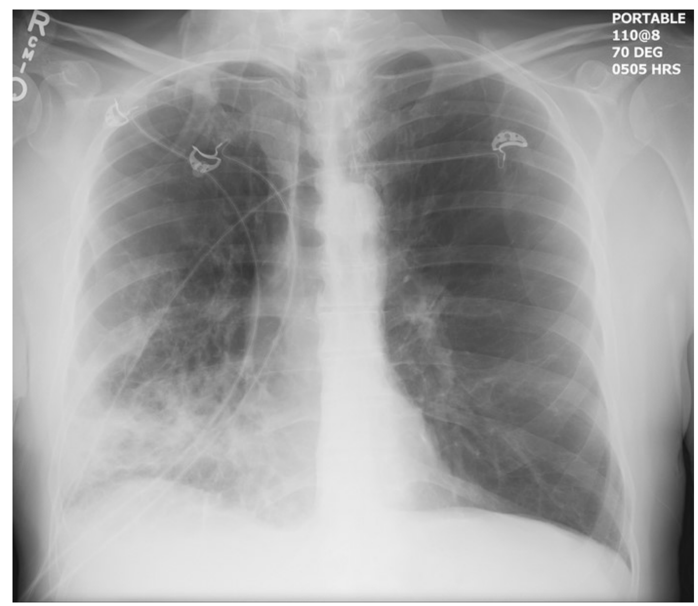
pH	7.350 - 7.450
pCO_2	35.0 - 45.0
pO_2	80.0 - 100.0
tHb	11.5 - 17.5
FO_2Hb	0.0 - 100.0
FCOHb	0.0 - 1.9
FMetHb	0.0 - 0.9
FHHb	0.0 - 100.0

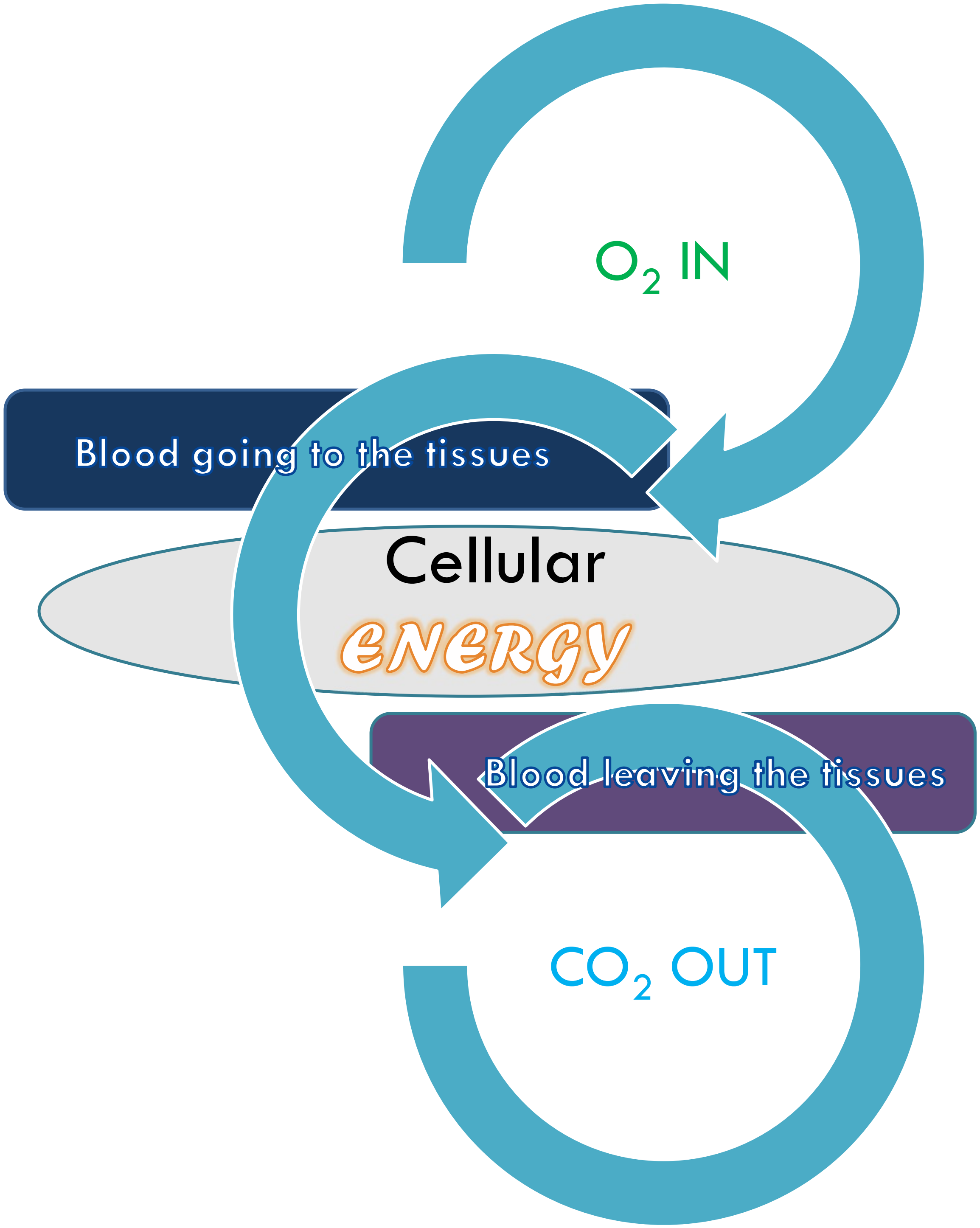
↓,↑=Out of range

COPD Exacerbation
FEV_1 55%
70 pyh smoker
Increased green sputum production

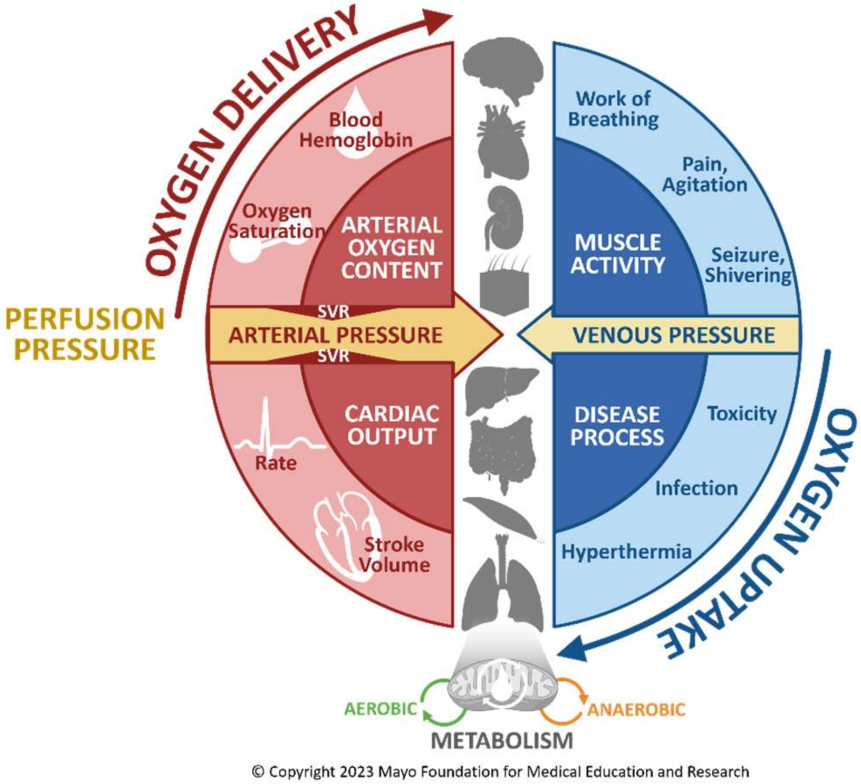
ORDERS
SVN- Albuterol/Atrovent x 3
ABG
Chest Xray
02 Therapy

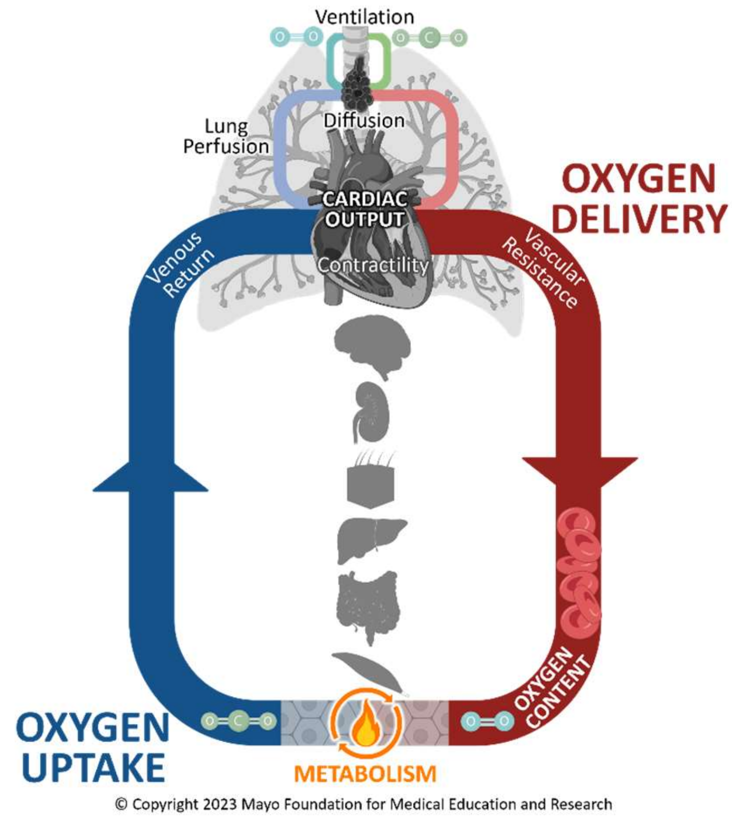






WHY DO WE BREATHE?





OXYGEN DELIVERY AND OXYGEN CONSUMPTION

NORMAL BREATHING

O2/CO2 MOVEMENT

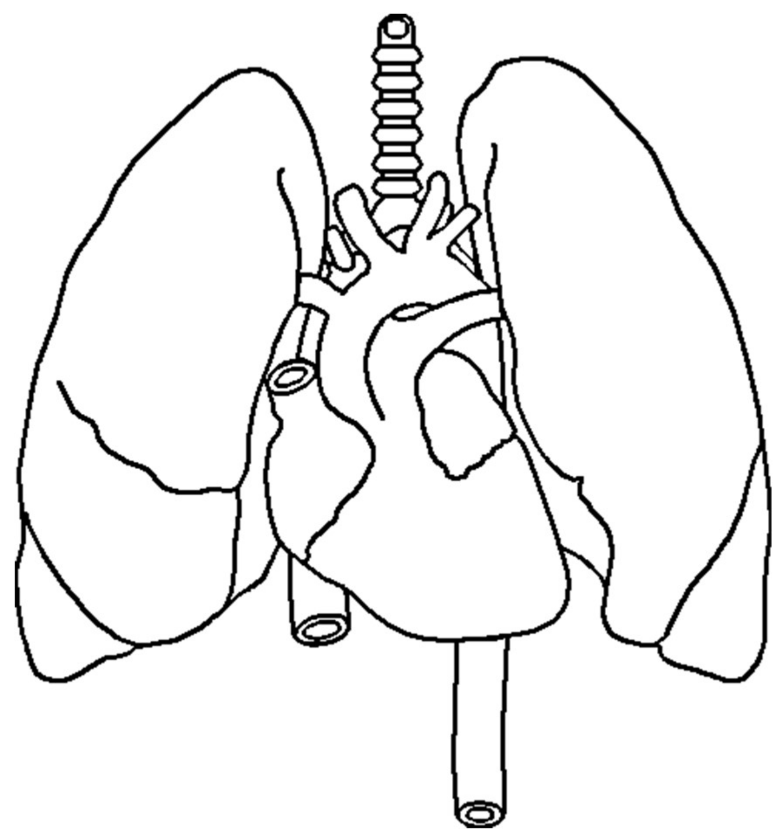
ENVIRONMENT
↕
PROXIMAL AIRWAYS
↕
DISTAL AIRWAYS
↕
ALVEOLI
↕
CAPILLARIES
↕
CIRCULATION
↕
TISSUES

NECESSARY COMPONENTS

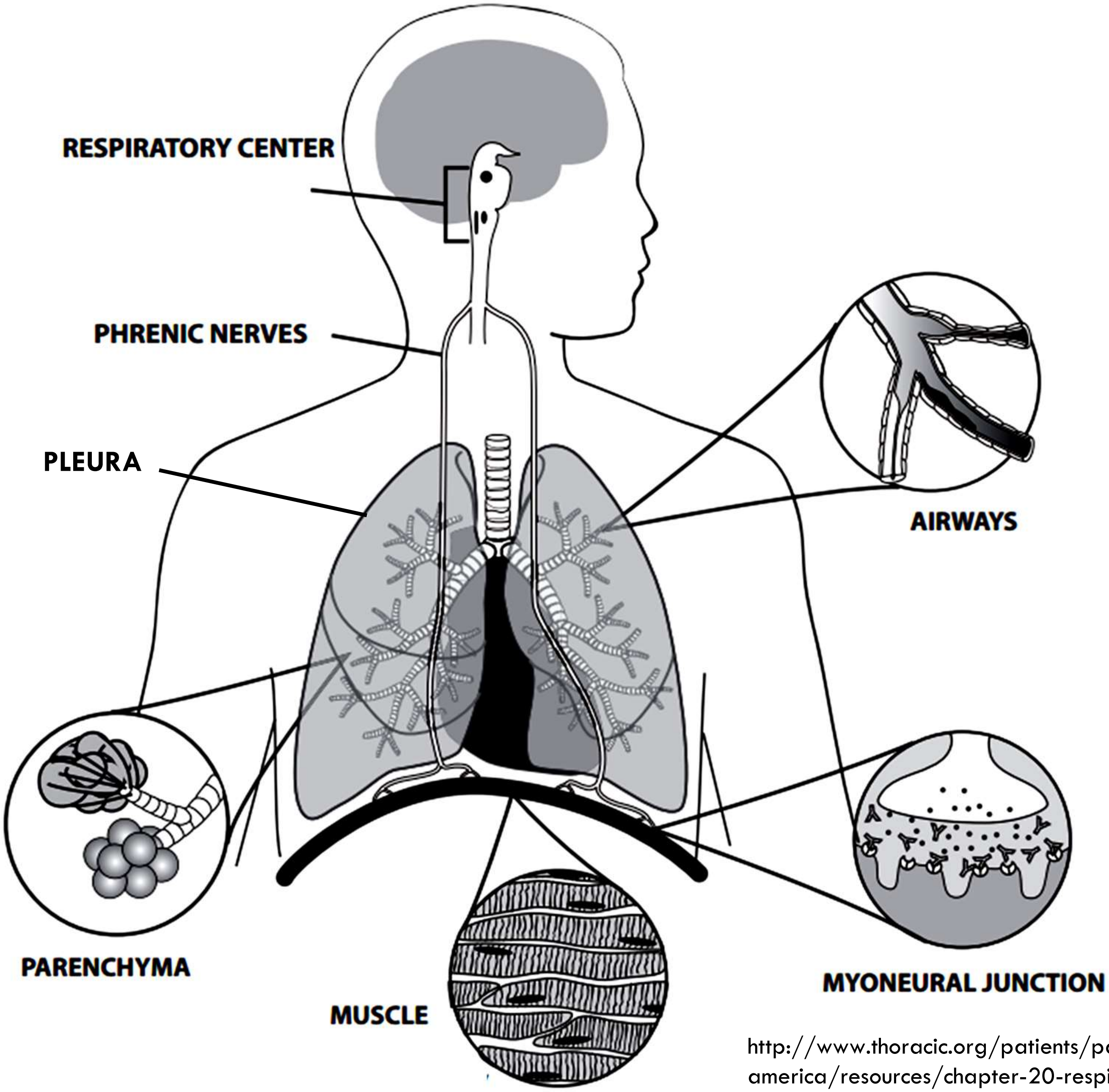
Respiratory Pump (V)

