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Disclosures

- No Disclosures

Objectives

1. Approach to Mechanical Ventilation Basics
    - Non-invasive and invasive mechanical ventilation
    - Combating hypoxia
    - Combating hypercapnia
2. Approach to Acute Respiratory
    - Shunt and dead space physiology
    - ARDS
    - Pulmonary Embolism
3. Approach to Shock
    - Hypovolemic
    - Cardiogenic
    - Distributive
    - Obstructive
4. Approach to Sepsis
    - Recognition of microvascular insufficiency
    - Sepsis management

Objectives: continued

5. Approach to Post-surgical Infection
    - Superficial and deep surgical site infection
    - Abdominal compartment syndrome
6. Approach to Poisonings and Overdoses
    - Analgesics
    - Cardiac medications
    - Toxic alcohols
    - Miscellaneous
7. More Critical Care

Mechanical Ventilation (non-invasive & invasive)

CASE

62-year-old man is admitted to tele 2-days ago for chest pain. His ACS workup has been grossly negative. He has a PMHx significant for chronic obstructive pulmonary disease and has had increasing shortness of breath for the past 2-days. You are called to the bedside.

- Heart rate (HR) 122 beats/min, blood pressure (BP) 140/90 mm Hg, respiratory rate (RR) 32 breaths/min, temperature 99°F (37.2°C)
- Arterial blood gas (ABG) on 2 L/min oxygen: pH 7.24, $PaCO_2$ 70mmHg, PaO_2 66 mmHg.

What is the best type of respiratory support to initiate at this time?

A. Bilevel non-invasive positive pressure ventilation (BiPAP)
B. High flow nasal cannula
C. Intubate and start the patient on volume assist control ventilation
D. Cannulate for veno-venous extracorporeal membrane oxygenation

Mechanical Ventilation Basics

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Non-invasive positive pressure ventilation

Basic Modes of NIPPV

Mode	Function	Effect	Indication	Ventilation	Oxygenation
CPAP	Constant airway pressure throughout the respiratory cycle	• Decreased work of breathing • Increases mean airway pressure • Maintains patency	• Work of breathing • Hypoxia	• Patient Effort • Respiratory Rate	• ↑ mean airway pressure- overall applied pressure • ↑FiO2
BPAP	Two different levels of airway pressure (IPAP & EPAP)	• Decreased work of breathing • Increases mean airway pressure • Maintains airway patency • Ventilation Gradient	• Work of breathing • Hypoxia • Hypoventilation	• ↑ vent gradient (IPAP – EPAP) • Patient Effort • Respiratory Rate	↑ mean airway pressure • applied pressure • ↑ EPAP • ↑FiO2

NIPPV: Hemodynamics

Non-invasive positive pressure ventilation

Benefit seen in moderate to severe exacerbation (COPD)

*respiratory conditions expected to improve in 24-48hrs

↓IMV, treatment failure, mortality (COPD)

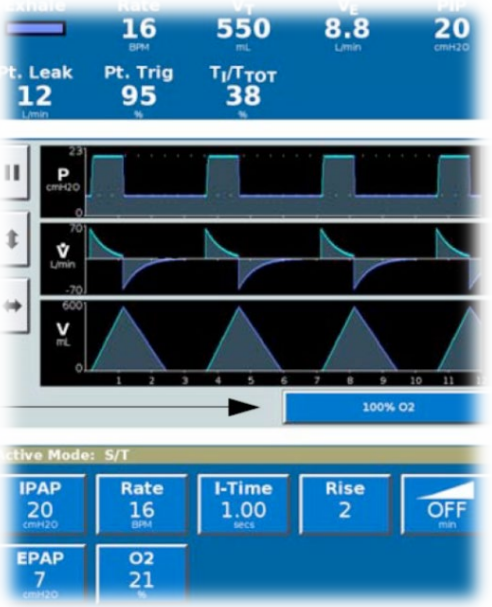
↓ rate of intubation by ~50% (COPD)

Overall NIPPV Failure Rate: ***5-40%***

Best predictor of Failure?

CO2 Coma?

BAP-65? CHEST 2011



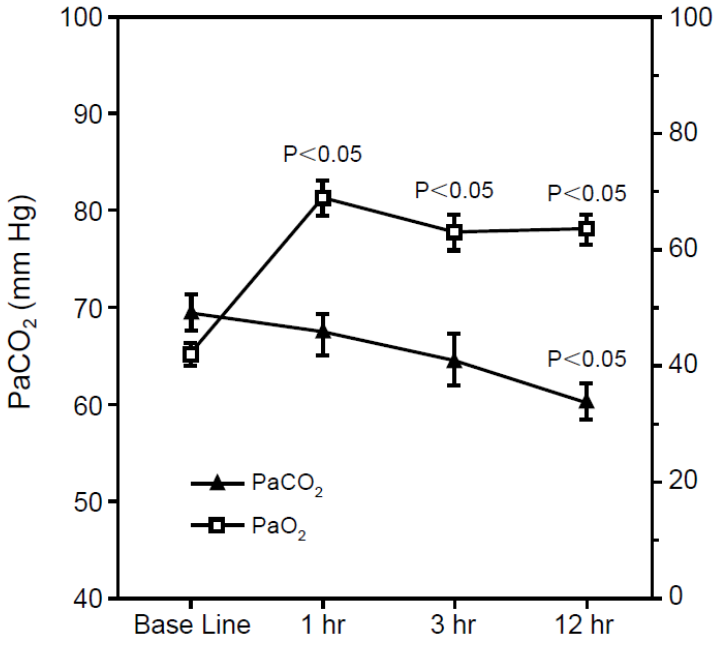
Predicting Success in NIPPV

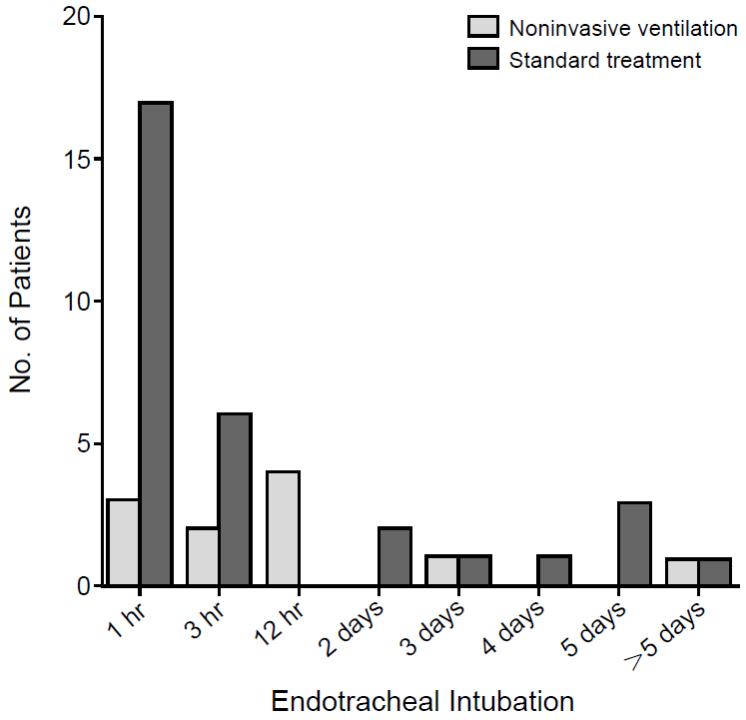
I say NO for vomiting

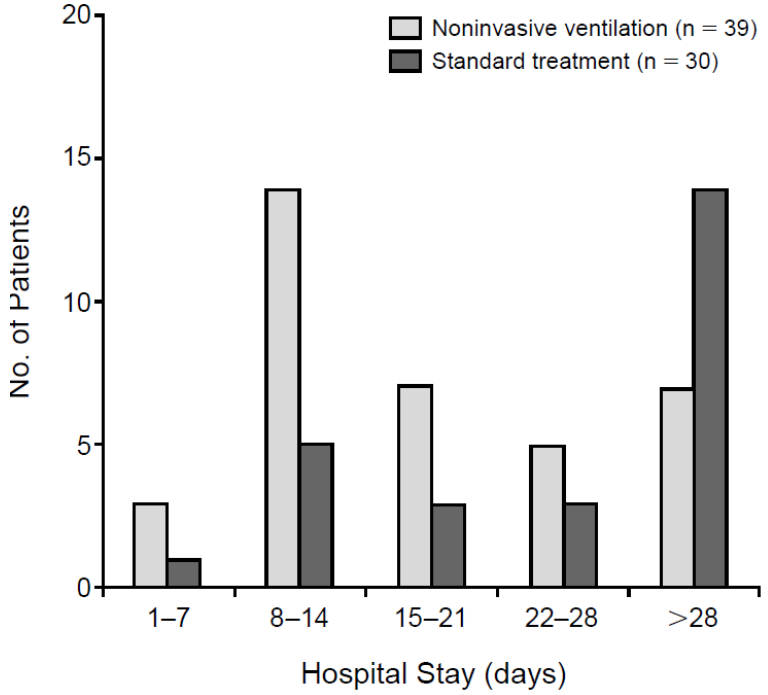
I say NO for uncontrolled secretions

I say NO for COMA……

I think about the Mask fit







Protocols are highly variable

NJEM, 1995 (n:85)

IPAP = 8, increased q15mins to a max 15 or RR < 25

EPAP = 5, increase q15mins to a max of 10

Limits?? *Original: 20/0*

Risk Stratification

Table 3 Final model for prediction of NIV failure in the derivation cohort and points assigned to each variable

Variables	Regression coefficient β per unit increase	Category (j)	Assigned points
		101–149	1
		≤ 100	2

NIV noninvasive ventilation, *GCS* Glasgow coma scale

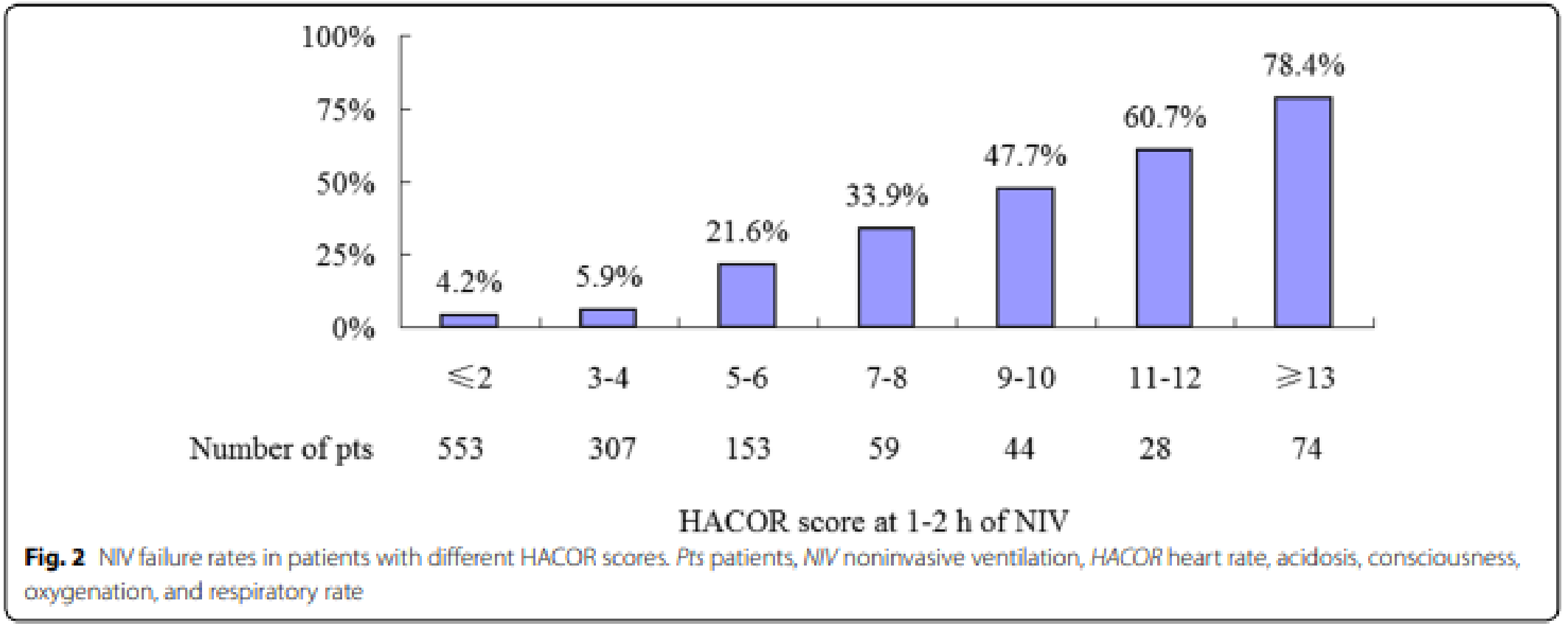
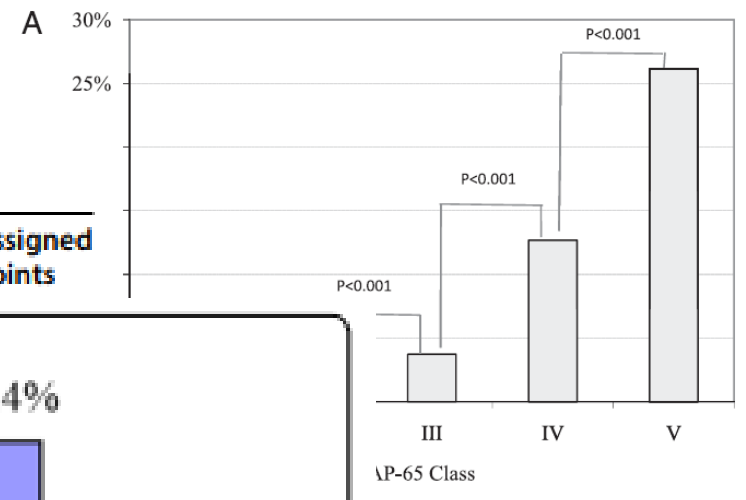
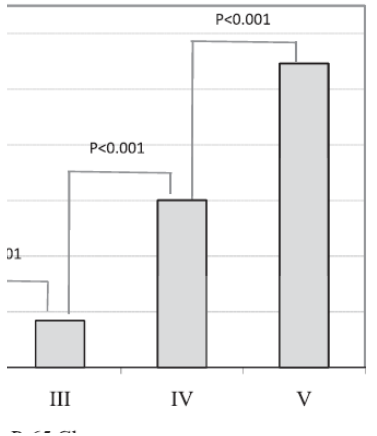
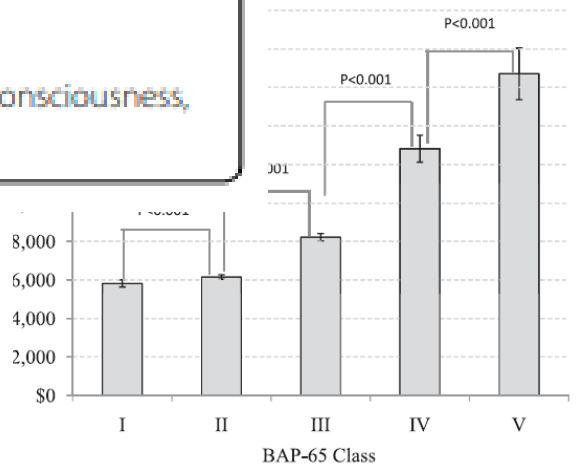


Fig. 2 NIV failure rates in patients with different HACOR scores. *Pts* patients, *NIV* noninvasive ventilation, *HACOR* heart rate, acidosis, consciousness, oxygenation, and respiratory rate







Duan, Ann Inten 2019

Shorr, CHEST 2011

Predicting NIPPV Failure

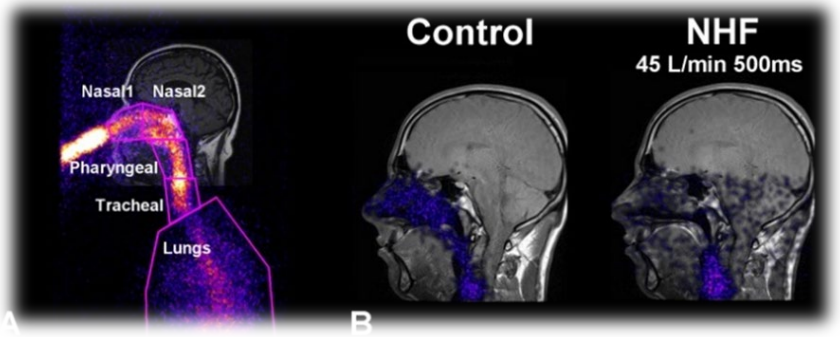
- *Rate of failure is inversely related to the severity of the respiratory acidosis*
  - *pH 7.3 (10-20%)*
  - *pH 7.25 (30-40)%)*
  - *pH < 7.25 (50-60%)*

20% of initial responders (1st 48hrs) experience a second episode of acute failure

**Failure usually occurs within the first 1hr*

**Mask intolerance, leak, and lack of reversibility*

High Flow Nasal Oxygen



J Appl Physiol. 2017 Jan 1;

10L flow = ~0.8cmH2O applied end alveolar pressure (PEEP)

50L flow = 4cmH2O

Oxygenation:

1. FIO2
2. Mean Airway Pressure

Work of breathing/CO2 clearance

1. Reduction in respiratory rate
2. Improved alveolar ventilation*
3. Reduction in wasted ventilation and the work of breathing

Adjunct Therapy

✓ Decrease the risk of reintubation in high-risk patients

✓ Thin secretions

The approach to NIPPV

- Benefits seen in acutely reversible conditions (COPD & CHF)
- Risk stratify risk for progression
- Identify contraindications
- Identify targets (WOB, O2, CO2)
- Reassess response and be be ready to escalate

CASE

Your 62-year-old man was placed on BPAP 10/5, FiO2 40%.

- Repeat arterial blood gas **(ABG): pH 7.18, $Paco_2$ 78mmHg, Pao_2 80 mmHg.**

How would you augment the NIPPV?

The patient becomes more somnolent

- Repeat arterial blood gas **(ABG): pH 7.10, $Paco_2$ 86mmHg, Pao_2 80 mmHg.**

Decision to Intubate

When to transition to invasive ventilation?

