Critical Care Board Questions

Rebecca Sternschein, MD

Associate Fellowship Program Director

Division of Pulmonary and Critical Care Medicine, Dept of Medicine

Brigham and Women's Hospital

Instructor in Medicine

Harvard Medical School

Disclosures

- Associate editor for NEJM Healer, a simulation-based medical education platform

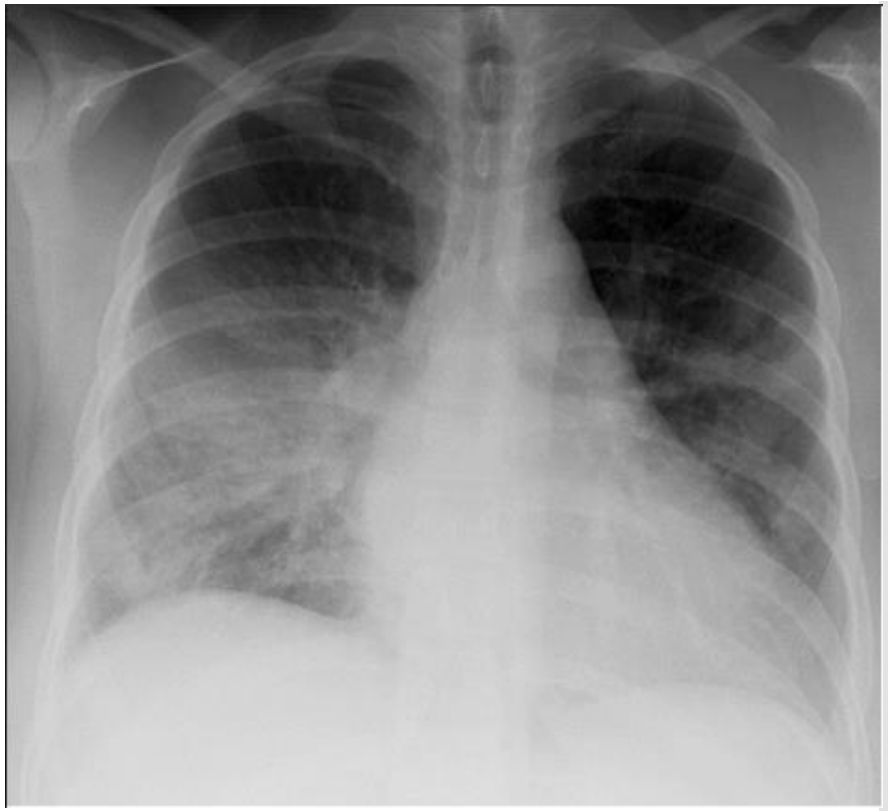
Overview

- Case-based review of 4 key critical care medicine concepts:
  - Respiratory failure
  - Liberation from mechanical ventilation
  - Targeted temperature management
  - Fluid resuscitation in sepsis

Question 1: Part A

A 45-year-old man with HTN, DM2, and a recent viral URI presents with 24 hours of worsening dyspnea, fever (Tmax 38.7 °C). He is placed on 40% FiO2 by facemask.

- BP 99/54
- WBC 19
- ABG: 7.30 / 30 / 67 / 15

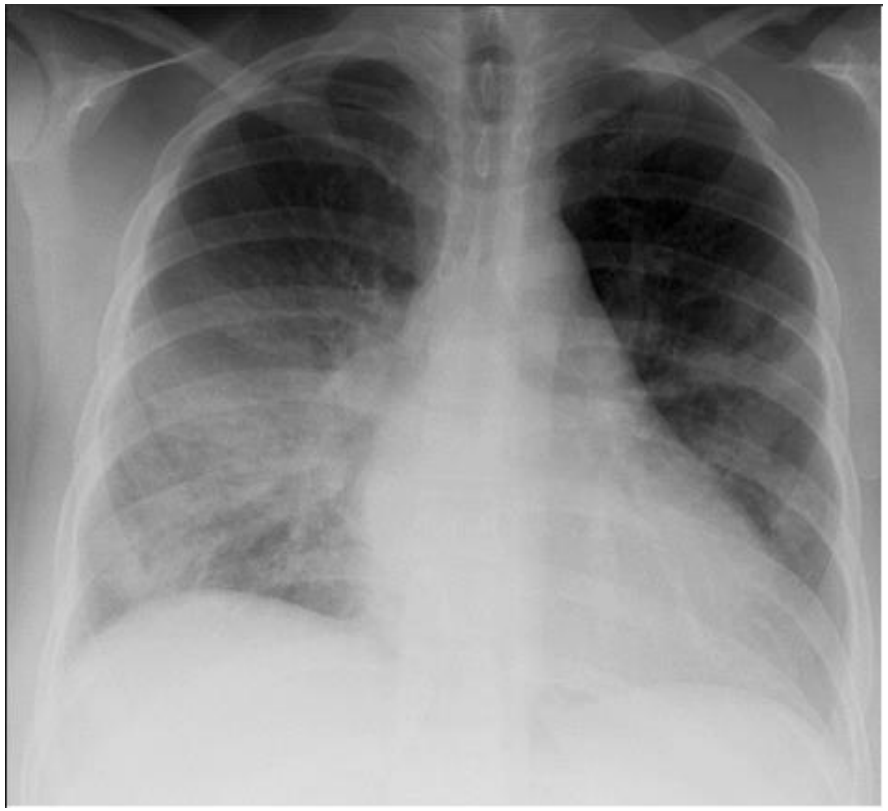


ABG: 7.30 / 30 / 67 / 15

- What is the acid/base abnormality?

Time to participate!

- Where is the CXR abnormality?