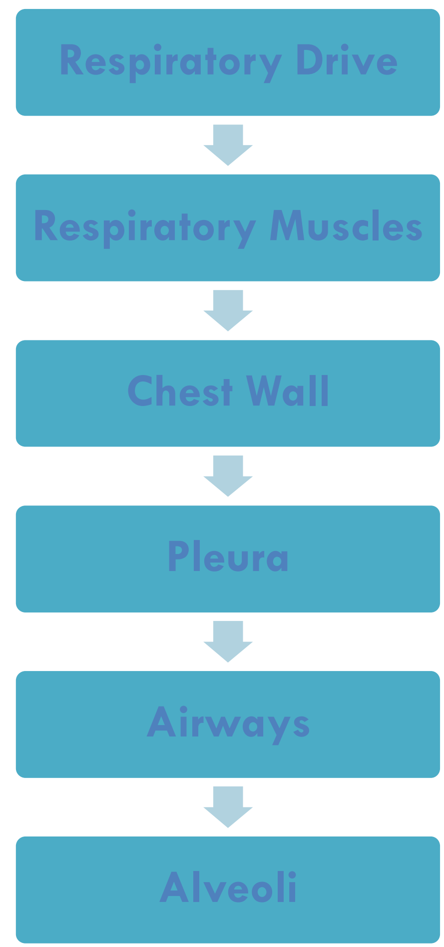
Circulatory Pump (Q)

Interface Between the Two



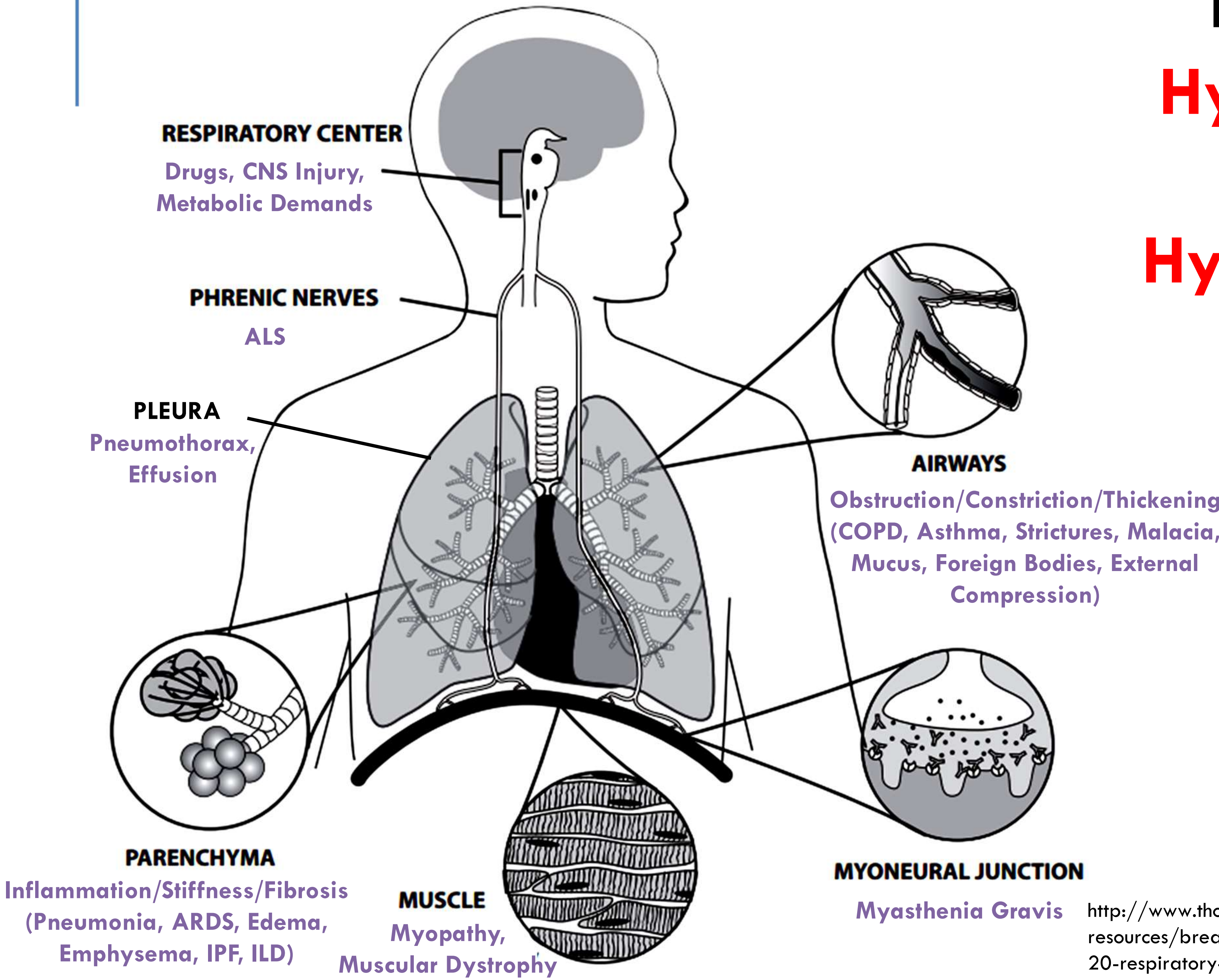
RESPIRATORY PUMP





http://www.thoracic.org/patients/patient-resources/breathing-in-america/resources/chapter-20-respiratory-failure.pdf

RESPIRATORY FAILURE



RESULT:

Hypoxemia and/or Hypercapnia

http://www.thoracic.org/patients/patient-resources/breathing-in-america/resources/chapter-20-respiratory-failure.pdf

RESPIRATORY FAILURE

Hypoxemic
TYPE I

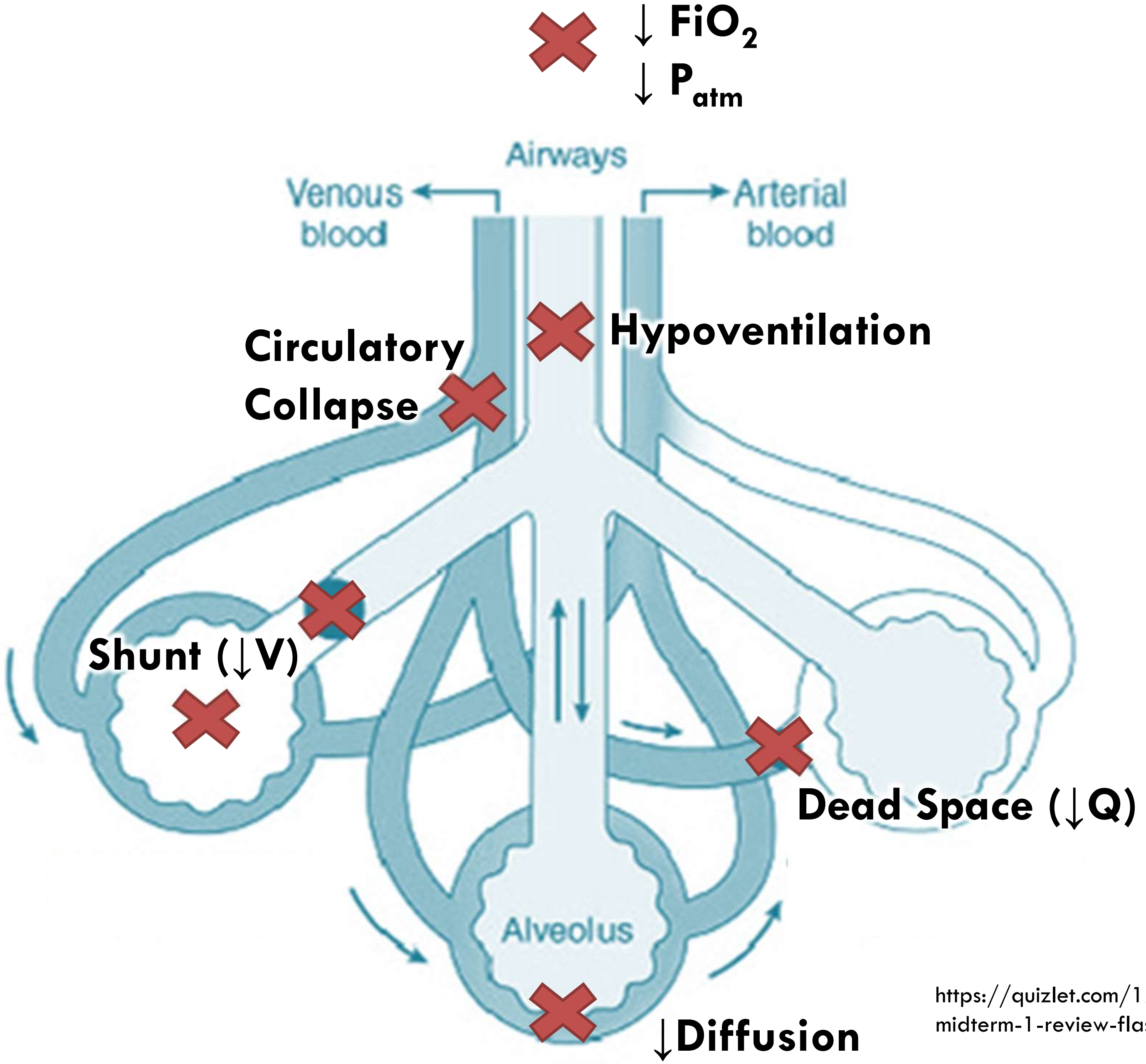
ACUTE and/or CHRONIC

Hypercapnic
TYPE II

↓ **SpO_2**
↓ **PaO_2**

↑ **$PaCO_2$**
↑ **$EtCO_2$**

TYPE I: HYPOXEMIC RESPIRATORY FAILURE



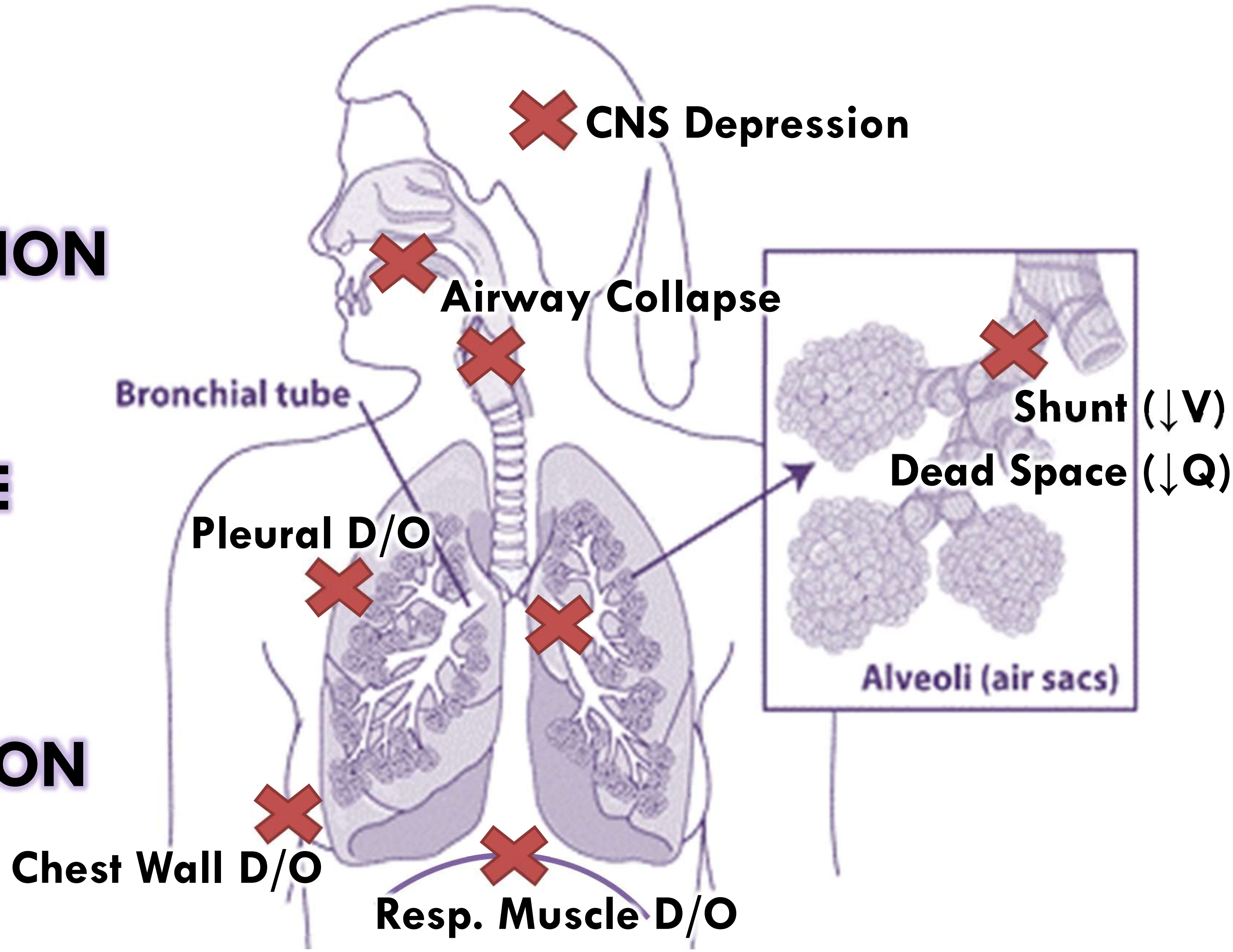
https://quizlet.com/12941757/patho-202-midterm-1-review-flash-cards/alphabetical

