# CRITICAL CARE MEDICINE

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ACP INTERNAL MEDICINE BOARD REVIEW COURSE

# DISCLOSURE STATEMENT

I have no commercial, non-commercial, or institutional financial interests or personal financial relationships to disclose regarding the material presented in this lecture

# Disclaimer: Boards vs. Real Life

Medicine (especially critical care) is rapidly advancing.

Current concepts and management can differ from board certification questions.

Therefore, board questions usually tend toward more durable or foundational concepts… but even those can change!

# PATIENT 1

A 39-year-old man weighing 70 kg comes to the ED with fever, shortness of breath, and malaise for 3 days. Blood pressure is 82/45 mm Hg, HR 122/min, WBC 28,000. His mental status deteriorates and he is intubated. He receives 1 L of Lactated Ringers (LR) solution and is started on a norepinephrine infusion. A central venous catheter is placed.

# QUESTION 1

Which of the following is the most appropriate next intervention?

A. Bolus with another liter of crystalloid
B. Increase the norepinephrine
C. Start a vasopressin infusion
D. Start a dopamine infusion
E. Start a dobutamine infusion

# QUESTION 1

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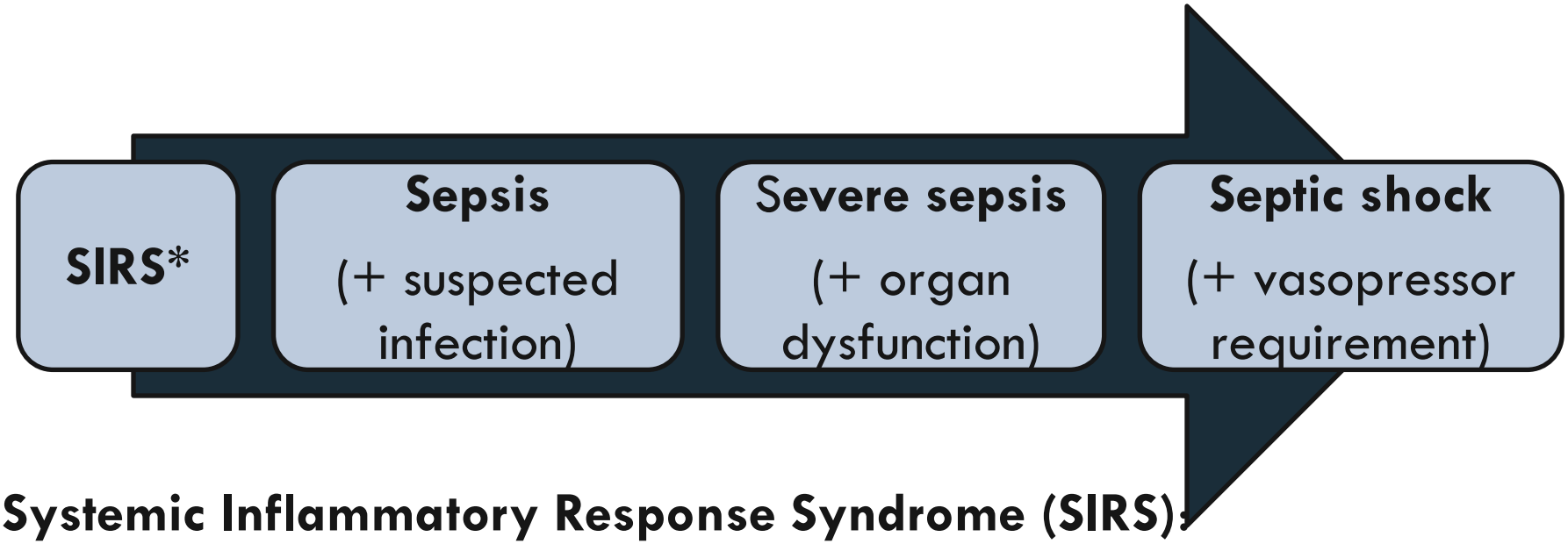
# SEPSIS AND SEPTIC SHOCK

# SEPSIS DEFINITIONS: THE OLD



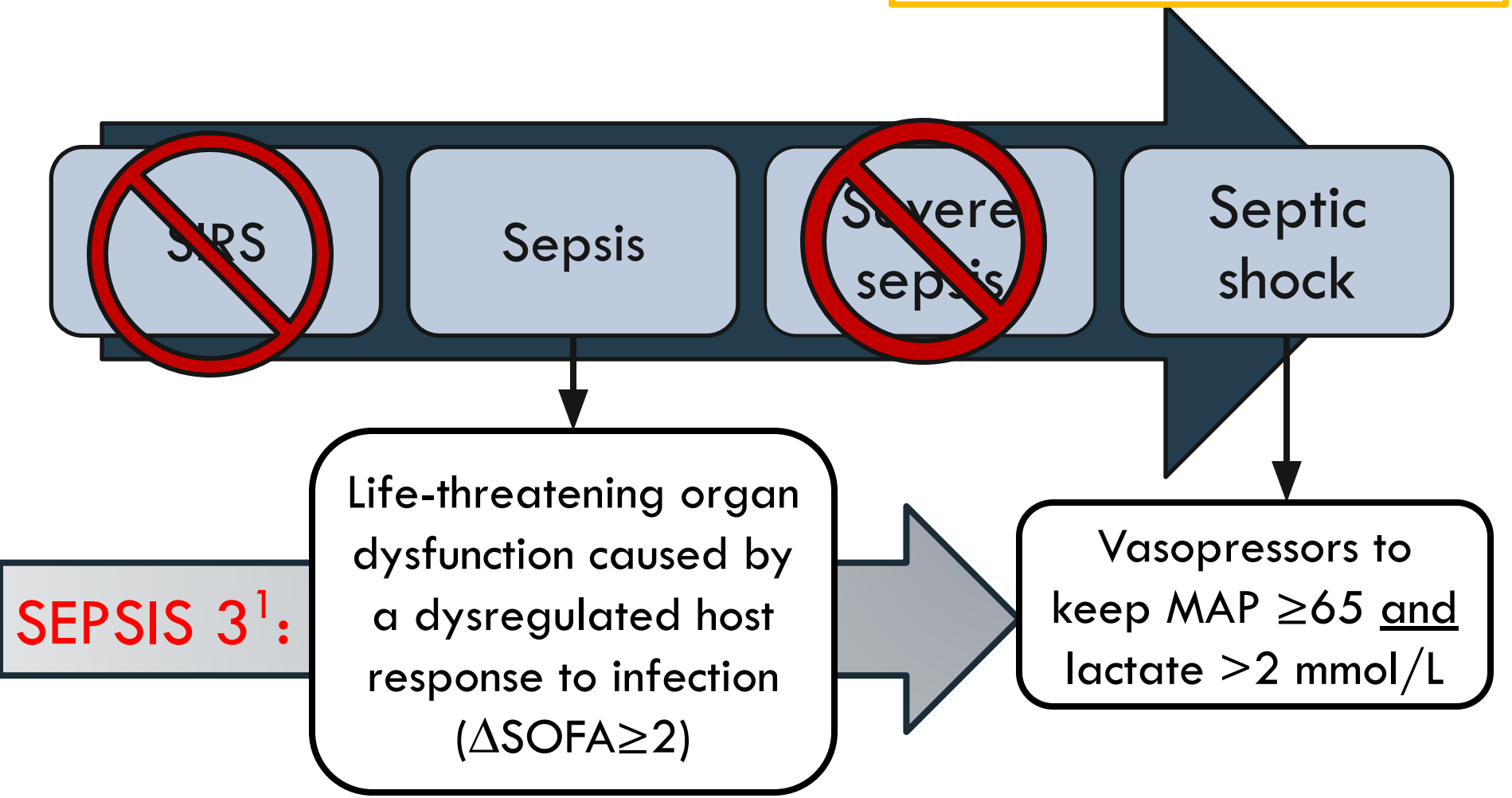

***Systemic Inflammatory Response Syndrome (SIRS):**

2 or more of:

- T > 38°C or < 36°C
- HR > 90/min
- WBC < 4 or > 12 or >10% bands
- RR > 30/min or $pCO_2$ < 32 mm Hg

# SEPSIS DEFINITIONS: 2016[1]

## Update: 2021[2]





1) Singer M, et al. *JAMA*. 2016;315 (8): 801-10

2) Evans, L et al. Crit Care Med. 2021;49(11) e1063-1143

# WHAT ABOUT SOFA?

## **S**equential (sepsis-related) **O**rgan **F**ailure **A**ssessment Score[1,2]

| System | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Respiration** PaO2/FiO2 (mmHg) | >400 | <400 | <300 | <200 with respiratory support | <100 with respiratory support |
| **Coagulation** Platelets ($x10^3$/uL) | ≥150 | <150 | <100 | <50 | <20 |
| **Liver** Bilirubin (mg/dl) | <1.2 | 1.2-1.9 | 2.0-5.9 | 6.0-11.9 | >12.0 |
| **Cardiovascular** (doses ug/kg/min for at least 1 hour) | MAP ≥70 mmHg | MAP <70 mmHg | Dopamine <5 or dobutamine any dose | Dopamine 5.1-15, epi ≤0.1, or NE ≤0.1 | Dopamine>15, epi>0.1, NE>0.1 |
| **CNS** GCS Score | 15 | 13-14 | 10-12 | 6-9 | <6 |
| **Renal** Creatinine (mg/dl) UOP (mL/day) | <1.2 | 1.2-1.9 | 2.0-3.4 | 3.5-4.9 <500 | >5 <200 |


1) Singer M, et al. *JAMA*. 2016;315 (8): 801-10

2) Evans, L et al. Crit Care Med. 2021;49(11) e1063-1143

# WHAT ABOUT SOFA?

**S**equential (sepsis-related) **O**rgan **F**ailure[2]

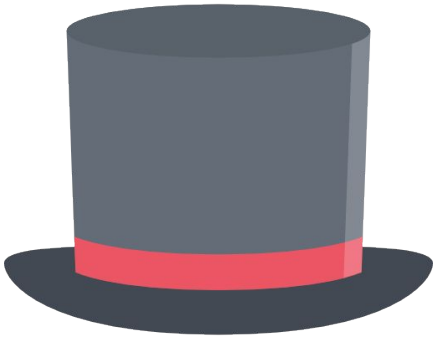
| System | 0 | 1 | 2 | | |
|---|---|---|---|---|---|
| **Respiration**<br>PaO2/FiO2 (mmHg) | >400 | <400 | <300 | | |
| **Coagulation**<br>Platelets (x$10^3$/uL) | ≥150 | <150 | <100 | | |
| **Liver**<br>Bilirubin (mg/dl) | <1.2 | 1.2-1.9 | 2.0-5.9 | | |
| **Cardiovascular**<br>(doses ug/kg/min for at least 1 hour) | MAP ≥70 mmHg | MAP <70 mmHg | Dopamine <5 or dobutamine any dose | ≤0.1 | |
| **CNS**<br>GCS Score | 15 | 13-14 | 10-12 | 6-9 | <6 |
| **Renal**<br>Creatinine (mg/dl)<br>UOP (mL/day) | <1.2 | 1.2-1.9 | 2.0-3.4 | 3.5-4.9<br><500 | >5<br><200 |