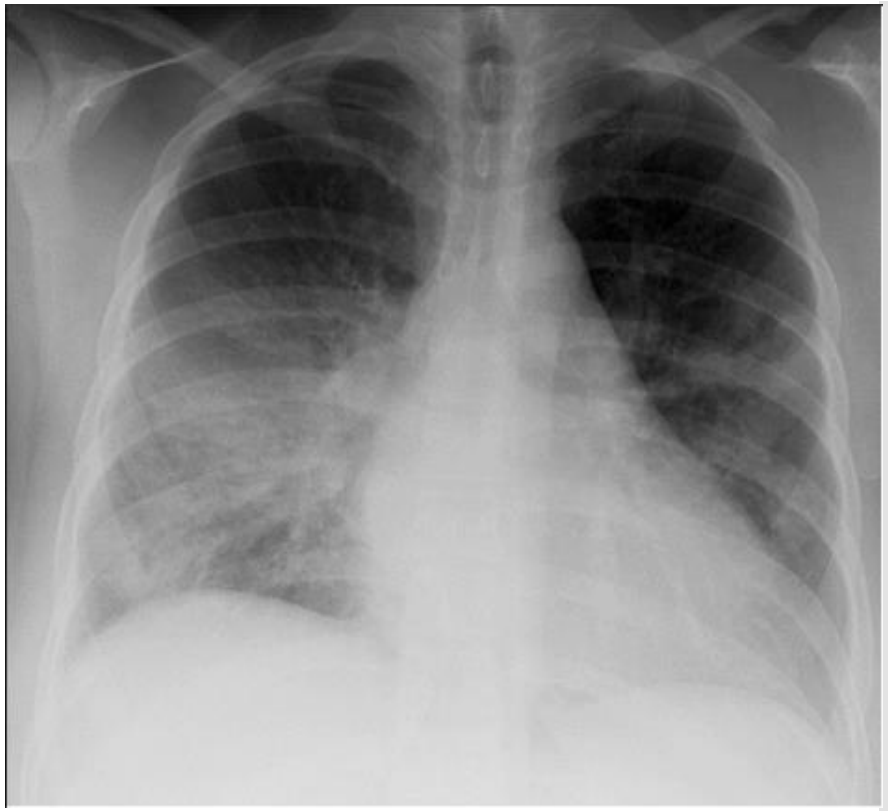
Time to participate!

Question 1: Part A

A 45-year-old man with HTN, DM2, and a recent viral URI presents with 24 hours of worsening dyspnea, fever (Tmax 38.7 °C). He is placed on 40% FiO2 by facemask.

- BP 99/54
- WBC 19
- ABG: 7.30 / 30 / 67 / 15

Pure metabolic acidosis
Hypoxemia despite 40% FiO2
Right lower lobe infiltrate

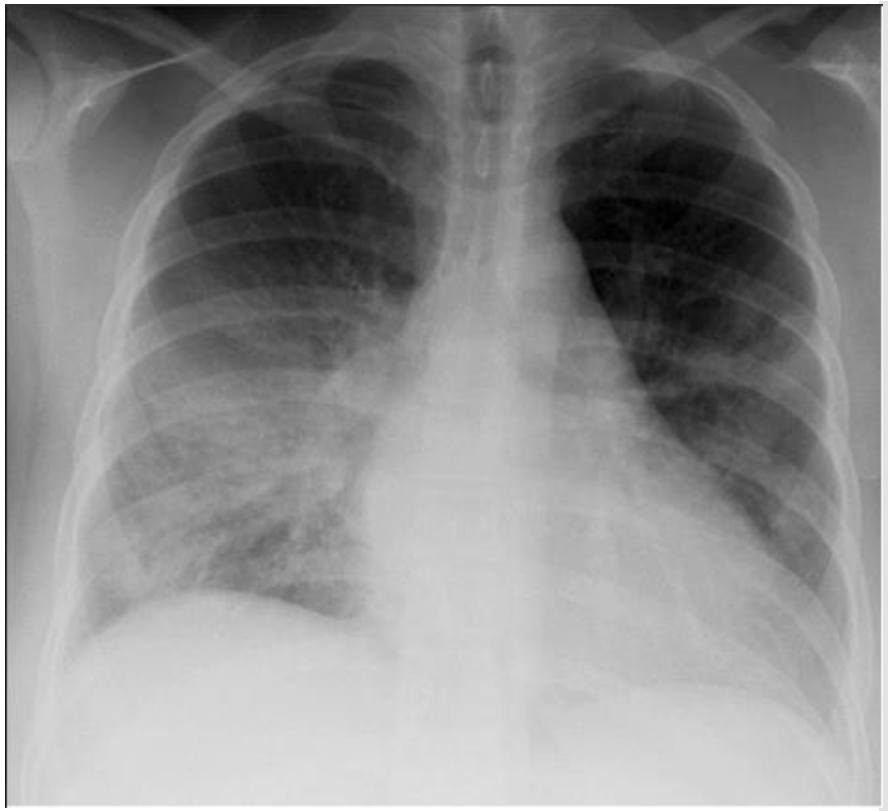


Question 1: Part A

He is admitted to the ICU, placed on broad spectrum antibiotics, given IV fluids, and increased to 60% FiO2 by facemask.

6 hours later he seems more tired and breathless; he remains lucid.

- ABG: 7.25 / 35 / 87 / 15



Question 1: Part A

What is the most appropriate next intervention?

(A) Intubate immediately for hypercarbic respiratory failure and begin assist control ventilation

(B) Decrease the FiO_2 for possibly causing the increased pCO_2

(C) Begin non-invasive positive pressure ventilation

(D) Decrease the IVF for possible CHF exacerbation

(E) Cannulate for Extracorporeal Membrane Oxygenation (ECMO)

Question 1: Part A

What is the most appropriate next intervention?

(A) Intubate immediately for hypercarbic respiratory failure and begin assist control ventilation

(B) Decrease the FiO_2 for possibly causing the increased pCO_2

(C) Begin non-invasive positive pressure ventilation

(D) Decrease the IVF for possible CHF exacerbation

(E) Cannulate for Extracorporeal Membrane Oxygenation (ECMO)

Non-Invasive Positive Pressure Ventilation (NIPPV)

- Evidence supports using NIPPV for:
  - **Acute exacerbation of COPD** → less intubation, shorter hospitalization, lower in-hospital mortality (NEJM 1995; Cochrane systematic review 2017)
  - **Cardiogenic pulmonary edema** → less intubation, lower in-hospital mortality (Cochrane systematic review 2019)
  - **Severe acute hypoxemic respiratory failure** → less intubation, decreased 90-day mortality (AJRCCM, 2003), less intubation, lower in-hospital mortality (CCM systematic review 2017)

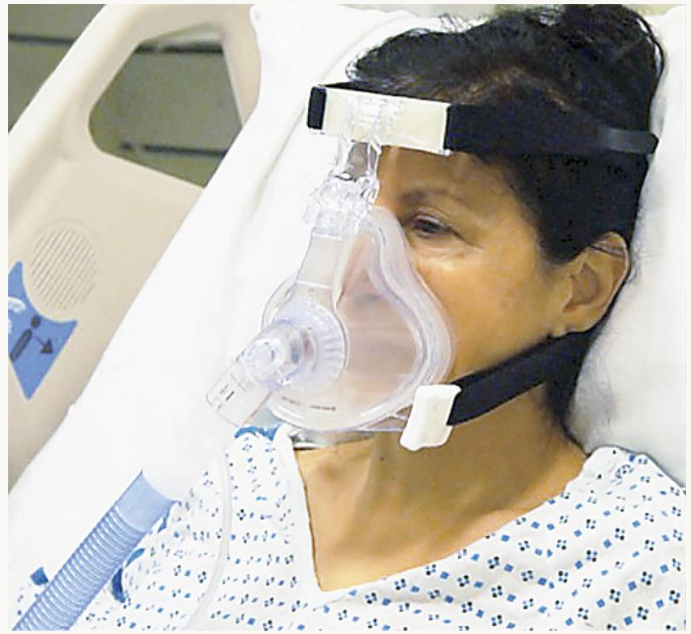


Image source: <https://www-nejm-org.ezp-prod1.hul.harvard.edu/doi/full/10.1056/NEJMvcm1313336>