TYPE II: HYPERCAPNIC RESPIRATORY FAILURE

HYPOVENTILATION

↑ DEAD SPACE VENTILATION

↑ CO2 PRODUCTION



CHRONIC RESPIRATORY FAILURE

- Results from any of the previously mentioned physiologic processes but sustained for weeks to months
- Often results in chronic metabolic changes seen in an arterial blood gas

Rule of Thumb	
Acute Ventilatory Failure	**Chronic Ventilatory Failure**
• pH decreases by 0.08 for every 10 mmHg increase in $PaCO_2$ (from 40)	• pH decreases 0.03 for every 10 mmHg rise in $PaCO_2$ (from 40)

Kacmarek, R., & Stoller, J. (2014) *Egans Fundamentals of Respiratory Care* (10th ed.). London: Elselvier Health Sciences

SIGNS OF RESPIRATORY FAILURE

EARLY

Tachypnea

Tachycardia

Hypertension

Use of accessory muscles

↓LOC

↓SpO_2

Circum-oral cyanosis

Nailbed paleness

FAST

LATE

Unconsciousness

Bradycardia

Bradynpnea

Hypotension

Generalized cyanosis

SLOW

RESPIRATORY INTERVENTIONS

INTERVENTIONS

Oxygen Therapy

Continuous Positive Pressure Ventilation

Bilevel Positive Pressure Ventilation

Mechanical Ventilation

Non-Invasive

Invasive

HOW TO CHOOSE THE INTERVENTION

ABG
- Acid-base
- Hypoxia
- Hypercapnia

WOB
- RR
- Pattern
- Effort

LOC
- Airway protection (gag, cough)
- GCS 8= intubate

Evidence
- Clinical Practice Guidelines
- Manufactures recommendations
- Literature

Hypoxia
- Oxygen Therapy
- CPAP

Hypercapnia
- Bilevel NIV
- Mechanical ventilation

↑WOB
- High Flow O_2
- Bilevel NIV
- Mechanical Ventilation

Airway Protection
- Mechanical Ventilation

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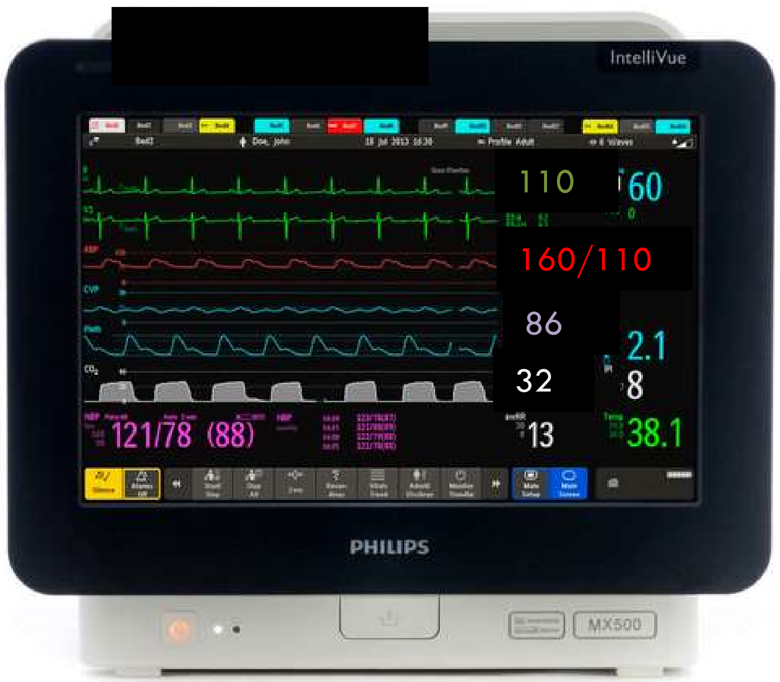

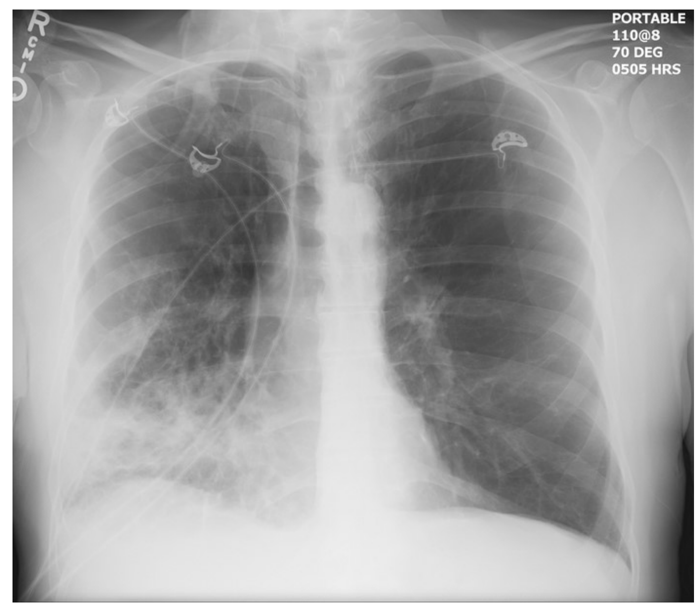

OXYGEN THERAPY

Nasal Cannula
1-6 LPM

- FIO2 variable- up to 0.44
- Not appropriate for patient with high work of breathing

Simple Mask
7-12 LPM

- FIO2 variable- up to 0.60
- Cannot be humidified
- Not a great choice for patients with high work of breathing

NRB Mask
10-15LPM*

- FIO2 variable- up to 0.95
  - *Can turn flowmeter up to 40LPM to keep bag inflated
- Cannot be humidified
- Not appropriate long term

High Flow Humidified Oxygen

- **0.21-1.0 FIO2 and 20-70 lpm Flow**
- Independent control of liter flow from FIO2
- Can generate positive end expiratory pressure (PEEP), minimal and variable
- Provides high quality gas humidification

LEARNING CHECK

You are called to see a patient for hypoxia :

- 65 year old male post-op left hip replacement on a PCA pump
- Obtunded, not –responding to painful stimuli, RR 4
- SpO_2 78% on NRB mask

WHAT IS THE MOST APPROPRIATE INTERVENTION?

- High flow nasal cannula
- CPAP
- BIPAP
- Bag-mask ventilation and intubation

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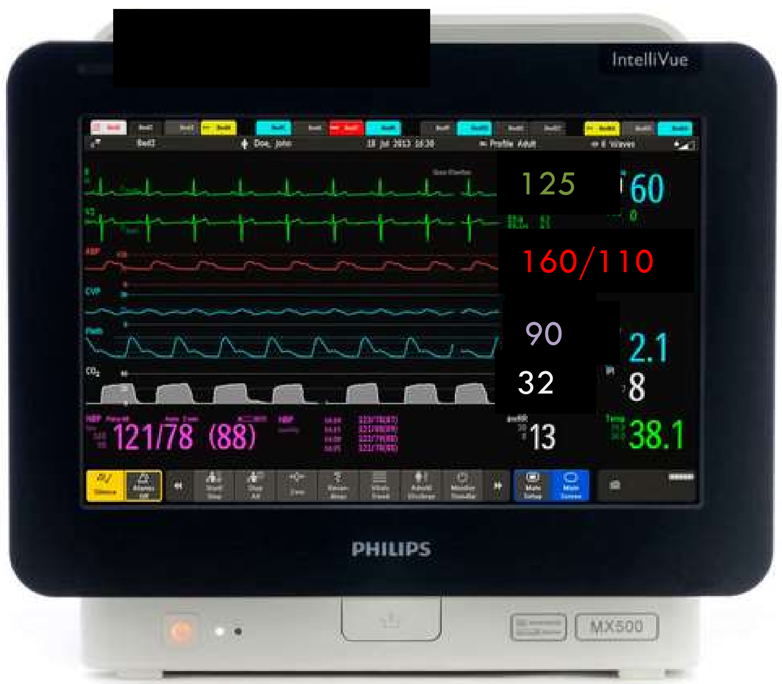
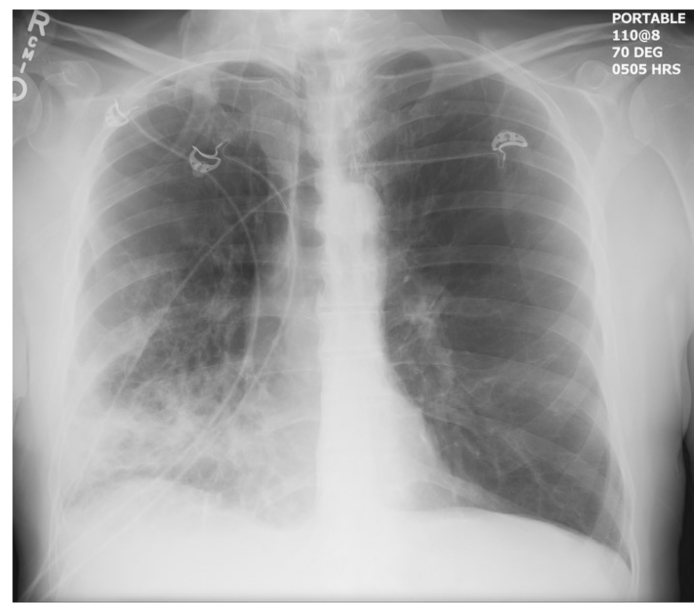
- ✓ ABG
- ✓ Chest Xray
- ✓ 02 Therapy





WHAT IS POSITIVE PRESSURE VENTILATION?

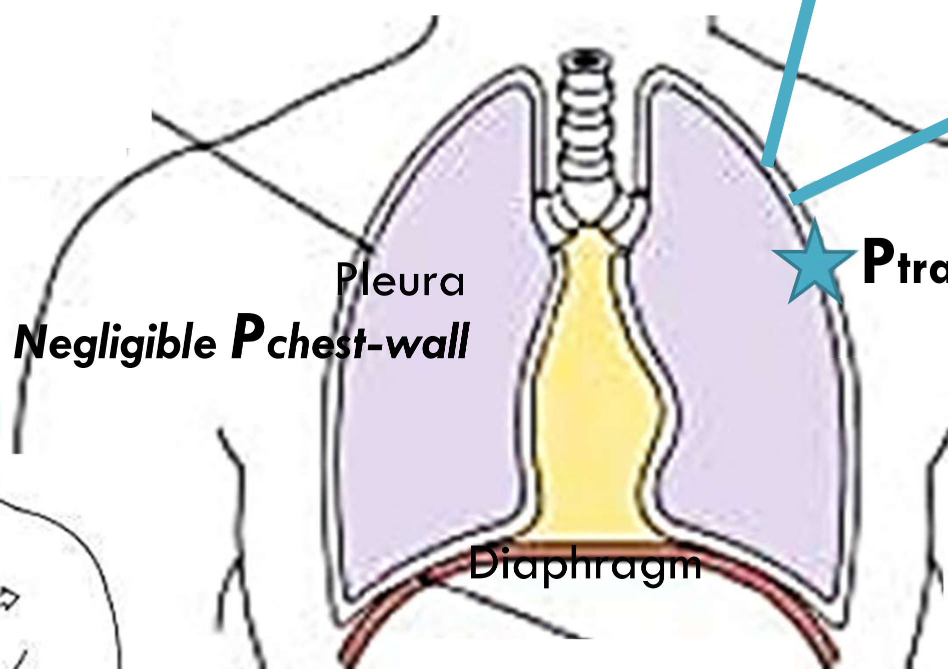
HOW DOES THIS DIFFER FROM NORMAL BREATHING?