✓No clinical improvement in the first 1-2 hours following initiation of NIPPV
✓Therapeutic goals have not been achieved in the first 4-6 hours of NIPPV

Reduced likelihood of a good patient outcome

1. *delay in intubation*
2. *inability to identify a difficult airway*
3. *inability to anticipate possible hemodynamic consequences*

Your Patient is Intubated

Which ventilator modes should be selected?

A. Volume control/assist-control ventilation (AC)
B. Pressure support ventilation (PSV)
C. Synchronized intermittent mandatory ventilation (SIMV)
D. High frequency oscillatory ventilation (HFOV)
E. Airway pressure release ventilation (APRV)

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Which ventilator modes should be selected?

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E. Airway pressure release ventilation (APRV)

Your Patient is Intubated

Which is the best initial tidal volume (V_t)

A. 2-4 ml/kg PBW
B. 6-8 ml/kg PBW
C. 8-10 ml/kg PBW
D. 12-14ml/kg PBW

Your Patient is Intubated

Which is the best initial tidal volume (V_t)

A. 2-4 ml/kg PBW

B. 6-8 ml/kg PBW

C. 8-10 ml/kg PBW

D. 12-14ml/kg PBW

Your Patient is Intubated

Your patient received RSI. He is placed on a V_t of 500ml for predicted body weight. Which respiratory rate should be selected?

A. 6-8 breaths/minute

B. 8-10 breaths/minute

C. 10-12 breaths/minute

D. Higher than 10-12 breaths/minute

Pre-intubation arterial blood gas
pH 7.10, $Paco_2$ 86mmHg, Pao_2 80 mmHg.

Your Patient is Intubated

Your patient received RSI. He is placed on a V_t of 500ml for ideal body weight. Which respiratory rate should be selected?

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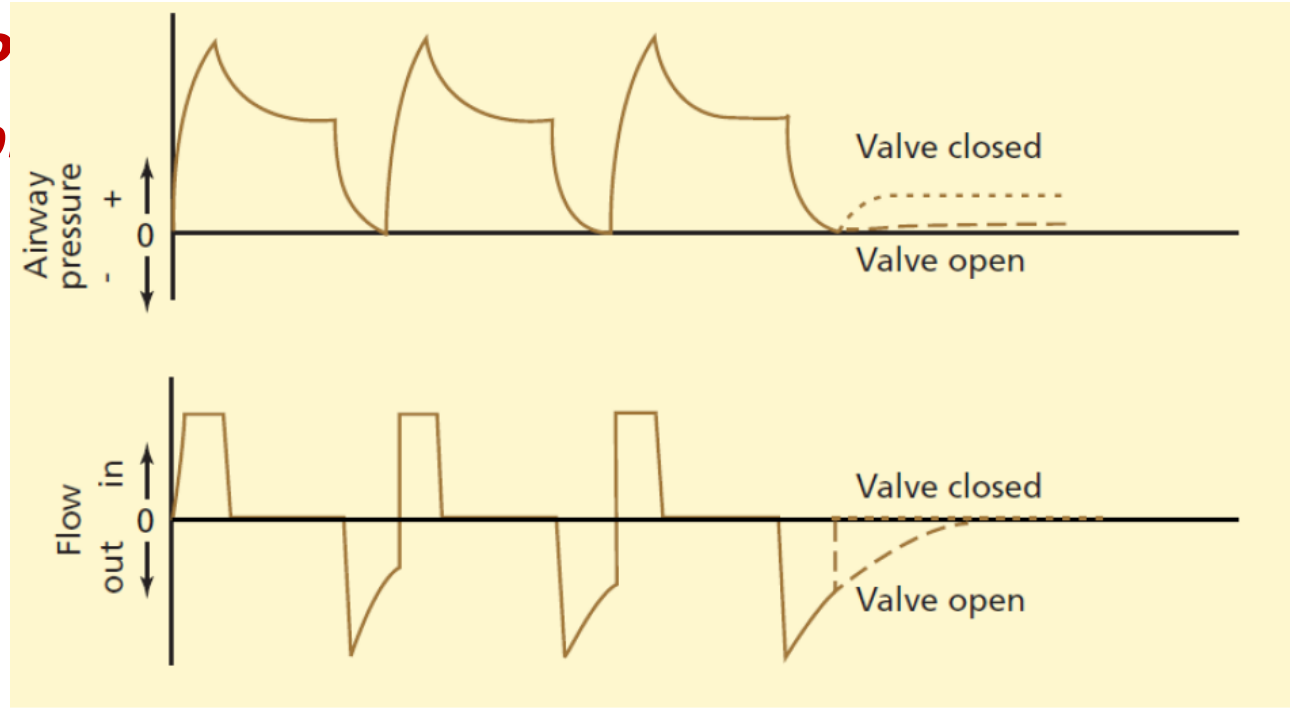

Your Patient is Intubated

Which is the best initial fraction of inspired oxygen (F_IO2)?

A. 21% (0.21)
B. 40% (0.4)
C. 60% (0.6)
D. 80% (0.8)
E. 100% (1.0)

**critical care consultant*

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Which is the best initial fraction of inspired oxygen (F_IO_2)?

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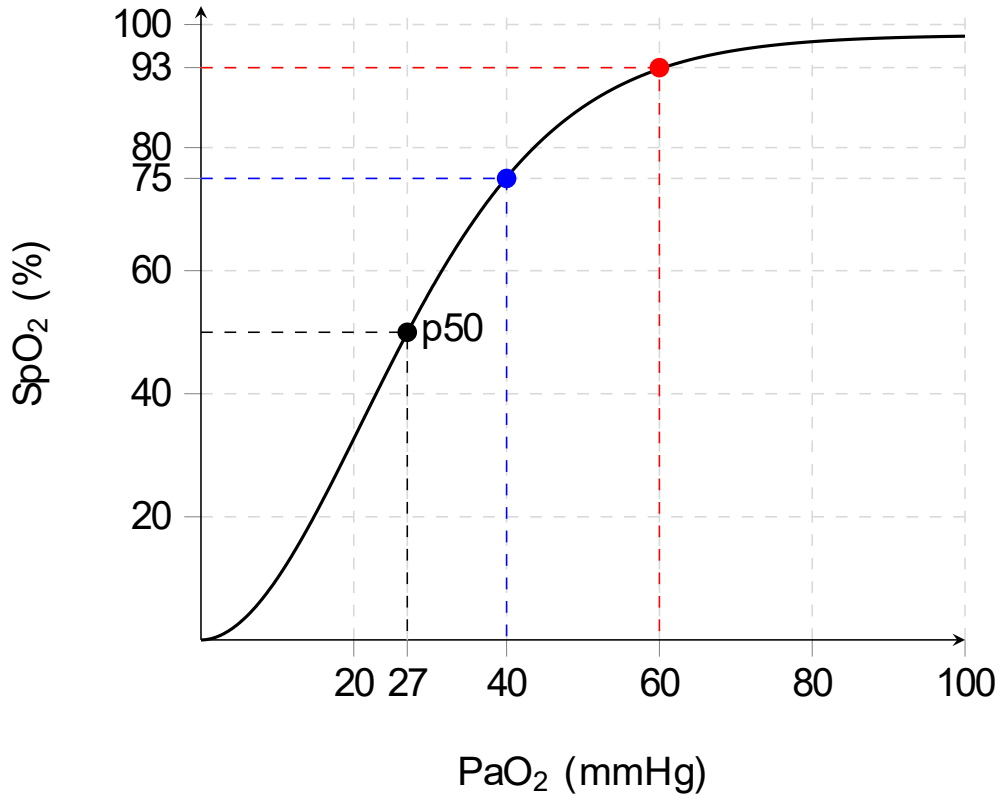


**critical care consultant*

Mechanical Ventilation Basics: Modes

Modes

Name	Nomenclature	Control Variable	Breath	Goal
Volume Control Volume Assist Control	VCV/VAC	Fixed tidal volume	Time triggered Patient triggered	Guaranteed minimum minute ventilation
Pressure Control Pressure Assist Control	PCV/PAC	Fixed Airway Pressure	Time triggered Patient triggered	Guaranteed pressure limit
Pressure Support Ventilation	PSV	Fixed airway pressure	Patient triggered	Patient dictates minute ventilation and flow timing
Synchronized Intermittent Mandatory Ventilation	PC-IMV VC-IMV	Either fixed airway pressure of Fixed volume	Mandatory breaths delivered at a set rate with spontaneous breaths permitted between mandatory breaths	Ensures a minimum minute ventilation while allowing for spontaneous breathing

Liberation from Mechanical Ventilation

1. Optimize

2. Risk Stratify

3. Need for Adjuncts?

4. Safety

The approach to invasive mechanical ventilation

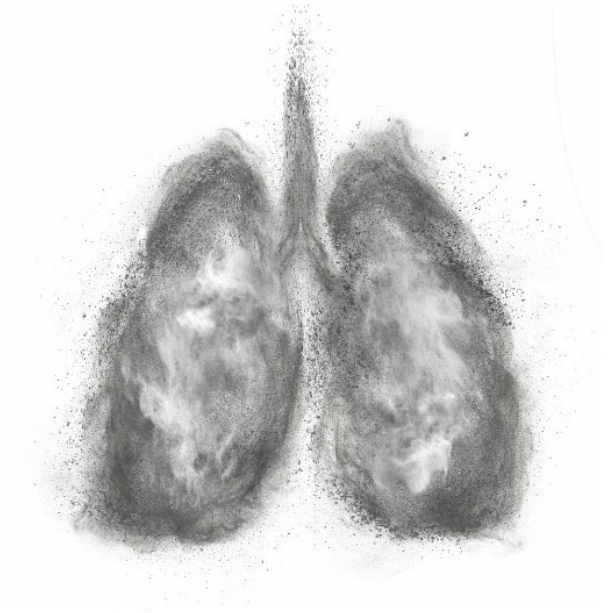
1. Choose the mode of mechanical ventilation you are most comfortable with
2. Know which variables are Dependent & Independent
3. Have a starting point & titrate based on the patient's response…***Reassess***
4. Escalate for expert opinion when faced with high-risk pathology and patient asynchrony

Acute Respiratory Failure

Defining Acute Respiratory Failure

Hypoxic Respiratory Failure (**Type 1**)

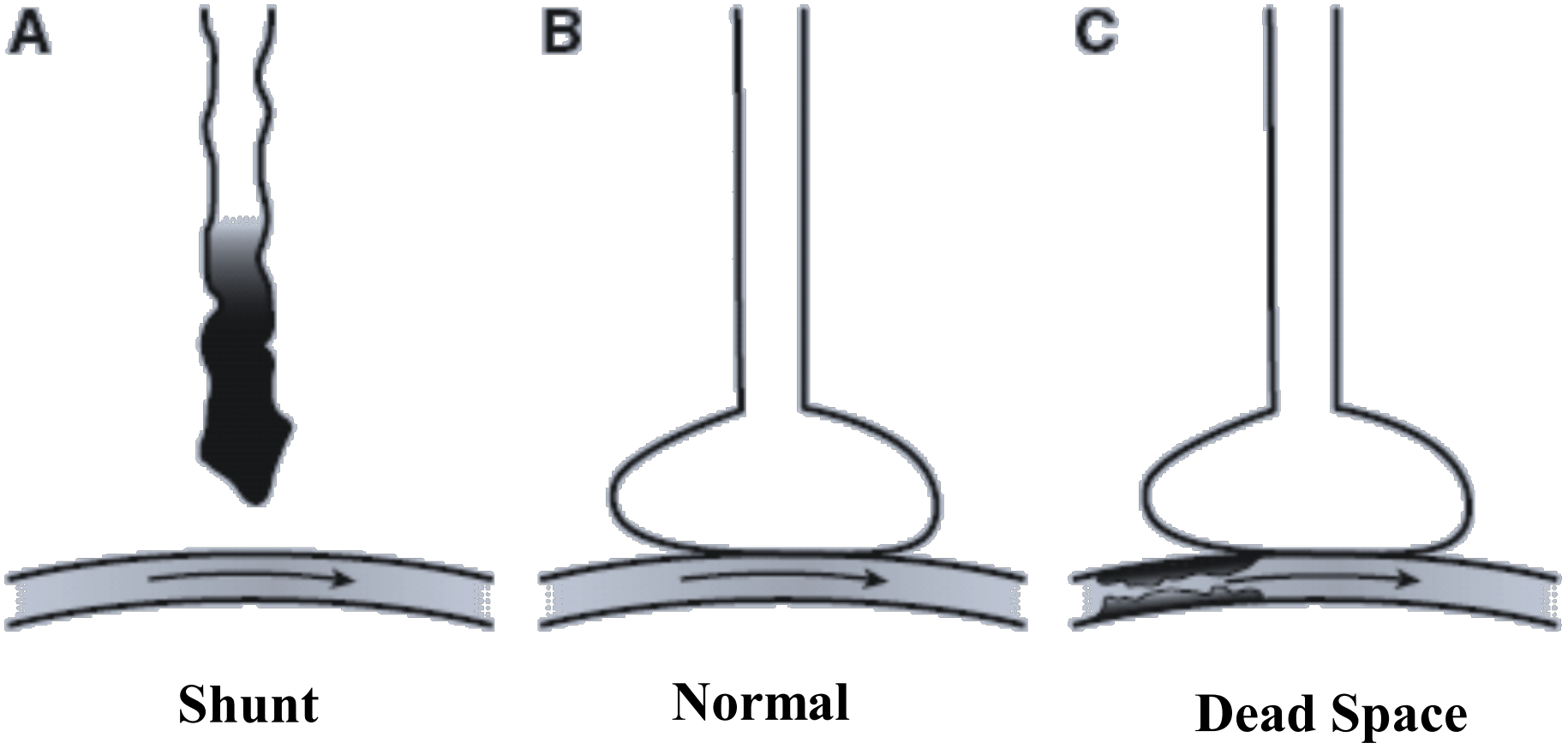
- $PaO_2 < 60mmHg$ on RA or P:F ratio < 400



Hypercapnic Respiratory Failure (**Type 2**)

- $PaCO_2 > 50mmHg$ & pH < 7.35

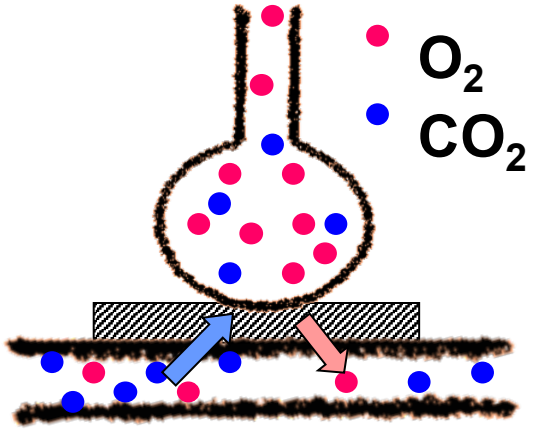
Ventilation/Perfusion Mismatch



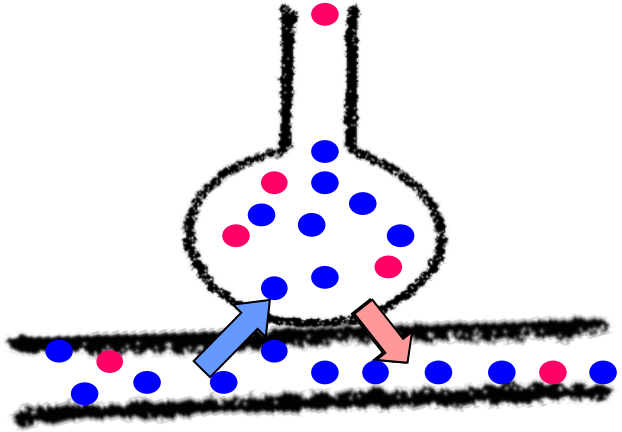
Society of Critical Care Medicine. FCCS. 2021

Hypoxemia

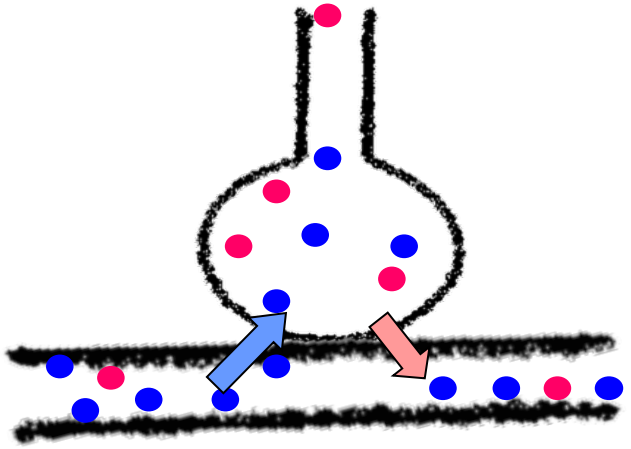
1. Impaired gas diffusion
2. Alveolar hypoventilation
3. High altitude



Impaired diffusion



Alveolar hypoventilation



High altitude

Society of Critical Care Medicine. FCCS. 2021

Acute Respiratory Distress Syndrome

- Laennec: 1821 “Idiopathic Pulmonary Edema” *Treatise on Diseases of the Chest*
- 1967 “Respiratory Distress Syndrome”
- Berlin Definition 2012

Common Causes	
Lung Injury	Systemic Inflammation
Aspiration	Pancreatitis
Drowning (saltwater vs freshwater)	Sepsis
Inhalation	Transfusion Reaction
Trauma	DIC

2012 Berlin ARDS Definition

2012 Berlin Definition: ARDS
ACUTE: Onset within 1 week of insult
Bilateral Pulmonary Opacities
Non-cardiogenic / volume overload
PaO2:FiO2 ratio < 300 (on at least $5_{cm}H2O$ end expiratory pressure)

Severity (once criteria of diagnosis have been met)
Mild = PF ratio 200-300
Moderate = PF ratio 100-200
Severe = PF ratio < 100

CASE

32yoM admitted 72hrs ago with hypertriglyceridemic pancreatitis (triglyceride level > 3,000mg/dL) is escalated to the ICU for progressive SOB and hypoxia. He is intubated on arrival to the ICU. CXR shown below (FIG 1). 2D echo shows normal biventricular function . He is placed on VAC, Vt 400cc (6cc/kg IBW), RR 18, PEEP 14, pPlat 28, FiO2 100%. He is synchronous.