Non-Invasive Positive Pressure Ventilation (NIPPV)

- Contraindications for NIPPV:
  - Absolute:
    - Cardiac or respiratory arrest
  - Relative
    - Concern for inability to protect airway
    - Unable to fit mask (facial hair, facial fracture)
    - Inability to tolerate mask
    - Copious secretions, recurrent vomiting
    - Recent upper airway or upper GI surgery

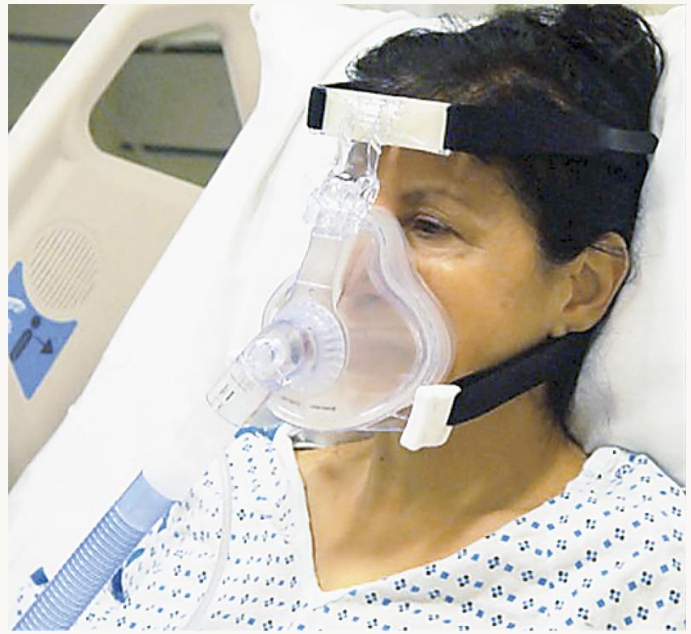


Image source: <https://www-nejm-org.ezp-prod1.hul.harvard.edu/doi/full/10.1056/NEJMvcm1313336>

Explaining other answers…

(A) Intubate immediately for hypercarbic respiratory failure and begin assist control ventilation	→ Not necessary as a first step, try less invasive intervention first
(B) Decrease the FiO_2 for possibly causing the increased pCO_2	→ Only an issue for those with obstructive lung disease
(C) Begin non-invasive positive pressure ventilation	→ Correct answer!
(D) Decrease the IVF for possible CHF exacerbation	→ IV fluids are necessary for this patient with probable sepsis, can manage this with NIPPV
(E) Cannulate for Extracorporeal Membrane Oxygenation (ECMO)	→ Too early in the course of respiratory failure, consider when hypoxemia is refractory

Learning Objectives: Respiratory Failure

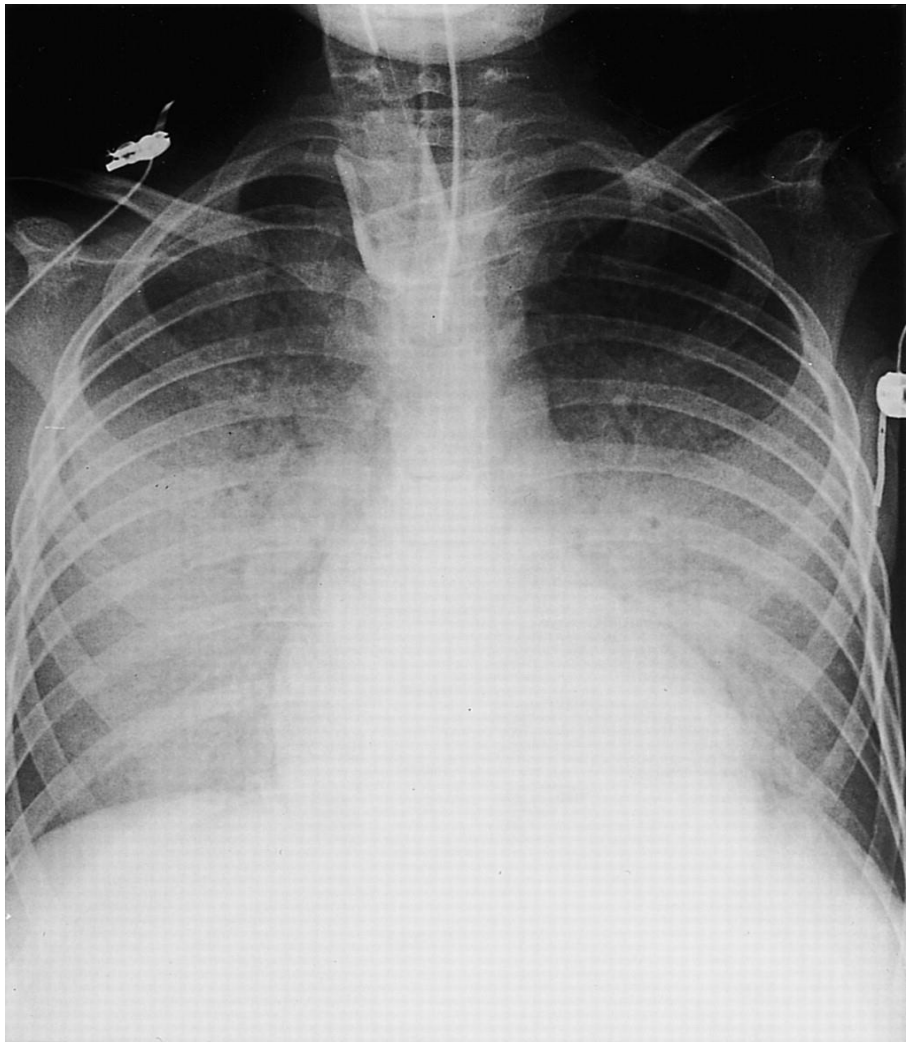
- **Non-invasive positive pressure ventilation (NIPPV) can help to avoid intubation** in patients with:
  - acute exacerbation of COPD
  - cardiogenic pulmonary edema
  - severe hypoxemic respiratory failure