NEGATIVE PRESSURE VENTILATION

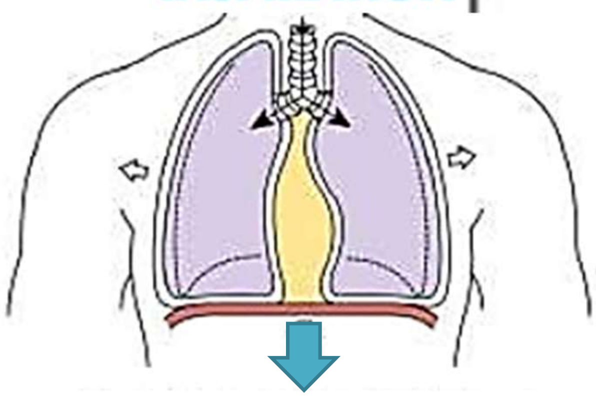
Patmosphere = Pintrapulmonary= 760mmHg (0)

Pintrapleural = 756mmHg (-4)

Ptranspulmonary = 4mmHg

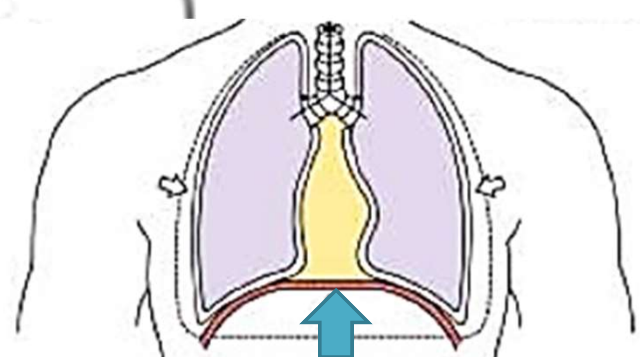


INSPIRATION



ACTIVE
When the diaphragm contracts
Ppleural more negative (-6 mmHg) than the atmosphteric pressure= pressure gradient high to low=
Gas moves into Lung

EXPIRATION

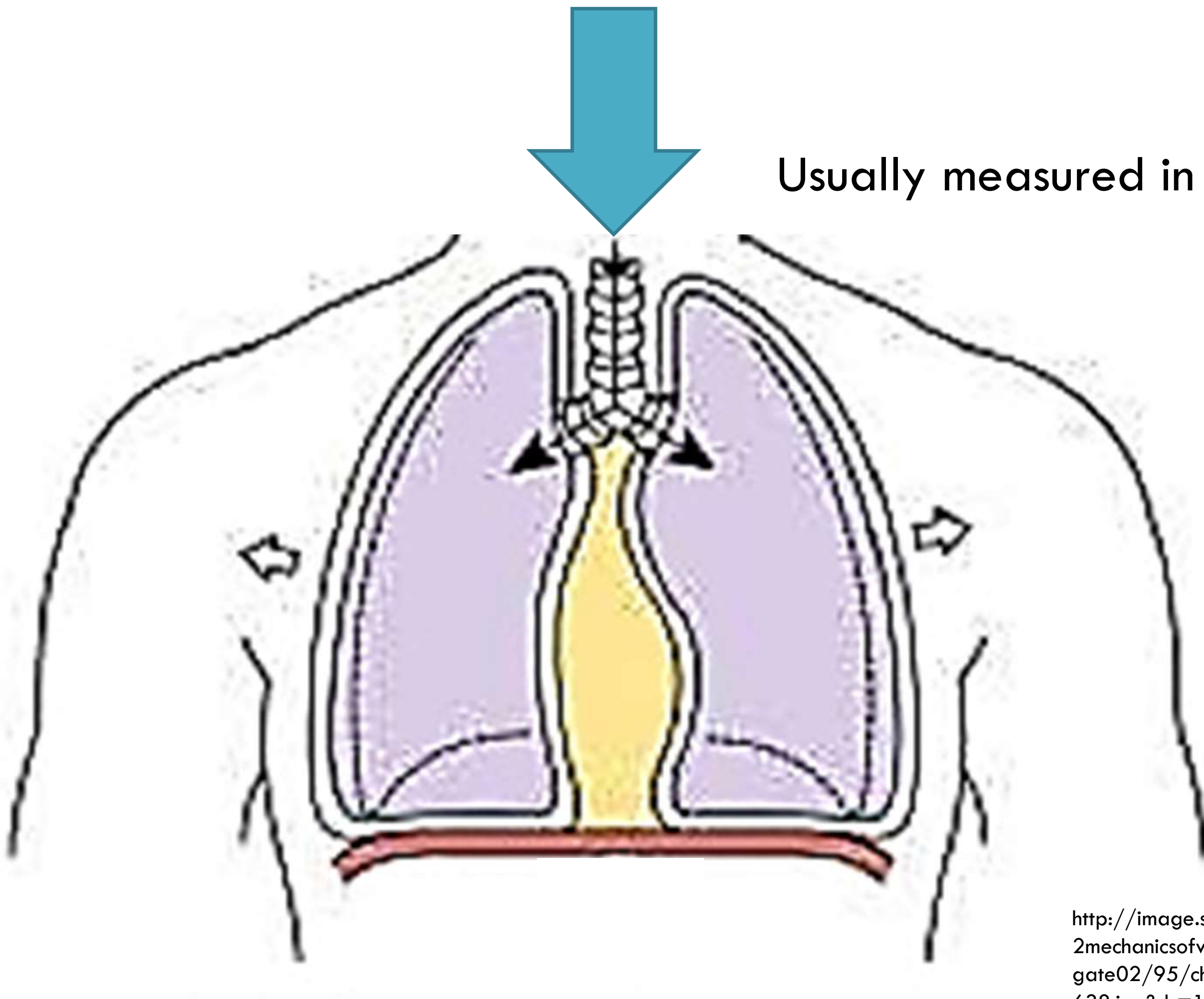


PASSIVE
Diaphragm relaxes
Ppleural normalizes (-4 mmHg)=
Gas moves out of the lung

http://image.slidesharecdn.com/chapter22respiratorysystem2mechanicsofventilation-150223173350-conversion-gate02/95/chapter-22-respiratory-system-2-23-638.jpg?cb=1424712985

POSITIVE PRESSURE VENTILATION

There is more pressure in the "atmosphere" aka ventilator circuit
Lungs expand due the "artificial" pressure gradient created between the circuit and the airways, does not require a contraction of the diaphragm



Usually measured in cmH_2O

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PHYSIOLOGIC CONSEQUENCES OF PPV

Gas Exchange

↑ alveolar recruitment

↑ alveolar surface area

↓/- V/Q matching

↑/↓ SpO_2 and PaO_2

↑/↓ O_2 Delivery

Hemodynamics

↓ LV and RV preload

↓ LV afterload

↑ RV afterload

↑/↓ cardiac output

↑/↓ blood pressure

Monitoring

↑ CVP

NIPPV GOALS

Acute Care

- Improve gas exchange
- Avoid Intubation
  - Decrease mortality
  - Decrease ventilator length of stay
  - Decrease length of hospitalization
  - Decrease incidence of ventilator associated pneumonia
- Relieve symptoms of respiratory distress
- Improve patient-ventilator synchrony
- Maximize patient comfort

Long-Term Care

- Relieve or improve symptoms
- Enhance quality of life
- Avoid hospitalization
- Increase survival
- Improve mobility

Kacmarek, R., & Stoller, J. (2014) *Egans Fundamentals of Respiratory Care* (10th ed.). London: Elselvier Health Sciences

PATIENT SELECTION

Acute Conditions

- Hypercapnic/Hypoxemic respiratory failure
- COPD exacerbation
- Acute cardiogenic pulmonary edema
- End of life/DNI
- Postoperative respiratory failure
- Prevention of reintubation in high risk patients
- Post extubation respiratory failure

Chronic Conditions

- Nocturnal hypoventilation
- Restrictive thoracic disease
- ALS
- COPD
- Obesity hypoventilation syndrome

Kacmarek, R., & Stoller, J. (2014) *Egans Fundamentals of Respiratory Care* (10th ed.). London: Elselvier Health Sciences

WHO SHOULD **NOT** GO ON NIPPV?

Cardiac arrest/respiratory arrest

Untreated pneumothorax

Non-respiratory organ failure

Facial surgery or trauma

Upper airway obstruction

Inability to protect the airway

High risk for aspiration

Mechanical Ventilation: Trends in adult and pediatric practice. (2009). Mount Prospect, IL: Society of Critical Care Medicine

LEARNING CHECK

- An 83 year old patient is post-op day 3 from parotid gland resection
- She is audibly gurgling and coughing but unable to expel secretions. Naso-tracheal suction reveals copious amounts of thick, white sputum
- The nurse tells you that she has just been made NPO because she was aspirating her food
- An ABG shows: pH 7.29, $PaCO_2$ 70, PaO_2 68, HCO_3 27

Is she an appropriate candidate for NIPPV? Y or N

Answer: NO, she cannot protect her airway and is at high risk for aspiration and needs aggressive pulmonary toilet. Intubation and mechanical ventilation are more appropriate.

THE EVIDENCE FOR NIPPV

Summary from the ERS/ATS Clinical Practice Guidelines

Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure

Bram Rochwerg [1], Laurent Brochard[2,3], Mark W. Elliott[4], Dean Hess[5], Nicholas S. Hill[6], Stefano Nava[7] and Paolo Navalesi[8] (members of the steering committee); Massimo Antonelli[9], Jan Brozek[1], Giorgio Conti[9], Miquel Ferrer[10], Kalpalatha Guntupalli[11], Samir Jaber[12], Sean Keenan[13,14], Jordi Mancebo[15], Sangeeta Mehta[16] and Suhail Raoof[17,18] (members of the task force)

TABLE 2 Recommendations for actionable PICO questions

Clinical indication[#]	Certainty of evidence[¶]	Recommendation
Prevention of hypercapnia in COPD exacerbation	⊕⊕	Conditional recommendation against
Hypercapnia with COPD exacerbation	⊕⊕⊕⊕	Strong recommendation for
Cardiogenic pulmonary oedema	⊕⊕⊕	Strong recommendation for
Acute asthma exacerbation		No recommendation made
Immunocompromised	⊕⊕⊕	Conditional recommendation for
***De novo* respiratory failure**		No recommendation made
Post-operative patients	⊕⊕⊕	Conditional recommendation for
Palliative care	⊕⊕⊕	Conditional recommendation for
Trauma	⊕⊕⊕	Conditional recommendation for
Pandemic viral illness		No recommendation made
Post-extubation in high-risk patients (prophylaxis)	⊕⊕	Conditional recommendation for
Post-extubation respiratory failure	⊕⊕	Conditional recommendation against
Weaning in hypercapnic patients	⊕⊕⊕	Conditional recommendation for

[#]: all in the setting of acute respiratory failure; [¶]: certainty of effect estimates: ⊕⊕⊕⊕, high; ⊕⊕⊕, moderate; ⊕⊕, low; ⊕, very low.

SUMMARY ERS/ATS RECOMMENDATIONS FOR NIV UTILIZATION

Question	Recommendation	Summary
Should NIV be used in COPD exacerbation?	1) To prevent acute respiratory acidosis, i.e. when the arterial CO2 tension (PaCO2) is normal or elevated but pH is normal 2) To prevent endotracheal intubation and invasive mechanical ventilation in patients with mild to moderate acidosis and respiratory distress, with the aim of preventing deterioration to a point when invasive ventilation would be considered. 3) As an alternative to invasive ventilation in patients with severe acidosis and more severe respiratory distress	Yes
Should NIV be used in ARF due to a COPD exacerbation to prevent the development of respiratory acidosis?	We suggest NIV not be used in patients with hypercapnia who are not acidotic in the setting of a COPD exacerbation. (Conditional recommendation, low certainty of evidence.)	Not to fix compensated chronic respiratory acidosis
Should NIV be used in established acute hypercapnic respiratory failure due to a COPD exacerbation?	We recommend bilevel NIV for patients with ARF leading to acute or acute-on-chronic respiratory acidosis (pH ⩽7.35) due to COPD exacerbation. (Strong recommendation, high certainty of evidence.) We recommend a trial of bilevel NIV in patients considered to require endotracheal intubation and mechanical ventilation, unless the patient is immediately deteriorating. (Strong recommendation, moderate certainty of evidence.)	Yes

SUMMARY ERS/ATS RECOMMENDATIONS FOR NIV UTILIZATION

Question	Recommendation	Summary
Should NIV be used in ARF due to cardiogenic pulmonary edema?	We recommend either bilevel NIV or CPAP for patients with ARF due to cardiogenic pulmonary edema. (Strong recommendation, moderate certainty of evidence.)	Yes
Should NIV be used in ARF due to acute asthma?	Given the uncertainty of evidence we are unable to offer a recommendation on the use of NIV for ARF due to asthma.	Not sure
Should NIV be used for ARF in immunocompromised patients?	We suggest early NIV for immunocompromised patients with ARF. (Conditional recommendation, moderate certainty of evidence.)	Yes
Should NIV be used in de novo ARF?	Given the uncertainty of evidence we are unable to offer a recommendation on the use of NIV for de novo ARF.	Not sure
Should NIV be used in ARF in the post-operative setting?	We suggest NIV for patients with post-operative ARF. (Conditional recommendation, moderate certainty of evidence.)	Yes
Should NIV be used in patients with ARF receiving palliative care?	We suggest offering NIV to dyspneic patients for palliation in the setting of terminal cancer or other terminal conditions. (Conditional recommendation, moderate certainty of evidence.)	Yes
Should NIV be used in ARF due to chest trauma?	We suggest NIV for chest trauma patients with ARF. (Conditional recommendation, moderate certainty of evidence.)	Yes

SUMMARY ERS/ATS RECOMMENDATIONS FOR NIV UTILIZATION

Question	Recommendation	Summary
Should NIV be used in ARF due to pandemic viral illness?	Given the uncertainty of evidence we are unable to offer a recommendation for this question.	Not sure *consider aerosolizing virus and resource limitations for infection control
Should NIV be used in ARF following extubation from invasive mechanical ventilation? Should NIV be used to prevent respiratory failure post-extubation?	=We suggest that NIV be used to prevent post-extubation respiratory failure in high-risk patients post-extubation. (Conditional recommendation, low certainty of evidence.) We suggest that NIV should not be used to prevent post-extubation respiratory failure in non-high-risk patients. (Conditional recommendation, very low certainty of evidence.)	Yes for high risk No for low risk
Should NIV be used in the treatment of respiratory failure that develops post-extubation?	We suggest that NIV should not be used in the treatment of patients with established post-extubation respiratory failure. (Conditional recommendation, low certainty of evidence.)	No- reintubation is recommended
Should NIV be used to facilitate weaning patients from invasive mechanical ventilation?	We suggest NIV be used to facilitate weaning from mechanical ventilation in patients with hypercapnic respiratory failure. (Conditional recommendation, moderate certainty of evidence.) We do not make any recommendation for hypoxemic patients.	Yes for respiratory acidosis Not sure for hypoxemic

NIV AND ARDS

Non-invasive Ventilation (NIV) of Patients with ARDS: Insights from the LUNG SAFE Study AJRCCM 2016 Oct

- 436/2813 (15.5%) of ARDS patients were initially managed with NIV regardless of severity
- NIV use independently associated with under recognition of ARDS 23.2%
- NIV Vt too large
  - 8.46 ± 2.77 ml/Kg vs. 7.53 ± 1.75 ml/kg invasive MV ($p \ll .001$)
- NIV PEEP inadequate
  - NIV 7cmH20 ± 2 vs. 8 cmH20 ± 3.1 invasive MV ($p < .001$)
- NIV failure occurred in 22.2% of mild, 42.3% moderate, 47.1% severe ARDS
- ICU mortality 10.6% NIV success vs. 42.7% NIV failure ($p < .001$)
- Hospital mortality 16.1% NIV success vs. 45.4 % NIV failure ($p < .001$)
- ICU Mortality P/F <150: NIV 36.2% vs. 24.7% Invasive MV ($p = 0.033$)

Conclusions: NIV was used in 15% of patients with ARDS, irrespective of severity category. NIV appears to be associated with higher ICU mortality in patients with a PaO_2/FiO_2 lower than 150 mmHg.