- **After 12hrs: ABG: 7.28, CO2 52, Pao2 130mmHg**

What is the next best step in management?

A. Increase Vt

B. Start inhaled epoprostenol

C. Place the patient in the prone position

D. Transfer to and ECMO capable center

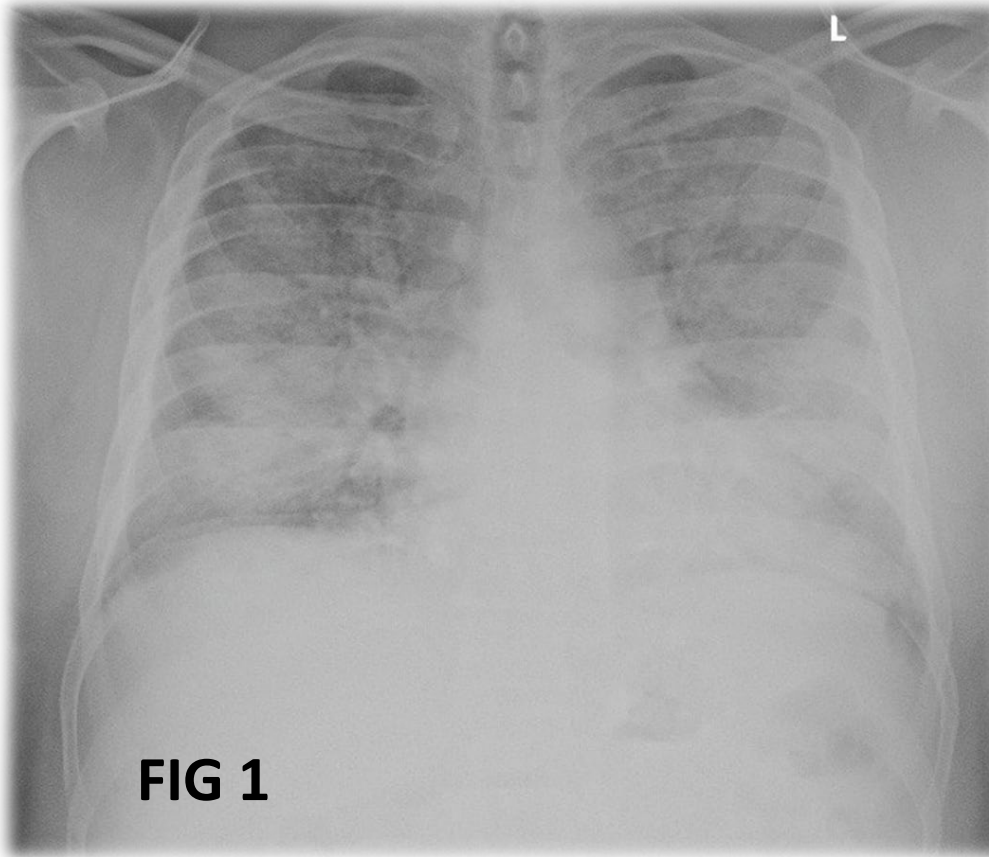


FIG 1

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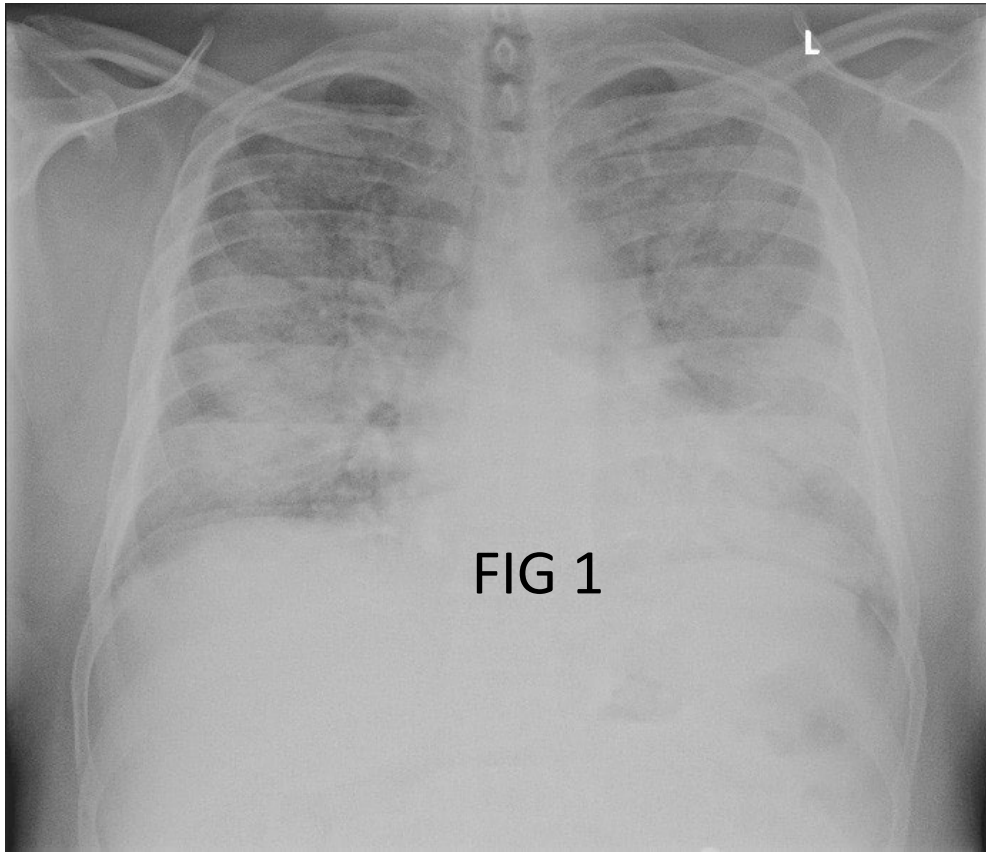

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Targets

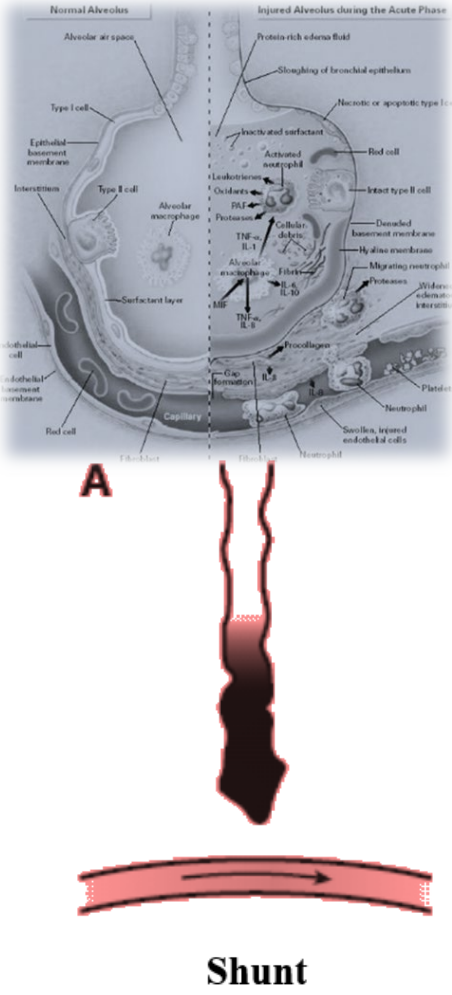
1. Improve gas exchange
2. Improve lung compliance
3. Minimize ventilator injury (VILI)

   Barotrauma- high end alveolar pressures causing tissue rupture

   Volutrauma – high end alveolar volumes casing tissue distortion

   Atelectrauma – high shear stress cause tissue distortion

   Self-inflicted lung Injury (SILI)-patient:ventilator asynchrony and eff



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Mortality Benefit

- ✓ **6cc/kg PBW**
  - 9% absolute risk reduction
  - NNT = 10

TABLE 1. SUMMARY OF VENTILATOR PROCEDURES.*

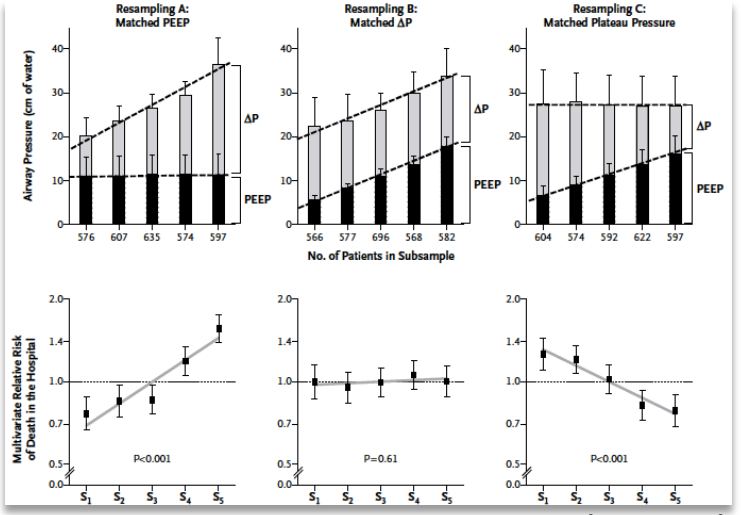
VARIABLE	GROUP RECEIVING TRADITIONAL TIDAL VOLUMES	GROUP RECEIVING LOWER TIDAL VOLUMES
Ventilator mode	Volume assist–control	Volume assist–control
Initial tidal volume (ml/kg of predicted body weight)†	12	6
Plateau pressure (cm of water)	≤50	≤30

Brower RG et al. N Engl J Med 2000

- ✓ **Driving Pressure ≤ 15**

pPLat – PEEP

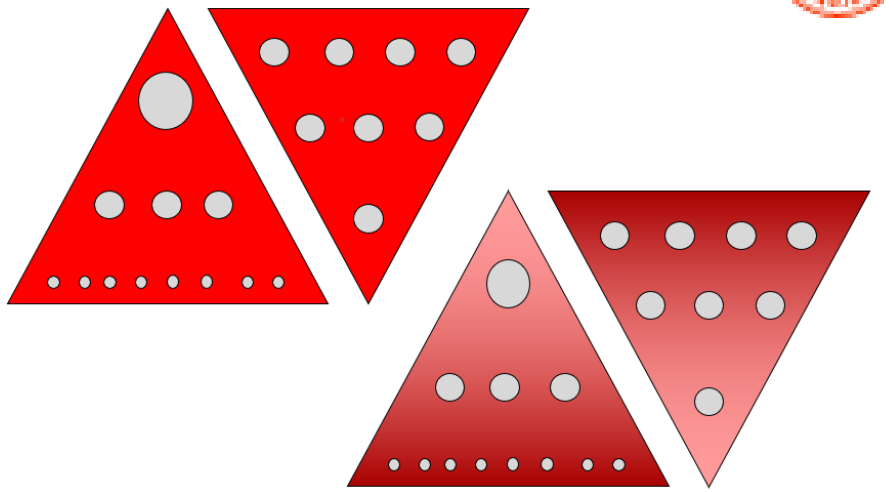
- augmenting ventilation to improve lung compliance



Amato MBP et al. N Engl J Med 2015

Mortality Benef

1. Improve ventilatory matching
2. Improve perfusion matching
3. Decrease compression, improve FRC
4. Improve lung compliance



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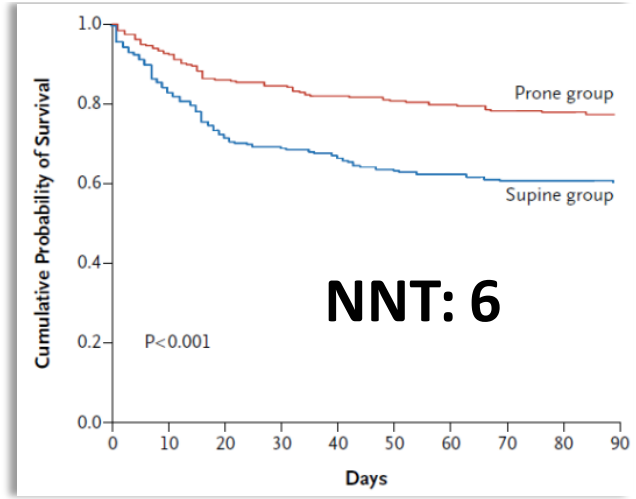
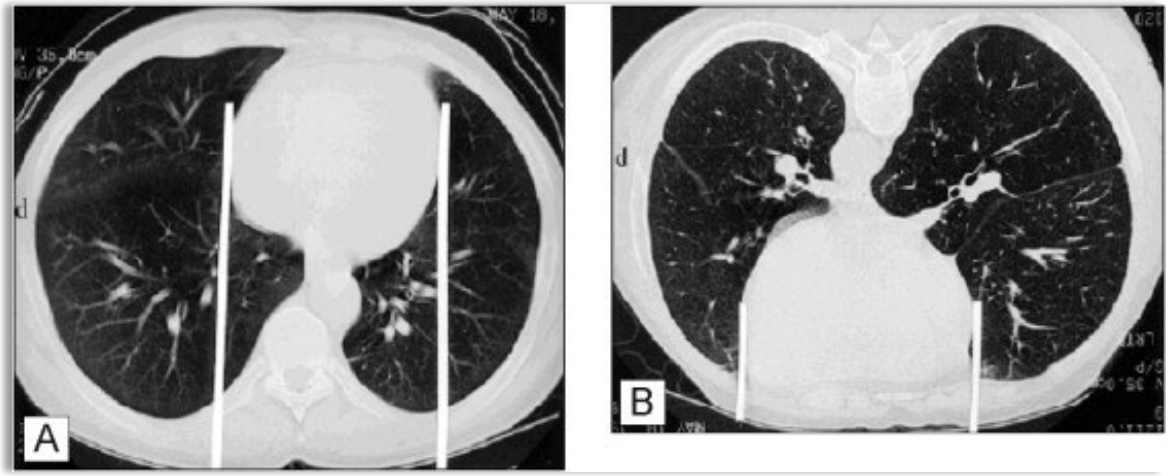


Early (within 12-24hr of optimization)

P:F ratio < 150

16hr down (at least)



Controversial Therapies

- Paralytic Therapy*
- Systemic Corticosteroids*
- ECMO*
- Inhaled Pulmonary Vasodilators

The Approach to ARDS

1. Identify
2. Mortality benefit
3. Reverse the underlying cause
4. Oxygen salvage strategies
5. Transplant referral

Case

29yoM who present to the ED after being found unconscious by a friend in a burning abandoned apartment building. He has been drinking alcohol, T 36C. Nares and skin are covered in soot. On exam T 36C, pulse 66bpm, respirations 18, 126/70mmHg, SaO2 100% on VAC/425ml/18/60%/5cmH2O. She is unresponsive off all sedation. CT brain is negative for acute changes.

LAB*:*

Alcohol: 100mg/dl

Carboxyhemoglobin level: 52%

What is the next best treatment?

A. Increased the ventilator to 100%
B. Check cyanide level
C. Support with hyperbaric oxygen therapy
D. All of the above

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LAB*:*

Alcohol: 100mg/dl

Carboxyhemoglobin level: 52%

What is the next best step in the management of this patient?

A. Increased the ventilator to 100%

B. Check cyanide level

C. Support with hyperbaric oxygen therapy

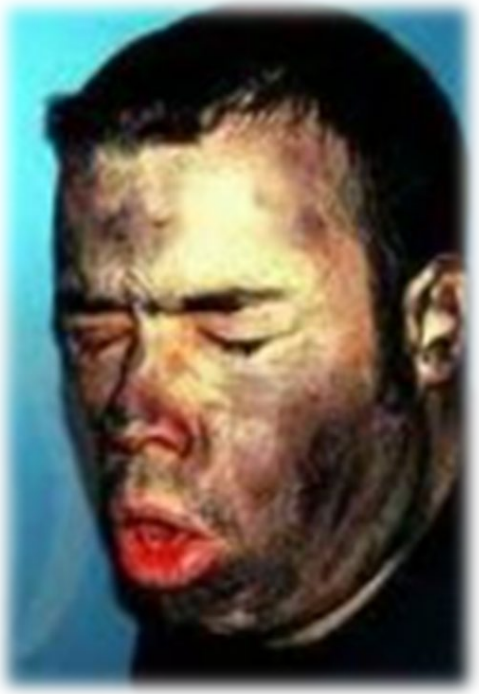
D. All of the above

Carbon monoxide poisoning

> 50,000 cases in the USA each year with > 1300^{+} deaths

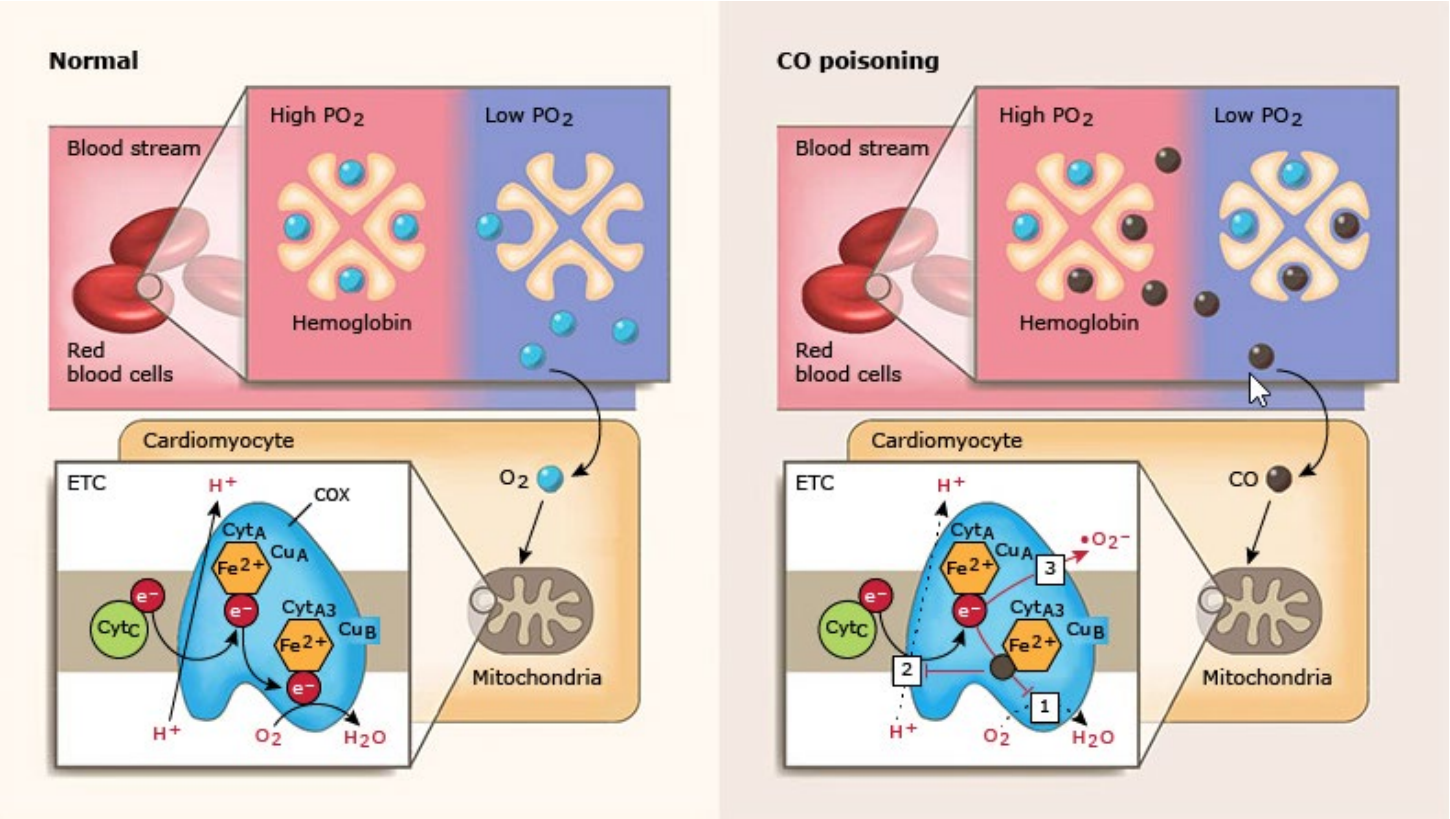
Odorless, tasteless, colorless, nonirritating gas formed by hydrocarbon combustion