*Higher SOFA score associated with increase probability of mortality*[3]

Acute ΔSOFA≥2 and suspected infection, think sepsis

3) Vincent, JL, et al. Critical Care Medicine. 1998; 26(11): 1193-1800

# WHAT ABOUT qSOFA?



Positive if ≥ 2 of following:

- **H**ypotension (SBP≤100 mm Hg)
- **A**ltered mental status (GCS <15)
- **T**achypnea (respirations ≥22/min)

**GOOD**: Identifies pts w/ suspected infection & high risk for in-hospital mortality from sepsis[1]

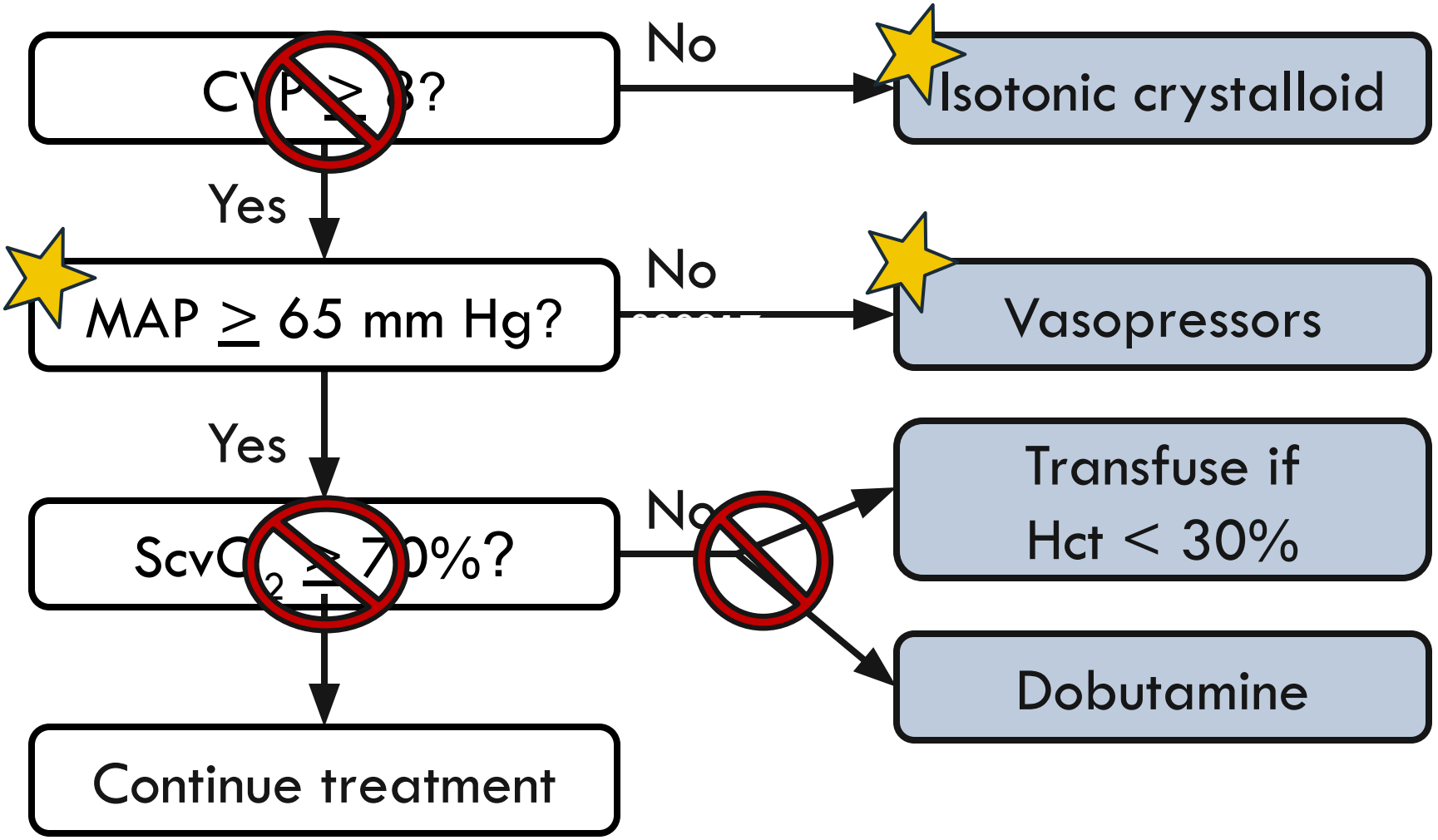
**BAD**: Not good screen (less sensitive vs. 2/4 SIRS)[2]

*2021 Surviving Sepsis Campaign: Recommends against qSOFA compared with SIRS, MEWS or NEWS as as single screening tool for sepsis or septic shock*[2]


1) Singer M, et al. *JAMA*. 2016;315 (8): 801-10

2) Evans, L et al. Crit Care Med. 2021;49(11) e1063-1143

# OLD: EARLY GOAL-DIRECTED THERAPY




Rivers E, et al. *N Engl J Med.* 2001;345(19):1368-77

# ALL ABOUT FLUIDS

| **Protocol-driven (e.g. EGDT) vs "Usual Care"** | **Volume of IV Fluids ("*Restrictive vs Liberal*")** | **Crystalloid Type** (0.9% NaCl vs Balanced (eg LR)) |
|---|---|---|
| PRoCESS<br>PRoMISe<br>ARISE | FEAST<br>CLASSIC<br>RIFTS<br>CLOVERS | BaSICS<br>SALT-ED<br>SMART$^{+}$<br>SPLIT |
| **No mortality difference** *("Usual care" quality has improved)* | **No mortality difference** *(Var. pop., timing, etc.)* | **Prob ↓ mortality$^{+}$ w/ Balanced Crystalloid** *Except TBI → 0.9%NaCl* |

**Good sepsis Rx = Fluids + Early Antibiotics**


The PRoCESS Investigators. *NEJM* 2014
The ARISE Investigators. *NEJM* 2014
Mouncey PR, et al. *NEJM* 2015

Meyhoff TS et al. CHEST 2020
Lat I et al. Crit Care Med 2021

# PRIORITIES IN SEPSIS TREATMENT

## Source Control & Antibiotics

- **Early antibiotics!!**

Every 1-hr delay: ↓survival 7.6% !!

- **Antibiotic choice = Source & Antibiogram**

## Fluid Resuscitation

- **Early!**
- **"30 mL/kg over 3h"***
- **Balanced Crystalloid$^{+}$**

**Individualize dose based on fluid responsiveness/tolerance, history, etc.*

$^{+}$*If Traumatic Brain Injury, may prefer 0.9% NaCl*

Surviving Sepsis Guidelines: Evans L et al. Crit Care Med. 2021;49(11) e1063-1143

Monnet, X. et al. How I personalize fluid therapy in septic shock?. *Crit Care* **27**, 123 (2023)

# QUESTION 1: THE OTHER ANSWERS

Which of the following is the most appropriate next intervention?

A. Bolus with another liter of crystalloid
B. Increase the norepinephrine (not yet adequately resuscitated)
C. Start a vasopressin infusion (not yet adequately resuscitated)
D. Start a dopamine infusion (not indicated in sepsis)
E. Start a dobutamine infusion (no suggestion of cardiogenic shock)

# PATIENT 1: THE CASE CONTINUES

The patient is now intubated and on low tidal volume ventilation (6 mL/kg) with $FiO_2$ 0.6 and PEEP 10 cm $H_2O$.

He remains hypotensive after 30 mL/kg crystalloid with MAP 52 mm Hg. He is in atrial fibrillation with heart rate of 100/minute.

Labs are notable for WBC 24,000/µL and creatinine 3.1 mg/dL. Urine output is 10 mL/hr.

# QUESTION 2

Which of the following will provide the best assessment of fluid responsiveness?

A. Pulmonary artery occlusion pressure
B. Passive leg raise maneuver
C. Pulse pressure variation
D. Stroke volume variation
E. IVC diameter variability

# QUESTION 2

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# FLUID RESPONSIVENESS

**Static Parameters**

- Physical Exam
- History
- CVP
- PAOP (aka “wedge”)

**Dynamic Parameters**

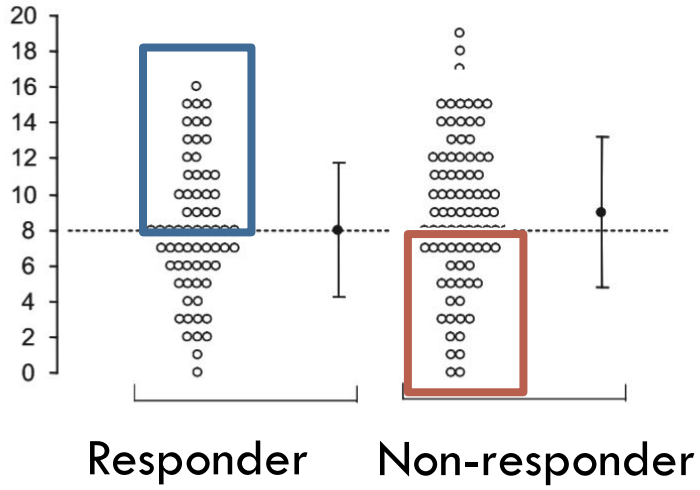
- Pulse pressure/stroke volume variation
- IVC diameter variation
- Passive leg raise testing
- ”Mini” fluid bolus

CVP: Central venous pressure

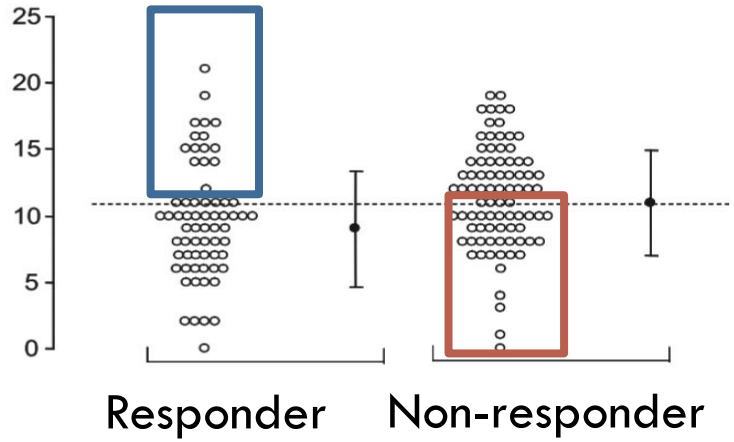
PAOP: Pulmonary artery occlusion pressure