NIV/NHF IN ARDS

1. Recognize ARDS !
2. Be careful ! (pt selection)
3. NIV settings to target
   a) IPAP: tidal volume (Vt) 6-8 ml/kg PBW
   b) EPAP: Sp02 88-95% with lowest Fi02
4. NHF setting: Highest flow lowest Fi02
5. Closely monitor for 1-6 hours!
   a) Work of breathing:
      a) Accessory muscles
      b) Respiratory rate
   b) High likelihood of failure:
      a) P/F ≤ 175 after 1 hr
      b) Vt > 9.5 ml/kg PBW

Role of Noninvasive Ventilation in Acute Lung Injury/Acute Respiratory Distress Syndrome: A Proportion Meta-analysis Respir Care 2010;55(12):1653–1660.

PP slides, courtesy of Steve Holets RRT, Mayo Clinic Rochester, 2018

LEARNING CHECK

A 75 year old male is in the Emergency Room with an exacerbation of his congestive heart failure after eating Thanksgiving dinner. The provider calls you to draw an arterial blood gas and place BIPAP on the patient. Your assessment reveals audible bilateral crackles, RR 30, SpO_2 85%. He is awake and alert and complains of dyspnea.

- The ABG results are: pH 7.35, $PaCO_2$ 45, PaO_2 50, HCO_3 26

Q_1: Is this patient appropriate for NIPPV?

YES

Q_2: What mode of NIPPV will best treat his symptoms?

- S/T (BIPAP)
- CPAP
- AVAPS
- PCV

NON-INVASIVE POSITIVE PRESSURE VENTILATION

Initiation, Management, and Weaning

INITIATION

- Determine mask/interface
- Determine MODE
- Choose INTIAL SETTINGS based on GOALS
- Apply Necessary Monitoring
- Adjust Settings as needed

https://ondemand.hill-rom.com/img_catalog/P7158_L.jpg

INTERFACES

- Mask types
- Headgear selection
- Soft, self-sealing cushions
- Anti-asphyxia features

WOUND PREVENTION- NIV RELATED PRESSURE INJURY

Incidence of skin breakdown

- Localized areas of tissue necrosis
- Develop when soft tissue is compressed between a bony prominence surface for an extended period of time

Most common on bridge of nose[1]

Extreme cases involve surrounding areas, like over the nose but also on the chin

In literature[8]

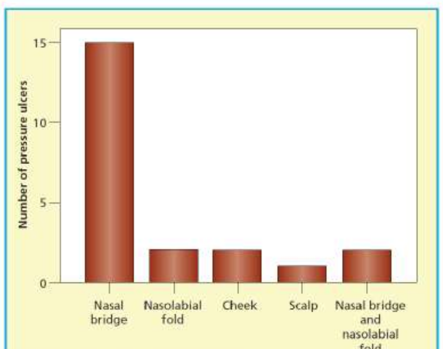


Figure 2 Location of pressure ulcers.

Results

- 20% of patients in the oro-nasal masks developed a pressure injury
- 2% of patients in the full-face masks developed a pressure injury
- Comfort scores significantly lower in the Full-face mask group

Conclusion:

Full-Face mask resulted in significantly fewer pressure injuries and was more comfortable for patients.

Use	Use a skin barrier device for all patients undergoing continuous NIV
Assess	Assess the skin under the mask at each system check
Ensure	Ensure the leak rate is appropriate (7-30 LPM)
Rotate	Rotate the type of mask if injuries are developing
Consult	Consult the wound care nursing team if evidence of a wound is present

[8] Schallom M, Cracchiolo L, Falker A. Pressure ulcer incidence in patients wearing nasal-oral versus full-face noninvasive ventilation masks. American Journal of Critical Care Medicine. 2015;24(4):349-356.

MODE OF VENTILATION- CPAP OR BILEVEL?

Define the ventilatory defect and cause of failure to determine the best mode

Mode	
BILEVEL (IPAP and EPAP)	CPAP (EPAP)
Positive Pressure Settings	
2 pressure levels to drive gas in	1 pressure level to create end expiratory resistance
Improves	
Ventilation (↓PaCO2/EtCO_2) and Oxygenation	Oxygenation (↑SpO_2/PaO_2)

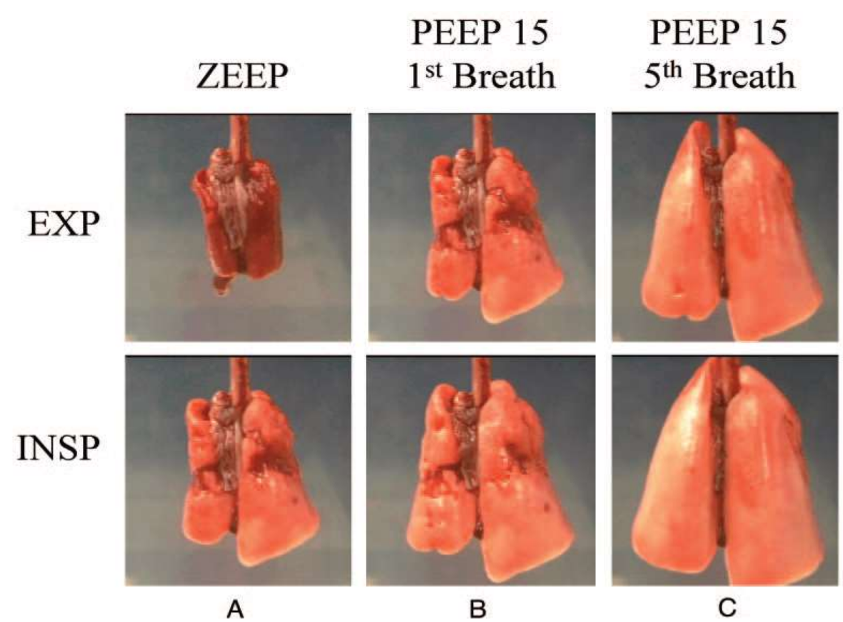
CPAP (Continuous Positive Airway Pressure)

Oxygenation

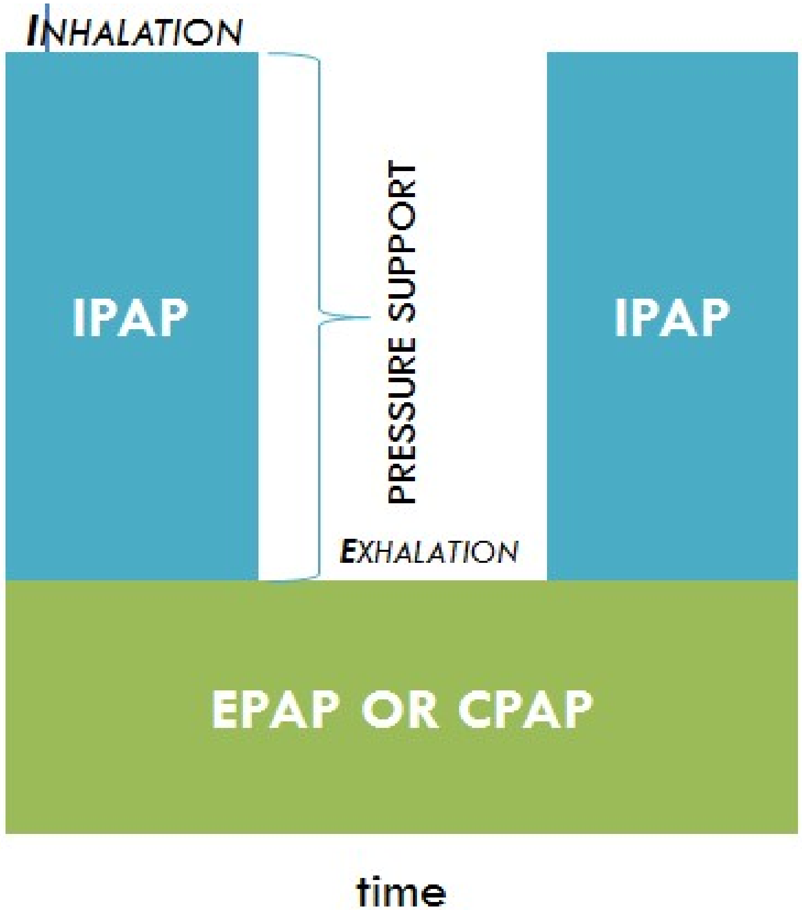
- Improves FRC
- CPAP can be used to improve oxygenation if the patients work of breathing is not high
  - CPAP fails to support inspiratory volume delivery so will provide insufficient support for high work of breathing

Congestive Heart Failure/Cardiogenic Pulmonary Edema

- Use of CPAP recommended



BIPAP (BILEVEL PPV)



IPAP- VENTILATION

Ventilation (CO_2)

- Driving pressure to deliver gas (creates the artificial pressure gradient)
- Increase Vt/alveolar ventilation
- Reduce $PaCO_2$

EPAP/CPAP- OXYGENATION

Oxygenation (O_2)

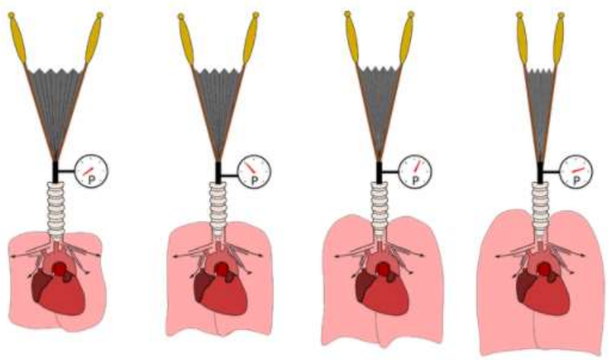
- Increased resistance to exhalation
- Increased alveolar surface area
- Reduce opening and closing of alveoli each breath
- Mimics physiologic end-expiratory pressure

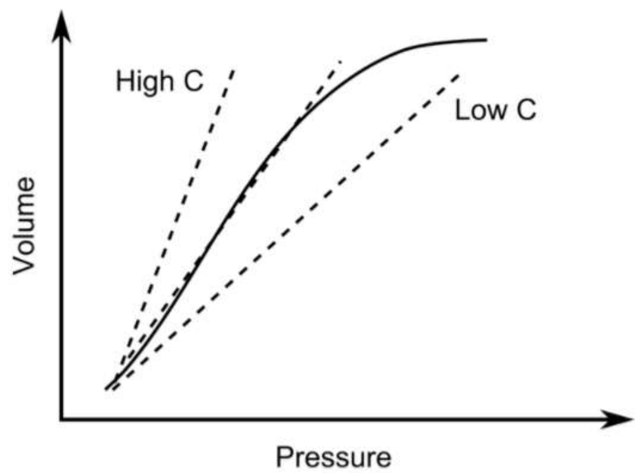
PRESSURE AND VOLUME RELATIONSHIP

$$C = \Delta V / \Delta P$$

Good rule of thumb:

- Expect > 40 ml of tidal volume for each cmH_2O you add
- Normal compliance = 60-100 ml/cmH_2O

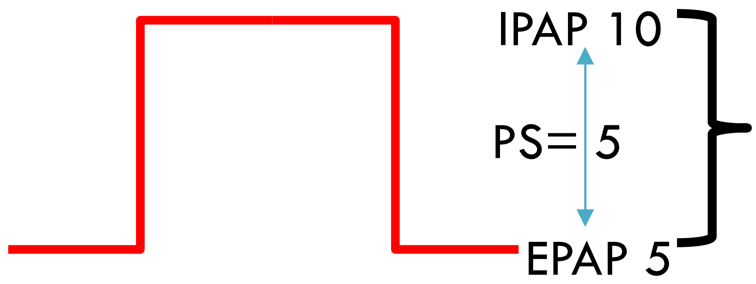




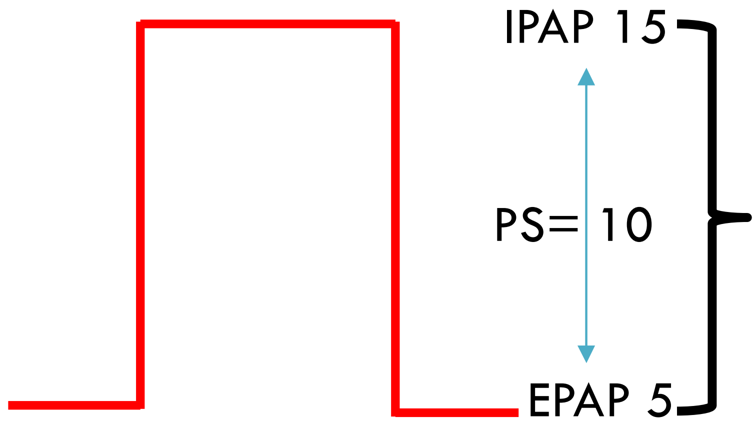
http://www.nataliescasebook.com/tag/lung-compliance

Kacmarek, R., & Stoller, J. (2014) *Egans Fundamentals of Respiratory Care* (10th ed.). London: Elselvier Health Sciences

WHAT IS PRESSURE SUPPORT?