- Smoke inhalation from fires
- Fuel burning devices: (propane/kerosene heaters)



CO poisoning

- Has a greater affinity for hemoglobin than oxygen



Half-life ~90 minutes

All victims get 100% oxygen

Hyperbaric (HBO)

- ✓ 25%
- ✓ 15% pregnant
- ✓ Acidosis/endorgan failure

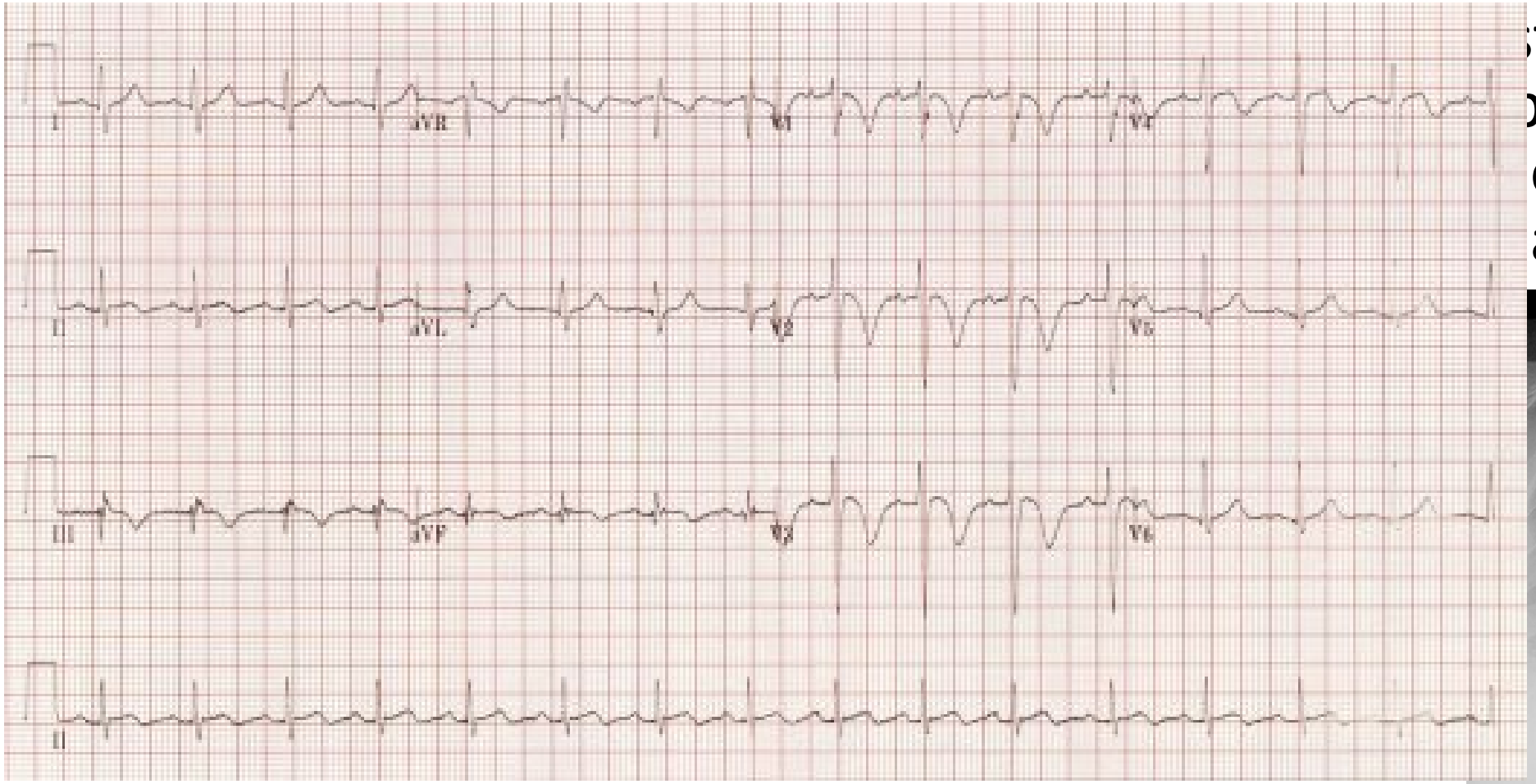
Smoke inhalation & cyanide

Don’t forget about checking for cyanide with smoke inhalation.

Give ***Hydoxoycobalamin***

-binds intracellular cyanide and coverts it to cyanocobalamin which is not harmful

CASE



tate of health
ain. She denies
onths ago. HR is
air and 90% 15L

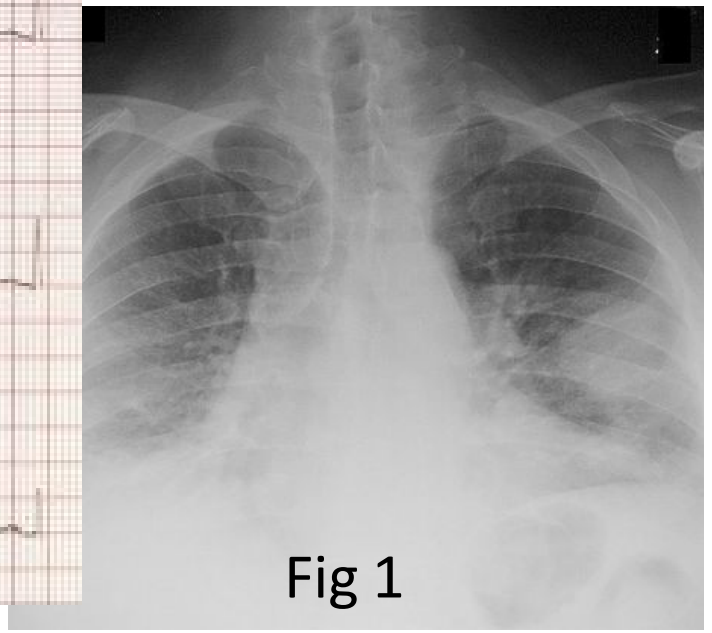


Fig 1

CASE

32yo F with no past medical history was in her usual state of health when she developed sudden onset of pleuritic chest pain. She denies any infectious Prodrome. She started taking OCTs 2 months ago. HR is 140bpm, BP 90/55mmHg, Saturation is 82% on room air and 90% 15L NC. CXR shown in FIG 1. ECG shown in FIG 2.

What is the next best test?

A. CT-PE scan

B. Doppler ultrasound of the lower extremities

C. High sensitivity troponin and cardiology consultation

D. 2D echocardiogram

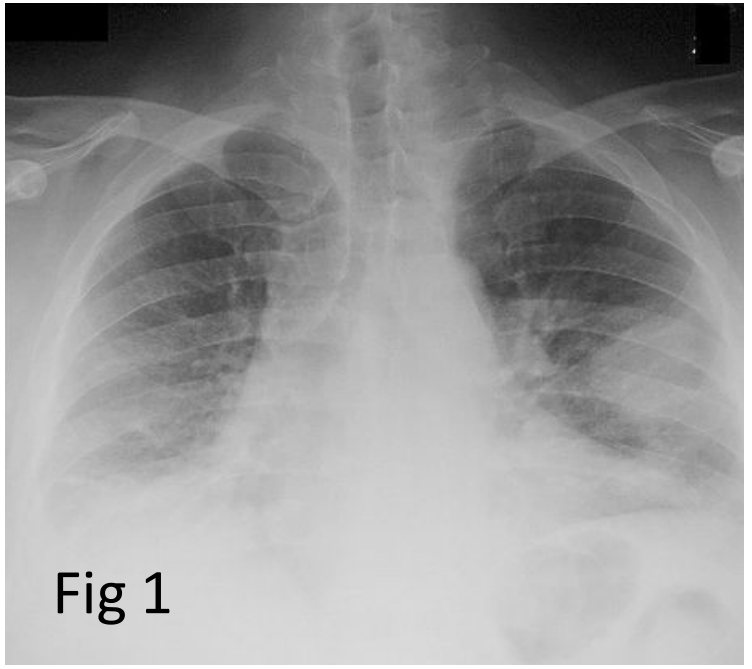
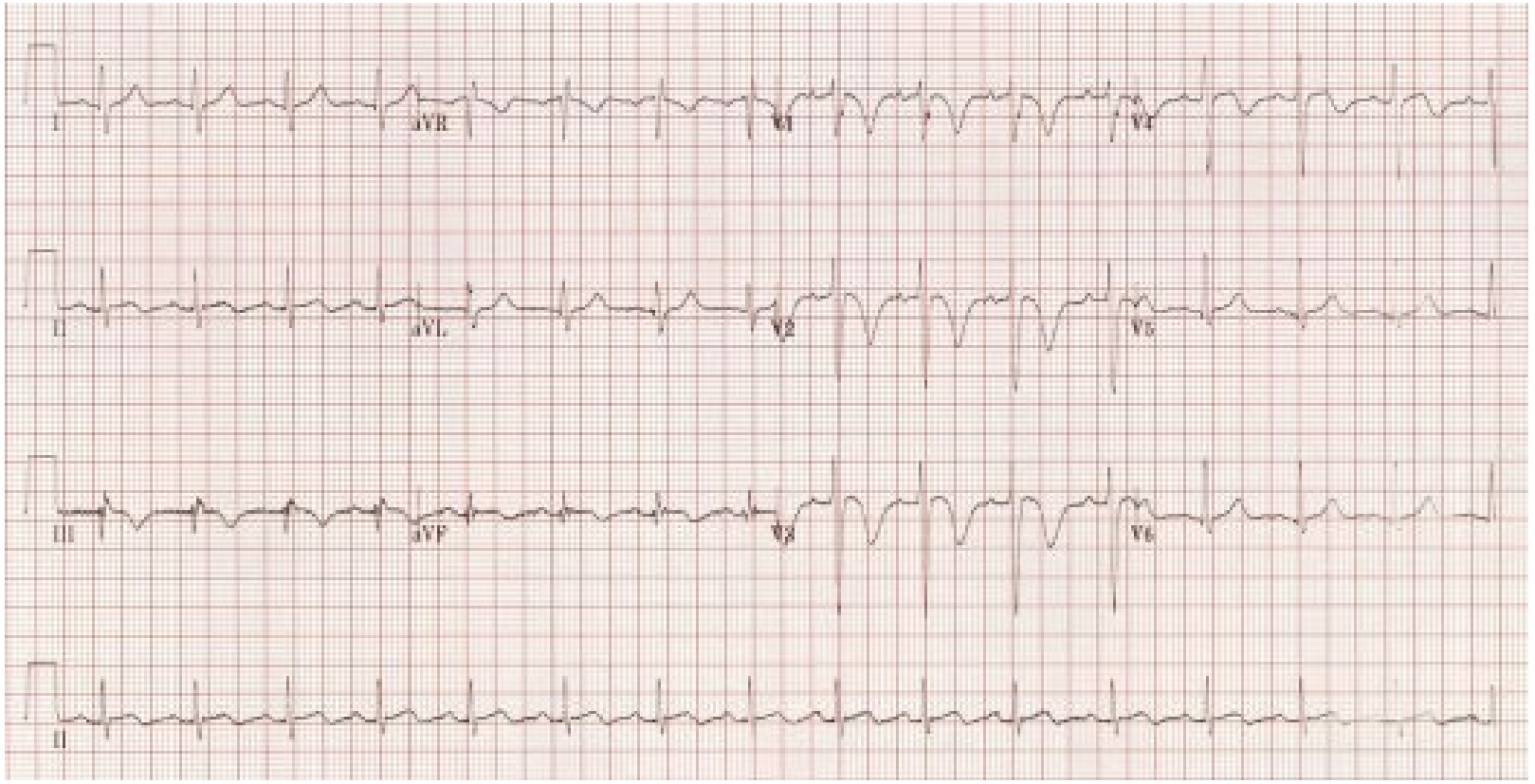


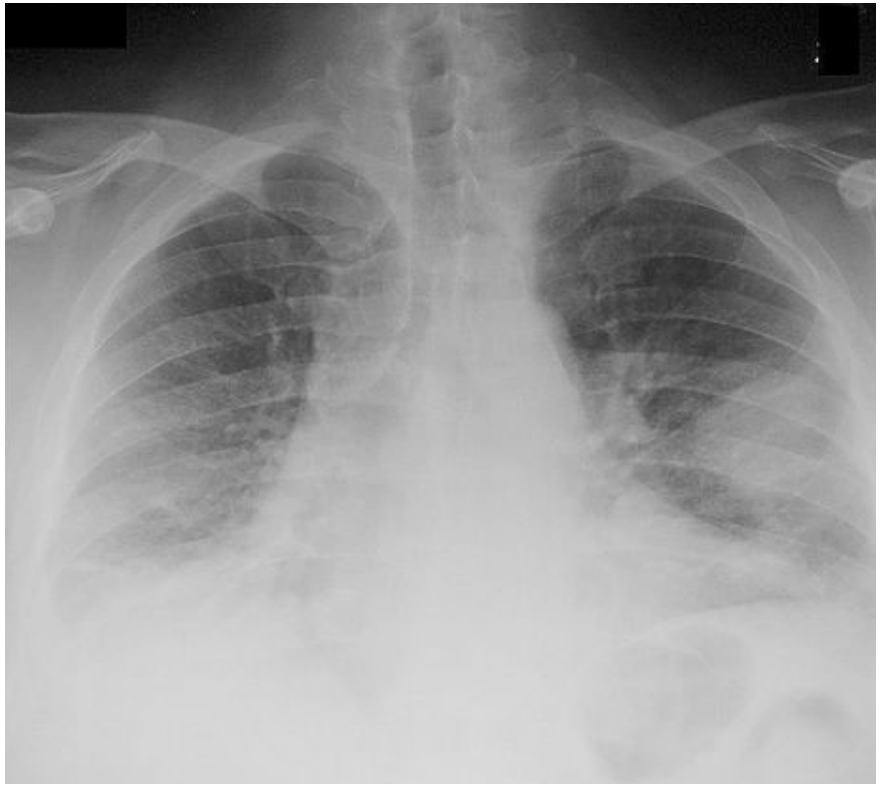
Fig 1

Diagnosis of Acute Pulmonary Embolism

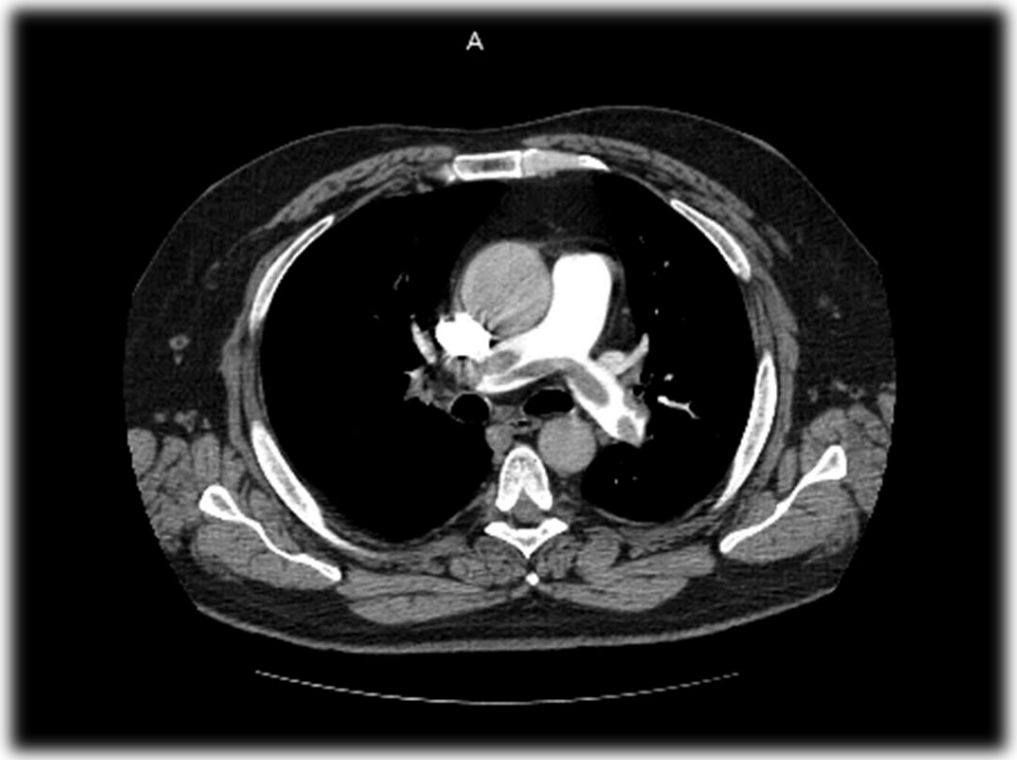
S1, Q3, T3,



Hampton's Hump



Stable Pulmonary Embolism

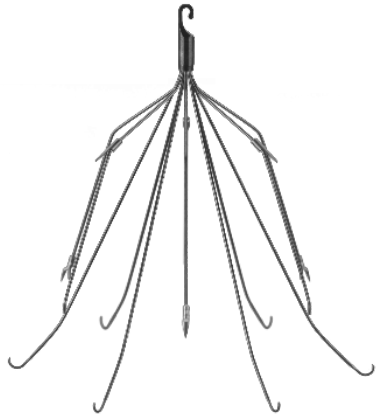


Systemic Anticoagulation

- Unfractionated heparin
- LMW heparin
- Fondaparinux
- Direct oral anticoagulant
- Warfarin