- **Contraindications for NIPPV** include:
  - Cardiac or respiratory arrest (absolute)
  - Need for airway protection
  - Inability to fit mask
  - Unstable hemodynamics

Question 1: Part B

Despite NIPPV, the patient deteriorates within hours and is intubated for progressive, refractory hypoxemia. He is diagnosed with ARDS based on the Berlin criteria defined in 2012:

- Acute onset (<7 days)
- PaO_2:FiO_2 < 300
- Bilateral pulmonary opacities
- Not fully explained by cardiac failure or volume overload

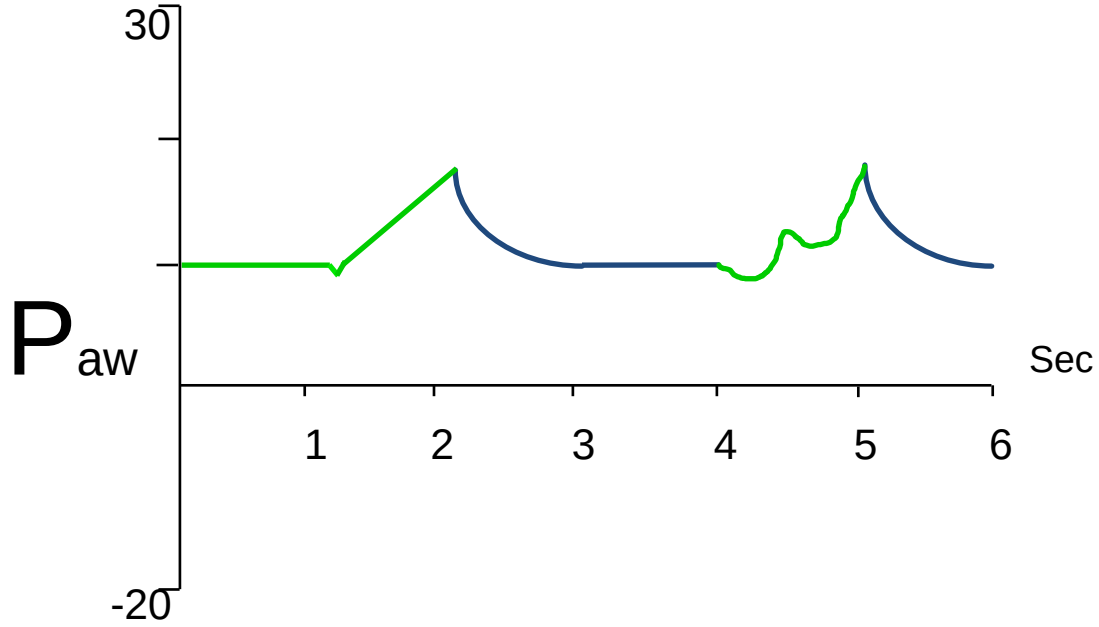


Question 1: Part B

You are called to evaluate the patient for agitation. His current vent settings are:

- Assist control ventilation
- Tidal volume 450cc (6cc/kg IBW)
- PEEP 10 cm H20
- RR 14 bpm
- FiO2 60%

His pressure/time waveform is displayed here:



Question 1: Part B

What is occurring at the arrow and what is the best way to address it?

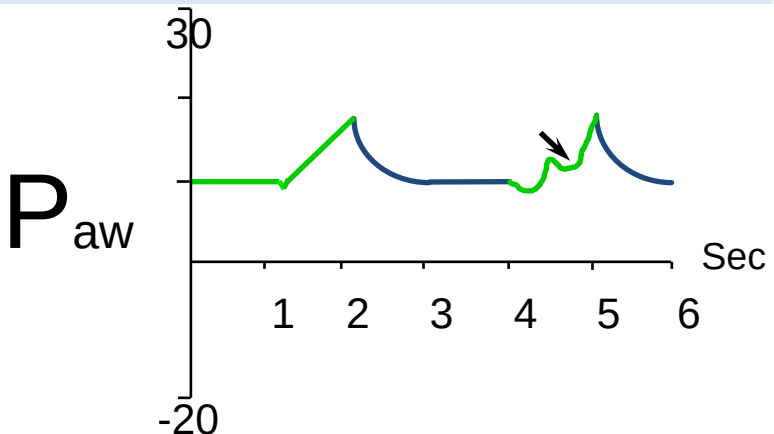
(A) Ventilator malfunction. Bag the patient and change the machine.

(B) Patient-ventilator dyssynchrony. Sedate the patient more heavily.

(C) Air hunger. Increase the tidal volume.

(D) Air hunger. Increase the inspiratory flow.

(E) Auto-PEEP. Increase the set PEEP to match the auto-PEEP and lessen his work of breathing.



Question 1: Part B

What is occurring at the arrow and what is the best way to address it?

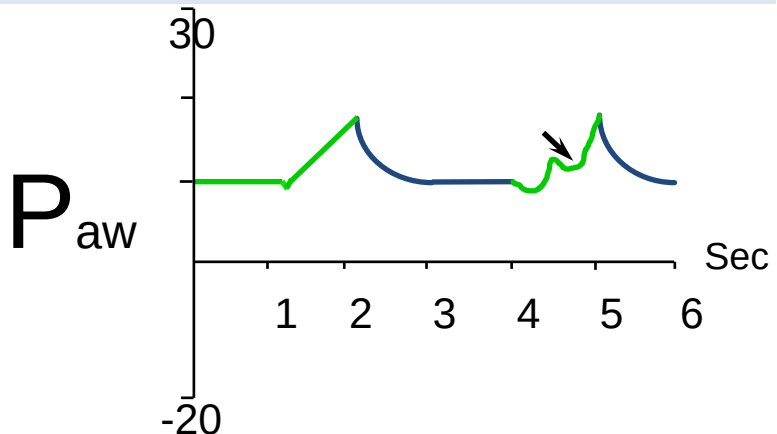
(A) Ventilator malfunction. Bag the patient and change the machine.

(B) Patient-ventilator dyssynchrony. Sedate the patient more heavily.

(C) Air hunger. Increase the tidal volume.

(D) Air hunger. Increase the inspiratory flow.

(E) Auto-PEEP. Increase the set PEEP to match the auto-PEEP and lessen his work of breathing.



Air hunger

- Patient wants more flow than is being delivered and so she/he initiates a negative pressure breath that causes downward scooping of the pressure curve during inspiration.