Pressure Support= driving pressure between IPAP and EPAP



Scenario:

1. Initial Settings:
   - PS= 5 (IPAP 10/EPAP 5) generates a 5 mL/kg tidal volume
     - *Target Vt 6-8 ml/kg IBW*
2. Modified settings:
   - Increased PS to 10 (IPAP 15/EPAP 5) generates a tidal volume of 8 mL/kg

INITIAL SETTINGS

Ventilation	Oxygenation
IPAP (tidal volume)	**EPAP**
Minute Ventilation (spontaneous RR x Vt)	**FIO_2**

https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcTCP4EKzG8Ty60xhxArBal8k5iDcHPxdvJoQ6RtNz1bXQdJYZhuyw

SETTING SELECTION

Setting	Adjustment	Anticipated Result
IPAP	↑	↑ Vt, minute ventilation, ↓ $PaCO_2$
	↓	↓Vt, minute ventilation, ↑ $PaCO_2$
EPAP	↑	↑ FRC, ↑ PaO_2, ↓ Vt* If intrinsic peep is present, fewer missed triggers and improved patient-ventilator synchrony
	↓	↓ FRC, ↓ PaO_2, ↑ Vt*, ↓ $PaCO_2$ Possible rebreathing of CO2 if EPAP < 4 cmH_2O

Kacmarek, R., & Stoller, J. (2014) *Egans Fundamentals of Respiratory Care* (10^{th} ed.). London: Elselvier Health Sciences

SETTING SELECTION

Setting	Adjustment	Anticipated Result
FIO2	↑	↑ PaO_2
	↓	↓ PaO_2
Rate control	↑	↑ minute volume

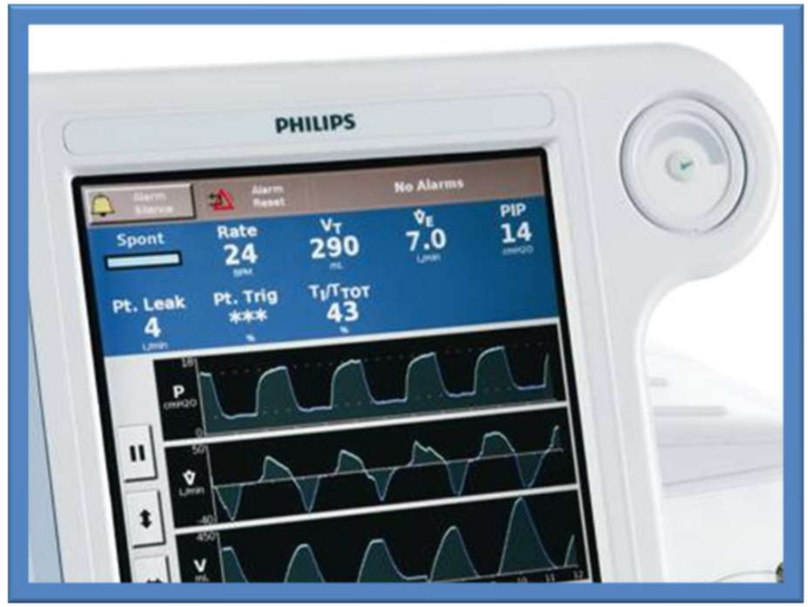
Kacmarek, R., & Stoller, J. (2014) *Egans Fundamentals of Respiratory Care* (10th ed.). London: Elselvier Health Sciences

MONITORING

Tidal Volume

Work of Breathing

Arterial Blood Gas

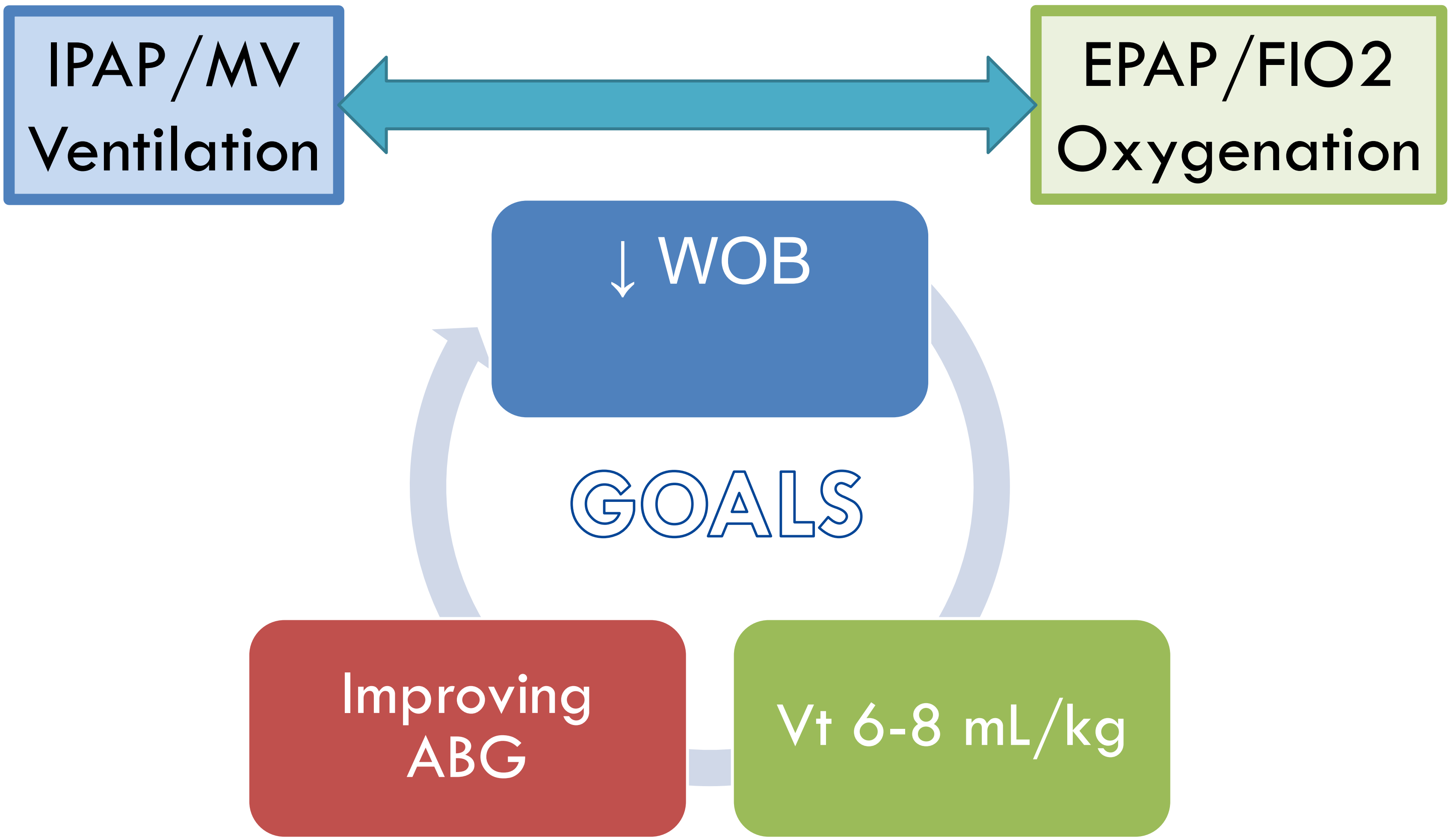


ACID/BASE	37.0 °C	
pH	7.201↓	
pCO_2	71.1↑	mmHg
pO_2	48.8↓	mmHg
HCO_3^-act	27.2	mmol/L
BE(B)	-1.0	mmol/L

ASSESSMENT

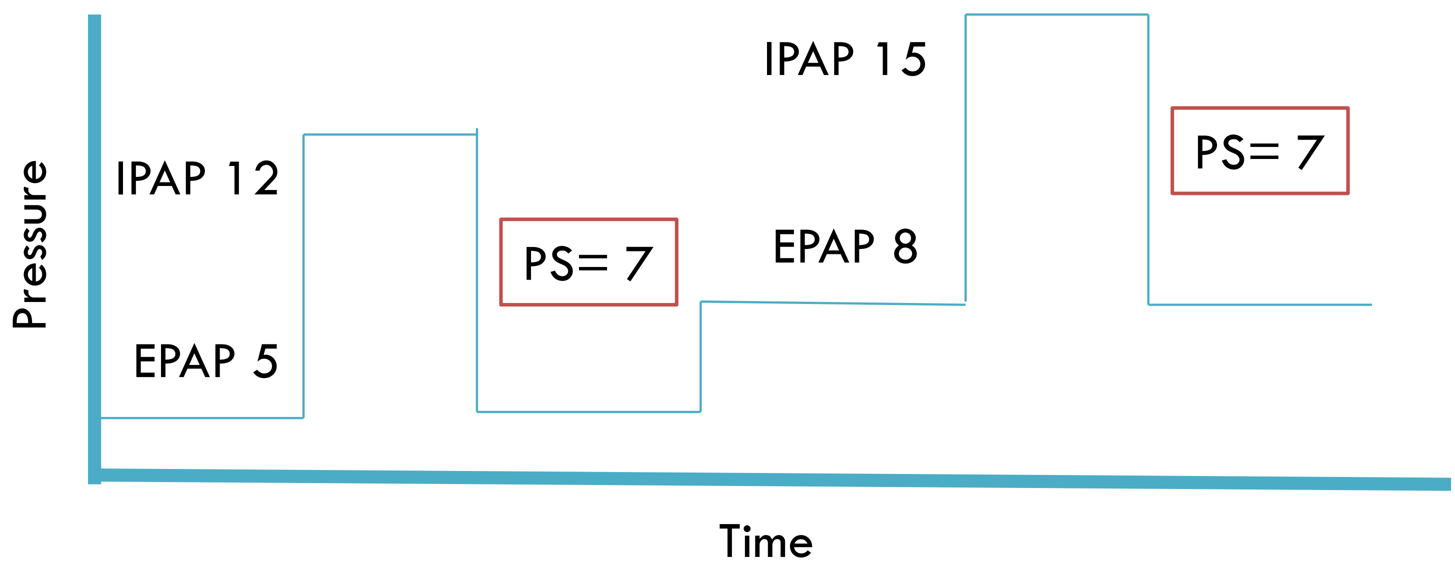
Goals		
↓ Work of breathing RR < 25 HR < 120* BP stable Physical work	**Deliver adequate tidal volume with PS < 20cmH_2O** Target 6-8 ml/kg of IBW	**Improve ABG** Reduce $PaCO_2$ Improve PaO_2 Normalize pH

ADJUSTMENTS



ADJUSTMENTS

- 2 cm H_2O ↑↓ max
- Aggressive weaning of FIO_2 for target SpO2
- If using BIPAP and EPAP needs to be titrated, IPAP also needs to be titrated to maintain pressure support:



IS IT WORKING?

15 minutes

↓WOB

Vt target achieved without significant PS requirement

1 hour

Improving ABG

↓WOB

Vt stable

@ 4 hours

Stay the course, wean or move to IMV

Consider:

- CXR improvement/worsening
- Hemodynamic improvement/worsening
- Level of consciousness

CONSIDERATIONS

- Need for:
  - Inhaled medication therapy
  - Bronchopulmonary Hygiene
- Mask wound assessment
- NG Tube
- Eating/drinking (aspiration risk/nutrition/pills)
- Communication
- Mobility

[11.3 Oxygenation Equipment – Nursing Skills (pressbooks.pub)]

WEANING

Consider: when respiratory failure is resolving

Wean IPAP and EPAP

- IPAP: Target 6-8 ml/kg with decreased support
- EPAP: minimum 5 cm H_2O
- Maintain ventilation/oxygenation

Wean FIO2

- If appropriate; can always support SpO_2 with Oxygen Therapy

Trials off

- When appropriate give the patient a break to eat, drink and do pulmonary toilet

MECHANICAL VENTILATION

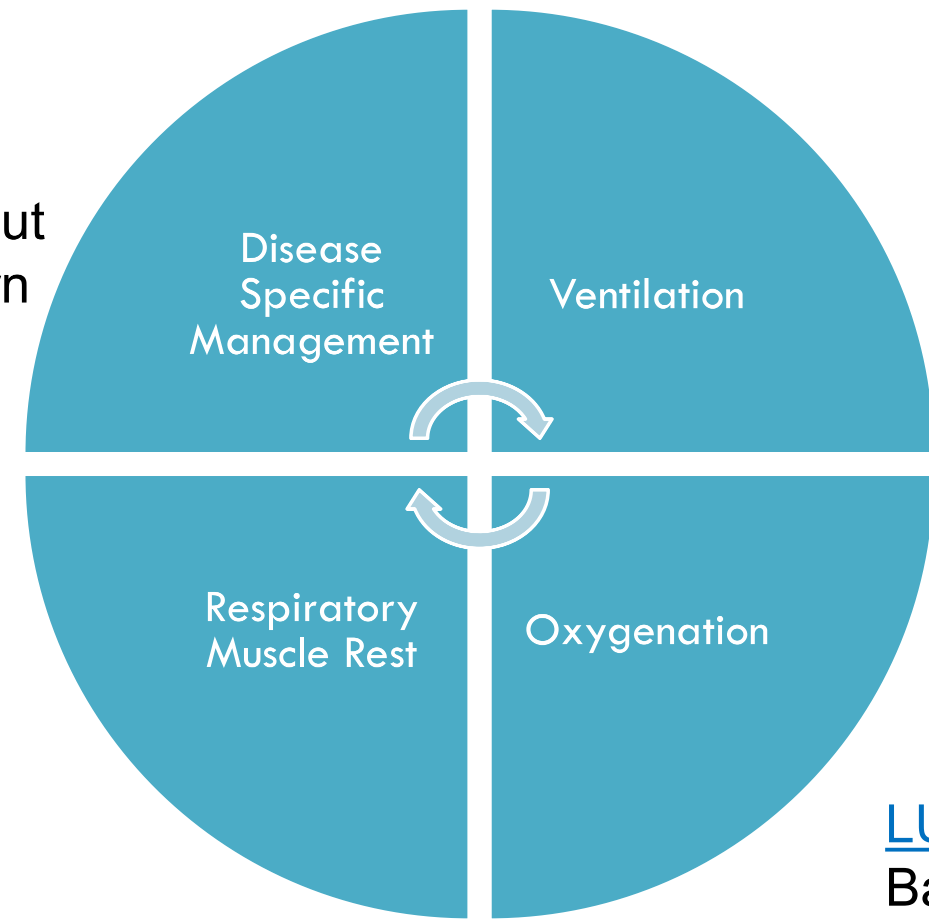
Basic Overview

INDICATIONS FOR MECHANICAL VENTILATION

Hypoxic respiratory failure	• Reduce shunt by opening collapsed alveoli • Delivery high FIO_2
Hypercapneic respiratory failure	• Reduced work of breathing preventing fatigue • Maintain alveolar ventilation to prevent respiratory acidosis
Excessive Work of Breathing	• Metabolic Acidosis • Sepsis • Respiratory failure
Unprotected or Unstable Airway	• Altered level of consciousness • Surgery