Cannot Anticoagulate

- Place IVC Filter and once the CI resolves start systemic AC



PE Risk Stratification

PESI Score

- Age (+age)
- Sex (+10 for male)
- History of malignancy (+30)
- History of chronic lung disease (+10)
- History of heart failure (+10)
- HR>110 beats/min (+20)
- RR >30 breaths/min (+20)
- AMS (+60)
- SBP<100 mm Hg (+30)
- Temp <36°C (96.8°F) (+20)
- SPO2 <90% (+20)

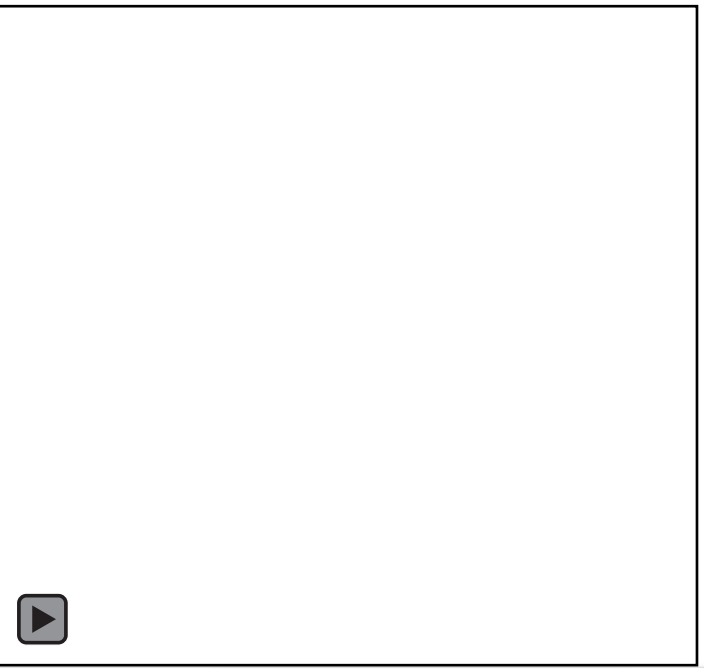
PESI 30-day Mortality

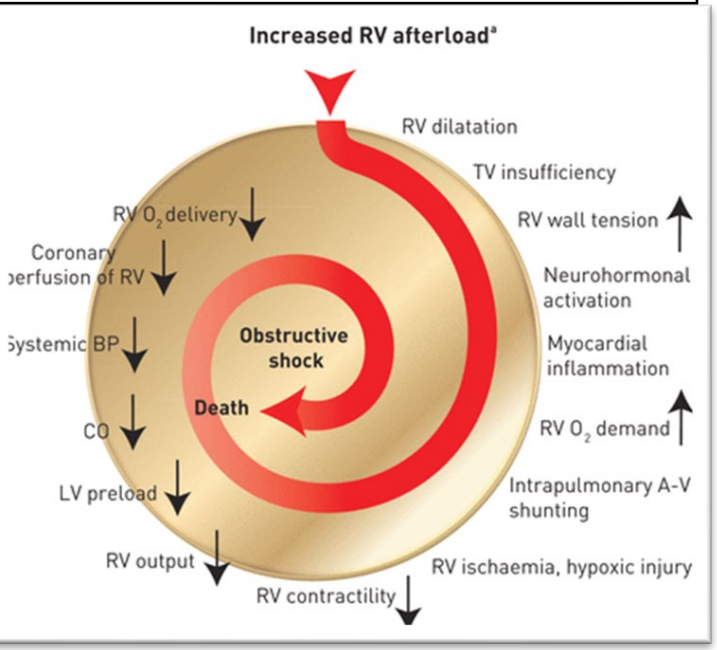
>100 : 7%

>140 : 25%

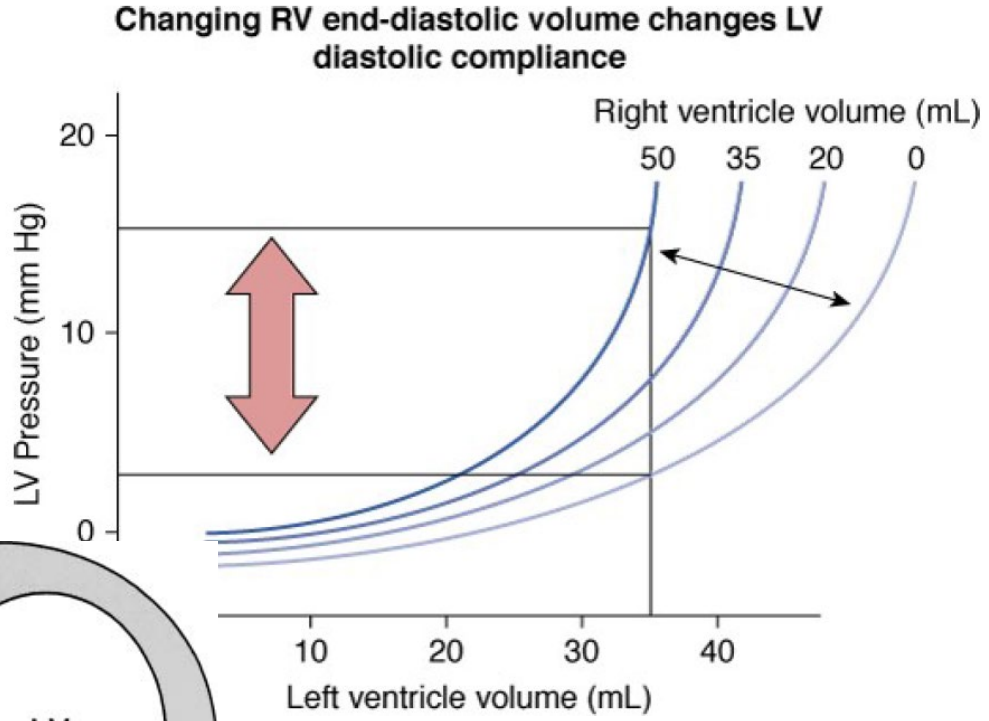
Classification	Massive PE	Submassive PE
Systolic blood pressure	<90 mm Hg or >40 mm Hg decrease for >15 min despite fluid resuscitation	>90 mm Hg
Vasopressor therapy	Initiated	No
Cardiac biomarker (troponin and/or beta-natriuretic peptide)	Elevated	Elevated
Imaging	Right ventricle (RV) dysfunction present	RV dysfunction present
Ratio of RV to left ventricle (LV)	Increase RV:LV >0.9	Increase RV:LV >0.9

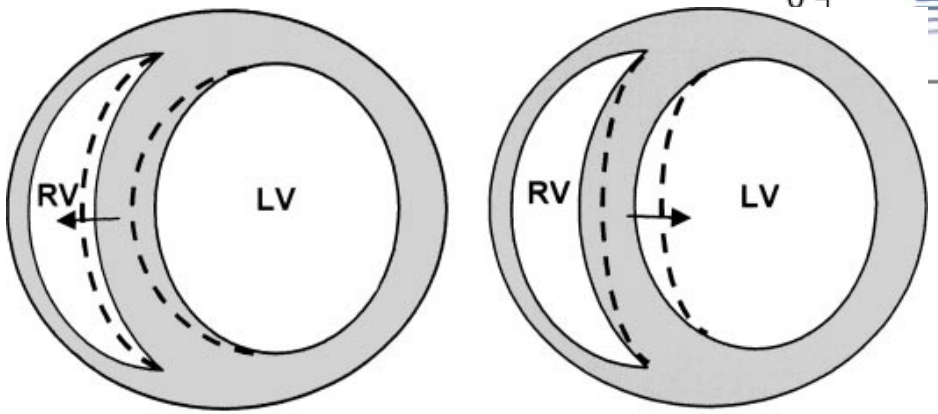
Acute Core Pulmonale & Interventricular Interdependence





Risk of Hemodynamic Collapse with PPV





Decreased RV inflow

Positive pressure inspiration
IVC constriction
Release of abdominal compression

Increased RV inflow

Positive pressure expiration
Release of inspiratory hold
Release of IVC constriction
Abdominal compression

Unstable pulmonary embolism (massive)

Hemodynamic collapse

Treatment: thrombolytics (2% risk of ICH)

✓Decrease Mortality

✓Improved Echocardiographic Finding

CI:

ICH on CT

Neurosurgery, Head Trauma, CVA within 3-months

History of ICH

Known intracranial ICH, aneurysm, neoplasm

Suspected or confirmed endocarditis

Platelet Count < 100,000

Caveats: role for surgical thrombectomy veno-arterial ECMO

Approach to Pulmonary Embolism

- Identification
- Risk Stratification (PESI)
- Risk Stratification if PPV needed
- If stable -> anticoagulate
- If hemodynamic collapse -> systemic thrombolysis
- Know the contraindications to systemic thrombolysis
- Expert opinion for refractory shock
    - surgical embolectomy / VA ECMO

Question

Which of the following is the expected metabolic compensation for serum bicarbonate with respect to chronic hypercapnia?

A. $HCO_3 \uparrow$ 3.5mEq/L for every 10mmHg $\uparrow$ $PaCO_2$

B. $HCO_3 \downarrow$ 3.5mEq/L for every 10mmHg $\uparrow$ $PaCO_2$

C. $HCO_3 \uparrow$ 1.0mEq/L for every 10mmHg $\uparrow$ $PaCO_2$

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C. HCO3 ↑ 1.0mEq/L for every 10mmHg ↑ PaCO2

D. HCO3 ↓ 1.0mEq/L for every 10mmHg ↑ PaCO2

Question

62yoF is being treated in the ICU for an acute myasthenic crisis. Daily vital capacity is check by respiratory therapy. Which of the following is indicative of a rapidly declining respiratory status requiring ***elective*** endotracheal intubation?

A. Vital Capacity of 65ml/kg-IBW
B. Vital Capacity of 30ml/kg-IBW
C. Vital Capacity of 18ml/kg-IBW
D. Negative Inspiratory Force of -50 cmH_2O

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C. Vital Capacity of 18ml/kg-IBW

D. Negative Inspiratory Force of -50 cmH_2O

Impending respiratory failure

Impending neuromuscular respiratory failure

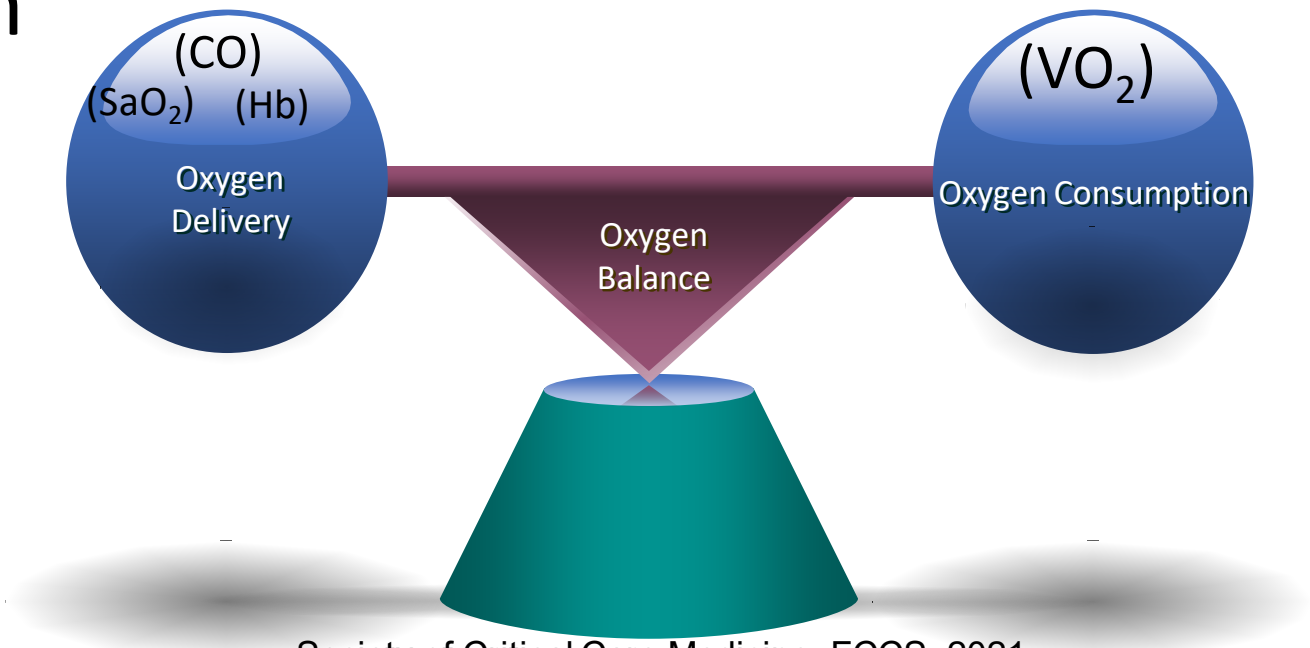
> 60% of myasthenic crisis patients admitted to the ICU will require intubation

Vital Capacity	
65ml/kg-IBW	Normal
30ml/kg-IBW	Weak Cough
<20ml/kg-IBW	Elective Intubation

Shock

Shock

- Syndrome of impaired O_2 delivery to tissue
- Absolute/relative decrease in O_2 delivery
- Ineffective tissue perfusion
- Ineffective O_2 utilization



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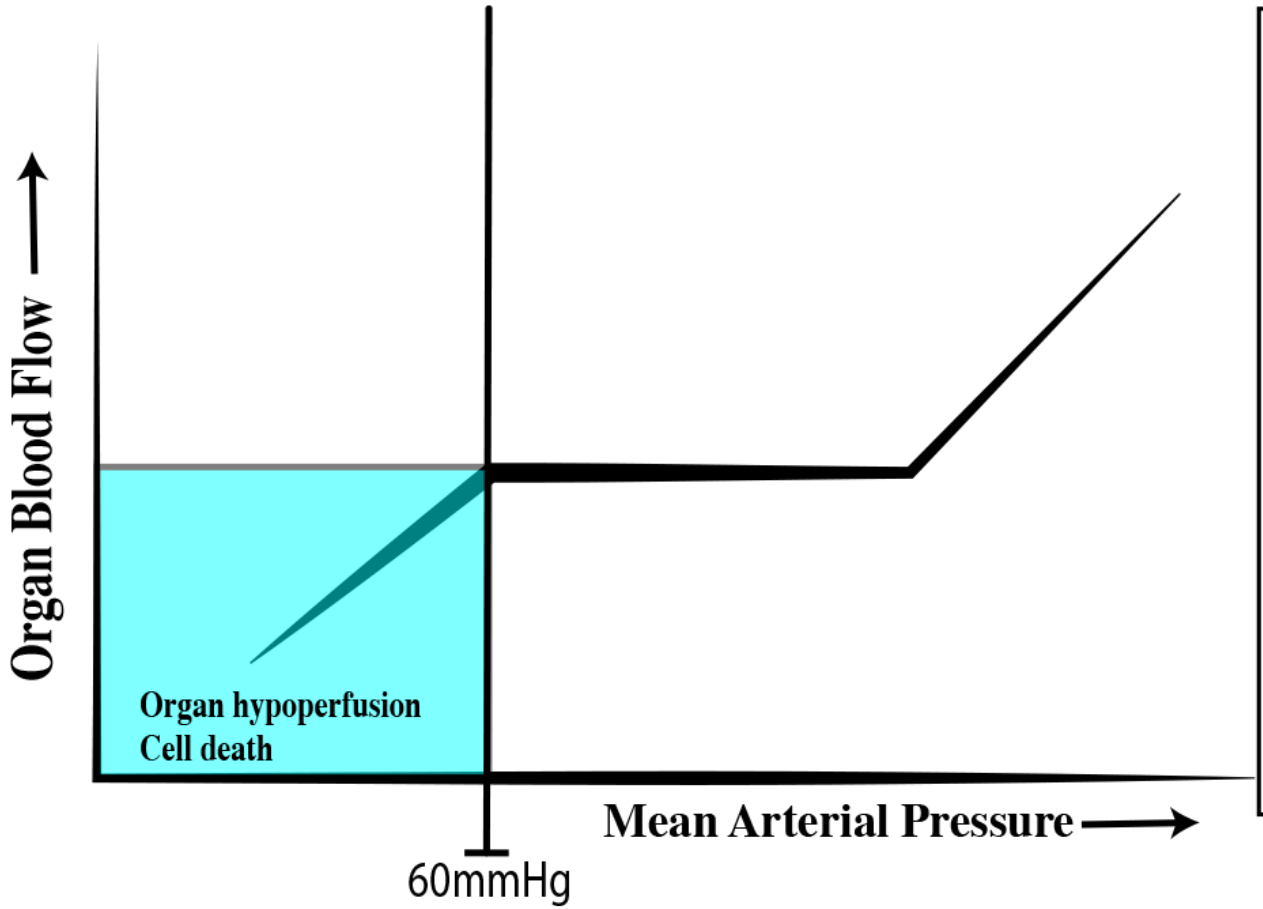
$$\text{Mean Arterial Pressure} = (\underbrace{\text{CO}}_{\text{Cardiac Output}} \times \underbrace{\text{SVR}}_{\text{Systemic Vascular Resistance}}) + \underbrace{\text{CVP}}_{\text{Central Venous Pressure}}$$



The Systemic Blood Pressure Autoregulation Curve

Organ perfusion is a balance between metabolic, myotenic, and tubuglomerular feedback mechanisms supporting blood flow autoregulation. At extremes of mean arterial pressure, the ability to autoregulate organ perfusion is lost. This figure illustrates the precipitous drop in organ blood flow below a MAP of 60mmHg. This relationship lead to a selection of a MAP of 65mmHg in most setpic shock studies.