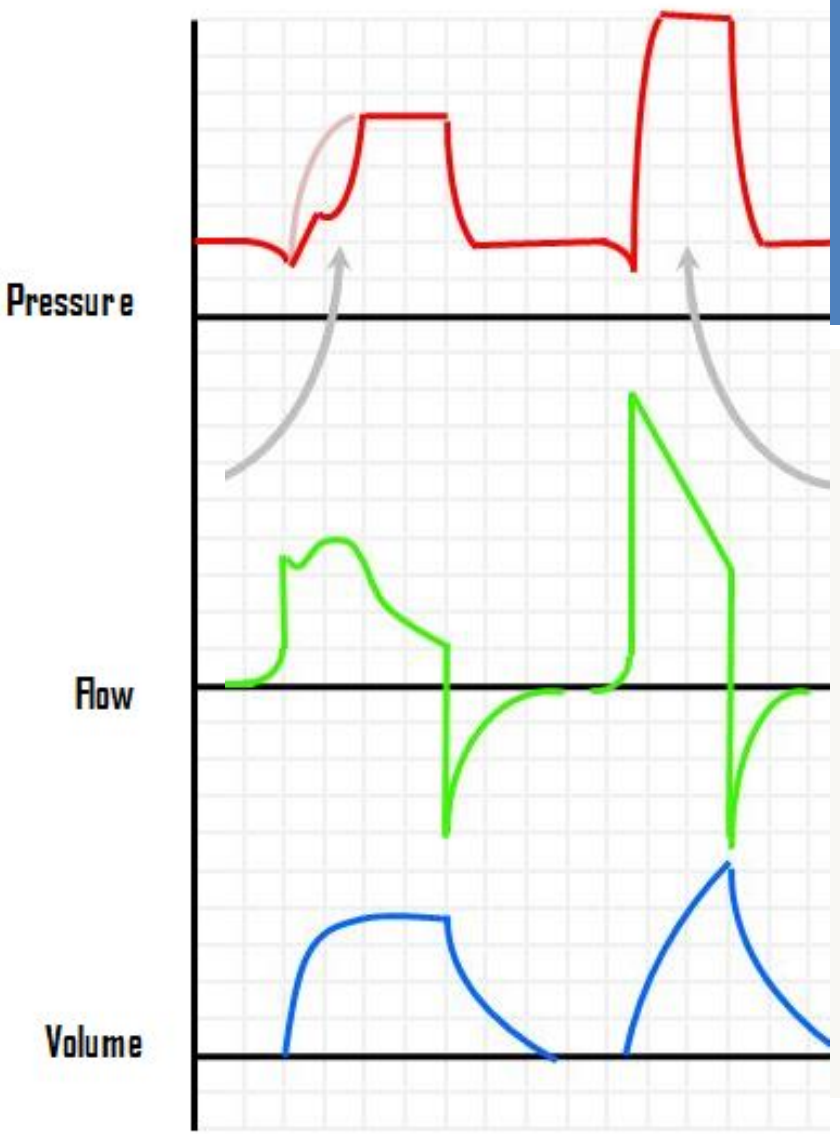


Image source: < https://derangedphysiology.com/main/required-reading/respiratory-medicine-and-ventilation/Chapter%20627/patient-ventilator-dyssynchrony >

- Increasing the flow rate will resolve this type of patient-ventilator dyssynchrony.

Explaining other answers…

(A) Ventilator malfunction. Bag the patient and change the machine.	→ There is no indication of vent malfunction.
(B) Patient-ventilator dyssynchrony. Sedate the patient more heavily.	→ This is a form of dyssynchrony, but best to explore other solutions before increasing sedation.
(C) Air hunger. Increase the tidal volume.	→ This is air hunger but more likely flow than volume problem, and with ARDS should maintain lung protective ventilation with low Vt
(D) Air hunger. Increase the inspiratory flow.	→ Correct answer!
(E) Auto-PEEP. Increase the set PEEP to match the auto-PEEP and lessen his work of breathing.	→ No indication of auto-PEEP on waveform, would not occur during inspiration.

Auto PEEP

- When flow does not return to zero by the end of expiration, gas trapping may occur and lead to dynamic hyperinflation.