# STATIC MEASURES ARE NOT HELPFUL

CVP

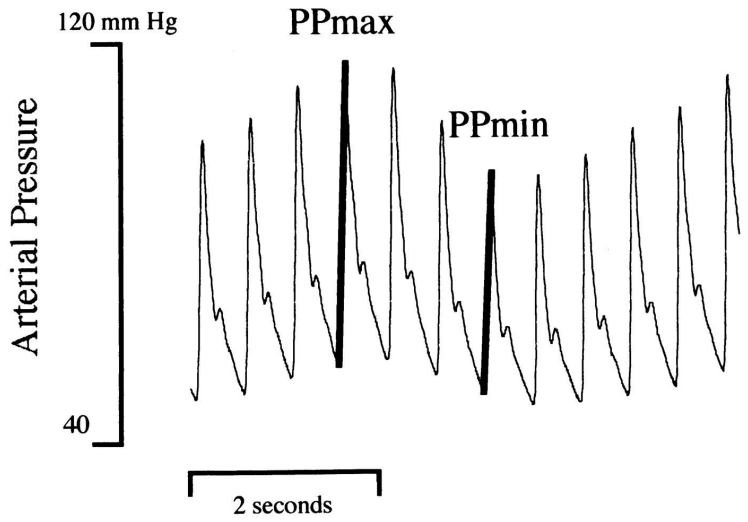



PAOP



Osman D, *et al. Crit Care Med.* 2007;35(1):64.8

# DYNAMIC MEASURES HAVE LIMITATIONS




$$PPV\ (\%) = \frac{(PPmax - PPmin)}{(PPmax + PPmin)/2} \times 100$$

**PPV threshold 12%**

- Sensitivity 88%
- Specificity 89%

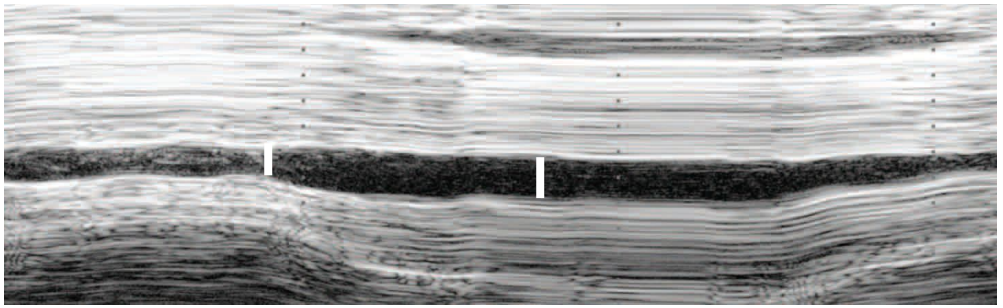
## Pulse Pressure Variation (PPV)

Inclusion Criteria:

- 8-10 mL/kg IBW tidal volume, passive ventilation
- Normal lung compliance
- No arrhythmia
- Chest not open
- Normal abdominal pressure

Michard F, *et al. Am J Respir Crit Care Med.* 2000;162(1):134-8

# IVC DIAMETER VARIATIONS

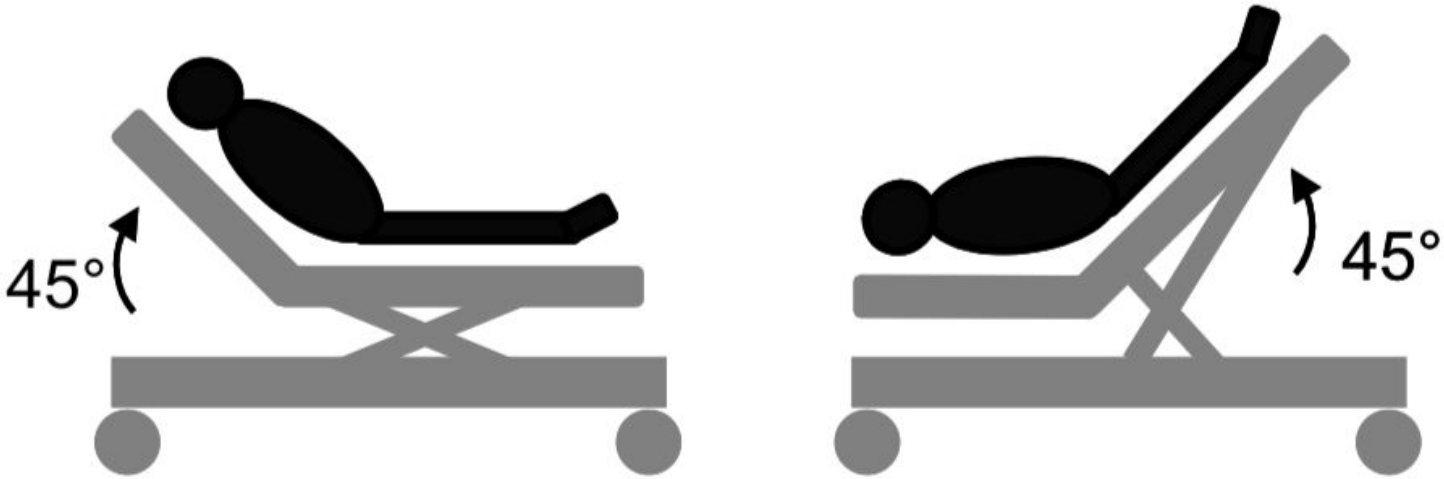


Dmin Dmax

Meta-analysis of 20 studies: "does not seem to be a reliable method to predict fluid responsiveness"

Bentzer P, *et al*. *JAMA*. 2016;316(12):1298-309
Orso D, *et al*. *J Intensive Care Med*. 2019:885066617752308

# PASSIVE LEG RAISE TEST PERFORMS BEST




Mimics effects of a 300 mL fluid challenge without the fluid …but threshold is **increase in cardiac output ≥ 10%** within 60 seconds

Bentzer P, *et al. JAMA*. 2016;316(12):1298-309
Monnet X, *et al. Intensive Care Med*. 2008;34(4):659-63

# FLUID RESPONSIVENESS

**Static Parameters**

- Physical Exam
- History
- CVP
- PAOP (aka “wedge”)

**Dynamic Parameters**

- PPV / SVV
- IVC diameter variation
- Passive leg raise testing
- ”Mini” fluid bolus

| 2021 SSC Recommendations | Level of Evidence |
|---|---|
| *For adults with sepsis or septic shock,* ***we suggest using dynamic measures to guide fluid resuscitation, over physical examination, or static parameters alone.*** | ***Weak****, very low quality of evidence* |

CVP: Central venous pressure
PAOP: Pulmonary artery occlusion pressure
PPV: Pulse pressure variation
SVV: Stroke volume variation

# QUESTION 2: THE OTHER ANSWERS

Which of the following will provide the best assessment of fluid responsiveness?

A. Pulmonary artery occlusion pressure (avoid invasive / static measures)
B. Passive leg raise maneuver
C. Pulse pressure variation (on low tidal volume ventilation, not sinus rhythm)
D. Stroke volume variation (on low tidal volume ventilation, not sinus rhythm)
E. IVC diameter variability (poor interoperator reliability; unproven pt centered outcomes)

# PATIENT 1: THE CASE CONTINUES

Despite fluids and norepinephrine, the patient's BP fails to respond. A pulmonary artery catheter is inserted.

| Parameter | *Normal* | Patient |
|---|---|---|
| **CVP** | *4-6* | 16 |
| **PAP** | *20/10* | 30/17 |
| **PAOP** | *8-12* | 18 |
| **CI** | *2.5-4.0* | 1.5 |
| **SVR** | *800-1200* | 2100 |

CVP: Central venous pressure
PAP: Pulmonary artery pressure
PAOP: Pulmonary artery occlusion pressure
CI: Cardiac index
SVR: Systemic vascular resistance

# QUESTION 3

Which of the following is the most appropriate next step in management?

A. Bolus another liter of LR
B. Administer stress-dose corticosteroids
C. Start vasopressin infusion
D. Start dobutamine infusion
E. Start phenylephrine infusion

| Parameter | *Normal* | Patient |
|---|---|---|
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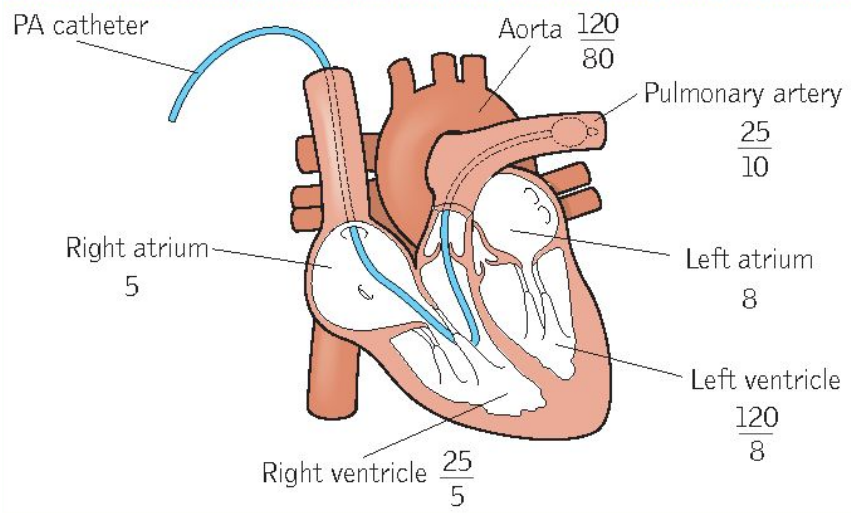
# PA CATHETERS ARE INFREQUENTLY INDICATED!

Numerous RCTs of ICU management with or without PA catheter found **no clinical benefit**

PA catheters are:

- Associated with complications
- More costly
- Often misinterpreted




…but they remain a favorite on the boards

# TYPES OF SHOCK

## Hypovolemic

- Blood loss (GI, trauma)
- Fluid loss (diarrhea, low PO, diuretics, etc.)

## Distributive

- Sepsis
- Anaphylaxis
- Adrenal insufficiency

## Cardiogenic

- CHF
- Valvular disease
- Pulmonary embolism
- Tension pneumothorax

# HEMODYNAMIC PATTERNS

| | CVP | PAOP | CI | SVR |
|---|---|---|---|---|
| Normal | 4-6 | 8-10 | 2.5-4.0 | 800-1200 |
| Hypovolemic shock | ↓* | ↓ | ↓ | ↑ |
| Cardiogenic shock | ↑ | ↑ | ↓* | ↑ |
| Distributive shock | ↓ | ↓ | ↑ | ↓* |

* Denotes primary derangement

# PATIENT 1

| Parameter | *Normal* | Patient |
|---|---|---|
| **CVP** | *4-6* | 16 |
| **PAP** | *20/10* | 30/17 |
| **PAOP** | *8-12* | 18 |
| **CI** | *2.5-4.0* | 1.5 |
| **SVR** | *800-1200* | 2100 |

Data: Low CI with high CVP, PAOP, and SVR

Dx: **Cardiogenic shock**

Rx: **Dobutamine** (increase inotropy)

# QUESTION 3: THE OTHER ANSWERS

Which of the following is the most appropriate next step in management?