Strandgaard S, Sengupta E. MacKenzie E: The lower and upper limits of autoregulation of cerebral blood flow. In: Cerebral Circulation and Metabolism. Lagfitt T, McHenry LC Jr, Reivich M, et al. (Eds). New York, Sppringer-Verlag, 1975, pp.3-6

Johnson P. Autoregulation of blood flow. Circ Res 1986; 59:483-495

Question

A 52yoM presents to the ED with shortness of breath and new-onset lower extremity swelling. VS: 37 °C (98.6 °F), heart rate 120bpm, RR 30 breaths/min, blood pressure 86/62 mm Hg, SaO2 92% on NRB mask. (+) JVD. He is intubated and transferred to the ICU. TTE shows significantly reduced left ventricular function. Hemoglobin is 9.2 g/dL, lactic acid 4.2 mg/dL, and central venous oxygen saturation 46%. Which of the following interventions will significantly improve oxygen delivery?

A. Administer a 1L isotonic crystalloid and start ceftriaxone and azithromycin
B. Start milrinone
C. Start phenylephrine
D. Transfuse RBCs to a goal of 10 g/dL

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Shock

End-organ hypoperfusion

Clinical findings

- Altered mental status
- Oliguria
- Hypotension
- Mottled skin

Laboratory findings

- ↑ Lactate
- ↑ LFTS or Cr
- ↓ Mixed venous oxygen saturation

Shock

Cardiogenic	ACS Mechanical Arrhythmia
Hypovolemic	Hemorrhagic Nonhemorrhagic
Distributive	Septic Adrenal crisis Neurogenic Anaphylactic
Obstructive	Massive pulmonary embolism Cardiac tamponade Tension pneumothorax Constrictive pericarditis

Management

Variable	Intervention
Blood pressure	Fluids, vasopressor, or vasodilator
Cardiac output	
Preload	volume, vasodilator
Contractility	Inotropic agents
Afterload	Vasopressor or vasodilator
Oxygen content	
Hemoglobin	Transfusion
Hemoglobin saturation	Supplemental oxygen, PPV
Oxygen demand	↓work of breathing, sedation/pain, fever control

MAP = (CO x SVR) + CVP

Shock Profile	CO	SVR	CVP	SvO_2
Cardiogenic	↓	↑	↑	↓
Inodilators: dobutamine, milrinone				
Hypovolemic	↓	↑	↓	↓
Volume expansion: crystalloid, colloid, Hb				
Distributive	↑ / N	↓	↓ / N	↑ / N
Inopressors: norepinephrine, dopamine, epinephrine Vaspressprs: phenylephrine, vasopressin, Ang II, methylene blue				
Obstructive	↓	↑	↑ / N	↓
Support MAP and reverse mechanical obstruction				

Recognizing the need for mechanical support

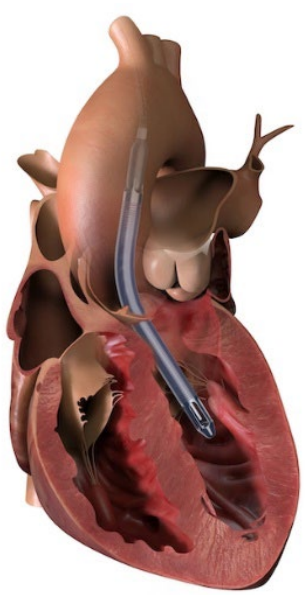
- There is no medical therapy for a mechanical problem
- Ask for **expert opinion** e.g., **Multidisciplinary Shock Team**
  - ❑ reversibility or destination/transplant ?

LV Failure

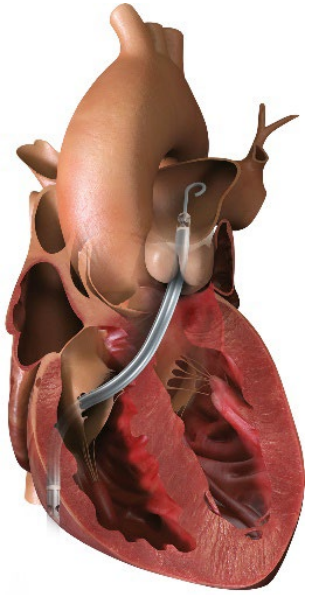
- ❑ ↑ vaso/inotrop = ↑ mortality
- ❑ CI <2.0, MAP<65mmHg, SVO2<50%
- ❑ rising lactic acid
- ❑ CPO = MAPxCO/451 = < 0.6

RV Failure

- ❑ ↑ vaso/inotrop = ↑ mortality
- ❑ CI <2.0, MAP<65mmHg, SVO2<50%
- ❑ rising lactic acid
- ❑ PAPI < 1.5



Impella 5.5



Impella RV

VA ECMO

Approach to Shock

1. Identify the shock state
2. Select the variable(s) you can impact
3. Understand supply/demand mismatch
   - ✓Intervene to improve oxygen delivery
   - ✓Intervene to reduce oxygen demand
4. Fix the underlying cause
5. Ask for expert option when *medical support* is not enough

Medical Shock Armamentarium			MAP = (CO X SVR) + CVP			
Medication	Action	Dose	CO	HR	SVR	Venous Tone
Norepinephrine	β 1> α1> β2	0.01-0.5mcg/kg/min	↑	↑	↑↑	↑↑
Epinephrine	β1= β2 >α1	0.01-0.5mcg/kg/min	↑	↑↑	↑	↑
Vasopressin	V1	0.01-0.04units/min			↑↑	
Angiotensin II	AT-1	10-20ng/kg/min			↑↑	
Phenylephrine	α1	25-300mcg/min			↑↑	
Dobutamine	β1 > β2 > α1	2-20mcg/kg/min	↑↑	↑↑	↓	
Dopamine	D1 ⇢ β1 ⇢ α1 dose dependent	5-20mcg/kg/min	↑	↑	↑	
Milrinone	PDE-3 Inhibitor	0.375-0.75mcg.kg/min	↑↑	↑	↓↓	↓

Reassess!

(example: sepsis)

$$\text{Mean Arterial Pressure} = (\underset{\text{Cardiac Output}}{\text{CO}} \times \underset{\text{Systemic Vascular Resistance}}{\text{SVR}}) + \underset{\text{Central Venous Pressure}}{\text{CVP}}$$

Distributive Shock from Sepsis

$$\downarrow\text{Mean Arterial Pressure} = (\uparrow\underset{\text{Cardiac Output}}{\text{CO}} \times \downarrow\underset{\text{Systemic Vascular Resistance}}{\text{SVR}}) + \downarrow_{\text{or}}^{\leftrightarrow}\underset{\text{Central Venous Pressure}}{\text{CVP}}$$

Shock Profile	Cardiac Output	Systemic Vascular Resistance	Central Venous Pressure
Distributive/Septic	↑	↓	↓ or normal
Norepinephrine followed by Vasopressin or Epinephrine			

Sepsis Induced Cardiomyopathy

$$\downarrow\text{Mean Arterial Pressure} = (\downarrow\underset{\text{Cardiac Output}}{\text{CO}} \times \underset{\text{or}}{\swarrow\!\!\searrow}\underset{\text{Systemic Vascular Resistance}}{\text{SVR}}) + \uparrow_{\text{or}}^{\leftrightarrow}\underset{\text{Central Venous Pressure}}{\text{CVP}}$$

Shock Profile	Cardiac Output	Systemic Vascular Resistance	Central Venous Pressure
Cardiogenic	↓	↓, normal, or ↑	↑ or normal
Norepinephrine + Dobutamine or Epinephrine alone			

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Sepsis

Question

A 22yoF is transferred from a satellite ED to your ICU with fever, tachycardia, and abdominal pain. She is s/p laparoscopic appendectomy 6-days ago at an OSH. VS: BP: 90/60mmHg, HR 126bpm, T 38.9 °C, lactic acid 4.8 mmol/L. WBC 22,000, 30% bandemia, temperature 38.9 °C (102 °F), heart rate 124 beats/minute, and lactic acid 4.8 mmol/L, Cr 1.8 (baseline 0.6). CT of the abdomen and pelvis reveals an 8 × 8-cm rim-enhancing fluid collection in the RLQ. She receives 30cc/kg of isotonic crystalloid along with IV vancomycin, cefepime and metronidazole. What is the next best step in her management?

A.IV hydrocortisone & oral fludrocortisone
B.Start norepinephrine infusion, target MAP 70-75mmHg
C.IR percutaneous drainage of the abdominal abscess
D.Stop cefepime and metronidazole, start piperacillin-tazobactam

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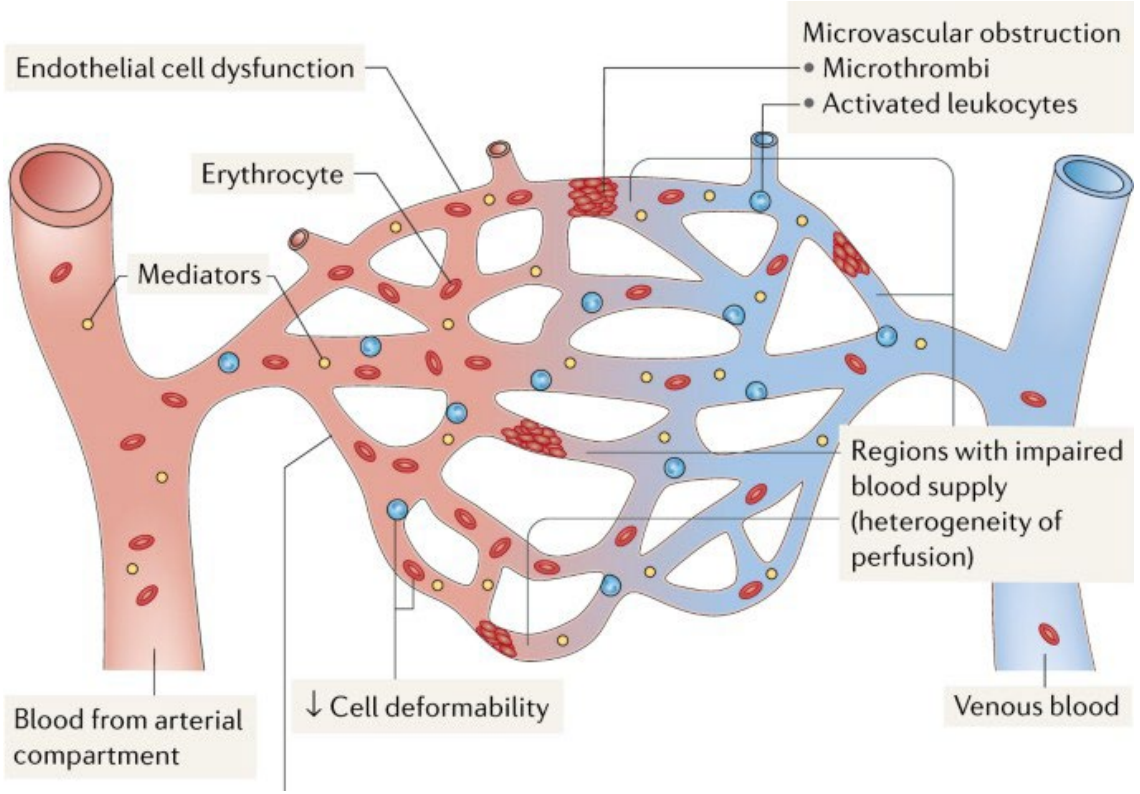
Microvascular insufficiency leading to Macrovascular collapse

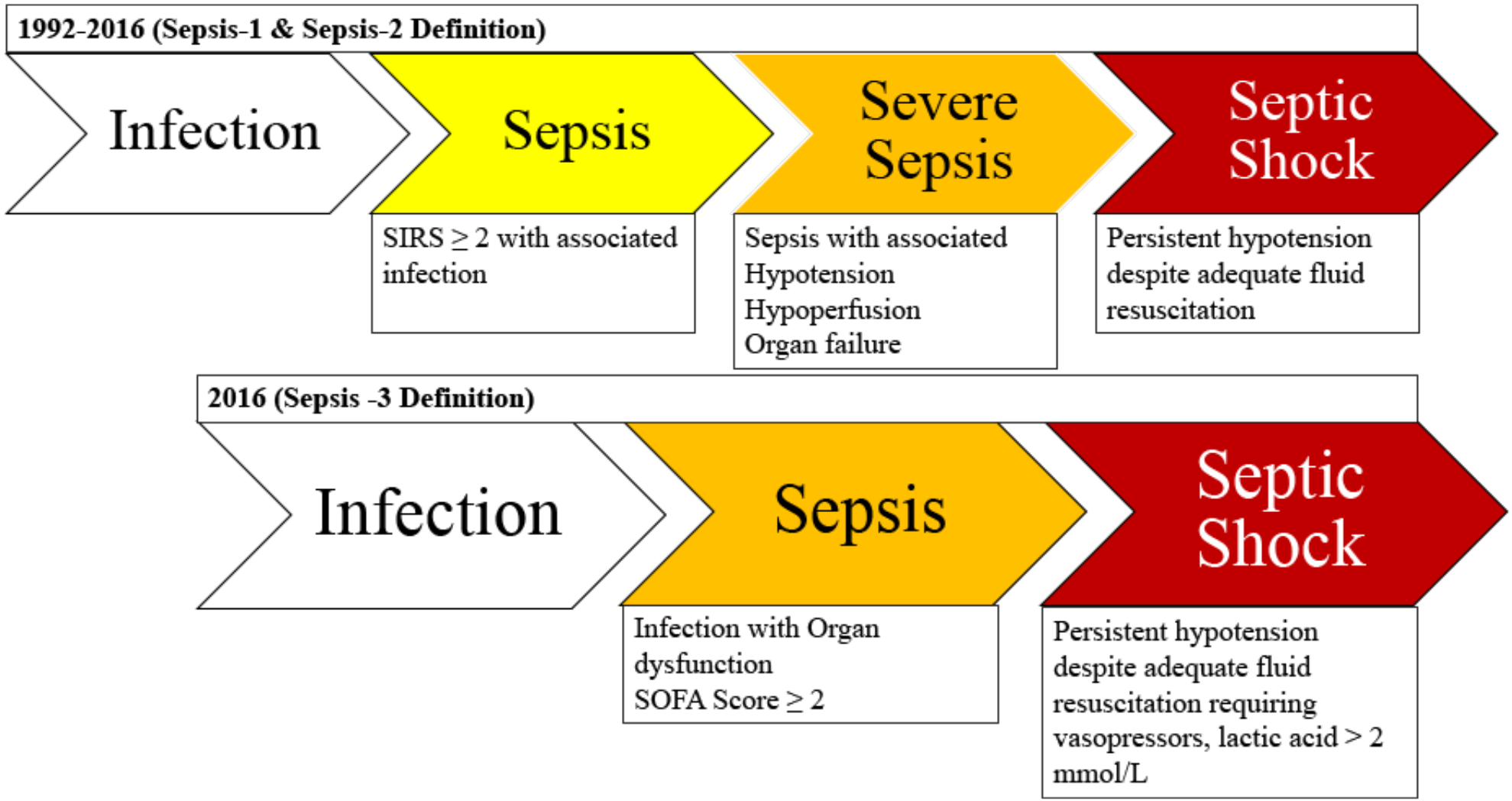
7 signs of microvascular insufficiency

1. **Altered Mental status**
2. **Tachycardia**
3. **Tachypnea**
4. **Temperature regulation**
5. **↑ Lactic acid**
6. **↓ Urine output**
7. **Skin mottling**



Lelubre, C., Vincent, JL. Mechanisms and treatment of organ failure in sepsis. *Nat Rev Nephrol* **14**, 417–427 (2018).

Sepsis Definitions Over Time



SIRS Criteria

Temperature >38°C (100.4° F) or < 36° C (96.8° F)

Heart rate > 90

Respiratory rate > 20 or Pa_{CO2}<32mmHg

WBC > 12,000 or < 4,000 or > 10% bands

Sequential (Sepsis-Related) Organ Failure Assessment Score					
Organ System	0	1	2	3	4
CNS Glasgow Coma Scale	15	13-14	10-12	6-9	< 6
Cardiovascular	≥ 70	≤ 70	dopamine ≤ 5 or dobutamine (any dose)	dopamine 5-15 or epinephrine ≤ 0.1 or norepinephrine ≤ 0.1	Dopamine >15 or epinephrine > 0.1 or norepinephrine >0.1
Respiratory Pa_{O2}/Fi_{O2}, mmHg	≥ 400	300-399	200-199	100-199 w/respiratory support	<100 w/respiratory support
Liver Bilirubin mg/dL	< 1.2	1.2-1.9	2.0-5.9	6.0-11.9	>12
Renal Creatinine mg/dL	< 1.2	1.2-1.9	2.0-3.4	3.5-4.9	> 5.0
Urine output ml/day				< 500	< 200
Hematology Platelets x $10^3/\mu L$	≥ 150	≤ 150	≤ 100	≤ 50	≤ 20
Vasoactive dose = mcg/kg/min for at least 1-hr					

Sepsis Definition

Sepsis

Life-threatening organ dysfunction cause by a dysregulated host response to infection

Septic Shock

Circulatory, cellular, and metabolic abnormalities drive an even greater risk of death than sepsis alone

*Sepsis and septic shock are medical **EMERGENCIES** for which treatment and resuscitation must begin early*

*When Infection Present = **LOOK FOR ORGAN DYSFUNCTION***

*When Organ Dysfunction Present = **LOOK FOR INFECTION***

Question

You are called to a rapid response for hypotension. 75yoF with a history of ischemic cardiomyopahty, is admitted of choledocholithiasis and ascending cholangitis. She was initially stable and planned for ERCP tomorrow. She is on oral ciprofloxacin. The nurse reports she has been more lethargic and hypotensive throughout the day. She refused all medications. The hospitalist has been “intermittently” giving small fluid bolus throughout the day for hypotension. On arrival at the bedside she is confused. VS: BP 80/50mmHg, HR 110bpm, RR 18, T 38C, Sao2 99% on RA. POC glucose 170mg/dl

Which of the following is the best choice?