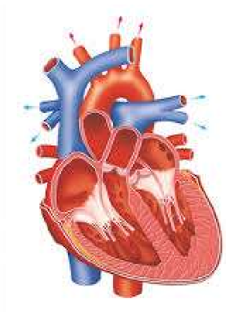
MECHANICAL VENTILATION: GOALS & HARM

NOT CAUSE HARM



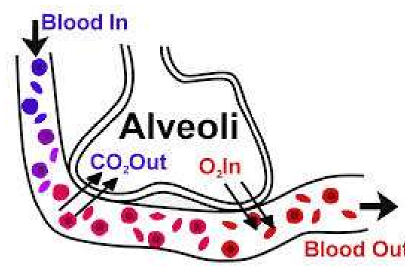
CARDIAC risk

Reduced cardiac output
Impaired venous return
Hypotension



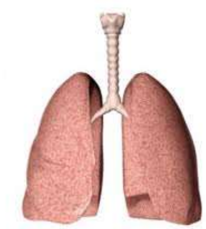
GAS EXCHANGE risk

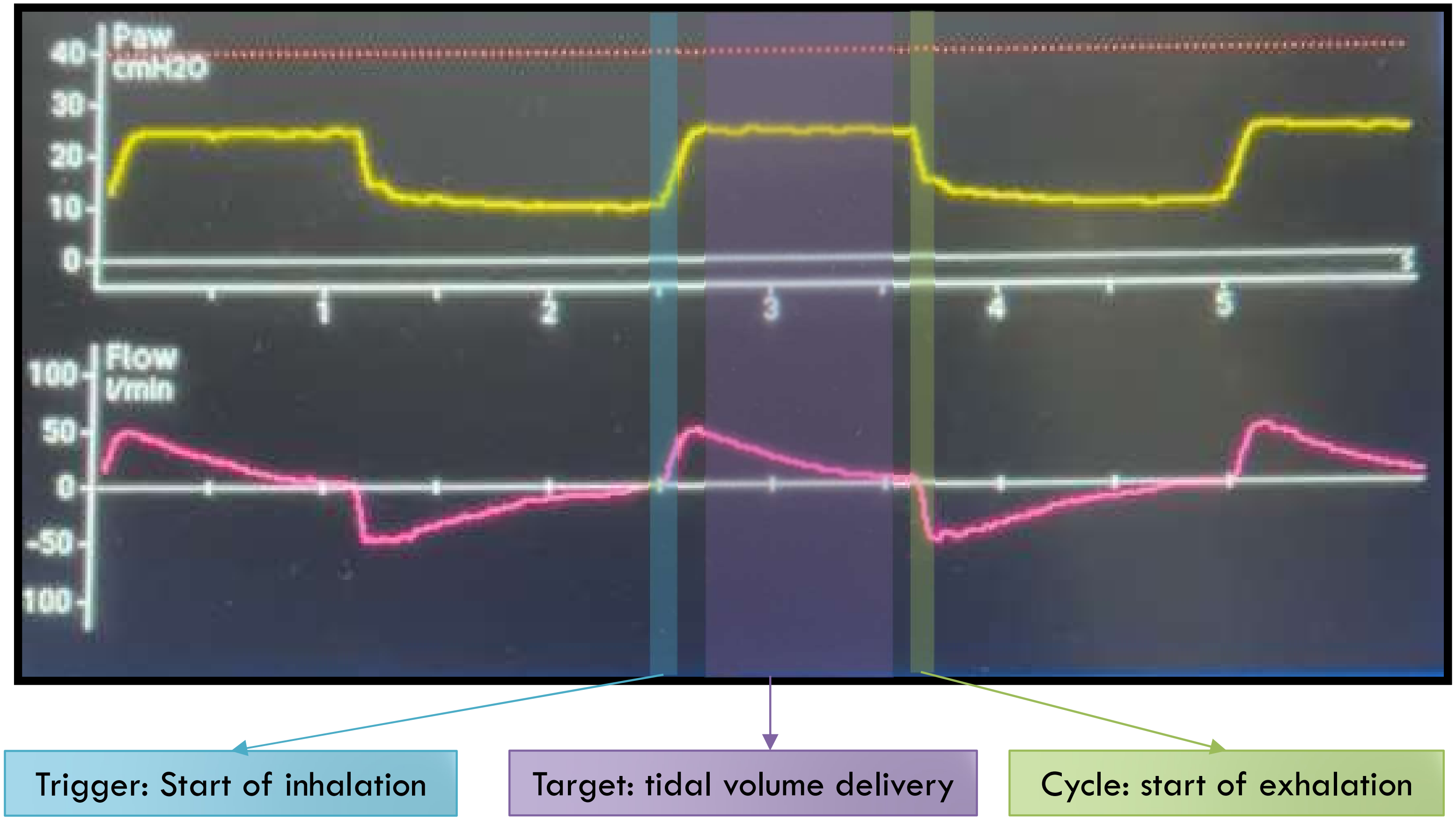
Worsen shunt with unilateral lung disease
Increased dead space



LUNG risk

Barotrauma
Vent induced lung injury
Air trapping





VENTILATOR MODE IS DEFINED BY WHAT HAPPENS IN THE 3 PHASES OF THE BREATH

CONTROLLED MODES AND BREATH TYPES

Volume
FIXED FLOW

- Trigger: machine (set RR) or patient effort
- Target: set flow/Vt
- Cycle: set flow/Vt achieved

Pressure
VARIABLE FLOW

- Trigger: machine (set RR) or patient effort
- Target: set pressure achieved
- Cycle: set inspiratory time

Dual
Pressure regulated, volume targeted
VARIABLE FLOW

- Trigger: machine (set RR) or patient effort
- Target: set pressure w/ target Vt achieved
- Cycle: set inspiratory time

SPONTANEOUS MODES AND BREATH TYPES

Dual

Pressure regulated/volume targeted

VARIABLE FLOW

- Trigger: patient effort
- Target: Pressure w/ target Vt achieved
- Cycle: Exp flow deceleration (%)

Pressure Support

VARIABLE FLOW

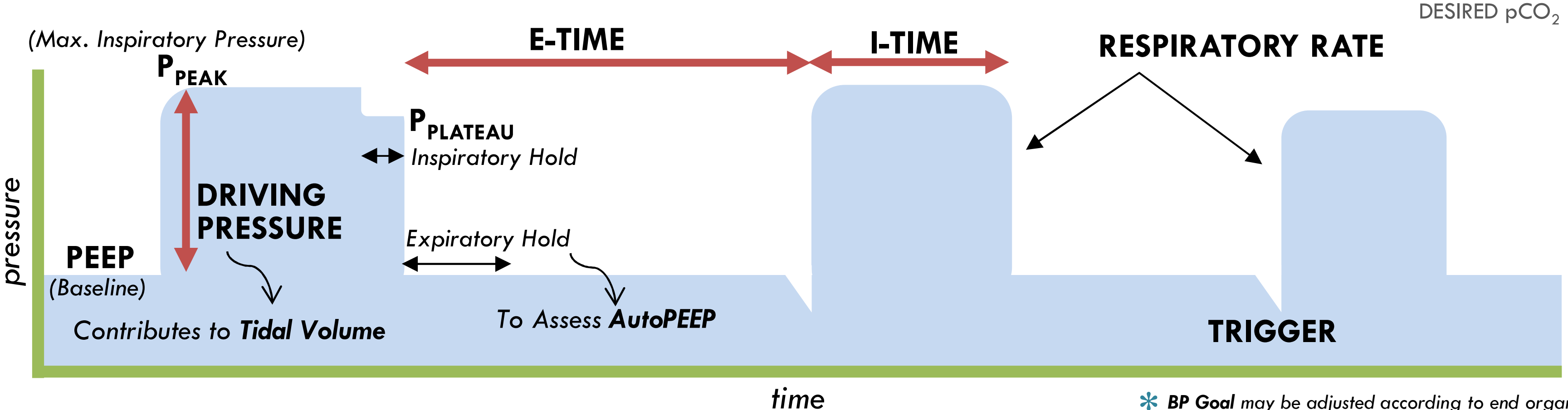
- Trigger: patient
- Target: set pressure
- Cycle: Exp flow deceleration (%)

MAYO CLINIC MECHANICAL VENTILATION GUIDE

PROBLEM	GOALS	SETTINGS	INITIATION (PB-840 / Hamilton)	MONITORING (ZP's)
AIRWAY COMPROMISE	PATENT AIRWAY	ENDOTRACHEAL TUBE CRIC / TRACH	7.0- 8.0 ETT	UNITS: SpO_2 : % $ETCO_2$, $PaCO_2$, PaO_2 : mmHg BP : mmHg AutoPEEP, P_{PLAT} .P_{PLAT} : cmH_20
↑ WORK OF BREATHING	COMFORT & SYNCHRONY	SEDATION LEVEL MODE TRIGGER	DEEP SEDATION AC (VC) / (S) CMV FLOW (3LPM) / FLOW (5LPM)	1 PATIENT – VENTILATOR SYNCHRONY
HYPOXIA	OXYGENATION	FIO_2 I -TIME PEEP	LOWEST TO ACHIEVE SPO2 90% 0.8-1.10 s PEAK FLOW 60LPM 5 (5-15) cmH_2O	2 SpO_2 > 90, PaO_2 > 60 * 3 SBP >90 * 4 P_{PLAT} < 30
HYPERCAPNIA	VENTILATION (V_E)	TIDAL VOLUME (V_T) RESPIRATORY RATE	8 (6-8) mL/kg IBW 14 (10-30) BPM	5 P_{DRIV} < 15 6 $ETCO_2$ 45, $PaCO_2$ 40 * 7 AutoPEEP < 1

$V_E = V_T \times RR$ (minimum = 5LPM)

$$\frac{\text{CURRENT } pCO_2}{\text{DESIRED } pCO_2} = \frac{\text{DESIRED } V_T \text{ or BPM or } V_E}{\text{CURRENT } V_T \text{ or BPM or } V_E}$$



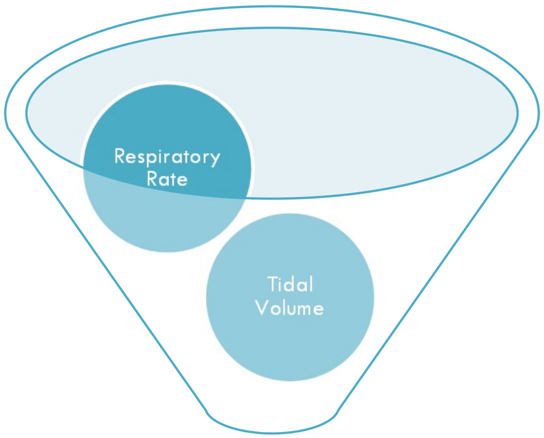
ALARM SETTINGS	MAX	MIN
P_{PEAK}	35	5
V_E	10LPM	4LPM
RATE	25	10
V_T	10 ML/KG	4 ML/KG
LEAK %	OFF	
APNEA	20 S	

* **BP Goal** may be adjusted according to end organ perfusion and congestion.
O_2 Goal may be adjusted according to end organ function/oxygen delivery.
CO_2 Goal may be adjusted to compensate for metabolic acidosis and improve arterial pH.

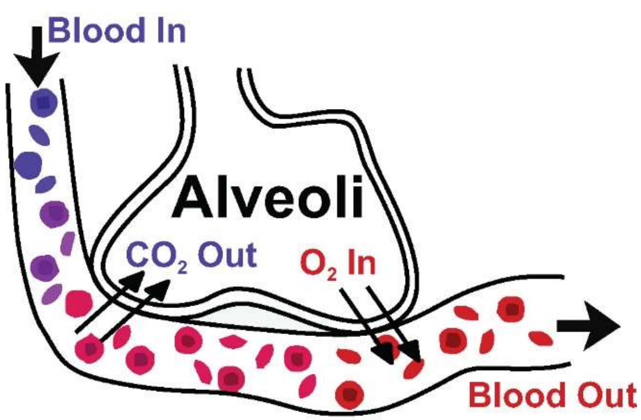
$PaCO_2$

VENTILATION SETTINGS

Respiratory Rate x Tidal Volume= Minute Ventilation



Minute Ventilation



Mechanics of Breathing | Boundless Anatomy and Physiology | | Course Hero

Initial Settings

Determine appropriate tidal volume

- 6-8 ml/kg ideal body weight

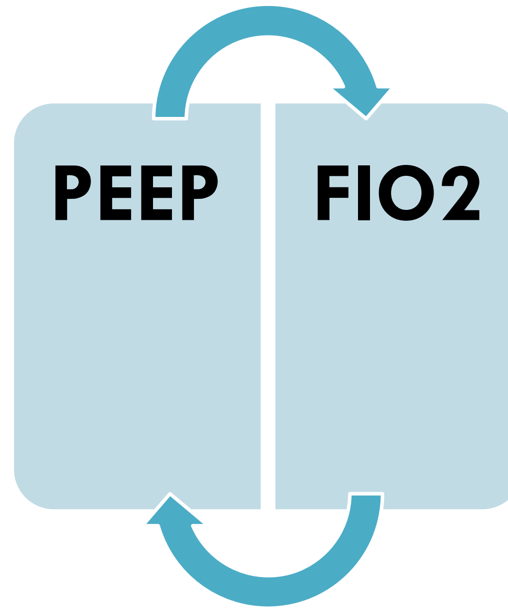
Set respiratory rate to achieve > 5-7 lpm

Adjust for optimal ventilation ($PaCO_2$)

PaO$_2$

OXYGENATION SETTINGS

- Select lowest FIO2 to achieve target SpO2/PaO2
- Therapeutic PEEP can be used to increase functional reserve capacity (FRC), increase surface area for gas exchange, reduce atelectrauma
- PEEP minimum should be 5 cmH2O, and titrated up to effect