A. Bolus another liter of fluids (if hypovolemic shock)

B. Administer stress-dose corticosteroids (for pressor-refractory distributive shock)

C. Start vasopressin infusion (for septic shock)

D. Start dobutamine infusion

E. Start phenylephrine infusion (reflex bradycardia can decrease cardiac output)

# PATIENT 2

A 67 year-old woman with severe hypotension three days following a myocardial infarction undergoes right heart catheterization.

| Parameter | *Normal* | Patient |
|---|---|---|
| **CVP** | *4-6* | 18 |
| **RVP** | *25/5* | 35/17 |
| **PAP** | *20/10* | 29/19 |
| **PAOP** | *8-12* | 18 |
| **CI** | *2.5-4.0* | 1.9 |
| **SVR** | *800-1200* | 1600 |

# QUESTION 4

What is the most likely etiology of the patient's shock?

A. Sepsis
B. Left ventricular failure
C. Gastrointestinal bleeding
D. Pericardial tamponade
E. Acute mitral regurgitation

| Parameter | *Normal* | Patient |
|---|---|---|
| CVP | *4-6* | 18 |
| RVP | *25/5* | 35/17 |
| PAP | *20/10* | 29/19 |
| PAOP | *8-12* | 18 |
| CI | *2.5-4.0* | 1.9 |
| SVR | *800-1200* | 1600 |

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| Parameter | *Normal* | Patient |
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| PAP | *20/10* | 29/19 |
| PAOP | *8-12* | 18 |
| CI | *2.5-4.0* | 1.9 |
| SVR | *800-1200* | 1600 |

# A FAVORITE ON THE BOARDS

| Parameter | *Normal* | Patient |
|---|---|---|
| **CVP** | *4-6* | **18** |
| **RVP** | *25/5* | 35/**17** |
| **PAP** | *20/10* | 29/**19** |
| **PAOP** | *8-12* | **18** |
| **CI** | *2.5-4.0* | 1.9 |
| **SVR** | *800-1200* | 1600 |

Equalization of end-diastolic pressures results from pericardial tamponade or constrictive pericarditis

# QUESTION 4: THE OTHER ANSWERS

What is the most likely etiology of the patient's shock?

A. Sepsis (low CVP/PAOP/SVR, normal-high CO)
B. Left ventricular failure (high CVP/PAOP/SVR, low CO)
C. Gastrointestinal bleeding (low CVP/PAOP/CO, high SVR)
D. Pericardial tamponade
E. Acute mitral regurgitation (looks like LV failure)

# BACK TO PATIENT 1…

After starting dobutamine, cardiac index increases. Over the course of the next 3 hours, he remains hypotensive. CVP is 18 cm $H_2O$. Norepinephrine is at 0.1 mcg/kg/min and dobutamine is at 10 mcg/kg/min.

You are called to bedside for new atrial fibrillation with a rapid ventricular response with a heart rate of ~130/min. Vasopressor requirements are unchanged.

# QUESTION 5

Which of the following is the most appropriate next step in management?

A. Increase dobutamine infusion rate
B. Increase norepinephrine infusion rate
C. Start a vasopressin infusion
D. Start a dopamine infusion
E. Bolus another liter of LR

# QUESTION 5

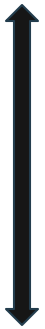
Which of the following is the most appropriate next step in management?

A. Increase dobutamine infusion rate
B. Increase norepinephrine infusion rate
C. Start a vasopressin infusion
D. Start a dopamine infusion
E. Bolus another liter of LR

# VASOPRESSORS

| Vasopressor | α activity | $B_1$ activity |
|---|---|---|
| Phenylephrine | +++++ | -- |
| Norepinephrine | +++ | ++ |
| Epinephrine | +++ | +++ |
| Dopamine | ++ | +++ |
| Dobutamine | -- | ++++ |
| Isoproterenol | -- | +++++ |

Vasoconstriction



Inotropy and chronotropy

Vasopressin binds to V1 receptors on smooth muscle to cause vasoconstriction

# KEY POINTS ON VASOPRESSORS

Vasopressors for septic shock:

1st) **Norepinephrine**

*Alt.) Epinephrine*

Vasopressin can be added* and may help decrease norepinephrine dosage

*Usually fixed rate ~0.01-0.03 U/kg/hr

Dopamine is associated with tachyarrhythmias

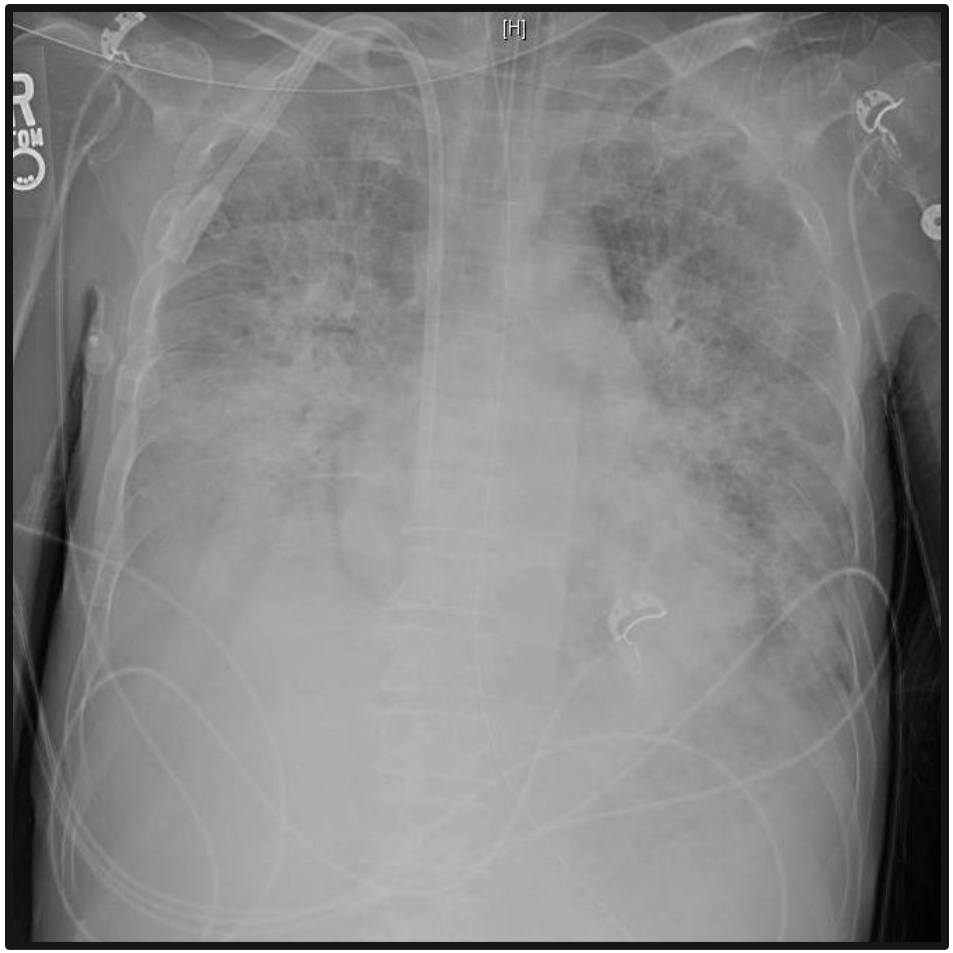
Surviving Sepsis Guidelines
Russell JA, et al. *N Engl J Med*. 2008;358(9):877-87
De Backer D, et al. *N Engl J Med*. 2010;362(9):779-89

# QUESTION 5: THE OTHER ANSWERS

Which of the following is the most appropriate next step in management?

A. Increase dobutamine infusion rate (could worsen arrhythmia)
B. Increase norepinephrine infusion rate (could worsen arrhythmia)
C. Start a vasopressin infusion
D. Start a dopamine infusion (could worsen arrhythmia)
E. Bolus another liter of LR (CVP is elevated)

# IT IS THE NEXT MORNING…



Ventilator Settings

Mode: Volume control

Tidal volume: 700 mL

Respiratory rate: 18

$FiO_2$ 0.5

PEEP 5 cm $H_20$

ABG: 7.29/35/58/20

# QUESTION 6

His predicted body weight is 75 kg. Which of the following is the most appropriate intervention?

A. Change to pressure control mode
B. Increase respiratory rate to 24
C. Decrease tidal volume to 450 mL
D. Start inhaled epoprostenol
E. Start high frequency oscillatory ventilation

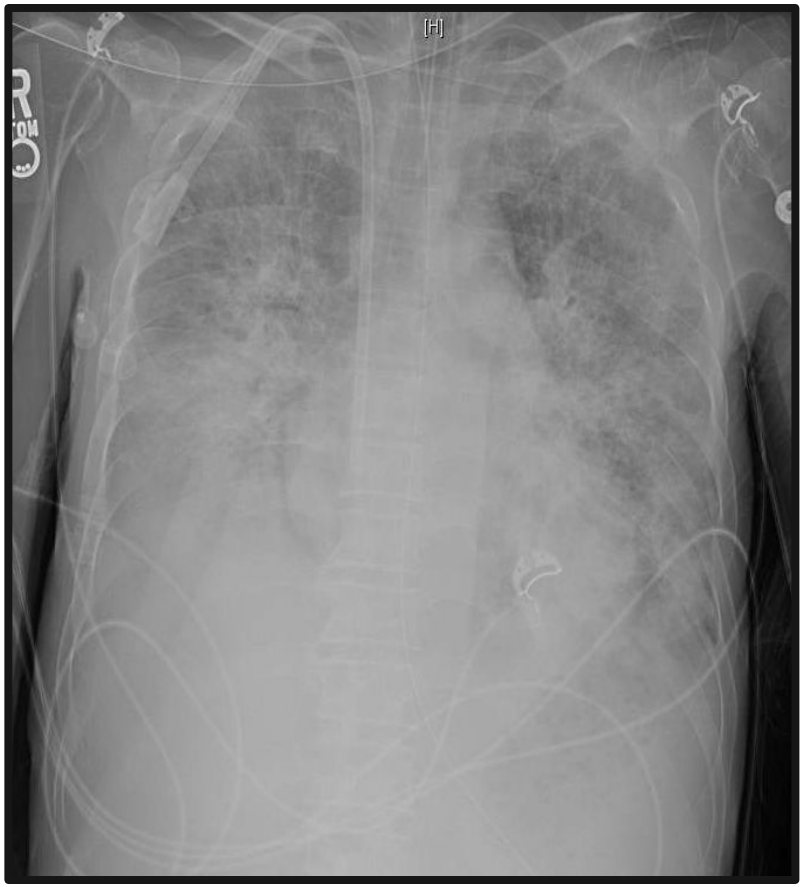
# QUESTION 6

His predicted body weight is 75 kg. Which of the following is the most appropriate intervention?