A.Obtain 2D echo

B.Stop ciprofloxacin, administer broad spectrum antimicrobials within 1-hour

C.Stop ciprofloxacin, administer broad spectrum antimicrobials within 3-hours

D.Administer subcutaneous insulin

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D.Administer subcutaneous insulin

Sepsis Management

Surviving Sepsis Campaign®

Hour-1 Bundles: Initial Resuscitation for Sepsis and Septic Shock	
1	Measure lactate level.*
2	Obtain blood cultures before administering antibiotics.
3	Administer broad-spectrum antibiotics.
4	Begin rapid administration of 30ml/kg crystalloid for hypotension or lactate ≥ 4mmol/L.
5	Apply vasopressor if hypotensive during or after fluid resuscitation to maintain a mean arterial pressure ≥ 65mmHg.

***Remeasure lactate if initial lactate is elevated (>2 mmol/L)**

$$\text{Mean Arterial Pressure} = (\ \underset{\text{Cardiac Output}}{\text{CO}} \times \underset{\text{Systemic Vascular Resistance}}{\text{SVR}}\ ) + \underset{\text{Central Venous Pressure}}{\text{CVP}}$$

Distributive Shock from Sepsis

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Shock Profile	Cardiac Output	Systemic Vascular Resistance	Central Venous Pressure
Distributive/Septic	↑	↓	↓ or normal
Norepinephrine followed by Vasopressin or Epinephrine			

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Corticosteroids in Septic Shock?

Recommendation	Indication	Corticosteroid	Duration
Adults with Septic Shock	Persistent Shock Norepinephrine or Epinephrine _____ ___ ≥ 0.25mcg/kg/min for at least 4-hours to maintain a MAP ≥ 65mmHg	Hydrocortisone 50mg intravenous every 6-hours or 200mg/day as a continuous infusion	5-7 days

Approach to Sepsis

1. Sepsis is an emergency
2. Idenificaiton is key
3. Follow resuscitation and antimicrobial guidelines
4. Use dynamic measure and reassess adequacy of oxygen delivery and source control
5. Reevaluate…Reevaluate….Reevlauate

Post-surgical Infection

Case

50yoM poorly controlled diabetes mellitus is admitted for fever and malaise 8 days after sigmoid resection for perforated diverticulitis. On exam he has no colostomy output. T 39C, BP 115/80mmHg, HR 110bpm, RR 20, Sao2 95% on 2L NC. WBC 24,000 -18% bandemia. Lactic acid 3.2mmol/L. Abdomen is tender to deep palpation. UA is negative. All other labs are pending.

What's going on?

Surgical site infections 20% of HAI

1. Deep surgical site infection
   - ✓Gram positive, gram negative, anaerobe coverage
   - ✓If progressing despite appropriate treatment for bacterial infections –consider antifungal coverage
   - ✓CT with IV and PO contrast
   - ✓Source control

   Abscesses may take up 5-7 days to visualize by CT

Case

You find an 8cm x 6cm rim enhancing fluid collection on CT. He undergoes exploratory laparotomy and washout. He improves significantly over the next 72hrs and is transferred to the surgical service.

Today a rapid response is called this patient to the surgical stepdown for hypotension. Incision site is painful, out-of-proportion to physical exam. The nurse reports erythema and drainage from the surgical wound for the last 24-hours. He is taken urgently to the operating room.

The wound is explored and the surgical team reports “dishwater-appearing fluid and areas of necrosis”

Diagnosis?

Surgical site infections 20% of HAI

2. Superficial surgical site infection
    - Necrotizing Soft Tissue Infection

Signs of Necrotizing Soft Tissue Infection (NSTI)	
Pain out of proportion to exam (70%)	Blistering and/or bullae (40%)
Erythema w/o margins (75%)	Crepitus (50%)
Soft tissue edema beyond erythema (75%)	Hemorrhagic blebs (40%)
Fever (60%)	Necrosis (40%)
HYPOTENSION	
SHOCK	

Necrotizing Soft Tissue Infection

- The diagnosis can only be made surgically
- CT imaging can be helpful but should not delay surgical exploration- clinical diagnosis

Risk Factor - NSTI
Trauma /skin breach
Mucosal breach (rectal fissure)
DM/Cirrhosis/neutropenia/HIV
Malignancy
Obesity
Alcoholism
GYN

Gas Present (Type I)	Gas Absent (Type II)
Polymicrobial	Group A Strep
Clostridial species	MSSA / MRSA
	Vibrio species (salt water)
	Aeromonas (fresh water)

Antimicrobial therapy

Empiric Therapy	
Gram (+) , Gram (-) , Anaerobe	Carbapenem **-or-** Piperacillin-tazobactam
PLUS	
MRSA coverage	Vancomycin **-or-** Daptomycin
PLUS	
Toxin binding coverage	Clindamycin **-or-** Linezolid

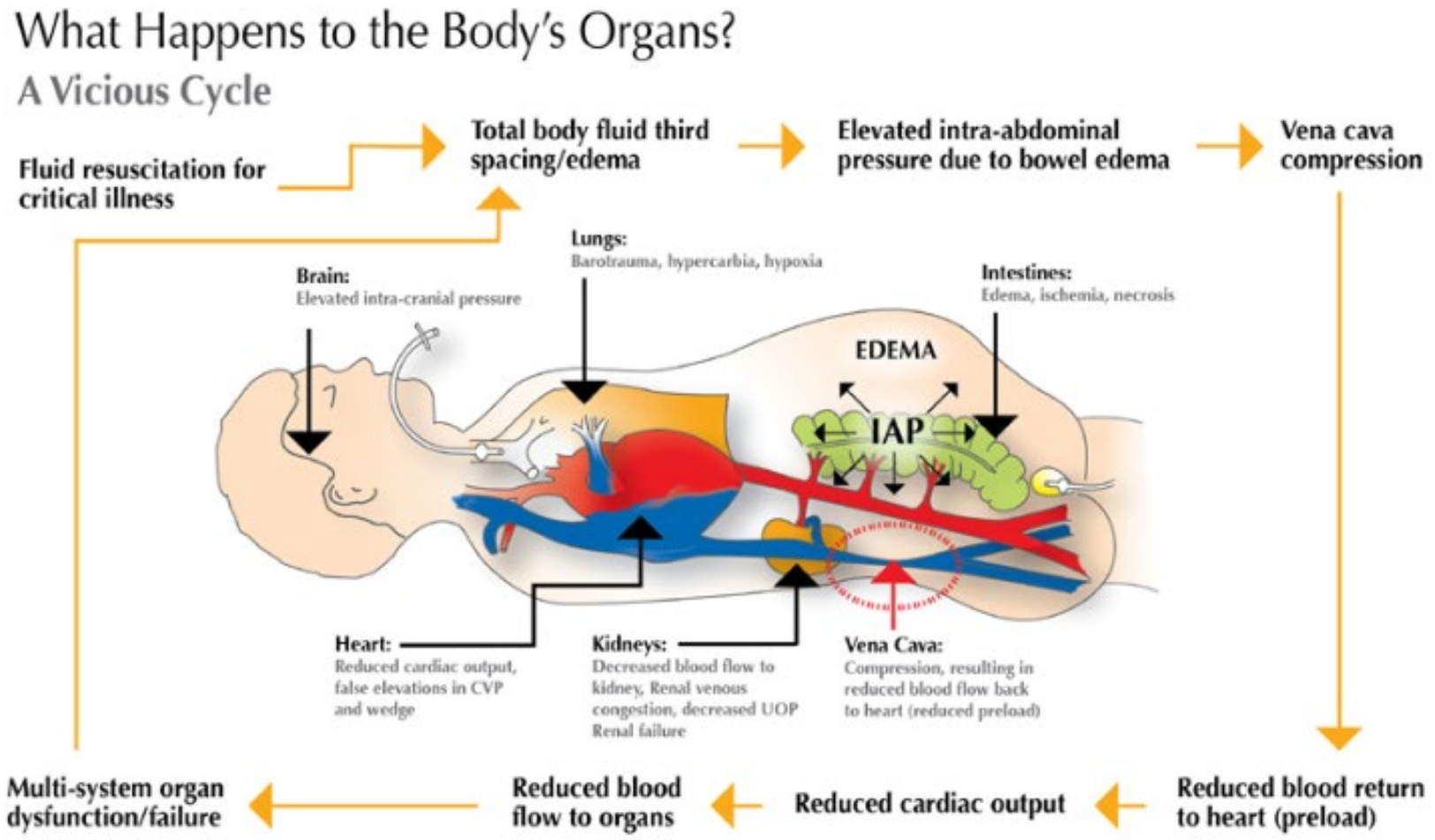
- Continue 4-7d after source control
- IVIG controversial (GAS toxic shock)

Case continued

The patient remain in the ICU. He is aggressively volume resuscitated and supported with vasoactive agents. The surgical team was able to obtain source control and close his fascia. Today his Cr has increased from 1.2mg/dl -> 3.4mg/dl. Overnight he was only documented as have 50ml of urine output for the entire shift despite being 12L (+) in the last 36hours. He is currently anuric. You have also noted an increase in his peak airway pressure and drop in his static compliance.

Concerns?

Intra-abdominal Hypertension (IAH)



Intra-abdominal Hypertension (IAH)

APP = (MAP-IAP) < 50 predictor of mortality

Abdominal Pressure (mm Hg)	Class	Intervention
<12	Normal	- Surveillance every 4 hours
12-15	Class I	- Continue surveillance of IAP - Start medical therapy to decrease IAH
16-20	Class II	- Continue surveillance of IAP - Optimize medical approaches to decrease IAH - Obtain early surgical consult
21-25	Class III	- Continue medical therapies - Consider surgical decompression
>25	Class IV	- Surgical decompression

Approach to post-surgical infection

1. Early recognition of post-surgical infection starts with understanding the surgery as well as RF
2. You can’t operate, but you can advocate
3. The most important part of managing post-surgical complications is communication with your surgical team

Toxicology

Case Fatalities

20,000 People die each year (USA)

Without targeted care: 10-20%
With targeted care: ≤ 0.5%

Toxicology

Nonspecific Therapies

(decreasing absorption or enhancing elimination)

-Induced Emesis

-Gastric Lavage

-Activated Charcoal

-Whole –Bowel Irrigation

-Enhanced Elimination

<u>"Normal"</u>

Osmolar gap > 10mOsm/kg

Osmolality – [(2xNa) + (glucose/18) + (BUN/2.8)

ABIM High AG: ≥ 14
ABIM Low AG: ≤ 6

Specific Therapies

(antidote)

- Acetaminophen
- Alcohols
- Amphetamines
- Benzodiazepines
- β-Blockers
- Ca++ Blockers
- Carbon Monoxide
- Cyanide
- Cyclic Antidepressants
- Digoxin
- GHB
- INH
- Iron
- Lithium
- Opiates
- Organophosphates
- Salicylates
- SSRI
- Theophylline
- Valproic Acid

Which of the following substances is eliminated by administering activated charcoal via an NGT/OGT at 1g/kg?

a. Theophylline
b. Lithium
c. Ethyl Alcohol
d. Cyanide
e. Iron
f. None of the above

Which of the following substances can be eliminated by administering activated charcoal via an NGT/OGT at 1g/kg?

a. Theophylline
b. Lithium
c. Ethyl Alcohol
d. Cyanide
e. Iron
f. None of the above

may require repeat dosing for proper elimination

1. carbamazepine
2. dapsone
3. phenobarbital
4. quinine
5. theophylline

Activated Charcoal *does not* work in:

1. Iron
2. Lithium
3. Cyanide
4. Strong acids
5. Strong bases
6. Alcohols
7. Hydrocarbons (tetrahydrocarbon, trichloroethylene)

Nonspecific Therapies

Gastric Lavage: w/in 1hr, lack of proven benefit, (CI acid/alkali ingestion)

Activated Charcoal: Benefit within 1st hr

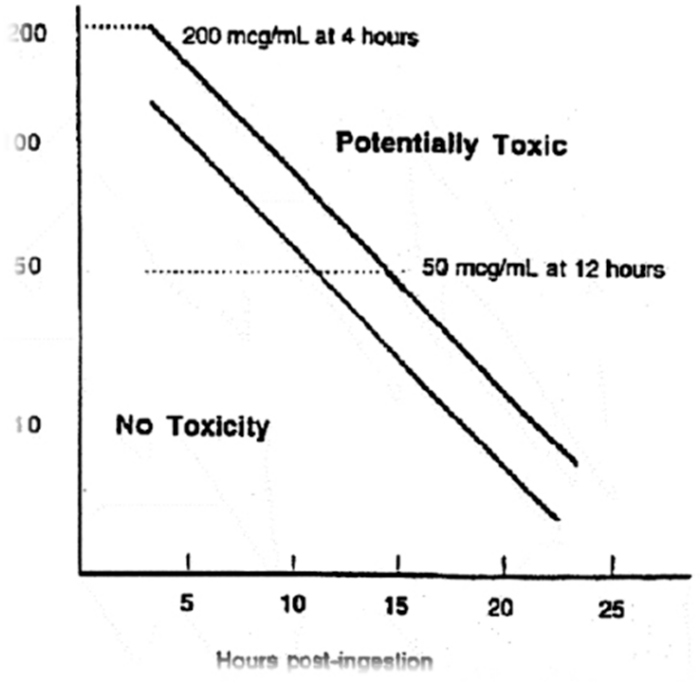
Whole Bowel Irrigation: 2L/h: Iron, Lithium, Drug packets (1st r/o obstruction)

Urine Alkalinization: *be cautious of hypokalemia*

HD: low MW compounds: EtOH, amphetamines, lithium, salisylates, theophylline

Hemoperfusion/Charcoal HD: carbamazepine, valproic acid, dilantin

28yoM Presents with an intentional overdose of acetaminophen. He was intubated in the field for somnolence. Vital: 120/80mmHg, HR 68bpm and sinus, RR 18 on AC 16/475/0.4/5cmH2O. Clinical suspicion for a 10g ingestion based on the number of tablets missing. Estimated time of ingestion is unclear. AST 110 IU/L and Acetaminophen level comes back at 28ug/ml.



What is the most appropriate therapeutic intervention in this patient?

A. Activate Charcoal 1g/kg
B. Supportive Care
C. Oral NAC, 68-Hr regimen
D. IV NAC, 21hr regimen

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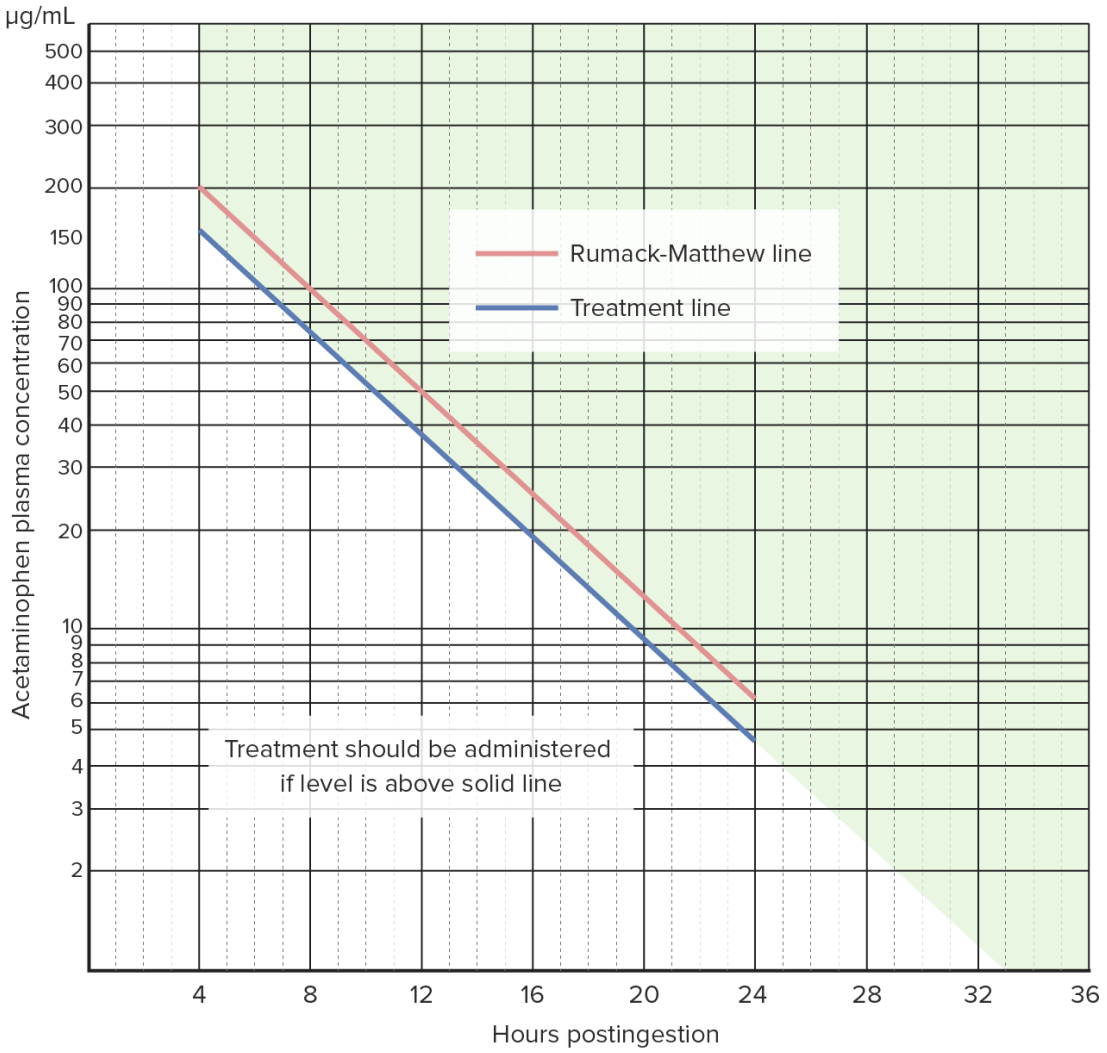

Acetaminophen Overdose

Who am I?