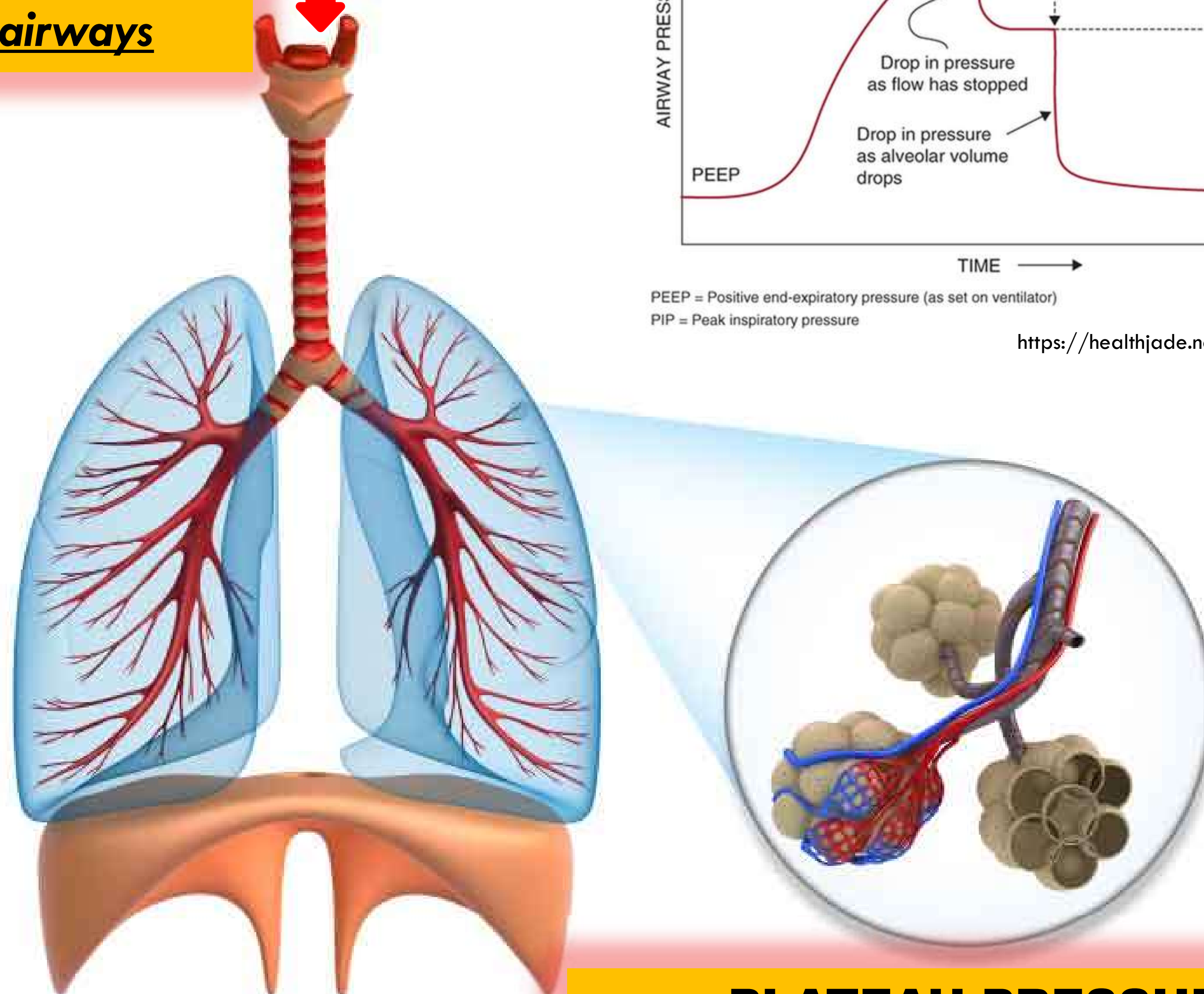


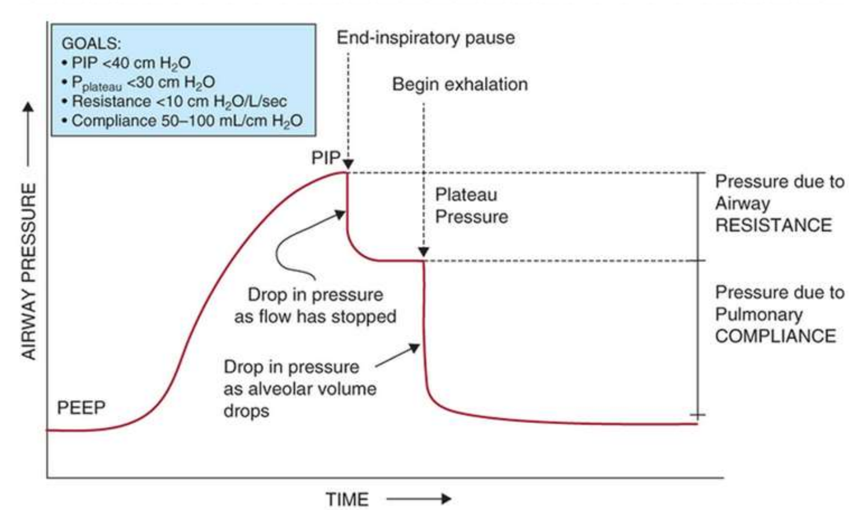
Setting	Range	Considerations
PEEP	**Min 5cmH$_2$O- Max (patient dependent)**	**SpO$_2$ target** **Effect on Blood Pressure**
FIO2	**Min .21- Max 1.0**	**SpO$_2$ target** **PaO$_2$ target** **Oxygen Toxicity** **Reabsorption atelectasis @ 1.0 FIO$_2$**

LUNG PRESSURE MONITORING

PEAK INSPIRATORY PRESSURE

Pressure it takes to get air from the machine through the ***big airways***





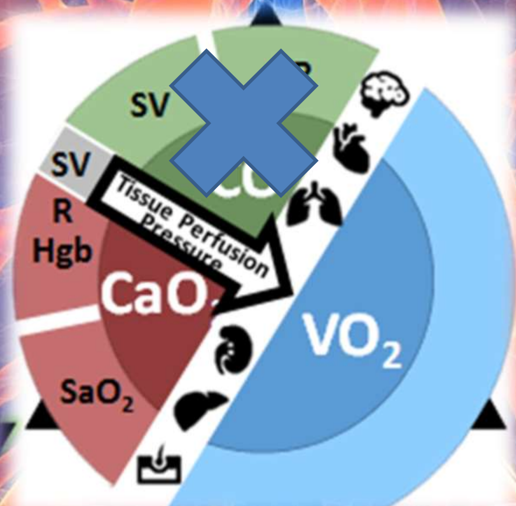
PEEP = Positive end-expiratory pressure (as set on ventilator)
PIP = Peak inspiratory pressure

https://healthjade.net/peak-inspiratory-pressure/

PLATEAU PRESSURE

Pressure it takes to hold the ***alveoli*** open

EFFECTS OF LUNG PRESSURE ON THE HEART



Autopeep (Intrinsic PEEP)

- Can't exhale all the way
- Lungs overfill
- Pressure ↑ in the chest
- Squeezes the heart
- Reduces blood pressure

ACUTE RESPIRATORY DISTRESS

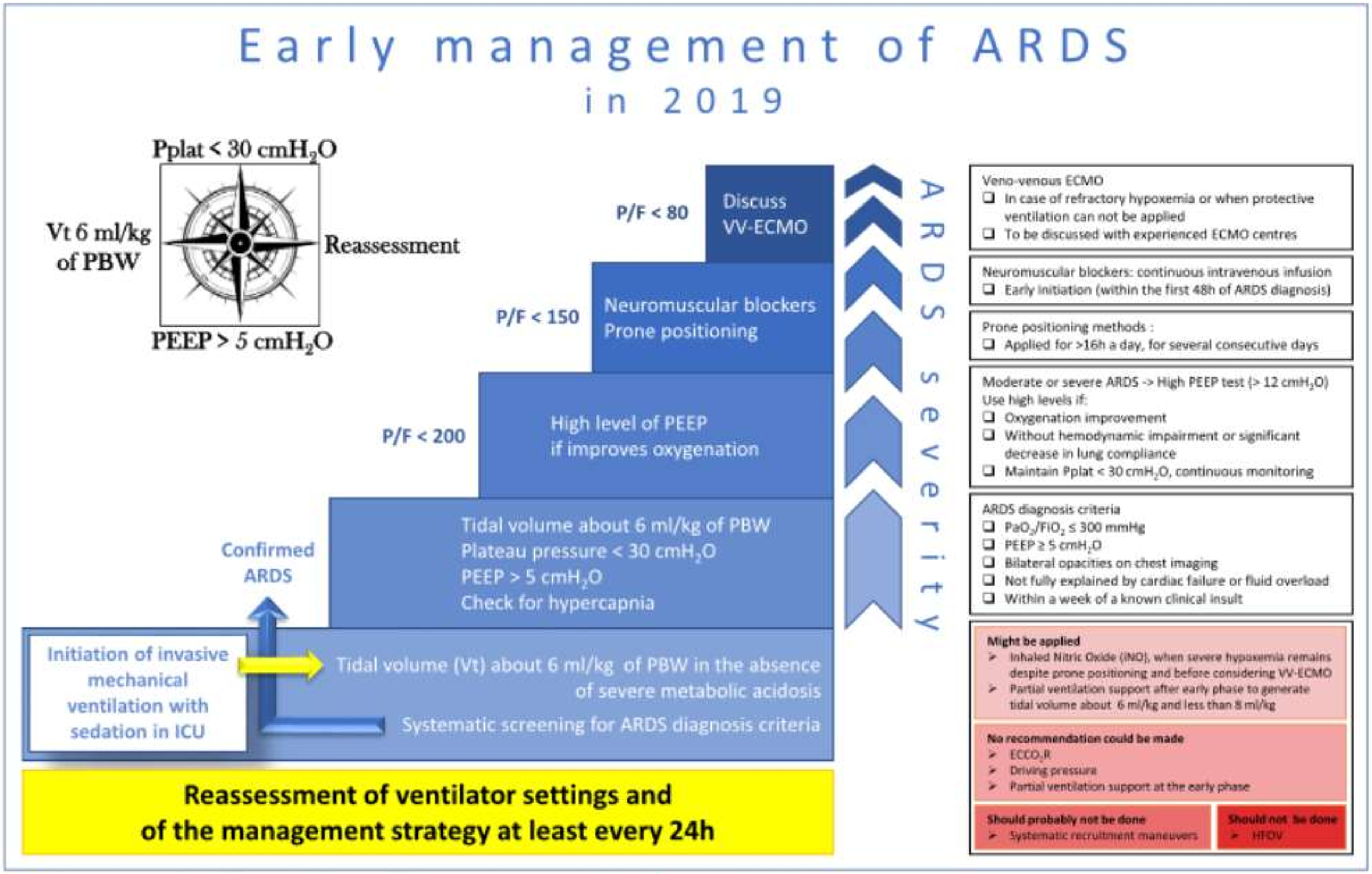


Fig. 1 Therapeutic algorithm regarding early ARDS management (EXPERT OPINION)

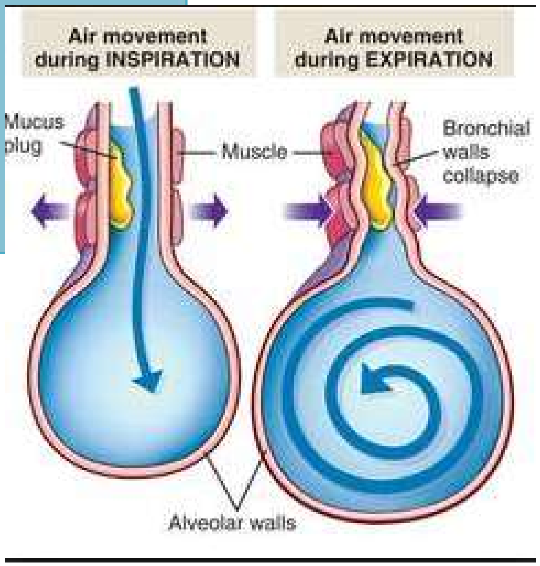
Papazian *et al. Ann. Intensive Care* (2019) 9:69
https://doi.org/10.1186/s13613-019-0540-9

Annals of Intensive Care

OBSTRUCTIVE DISEASE

Initial ventilator settings:

- Mode: Volume- controlled ventilation
- Minute ventilation: <10 l/min
- Tidal volume: 6–10 ml/kg ideal body weight
- Respiratory rate: 10–14 cycles/min
- Plateau pressure: <30 cmH2O
- Inspiratory flow rate: 80-100 l/min
- Inspiratory flow waveform: Decelerating waveform
- Expiratory time: 4–5 s
- PEEP: 5 cmH2O
- FIO2: SaO2 of >90%



WEANING AND EXTUBATION

WHEN TO CONSIDER *EXTUBATION*

Resolution of Disease

- ABG
- CXR
- Minimal vent settings (PS 10/peep5/FIO2 0.40)

Sedation

- Sedation vacation
- Minimal sedation

Hemodynamic Stability

- Off pressors *

WEANING PARAMETERS

MCH Specific (assessed on SPONT PS 0/peep 5):

NIF > -25

Vital Capacity > 10 ml/kg IBW

Tidal Volume > 5 ml/kg IBW

STRENGTH

Hand squeeze

Lift head off pillow

Cough and secretions

EXTUBATION

Assemble equipment

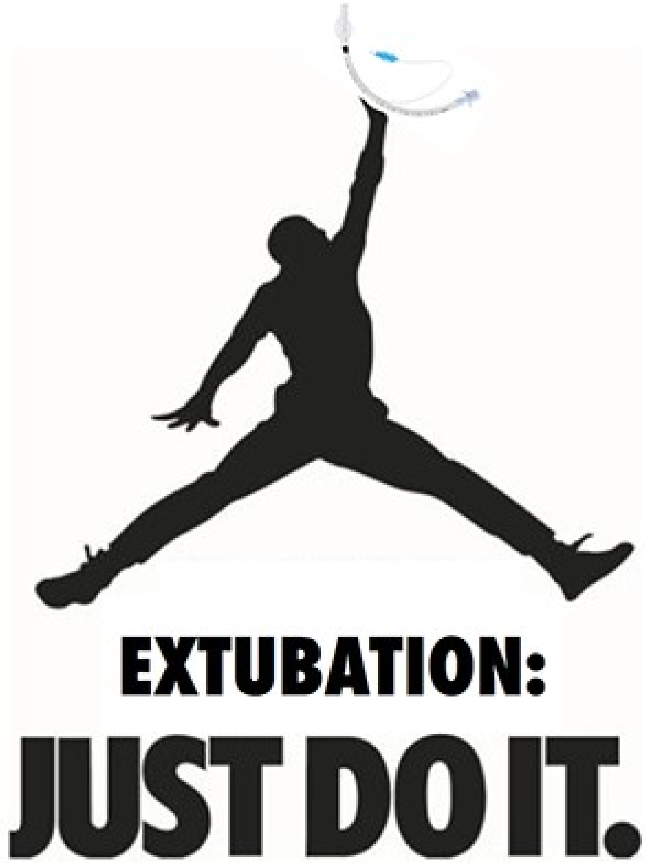
- Nasal cannula
- Oral suction
- Syringe
- Towel

Instruct the patient to cough

Deflate the cuff, remove the tube

Suction the mouth

Apply oxygen therapy



CONCLUSIONS

Early recognition and accurate identification of the type of respiratory failure is key to treatment

The type of failure, the patient's symptoms and considering the evidence will help determine the appropriate intervention

Settings selection and adjustments should be targeted to improve ventilation, oxygenation, patient comfort and balanced with hemodynamic considerations

REFERENCES (NOT REFERENCED IN TEXT)

1. Rochwerg B, Brochard L, Elliott MW, et al. Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. *Eur Respir J*. Aug 2017;50(2)doi:10.1183/13993003.02426-2016

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