A. Change to pressure control mode
B. Increase respiratory rate to 24
C. Decrease tidal volume to 450 mL
D. Start inhaled epoprostenol
E. Start high frequency oscillatory ventilation

# MECHANICAL VENTILATION

# ACUTE RESPIRATORY DISTRESS SYNDROME



**Berlin Criteria (2012)**

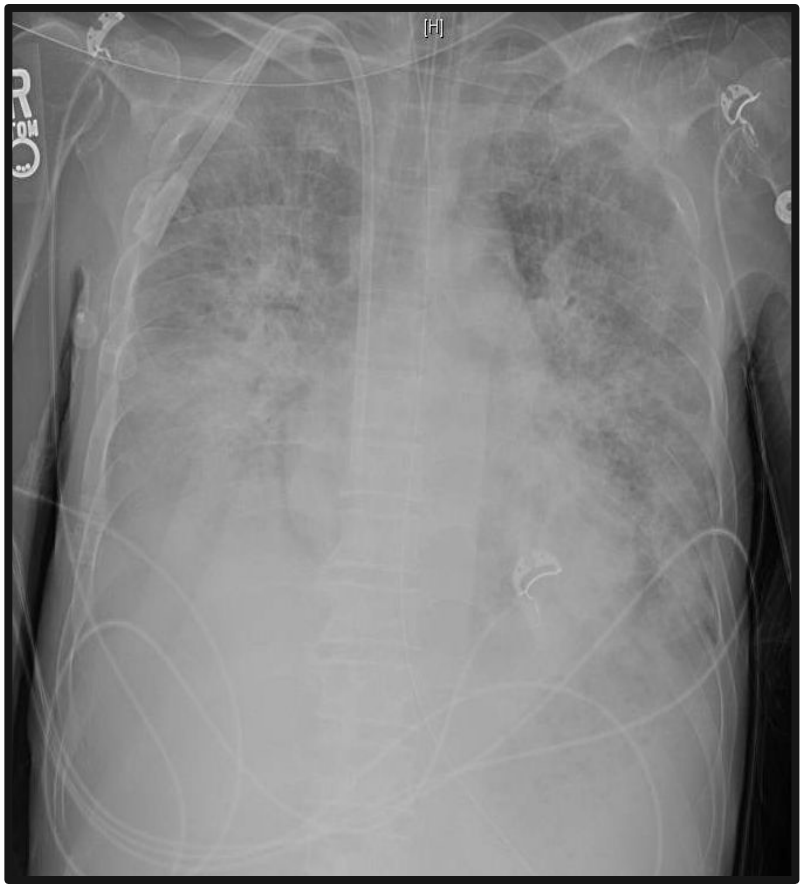
- Onset within 7 days of insult
- Bilateral opacities on CXR
- $PaO_2/FiO_2 \leq 300$ on PEEP $\geq 5$
- Not fully explained by CHF

**Shortcomings:**

- High Flow Nasal Cannula
- CXR insensitive & variable
- Definition is heterogeneous
- Diagnosis should work in resource-poor settings (eg include u/s in definition)

Ranieri VM et al. JAMA 2012;307:2526-2533

# ACUTE RESPIRATORY DISTRESS SYNDROME



**"New Global Definition of ARDS"**

- Bilateral opacities on any imaging modality (CXR, U/S, CT)
- HFNC at ≥ 30L / min, or NIPPV or IMV w/ PEEP ≥ 5
- $PaO_2/FiO_2 \leq 300$ or SpO2/FiO2 ≤ 315

**Criticisms:**

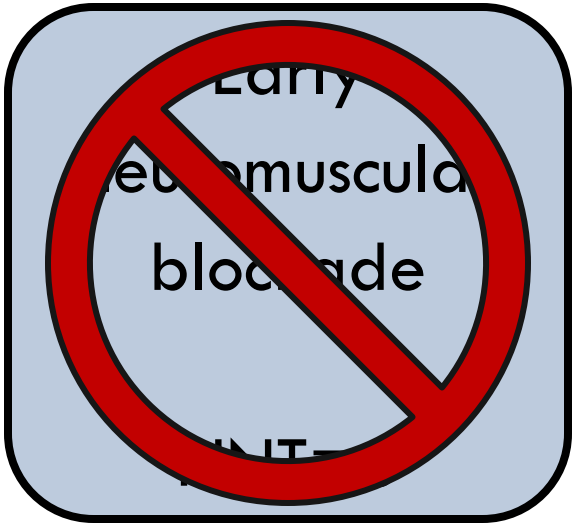
- Too inclusive, not specific
- Redefining ARDS dilutes meaning

Mathay et al. Am J Respir Crit Care Med. 2023;207:A6229

# MORTALITY BENEFIT IN ARDS

Low tidal volume ventilation

NNT=11



Prone positioning for 16 hours/day, w/in 36 hours of ICU admission

("early and often")

NNT=7

*2023 concepts: ARDS pre-IMV, lung-protective ventilation pre-ARDS, driving pressure, ventilator-induced lung injury, corticosteroids, ECMO, mobility, delirium, …*

**NNT**: Number needed to treat


ARDSNet. *N Engl J Med* 2000;342:11301-11308

Papazian L, et al. *N Engl J Med* 2010;363:1107-1116

Guérin C, et al. *N Engl J Med* 2013;368:2159-2168

NHLBI PETAL Network. N Engl J Med 2019; 380:1997-2008

# LOW TIDAL VOLUME VENTILATION

Patients: 861 patients with ARDS, multi-center RCT

Intervention: Tidal Volume 6 mL/kg vs. 12 mL/kg IBW

Primary outcome: Death

Result: Trial stopped early due to lower mortality in intervention (6ml/kg) group: 31% v 39%

Secondary Outcomes: All favored 6ml/kg

(e.g. Ventilator free days, non-pulmonary organ injury)

ARDSNet. *N Engl J Med* 2000;342:11301-11308

# LOW TIDAL VOLUME VENTILATION

| Variable | Low Tidal Volume | Traditional Tidal Volume | P Value |
|---|---|---|---|
| **Mortality, %** | 31.0 | 39.8 | 0.007 |
| **Breathing without assistance by day 28, %** | 65.7 | 55.0 | <0.001 |
| **Ventilator-free days** | 12±11 | 10±11 | 0.007 |
| **Days without non-pulmonary organ failure** | 15±11 | 12±11 | 0.006 |

ARDSNet. *N Engl J Med* 2000;342:11301-11308

# QUESTION 6: THE OTHER ANSWERS

His predicted body weight is 75 kg. Which of the following is the most appropriate intervention?

A. Change to pressure control mode (no one mode is superior to another)
B. Increase respiratory rate to 24 (allow for permissive hypercapnea with pH > 7.15)
C. Decrease tidal volume to 450 mL
D. Start inhaled epoprostenol (improves oxygenation, but no mortality benefit)
E. Start high frequency oscillatory ventilation (no role in adults)

# MORE VENTILATOR DATA

Mode: Volume control

Tidal volume: 450 mL

Set respiratory rate: 22

Actual respiratory rate: 22

$FiO_2$: 0.5

PEEP: 5 cm $H_2O$

New ABG: 7.51/32/76/20

# QUESTION 7

What is the most appropriate intervention at this time?

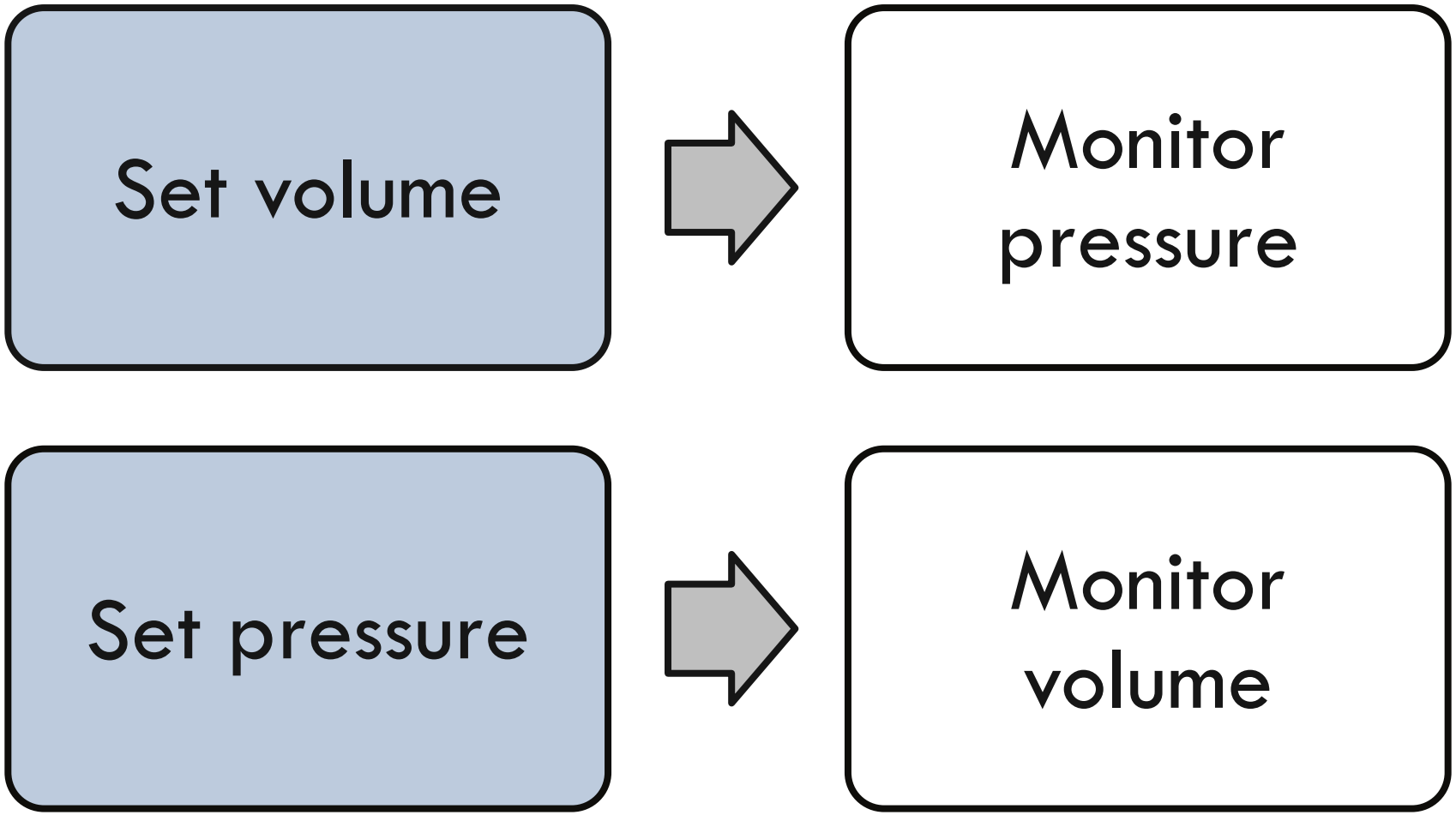
A. No change in ventilator settings
B. Increase PEEP to 10 cm $H_2O$
C. Decrease $FiO_2$ to 0.4
D. Increase tidal volume to 600 mL
E. Decrease respiratory rate to 18

# QUESTION 7

What is the most appropriate intervention at this time?