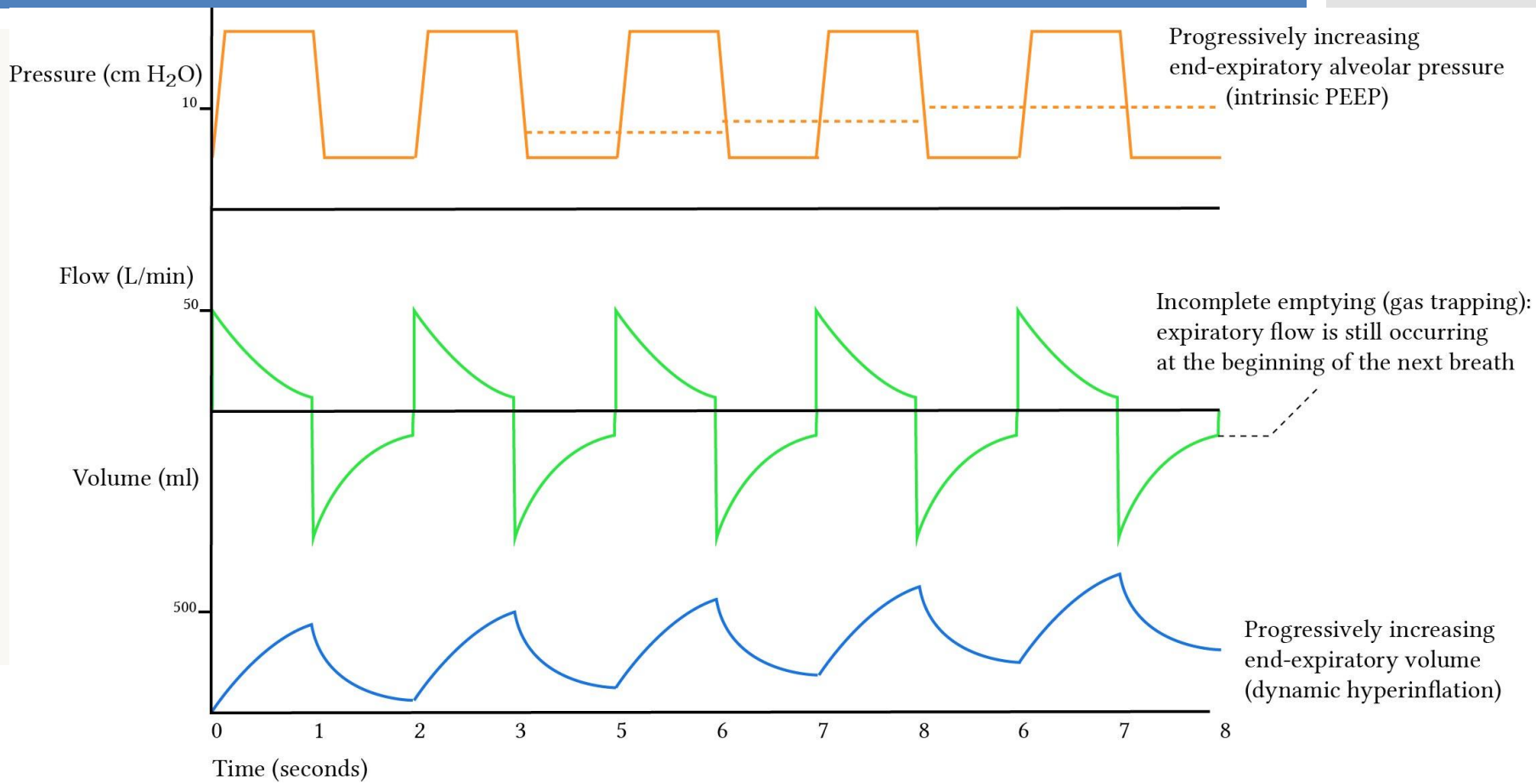


Image source: <https://derangedphysiology.com/main/cicm-primary-exam/required-reading/respiratory-system/Chapter%205215/intrinsic-peep-and-positive>

Learning Objectives: Ventilator Dyssynchrony

- Think about **air hunger** when the pressure tracing scoops downward during the delivered breath:
  - Address this by increasing inspiratory flow
  - Do not reflexively increase sedation

- Think about **auto PEEP** when the flow tracing does not return to baseline at the end of expiration:
  - This can cause increased work of breathing and dyssynchrony, predispose to barotrauma, and impact hemodynamics

Question 1: Part C

After 6 days, the patient is improving. He no longer has fever. He is hemodynamically stable. He just had a CT chest that demonstrated improvement in bilateral opacities. His current ventilator settings are:

- Assist control ventilation
- Tidal volume 450 cc (6cc/kg IBW)
- PEEP 6
- RR 10 bpm
- FiO2 40%

You are called because his vent is alarming for high pressures.

- What is your fist action when you are told the high-pressure alarm is going off?

Time to participate!

Question 1: Part C

After 6 days, the patient is improving. He no longer has fever. He is hemodynamically stable. He just had a CT chest that demonstrated improvement in bilateral opacities. His current ventilator settings are:

- Assist control ventilation
- Tidal volume 450 cc (6cc/kg IBW)
- PEEP 6
- RR 10 bpm
- FiO2 40%

You are called because his vent is alarming for high pressures.

The respiratory therapist tells you that the peak inspiratory pressure has acutely increased from 22 to 34 and the plateau pressure has increased from 15 to 28.

Question 1: Part C

Which of the following is most likely cause of the high pressure alarm?

(A) His endotracheal tube migrated into his right mainstem bronchus.

(B) His endotracheal tube is kinked.

(C) He has a mucus plus in a main airway.

(D) He has developed an acute pulmonary embolism.

(E) This is part of the natural history of ARDS.

Question 1: Part C

Which of the following is most likely cause of the high pressure alarm?

(A) His endotracheal tube migrated into his right mainstem bronchus.

(B) His endotracheal tube is kinked.

(C) He has a mucus plus in a main airway.

(D) He has developed an acute pulmonary embolism.

(E) This is part of the natural history of ARDS.

Elevated Airway Pressures

- Peak Airway Pressure = Airway Resistance Pressure + Plateau Pressure
  - Airway Resistance Pressure = Flow x Airway resistance
  - Plateau Pressure = Tidal volume / Compliance
    *measured when flow = 0 (inspiratory hold)

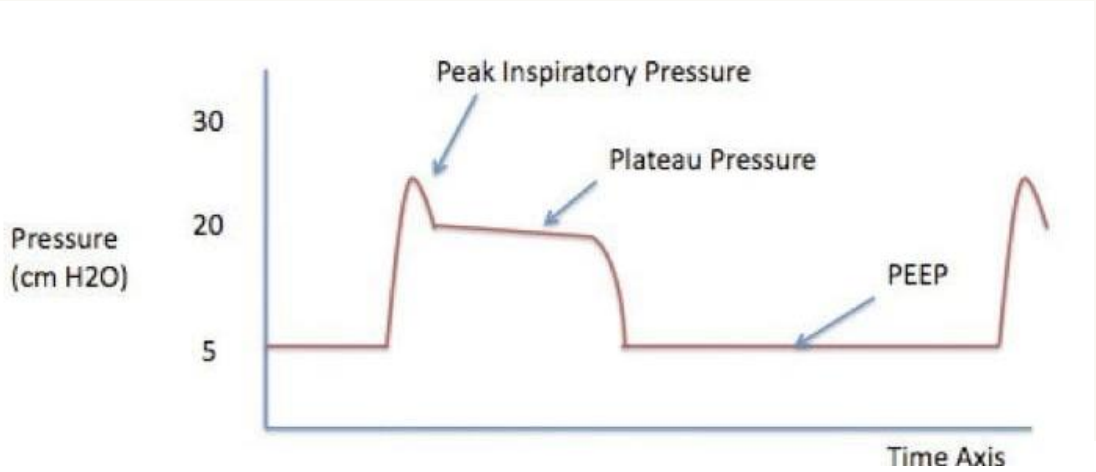


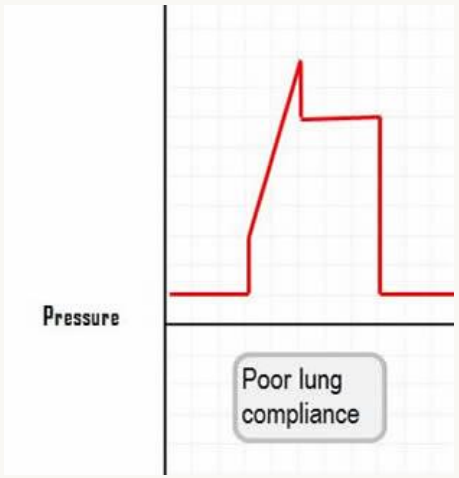
Image source: <https://litfl.com/pressure-versus-time-graph/>

Elevated Airway Pressure

High peak + high plateau

→ **Poor compliance**

- Mainstem intubation
- CHF
- Pulmonary fibrosis
- Pneumothorax
- Abdominal compartment syndrome
- Circumferential burn of thorax