I am the most common OD in the West

I am asymptomatic -> nausea -> RUQ tenderness -> fulminant hepatic failure

I am potentially deadly > 140mg /kg single ingestion (10g)

I cause massive hepatic necrosis > 250mg/kg (17.5g)

Unclear dose: AST > 50 IU/L or Acetaminophen level > 10ug/ml

What am I?

NAPQI (Toxic metabolite)

Why am I BAD?

Glutathione depletion -> unable to conjugate NAPQI -> hepatocellular death

What are YOU going to do about it?

NAC (glutathione substitute)

NAC 150mg/kg IV Load over 1hr, 50mg/kg over 4hrs, 100mg/kg over 16hr

*Anaphylaxis 14-18%; NEED MONITORING

Most effective in first 8hrs (can give up to 24hrs, >24hrs)

Hello! I just overdosed on β-Blockers. On top of hypotension and sinus bradycardia I am going to develop CNS depression ☺ Which agent listed below is not associated with CNS depression?

A. Atenolol
B. Propranolol
C. Metoprolol
D. Timolol
E. Acebutolol

Hello! I just overdosed on β-Blockers. On top of hypotension and sinus bradycardia I am going to develop CNS depression ☺ Which agent listed below is not associated with CNS depression?

A. Atenolol - water soluble
B. Propranolol
C. Metoprolol
D. Timolol
E. Acebutolol

- lipophilic beta-adrenoceptor blockers appeared in brain tissue at concentrations 10-20 times greater than that of hydrophilic atenolol
- *? Lipid Rescue for Refractory cases? Probably not on the boards.*

β-blocker Overdose

Who am I?

Sinus bradycardia

Hypotension

Depressed Mental status (*lipid soluble: propranolol, metoprolol, acebutolol)*

What am I?

B-adrenergic blocker

Why am I BAD?

Chronotropic blockade: sinus bradycardia

Inotropic blockade: myocardial depression, hypotension

Sotolol: block potassium efflux->hypokalemia->Torsade de pointes

Propranolol: sodium channel blockade (TCA-like effect) QRS wide- VT

What are YOU supposed to do about it?

Glucagon: 5mg IV, followed by 2-10mg/h

Calcium Chloride: 2mg

Insulin & Euglycemia

Lipid Rescue Therapy **

ECMO

Calcium Channel Blocker Overdose

Who am I?

Hypotension

Bradycardia

What am I?

Non-Dihydropyridine (Verapamil/Diltiazem): “The PUMP”

Dihydropyridines (Amlodipine/Nifedapine/Nimodipine): ‘The PIPES”

at very high doses selectivity of dihydropyridines is lost*

Why am I BAD?

Chronotropic blockade: bradycardia, heart block

Inotropic blockade: refractory shock

What are YOU supposed to do about it?

Hemodynamic instability: 10ml 10% calcium chloride (rvs 50% of overdoses)

Insulin Euglycemia (0.1-10U/kg/hr + glucose 10-75g/hr)..takes 30-45mins

*Lipid rescue

*ECMO

A 48-year-old male presents to the ED ~20 minutes after ingesting over 500 tablets of extra-strength acetaminophen. His girlfriend reports they were partying all weekend and drinking “country wine”. He was becoming more “unusual” and “unsteady” over the last 24hrs when they began fighting and he locked himself in a nearby bedroom. Upon presentation, N-acetylcysteine infusion was initiated. Subsequently patient required intubation and mechanical ventilation due to worsening hypoxia and bibasilar crackles. Initial laboratory work up revealed an acetaminophen level of 86 mg/L, Osmolar GAP 8, anion gap metabolic acidosis 36, negative urine analysis and serum drug screen. What is the most appropriate next step in the management of this patient?

A. IV leucovorin
B. IV Folic Acid
C. IV thiamine
D. Bacardi 151, OGT, maintain serum level 100-150mg/dl
E. Hemodialysis

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Methanol Toxicity

Who am I?

toxic alcohols have AGMA, ataxia, pulmonary edema, hypotension, seizure, coma

Osmolar gap may not be present late if the alcohols have been met to acid

I have blurred vision , photophobia, and optic disc hyperemia

My “eye symptoms” can be delayed up to 24hrs after ingestion

Normal ionized calcium

What am I?

methanol -> formaldehyde -> formic acid

Why am I BAD?

Neurotoxic to the optic nerve and retina

What are YOU supposed to do about it?

Oral ethanol (100-150mg/dl) – competitive inhibitor

Fomepizole 15mg/kg LD, 10mg/dl q12hr x 4 doses, 15mg/hg q12hr resolved

Leucovorin or folic acid 50mg q4-6hrs for 24hr : cofactor for formate elimination

HD-for visual impairment, pulmonary edema, refractory acidosis or a **LEVEL >25mg/dl**

Ethylene Glycol Toxicity

Who am I?

toxic alcohols have AGMA, ataxia, pulmonary edema, hypotension, seizure, coma

Osmolar gap may not be present late if the alcohols have been met to acid

I have Urinary Calcium Oxalate Crystals

What am I?

Ethylene Glycol -> Glycolic acid & metabolites -> Oxalic Acid

Why am I BAD?

Glycolic acid and metabolites - > HAGMA

Oxalic Acid and Calcium -> crystal formation -> renal tubules, myocardium, brain

cardiogenic shock, tetany, nystagmus, seizure, coma, renal failure, death

What are YOU supposed to do about it?

Oral ethanol (100-150mg/dl)

Fomepizole 15mg/kg LD, 10mg/dl q12hr x 4 doses, 15mg/hg q12hr resolved

Renal failure, pulmonary edema, refractory acidosis or a LEVEL >25mg/dl

88yoF is admitted to your CCU with a new systolic cardiomyopathy, EF of 15% and new onset oliguric AKI (Cr 2.8). She has a PMHx only for obstructive lung disease on Theophylline. Her obstructive lung disease is well controlled and she is compliant with her home theophylline regimen. Serum theophylline level is 16ug/ml. She is tachycardic, HR 121bpm. BP 80/50mmHg and improves to 106/66mmHg and her urine output improves to 55cc/hr with the addition of IV milrinone. You are called by the ICU RN for a generalized tonic-clonic seizure which has lasted >10minutes. Seizures are aborted with 6mg IV lorazepam and she is intubated for airway protection. What is the next best step in the management of this patient?

A. Place the patient on cEEG
B. Stop Milrinone and start Dobutamine
C. Stop Theophylline
D. All of the Above
E. None of the Above

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Theophylline Toxicity

-Carries a 50% mortality
-Uses: bronchodilator or apnea/bradycardia in infants
-action: adenosine antagonist w/indirect adrenergic activity
bronchodilation/arrythmia/seizure/cerebral vasoconstriction

Poisoning: ↑ Elderly
(therapeutic range 10-20), narrow range/window; 50/50 liver: urine met
Acute toxicity 8x ↑ in circulating epi levels
PDE inhibition -> ↑ cAMP -> hyperstimulation -> ↓ seizure threshold
Cytochrome oxidase (-): cipro/erythro/azithro/cimetidien/St. John's Wort

30% of Theophylline Seizures present with level NORMAL LIMITS
Addition of other PDE ↑ ↑ ↑ risk of seizure (milrinone)

Which of the following is *NOT* recommended as a first-line intervention in the treatment of acute Cyanide Toxicity?

A. mouth-to-mouth resuscitation

B. activated charcoal

C. Sodium Thiosulfate

D. Hydroxocobalamin

Which of the following is *NOT* recommended as a first-line intervention in the treatment of acute Cyanide Toxicity?

A. mouth-to-mouth resuscitation

B. Activated charcoal

C. Sodium thiosulfate

D. Hydroxocobalamin

Cyanide Toxicity

Who am I?

Smoke inhalation, sodium nitroprusside, rodenticides

AGMA, N/V, Seizure, Coma, apnea, rhabdomyolysis, hepatic necrosis, ARDS

What am I ?

Inhibitor of cytochrome oxidase in mitochondria

Why am I BAD?

Lactic acidosis

Targets vascular endothelium –> increased permeability and hemorrhage

NMDA (+)

>20uM symptomatic, >40uM toxic, >100uM lethal

What are YOU supposed to do about it?

Amyl Nitrite Pearls -> methemoglobinemia (higher affinity for cyanide)

3% IV Sodium Nitrite -> methemoglobinemia (higher affinity for cyanide)

Sulfur donation for rhodanese:

25 % IV Sodium thiosulfate + Cyanide -> thiocyanate -> renal excretion

Direct binding:

Hydroxycobalamine + Cyanide -> Cyanocobalamine (vitamin B12)

Cyclic Antidepressants

Who am I?

Drugs ending – ine (imipramine, nortriptyline)

Seizure, AMS, hypotension, arrhythmia

What am I ?

Sodium channel blocker toxicity resulting in arrhythmia

Why am I BAD?

Slow sodium influx into myocardial cells -> conduction delay ->wide complex arrhythmia & negative inotropy

What are YOU supposed to do about it?

Gastric Lavage if within 1hr?

Activated charcoal

Alkalinization of the blood and sodium bicarbonate load 1-2meq.Kg

a pH 7.45-7.55 (wide complex). Also benefit from the sodium load for prolonged QRS.

Maintain 4-6hrs

Hypertonic saline for pt refractory to sodium bicarbonate.

?ILE? For refractory cases to sodium bicarbonate

MgSo4 for Torsades de pointes

Norepinephrine over Dopamine for hypotension

A 77yoF presents to the ED following a witnessed seizure at home. Her husband reports 3 days of nausea vomiting and diarrhea. She is 44kg and appears quite cachectic. She has a known history of Bipolar disorder and takes Lithium. Temp 37C. HR 102bpm. 110/80mmhg, Sat 96% on 2L. On exam she has irregular coarse tremors in her upper and lower extremities. Sodium 133, Potassium 3.8, Cl 89, Bicarb 22, BUN 26, Cr 1.1. Lithium Level 2.8mmol/L. What is the next best therapy for this patient?

A. Emergent Hemodialysis
B. 0.45% saline to expand both intravascular volume and provide free water in the anticipation of NDI
C. 0.9% saline and targeting a serum sodium of 140-145meq/L
D. A & C
E. None of the above

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Lithium Toxicity

Who am I?

Delirium, Seizure, Arrythmia, GI distress, polyuria, polydypsia, *LOW/NEGATIVE ANION GAP*

What am I?

Lithium

Why am I BAD?

Narrow therapeutic range. Chronic ingestion more prone to toxic effect. Not absorbed by charcoal

What are YOU supposed to do about it?

Volume resuscitation (forced diuresis not effective in enhancing excretion)

Hyponatremia can impair lithium clearance

Hemodialysis Indications

1. Renal dysfunction
2. Neurologic dysfunction
3. > 4 mmol/L in acute ingestions
4. > 2.5mmol/L in chronic ingestions

*rebound seen after HD with shift between intracellular and extracellular space 6-8hrs post HD, recommend checking level 12hrs post HD

Organophosphate Toxicity

Who am I?

Sarin gas, insecticides -> Cholinergic syndrome

What am I ?

Inhibitor acetylcholine esterase enzyme at the nerve ending

Why am I BAD?

Excess of acetylcholine

muscarinic: bronchorrhea, bradycardia, salivation, lacrimation, defecation

nicotininc: muscle weakness

CNS: confusion, slurred speech, respiratory depression

What are YOU supposed to do about it?

IV atropine & Pralidoxime: Bronchorrhea, Bronchospasm, respiratory depression

Atropine does not reverse nicotinic manifestations (muscle weakness) and therefore must use pralidoxime

*20% -> Intermediate Syndrome: respiratory paralysis, proximal limb weakness, decrease reflexes may develop 24-96hrs after resolution of cholinergic crisis. Resolves with supportive care

*depolarizing neuromuscular blockers contraindicated

Salicylates Toxicity

Who am I?

Tinnitus, nausea, vomiting, depressed CNS

What am I ?

Inhibitor of oxidative phosphorylation

Why am I BAD?

Stimulate medulla -> respiratory alkalosis

Block TCA cycle -> lactic acidosis

Alterations in capillary integrity -> pulmonary and cerebral edema

Worse acidosis = more drug across BBB = more severe toxicity

***Euglycemic Neuroglycopenia ***

What are YOU supposed to do about it?

Give IV dextrose regardless of serum glucose, target serum glucose ~180-220

Alkalinization of the urine (pH >7.5) : > 35mg/dl

Hemodialysis: >100mg/dl

SSRI Toxicity

Who am I?

AMS, autonomic dysfunction, QT prolongation, tremor, rigidity, myoclonus, seizure

What am I ?

Inhibitor of serotonin uptake on presynaptic neurons

Why am I BAD?

Commonly mistaken for NMS

QT prolongation may precipitate Torsade de pointes

What are YOU supposed to do about it?

Activated charcoal

Severe toxicity: Cyproheptadine

No role for bromocriptine or dantrolene

Valproic Acid Toxicity

Who am I?

CNS depression, respiratory depression, pancreatitis

What am I ?

Inhibitor of voltage gated sodium channels increased concentration of GABA

Why am I BAD?

Metabolites are inhibited in hepatotoxicity

Hyperammonemia -> mechanism & treatment?

Cerebral edema reported 48-72hrs

Refractory hypotension

450-850mg/L: moderate toxicity

>580mg/L: severe toxicity

What are YOU supposed to do about it?

Activated charcoal

Whole bowel irrigation

Hemodialysis /Hemoperfusion

Miscellaneous

Propofol

- Mitochondrial uncoupling /utilization of free FA
- Cardiovascular Collapse; distributive and cardiogenic shock
- Refractory bradycardia-> asystole
- Severe metabolic acidosis, Lactic Acidosis
- Elevated CK
- Young, steroids, sepsis, low o2 delivery
- +4mg/kd/h > 48hrs

Prevention by early adequate carbohydrate intake
Early recognition and removal of the drug
?VA ECMO?

Ginko biloba

- Spontaneous bleeding : SDH

Kava kava

- Hepatic failure

Approach to the poisoned patient

1. “Attempts to identify the poison should not delay care.”
2. Initial management of the poisoned patient begins with the ***ABC’s***.
3. ACLS algorithms apply in toxicology with only a few exceptions.
4. Once stabilized, begin considering how to minimize bioavailability, then you may begin your history and physical.

More Critical Care

Question

You are called to the floor for a patient with massive hematemesis. The patient need emergent EGD but is not protecting his airway. You intubate him for the procedure after pushing 20 mg of etomidate followed by 100 mg of succinylcholine IV without difficulty. He develops recurrent hypotension 2 min after intubation with systolic BP of 82 mm Hg, which responds appropriately to 1,000 mL fluid bolus of lactated Ringer's and one-time push of 100 µg of phenylephrine. Ten minutes later, the nurse calls you to tell you that he is having a tonic-clonic seizure. On arrival, he has tonic-clonic movements of all 4 extremities and his jaw is clenched from masseter muscle contraction. The ventilator is alarming for high peak airway pressures. He is febrile with a temperature of 40°C; BP, 114/70 mm Hg; and pulse is 163/min. His seizure breaks with 10 mg of IV lorazepam.

What is the next best step in his management?

1. Administer phenytoin
2. Start continuous EEG
3. Send for CTA head and neck
4. Administer dantrolene

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1. Administer phenytoin
2. Start continuous EEG
3. Send for CTA head and neck
4. ***Administer dantrolene***

Malignant hyperthermia

Malignant hyperthermia after rapid sequence intubation with succinylcholine.

-life-threatening -> hypermetabolism resulting from calcium dysregulation in the skeletal muscle

-1:10,000 + receiving anesthetics.

-volatile inhalational anesthetic agents

-muscle relaxant succinylcholine

- release of a large quantity of calcium from the sarcoplasmic reticulum of skeletal muscle after exposure
- increased carbon dioxide production (EtCO2)
- increased oxygen consumption
- metabolic and respiratory acidosis
- heat production
- Hyperkalemia
- Seizures (sympathetic nervous system activation)

What do you Do?

Stop the offending agent
Initiate external cooling
Give Dantrolene

Dantrolene binds to ryanodine receptor type 1 (RYR-1) and inhibiting calcium ion release from the sarcoplasmic reticulum
2.5 mg/kg, every 5-mins until reversal (max dose 10mg)
Can recur within the first 24 h, treat with repeated doses

Neurotoxidromes

Serotonin Syndrome

Hunter Toxicity Criteria Decision Rules

1+ highest sensitivity

-Spontaneous Clonus

-Inducible Clonus + diaphoresis/agitation

-Ocular Clonus + diaphoresis/agitation

-Tremor + Hyperreflexia

-Fever + Hyperreflexia

Neuroleptic Malignant Syndrome

Altered Mental Status

Muscle Rigidity

Hyperthermia (> 40C, 104F)

Autonomic Instability

Question

81yoF was admitted to the ICU with sepsis and acute hypoxic respiratory failure secondary to UTI. She is stabilized and extubated on ICU day 4. On nursing assessment her CAM-ICU assessment is consistent with hyperactive delirium. Which intervention has been shown to reduce the overall duration of her delirium?

A. Haldolperidol
B. Ziprasidone
C. Melatonin
D. None of the above

Question

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D. None of the above

Delirium

ICU patients who develop delirium have a higher mortality and worse outcomes than those who do not.

Risk Factors

age, dementia, previous episode of delirium

Lack of sleep-wake cycle regulation, GABA (+), immobilization

Marginal Success

-early mobility

-sleep hygiene

-limiting benzodiazepines

NJEM 2019 (n: 1183)

- Haldol & Geodon

hypoactive or *hyperactive* delirium in the ICU did not significantly alter the duration of delirium.

Melatonin & Remelteon

- Lower incidence in two small trials
- Preoperative administration had a signal for reducing post-op delirium

Overall, very inconsistent

THANK YOU!

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