A. No change in ventilator settings
B. Increase PEEP to 10 cm $H_2O$
C. Decrease $FiO_2$ to 0.4
D. Increase tidal volume to 600 mL
E. Decrease respiratory rate to 18

# VENTILATORS: A GENERAL RULE



# VOLUME CONTROL: THE SETTINGS

- Tidal volume ($V_T$)
- Respiratory rate (RR)

Ventilation

- $F_IO_2$
- Positive end-expiratory pressure

Oxygenation

Minute ventilation ($V_E$) = $V_T$ x RR

# VC: "OUT OF THE BOX" SETTINGS

| | |
|---|---|
| $V_T$ | 6-8 mL/kg IBW |
| RR | Depends…what $V_E$ is needed? |
| $F_IO_2$ | 1.0, decrease by following $SpO_2$ |
| PEEP | In most cases, start at 5 cm $H_20$ |

# VENTILATION PHYSIOLOGY

$$pCO_2 \propto \frac{\dot{V}CO_2}{\dot{V}_A}$$

Increase RR to decrease $PaCO_2$

Decrease RR to increase $PaCO_2$

Minute ventilation ($\dot{V}_E$) = $V_T$ x RR

$\dot{V}_E$ = Alveolar ventilation ($\dot{V}_A$)+ Dead space ventilation ($\dot{V}_D$)

# QUESTION 7: THE OTHER ANSWERS

What is the most appropriate intervention at this time?

A. No change in ventilator settings (avoid respiratory alkalosis)

B. Increase PEEP to 10 cm $H_20$ (already meets ARDS $PaO_2$ goal of 55-80 mm Hg)

C. Decrease $FiO_2$ to 0.4 (already meets ARDS $PaO_2$ goal of 55-80 mm Hg)

D. Increase tidal volume to 600 mL (should continue low tidal volume ventilation)

E. Decrease respiratory rate to 18

# PATIENT 3

A 74-year-old man arrives in the ED after calling 911 for difficulty breathing. He is in moderate distress and using accessory muscles to breathe. He is alert. He has severe COPD and uses home oxygen.

VS: T 36.5°C, BP 160/92, HR 118, RR 35

ABG: 7.26/88/72 on 35% $FiO_2$ via face mask

# QUESTION 8

He is treated with corticosteroids and nebulized albuterol and ipratropium and remains in distress. What is the most appropriate next step?

A. Intubate and start mechanical ventilation
B. Start heliox via face mask
C. Start continuous positive airway pressure (CPAP)
D. Start bi-level non-invasive positive pressure ventilation (Bi-level NIPPV)
E. Perform bilateral tube thoracostomy

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He is treated with corticosteroids and nebulized albuterol and ipratropium and remains in distress. What is the most appropriate next step?

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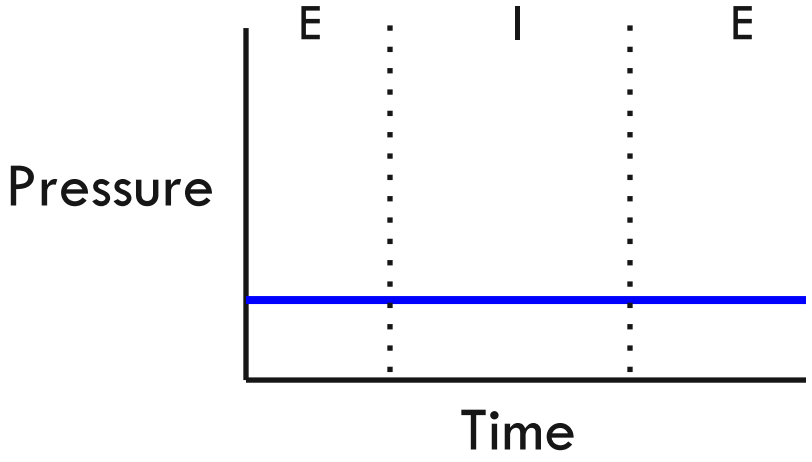
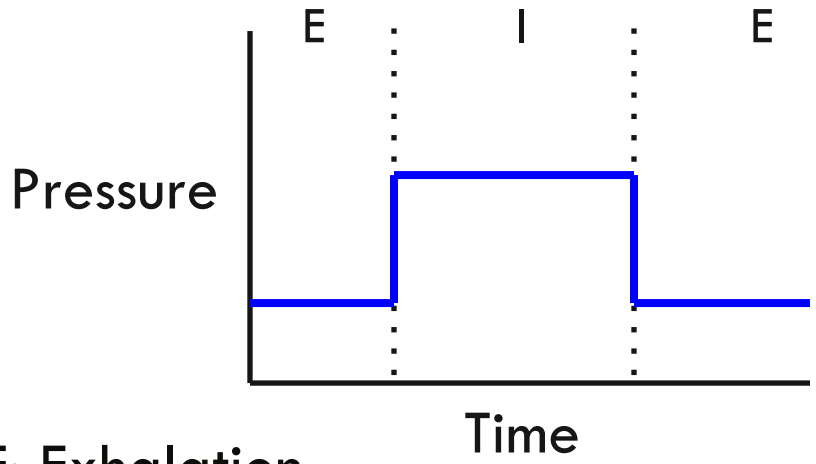
# CPAP AND NIPPV




**Continuous positive airway pressure (CPAP)**

Oxygenation




**Bi-level Non-invasive positive pressure ventilation (NIPPV)**

Oxygenation & Ventilation

E: Exhalation

I: Inhalation

# CPAP AND NIPPV

## Indications

- Acute hypercarbic respiratory failure (e.g., COPD exacerbation)
- Acute cardiogenic pulmonary edema
- *Immunocompromised patients with pneumonia*
- *Support in patients who decline intubation*
- *Prevent failed extubation*

## Contraindications

- Cardiac or respiratory arrest
- Inability to protect airway
- Excessive secretions
- Facial surgery/trauma/ deformity

**Avoid in progressive respiratory failure (e.g., ARDS)**

# COPD EXACERBATIONS IN THE ICU

**Treatment**

- Bronchodilators
- Oxygen
- Corticosteroids
- Antibiotics
- Non-invasive positive pressure ventilation (NIPPV)

**NIPPV in COPD**

- Fewer intubations
- Fewer complications
- Lower mortality (vs IMV)

Intubate if NIPPV fails or is contraindicated

Lightowler JV, et al. *BMJ*. 2003;326(7382):185

# QUESTION 8: THE OTHER ANSWERS

He is treated with corticosteroids and nebulized albuterol and ipratropium. What is the most appropriate next step?

A. Intubate and start mechanical ventilation (Bi-level NIPPV may prevent intubation)
B. Start heliox via face mask (used in upper airway obstruction, no role in COPD or asthma)
C. Start continuous positive airway pressure (CPAP) (only affects oxygenation, not ventilation)
D. Start bi-level non-invasive positive pressure ventilation (Bi-level NIPPV)
E. Perform bilateral tube thoracostomy (doesn't have bilateral pneumothoraces)

# PATIENT 3: THE CASE CONTINUES

Despite NIPPV, the patient deteriorates with obtundation and is intubated. Tidal volume is 800 mL and respiratory rate is 20/minute.

Five minutes later, his BP falls precipitiously and he becomes bradycardic. The ventilator alarms report high pressures. On exam, there is diminished air movement throughout, but breath sounds are equal bilaterally.

# QUESTION 9

What is the most appropriate next step?

A. Remove the endotracheal tube and attempt re-intubation
B. Pull back the endotracheal tube 3 cm
C. Temporarily disconnect the ventilator from the endotracheal tube
D. Place bilateral chest tubes
E. Administer subcutaneous epinephrine

# QUESTION 9

What is the most appropriate next step?

A. Remove the endotracheal tube and attempt re-intubation
B. Pull back the endotracheal tube 3 cm
C. Temporarily disconnect the ventilator from the endotracheal tube
D. Place bilateral chest tubes
E. Administer subcutaneous epinephrine

# DECOMPENSATION AFTER INTUBATION

**Worsening primary process**

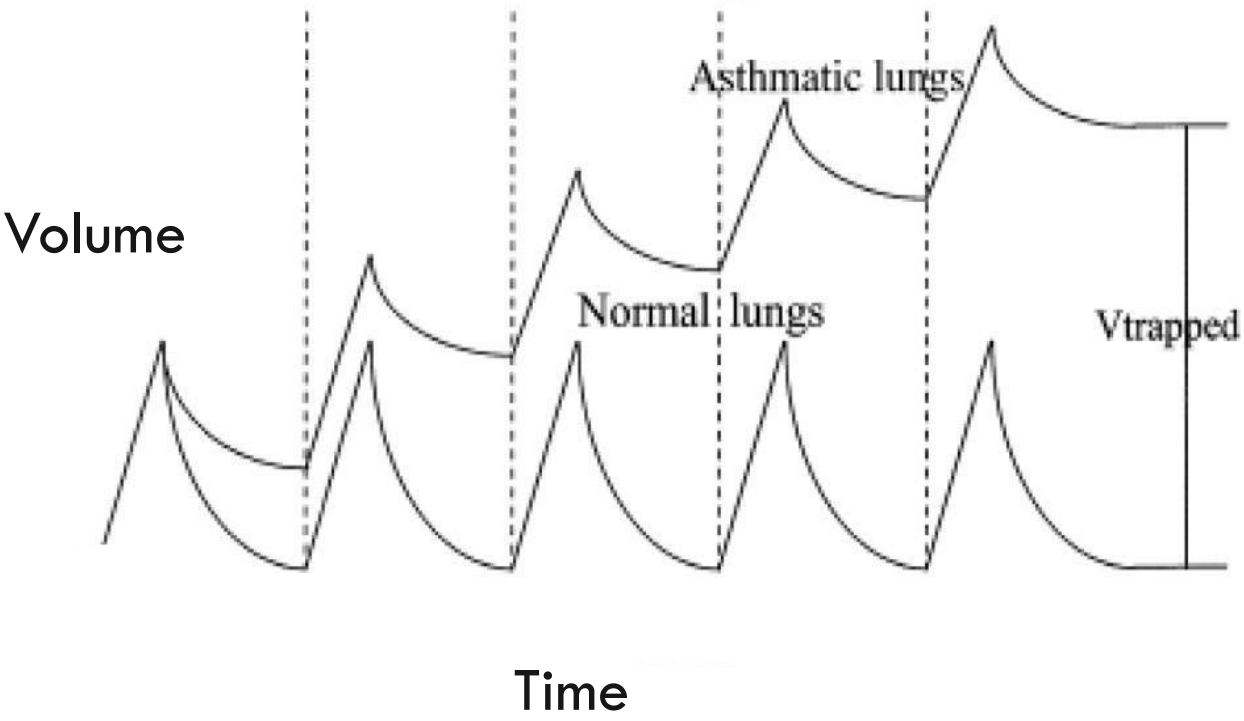
**Procedural Effect**

- Esophageal intubation
- Mainstem intubation
- Induction side effect

**Positive Pressure Effect**

- In hypovolemia or right heart failure
- Tension pneumothorax
- Dynamic hyperinflation (“auto-PEEP”)

# DYNAMIC HYPERINFLATION




Increased intrathoracic pressure

Decreased venous return

Decreased cardiac output

Rx: Temporarily disconnect the ventilator

Stather DR, et al. *Crit Care*. 2005;9(6):581-7

# QUESTION 9: THE OTHER ANSWERS

What is the most appropriate next step?