High peak + normal plateau

→ **Poor resistance**

- Bronchospasm
- Mucous plug
- Kinked endotracheal tube

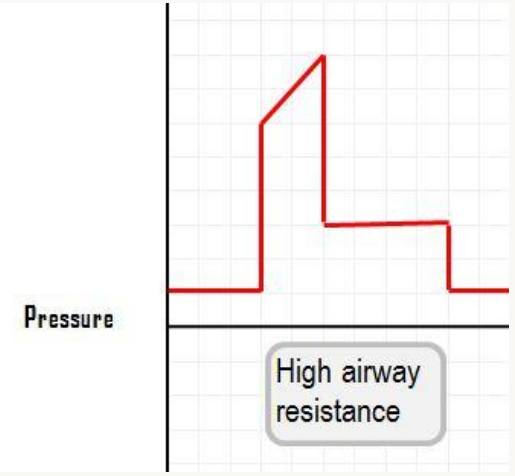


Image source: < https://derangedphysiology.com/main/cicm-primary-exam/required-reading/respiratory-system/Chapter%20552/interpreting-shape-pressure-waveform >

Explaining other answers…

(A) His endotracheal tube migrated into his right mainstem bronchus. → Correct answer!

(B) His endotracheal tube is kinked. → This would cause increased resistance; plateau pressure would be normal.

(C) He has a mucus plus in a main airway. → This would cause increased resistance; plateau pressure would be normal.

(D) He has developed an acute pulmonary embolism. → This would not have significant immediate effect on peak pressure or plateau pressure.

(E) This is part of the natural history of ARDS. → The natural history of ARDS does not include a sudden worsening of compliance, in fact over time compliance usually improves slowly.

Learning Objectives: Elevated Peak Airway Pressures

- When the vent alarms for elevated peak airway pressures, **use the plateau pressure to determine whether the issue is airway resistance or lung compliance**
  - If the plateau pressure is normal, think about causes of increased airway resistance
  - If the plateau pressure is elevated, think about causes of decreased lung compliance

Question 2:

- A 64-year-old woman with a history of HTN, HLD and diverticulosis, presents to the ED with abdominal pain, altered mental status, and hypotension.
- She is found to have a perforated sigmoid on CT scan. She is resuscitated in the ED and started on vasopressors for persistent hypotension. She goes to the OR for laparotomy where she is found to have a grossly contaminated abdomen; the surgeons repair the perforation and washout the peritoneal cavity.
- She is transferred to the ICU from the OR intubated and sedated on appropriate antimicrobial coverage and requiring minimal vasopressor support.

- Are you thinking about liberation from MV when this patient arrives in the ICU?

Time to participate!

Question 2:

- The following day, the patient is hemodynamically stable off vasopressors and afebrile. She is weaned off sedation and her mental status improves so that she now follows simple commands.
    - SBT goes well
    - She is on pressure support ventilation with low level support
    - She has strong cough when suctioned
    - She has minimal secretions

- Is there any other information that you think would be useful to decide about liberation from mechanical ventilation in this patient?

Time to participate!

Question 2: Part B

- It has been 36hrs since she was intubated in the OR for her surgery.
- Anesthesia documented that the intubation was challenging and there was minimal trauma to the airway during the intubation.
- She currently has a 7.5mm endotracheal tube in place.

Question 2: Part A

Which of the following statements regarding liberation from mechanical ventilation is correct?

(A) Only patients at high risk for extubation failure should have a spontaneous breathing trial (SBT) before extubation

(B) Using non-invasive ventilation (NIV) immediately after extubation for patients at high risk for extubation failure does not impact mortality

(C) Patients who fail a cuff leak test but are otherwise ready for extubation should have extubation delayed by at least 48 hours

(D) Patients who fail a cuff leak test but are otherwise ready for extubation should receive systemic steroids prior to extubation

(E) Men are at higher risk than women for developing postextubation stridor

Question 2: Part A

Which of the following statements regarding liberation from mechanical ventilation is correct?

(A) Only patients at high risk for extubation failure should have a spontaneous breathing trial (SBT) before extubation

(B) Using non-invasive ventilation (NIV) immediately after extubation for patients at high risk for extubation failure does not impact mortality

(C) Patients who fail a cuff leak test but are otherwise ready for extubation should have extubation delayed by at least 48 hours

(D) Patients who fail a cuff leak test but are otherwise ready for extubation should receive systemic steroids prior to extubation

(E) Men are at higher risk than women for developing postextubation stridor

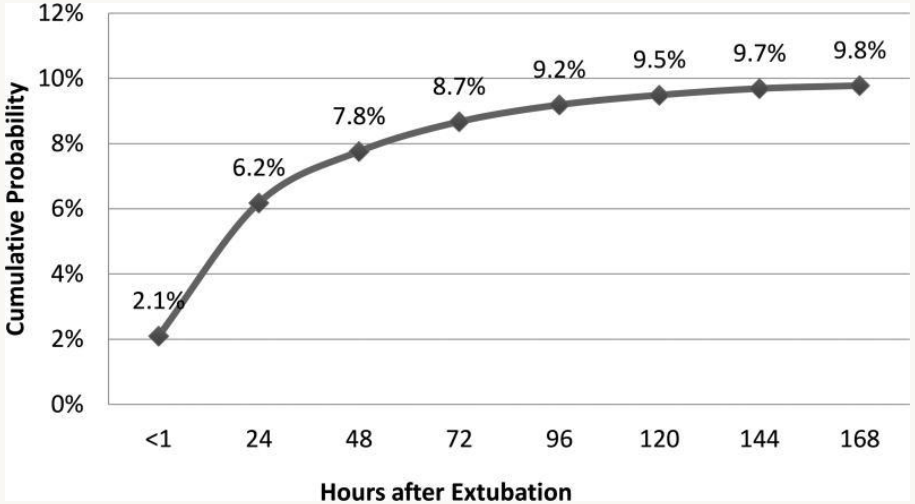
Liberation from Ventilation

- Daily SAT + SBT (if no contraindications) for all patients who have been on mechanical ventilation >24 hours is standard of care
  - RCT from Lancet 2008 → improved ICU outcomes (MV days, ICU LOS, and mortality- NNT 7.4)
  - Initial SBT should be performed with 5-8 cm H_2O inspiratory pressure augmentation (ATS/CHEST consensus recommendation, 2017)

Girard, T. et al. "Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care: a randomized controlled trial" Lancet 2008; 371: 126-134.