A. Remove the endotracheal tube and attempt re-intubation (tube is already in trachea)

B. Pull back the endotracheal tube 3 cm (equal breath sounds suggests not mainstem)

C. Temporarily disconnect the ventilator from the endotracheal tube

D. Place bilateral chest tubes (equal breath sounds suggests no pneumothoraces)

E. Administer subcutaneous epinephrine (nothing to suggest anaphylaxis)

# PATIENT 3: THE CASE CONTINUES

After your intervention, the patient stabilizes, and you return him to mechanical ventilation with a lower tidal volume. The new ventilator settings are: volume control mode with tidal volume 500 mL and rate 20/minute.

A repeat ABG reveals: 7.55/42/120/38.

# QUESTION 10

What is the most appropriate next step?

A. Increase tidal volume to 750 mL
B. Administer acetazolamide
C. Decrease respiratory rate to 12
D. Change to pressure control ventilation
E. Continue current management

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# CHRONIC $CO_2$ RETENTION

ABG: 7.55/42/120/38

Look at prior ABGs and $HCO_3$ on chemistry panel to determine if the patient retains $CO_2$ at baseline

Set the ventilator to achieve $PaCO_2$ close to their baseline value

Goal is normal pH, <u>not</u> normal $PaCO_2$

# QUESTION 10: THE OTHER ANSWERS

What is the most appropriate next step?

A. Increase tidal volume to 750 mL (will worsen respiratory alkalosis)

B. Administer acetazolamide (respiratory stimulant with no proven benefit in COPD)

C. Decrease respiratory rate to 12

D. Change to pressure control ventilation (mode of ventilation not the issue, need less minute ventilation)

E. Continue current management (avoid respiratory alkalosis)

# PATIENT 3: THE CASE CONTINUES

You anticipate that your 74-year-old patient will remain critically ill and need mechanical ventilation for several days due to the overall severity of his illness.

# QUESTION 11

Which of the following is the most appropriate sedation and analgesia for this patient?

A. Uninterrupted fentanyl and lorazepam infusions
B. Uninterrupted propofol infusion
C. Uninterrupted morphine and midazolam infusions
D. Fentanyl and midazolam infusions with weekly interruption
E. Fentanyl boluses and propofol infusion with daily interruption

# QUESTION 11

Which of the following is the most appropriate sedation and analgesia for this patient?

A. Uninterrupted fentanyl and lorazepam infusions
B. Uninterrupted propofol infusion
C. Uninterrupted morphine and midazolam infusions
D. Fentanyl and midazolam infusions with weekly interruption
E. Fentanyl boluses and propofol infusion with daily interruption

# SEDATION AND ANALGESIA PEARLS

Daily interruption of infusions improves outcomes

Bolus sedation is better than continuous infusions

Daily sedation "vacations" coupled with spontaneous breathing trials improve outcomes

Opiate-only regimens (without benzodiazepines) improve outcomes

Early Mobility improves outcomes!

Sedation Rx "ranking": Opiate, propofol, dexmedetomidine, …, benzo

Kollef MH, et al. *Chest*. 1998;114(2):541-8
Kress JP, et al. *N Engl J Med*. 2000;342(20):1471-7

Girard TD, et al. *Lancet*. 2008;371(9607):126-34
Strøm T, et al. *Lancet*. 2010;375(9713):475-80

# QUESTION 11: THE OTHER ANSWERS

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B. Uninterrupted propofol infusion
C. Uninterrupted morphine and midazolam infusions
D. Fentanyl and midazolam infusions with weekly interruptio
E. Fentanyl boluses and propofol infusion with daily interruption

(Best practice: bolus > infusion; at least daily interruption, benzos last choice)

# PATIENT 3: THE CASE CONTINUES

The patient has no known history of diabetes, but you notice that his blood glucose has been fluctuating between 240 and 310 mg/dL for the past 2 days.

# QUESTION 12

What is the most appropriate next step?

A. Continue to observe
B. Check hemoglobin A1c and begin oral hypoglycemic if elevated
C. Begin an oral hypoglycemic agent
D. Start insulin to maintain blood glucose between 80 and 110 mg/dL
E. Start insulin to maintain blood glucose between 140 and 180 mg/dL

# QUESTION 12

What is the most appropriate next step?

A. Continue to observe

B. Check hemoglobin A1c and begin oral hypoglycemic if elevated

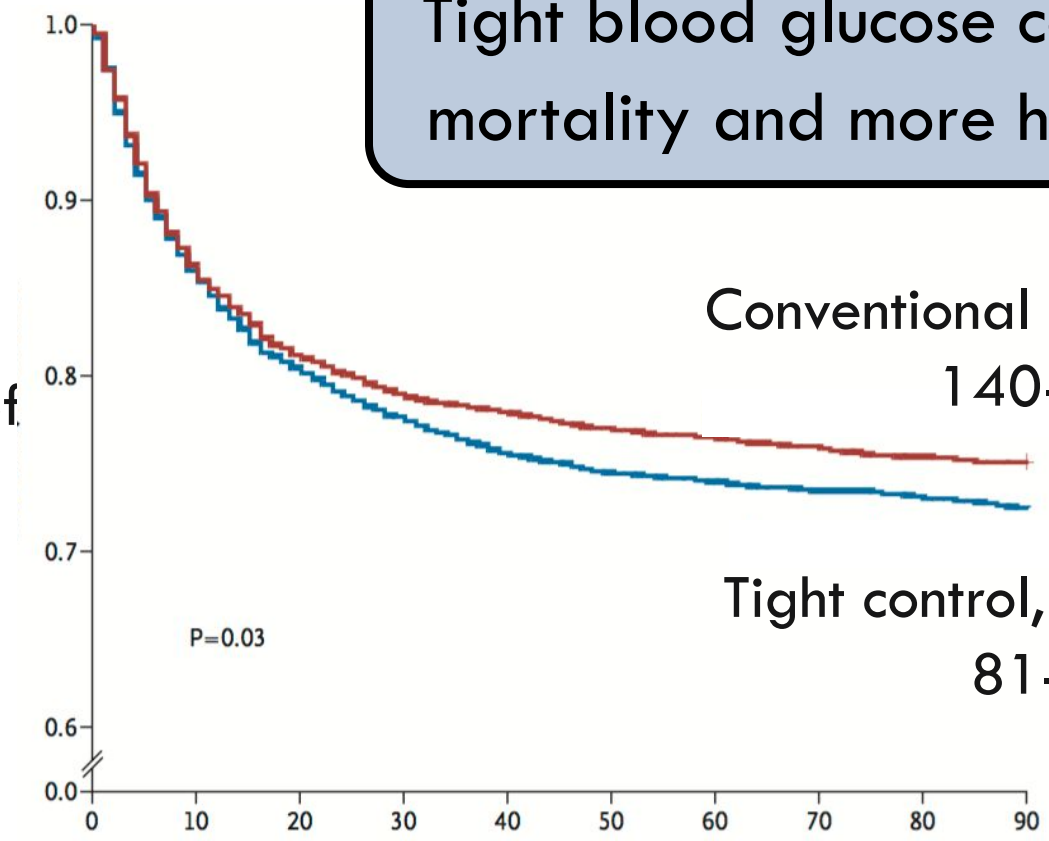
C. Begin an oral hypoglycemic agent

D. Start insulin to maintain blood glucose between 80 and 110 mg/dL

E. Start insulin to maintain blood glucose between 140 and 180 mg/dL

# GLUCOSE CONTROL IN THE ICU

Tight blood glucose control: higher mortality and more hypoglycemia




Conventional blood glucose 140-180

Tight control, blood glucose 81-108

NICE-SUGAR. *N Engl J Med.* 2009;360(13):1283-97

# QUESTION 12

What is the most appropriate next step?

A. Continue to observe (hyperglycemia associated with worse outcomes)

B. Check hemoglobin A1c and begin oral hypoglycemic if elevated (hyperglycemia may be stress response, not due to DM; avoid oral hypoglycemics in critically ill)

C. Begin an oral hypoglycemic agent (avoid oral hypoglycemics in critically ill)

D. Start insulin to maintain blood glucose between 80 and 110 mg/dL (tight control increases mortality)

E. Start insulin to maintain blood glucose between 140 and 180 mg/dL

# PATIENT 3: THE CASE CONTINUES

On ICU day 12, you note that the patient's hemoglobin is 7.4g/dL. His hemoglobin was 11g/dL on admission and it has drifted down by 0.4g per day since then. There are no signs of bleeding. Platelets are 156,000 and INR is 1.3.

# QUESTION 13

What is the most appropriate next step?

A. Continue to observe
B. Initiate a workup for hemolysis
C. Transfuse packed red blood cells
D. Transfuse fresh frozen plasma
E. Start weekly subcutaneous erythropoietin

# QUESTION 13

What is the most appropriate next step?

A. Continue to observe
B. Initiate a workup for hemolysis
C. Transfuse packed red blood cells
D. Transfuse fresh frozen plasma
E. Start weekly subcutaneous erythropoietin

# TRANSFUSIONS IN THE CRITICALLY ILL

Transfusion for Hb < 7 g/dL vs. Hb < 10 g/dL → No difference in mortality with restrictive strategy

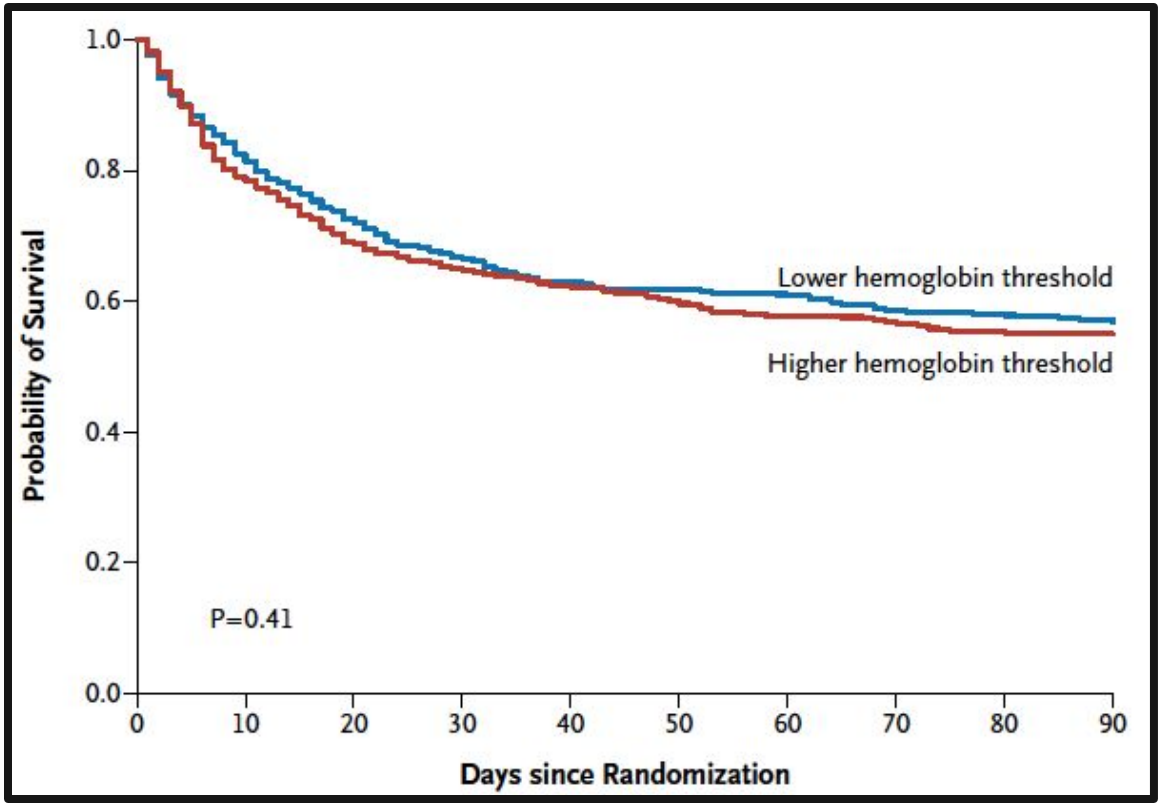
Transfuse if Hemoglobin < 7 g/dL unless:

- **Active bleeding**
- Acute coronary syndrome (consider transfusion at Hb < 8-10 g/dL)
- *Heme malignancy & thrombocytopenic*
- *Trauma, neurologic injuries*

Hébert PC, et al. *N Engl J Med* 1999;340:409-417
Yataco, A, et al. Chest 2024;167:p477-489

# TRANSFUSIONS IN SEPTIC SHOCK

998 patients with septic shock in 32 ICUs transfused to keep hemoglobin 7 vs. 9 g/dL




No difference in 90-day mortality, rates of ischemia, or need for life support

Holst LB, et al. *N Engl J Med* 2014;371:1381-1391

# TRANSFUSIONS IN SEPTIC SHOCK

Median cumulative number of blood transfusions

- 1 units (Hgb > 7)
- 4 units (Hgb > 9)

122 less gallons (463 liters) of blood transfused

Cost savings of ~$300,000

Avg. ICU pt phlebotomy: >30mL/day = 300mL/week!

Holst LB, et al. *N Engl J Med* 2014;371:1381-1391

# QUESTION 13: THE OTHER ANSWERS

What is the most appropriate next step?

A. Continue to observe

B. Initiate a workup for hemolysis (no suggestion of hemolysis)

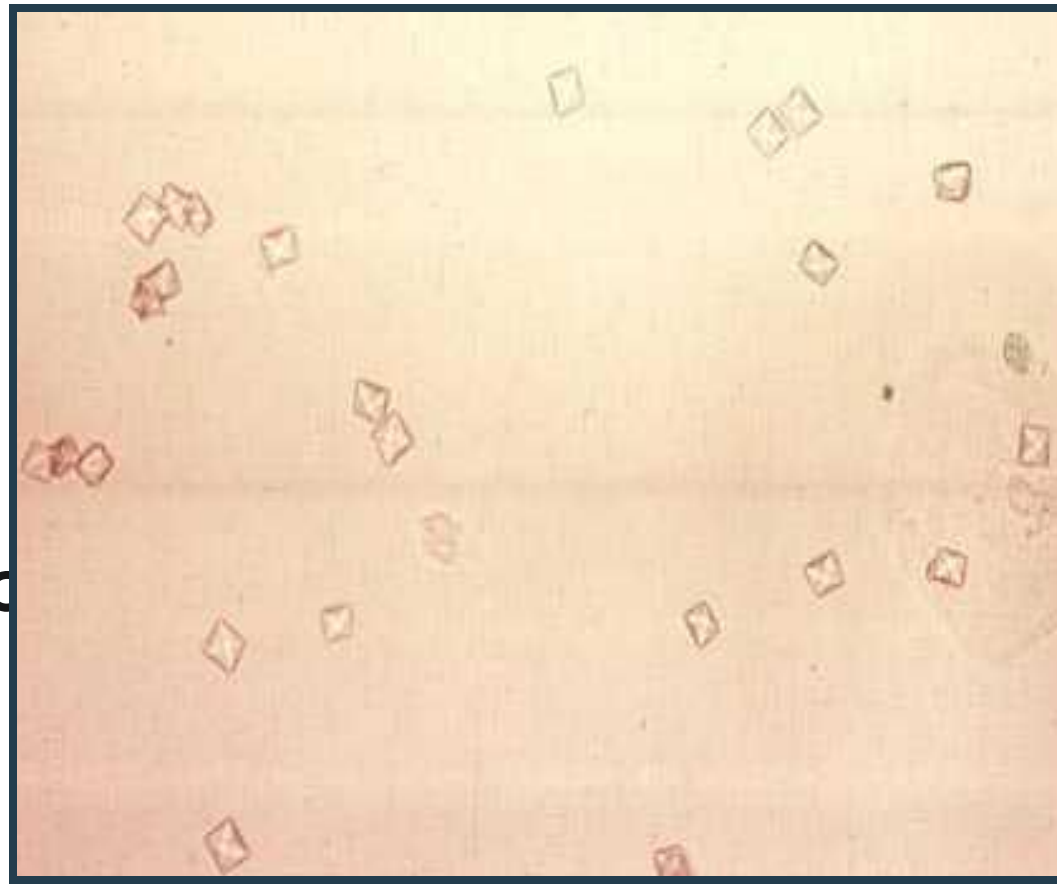
C. Transfuse packed red blood cells (hemoglobin currently > 7 g/dL)

D. Transfuse fresh frozen plasma (INR normal, FFP cannot correct further)

E. Start weekly subcutaneous erythropoietin (not approved for use in ICU patients)

# PATIENT 4

A 27-year-old man is unresponsive on arrival to the ED. He has a severe anion gap metabolic acidosis. Urine microscopy is shown.



# QUESTION 14

You start IV fluids and intubate for airway protection. What is the most appropriate next step in management?

A. Begin bicarbonate infusion
B. Administer physostigmine
C. Administer atropine
D. Administer fomepizole
E. Continue supportive care

# QUESTION 14

You start IV fluids and intubate for airway protection. What is the most appropriate next step in management?

A. Begin bicarbonate infusion
B. Administer physostigmine
C. Administer atropine
D. Administer fomepizole
E. Continue supportive care

# TOXICOLOGY IN THE ICU

# TOXIC ALCOHOL INGESTION

| Agent | Use | Clinical Clues | Treatment |
|---|---|---|---|
| Methanol | Windshield wiper fluid<br>Home distillery | Visual disturbances (Optic nerve & basal ganglia) | Ethanol or fomepizole<br>Dialysis |
| Ethylene glycol | Antifreeze | Renal failure, calcium oxalate crystals in urine | Ethanol or fomepizole<br>Dialysis |
| Isopropyl alcohol | Rubbing alcohol | **No anion gap** metabolic acidosis | Supportive care<br>Dialysis |

**Osmol Gap = Measured Osm – (2x Na + Glucose/18 + BUN/2.6 + ETOH/4.5)**

Suspect alcohols in serum when osmolal gap > 10

# RECOGNIZE TOXIDROMES

| Drug | Syndrome | Treatment |
|---|---|---|
| **Aspirin** | Tinnitus<br>Respiratory alkalosis+ anion-gap metabolic acidosis | Urinary alkalinization, hemodialysis |
| **Anticholinergics** | Anhidrosis, fever, mydriasis, delirium, urinary retention (“hot as a hare…”) | Physostigmine |
| **Antipsychotics** | NMS: Altered mentation, high fever, rigidity, dysautonomia | Dantrolene, bromocriptine |
| **SSRIs** | Serotonin syndrome: Delirium, hyperthermia, elevated muscle tone/clonus | Supportive care<br>Cyproheptadine |
| **Organophosphate** | Salivation, lacrimation, urination, defecation, bradycardia | Atropine, pralidoxime |
| **Tricyclic antidepressants** | Hypotension, anticholinergic symptoms, widened QRS | Sodium bicarbonate |

# KNOW THE ANTIDOTES

| Drug | Treatment |
|---|---|
| **Acetaminophen** | N-acetylcysteine |
| **Benzodiazepines** | Flumazenil |
| **β-blockers, CCB** | Glucagon |
| **Cyanide** | Amyl nitrate, sodium thiosulfate |
| **Digoxin** | Fab fragments (“Digibind”) |
| **Heparin** | Protamine |
| **Lithium** | Dialysis |
| **Opiates** | Naloxone |

# QUESTION 14: THE OTHER ANSWERS

You start IV fluids and intubate for airway protection. What is the most appropriate next step in management?

A. Begin bicarbonate infusion (TCA overdose or QRS widening with toxic overdose)
B. Administer physostigmine (anticholinergic toxicity)
C. Administer atropine (organophosphate poisoning)
D. Administer fomepizole
E. Continue supportive care (need to prevent further metabolism of ethylene glycol)

# PATIENT 5

A 42-year-old man is in the ICU with pneumonia and ARDS. He is on propofol and fentanyl infusions and is also receiving cefepime, ondansetron, enoxaparin, and trazodone. After 2 days of stability, you are called to the bedside:

T 41.4°C, HR 125/min, BP 188/110 mm Hg. He is agitated, diaphoretic, tremulous, and has sustained ankle clonus. Pupils are dilated and symmetric.

# QUESTION 15

What is the most appropriate next step in management?

A. Increase fentanyl and propofol infusions
B. Discontinue fentanyl, trazodone, and ondansetron; start intravenous lorazepam
C. Administer intravenous haloperidol
D. Discontinue enoxaparin, obtain urgent head CT
E. Administer dantrolene

# QUESTION 15

What is the most appropriate next step in management?

A. Increase fentanyl and propofol infusions
B. Discontinue fentanyl, trazodone, and ondansetron; start intravenous lorazepam
C. Administer intravenous haloperidol
D. Discontinue enoxaparin, obtain urgent head CT
E. Administer dantrolene

# DISTINGUISHING TOXIDROMES

| | Serotonin syndrome | Neuroleptic malignant syndrome |
|---|---|---|
| **Clinical Presentation** | Hyperthermia, increased tone, **clonus, tremor, mydriasis** | Hyperthermia, "lead-pipe" **rigidity, diminished reflexes, normal pupils** |
| **Timeline** | **Hours** | **Days-weeks** |
| **Offending Drugs** | Serotonergic agents | Dopamine antagonists |
| **Treatment** | Stop drug, **benzodiazepines,** neuromuscular blockade | |
| | Cyproheptadine | Bromocriptine, dantrolene |

# QUESTION 15: THE OTHER ANSWERS

What is the most appropriate next step in management?

A. Increase fentanyl and propofol infusions (this is not simple agitation)

B. Discontinue fentanyl, trazodone, and ondansetron; start intravenous lorazepam

C. Administer intravenous haloperidol (this is more than agitated delirium

D. Discontinue enoxaparin, obtain urgent head CT (nothing to suggest acute stroke/hemorrhage)

E. Administer dantrolene (this is not neuroleptic malignant syndrome)

# THANK YOU. YOU'VE GOT THIS!

margaret.ragland@commonspirit.org

# ANSWERS

1. A
2. B
3. D
4. D
5. C
6. C
7. E
8. D
9. C
10. C
11. E
12. E
13. A
14. D
15. B