Liberation from Ventilation: Risk of Failure

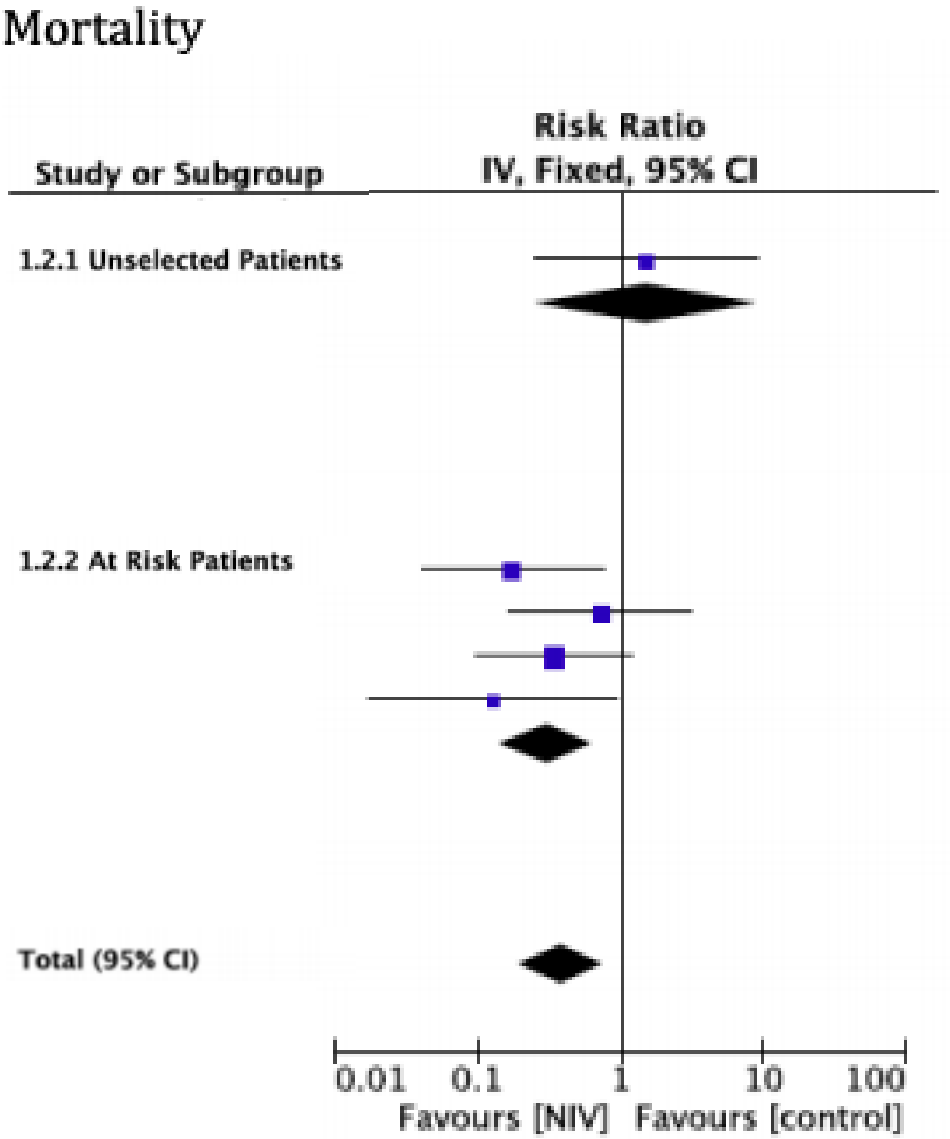
- Failure of liberation = requirement for reintubation
  - Approximately 10% patients require reintubation
  - Median time to reintubation 15 hours
  - In the ICU, 90% of reintubation occurs within 96hrs of initial extubation



Miltiades, A. et al. "Cumulative Probability and Time to Reintubation in US ICUs" Critical Care Medicine. 2017; 45: 835.

Postextubation NIV

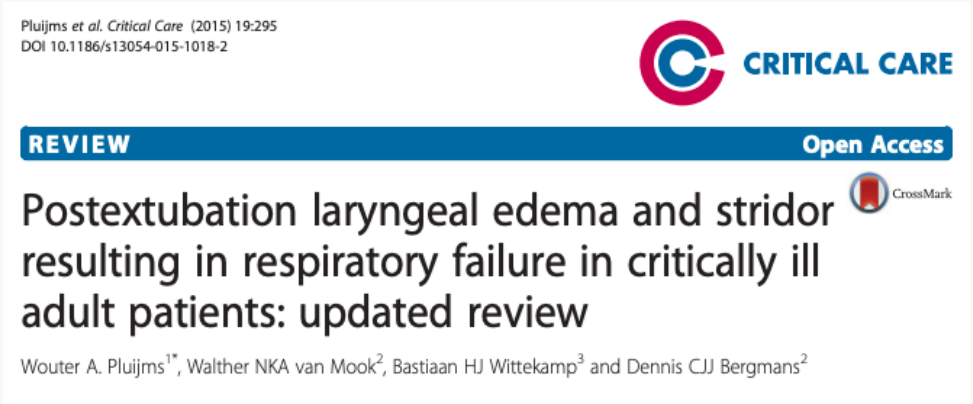
- Patients at risk for failure of liberation
  - >65 years and/or significant underlying cardiac and respiratory disease
  - ATS/ERS clinical practice guidelines from 2017 support **use of NIV immediately postextubation for high risk patients** based on pooled analysis from RCTs demonstrating mortality benefit



Rochwerg, B., et al. "Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure." ERJ. 2017; 50.

Postextubation Stridor (PES)

- Laryngeal edema is an established complication of intubation that can cause a decrease diameter of laryngeal lumen
- Clinically, LE presents as postextubation stridor (PES) and/or postextubation respiratory distress
- Stridor in PES occurs are a result of increase in airflow velocity through narrow laryngeal lumen


Pluijms *et al. Critical Care* (2015) 19:295
DOI 10.1186/s13054-015-1018-2

CRITICAL CARE

REVIEW Open Access

Postextubation laryngeal edema and stridor resulting in respiratory failure in critically ill adult patients: updated review

Wouter A. Pluijms[1*], Walther NKA van Mook[2], Bastiaan HJ Wittekamp[3] and Dennis CJJ Bergmans[2]

Postextubation Stridor (PES)

- PES incidence varies
  - reported from 5% - 54%
- Reintubation rate in patients with PES varies (10%-100%)
  - Not all patients with PES require reintubation

Risk Factors for PES

Female gender
Longer duration of intubation
Difficult/traumatic intubation
Higher endotracheal tube size
Higher cuff pressure

Pluijms, W., et al. "Postextubation laryngeal edema and stridor resulting in respiratory failure in critically ill adult patients: updated review." Critical Care. 2015; 19: 295-314.

Cuff Leak Test

- One approach to predicting PES is to perform a **cuff leak test** prior to extubation

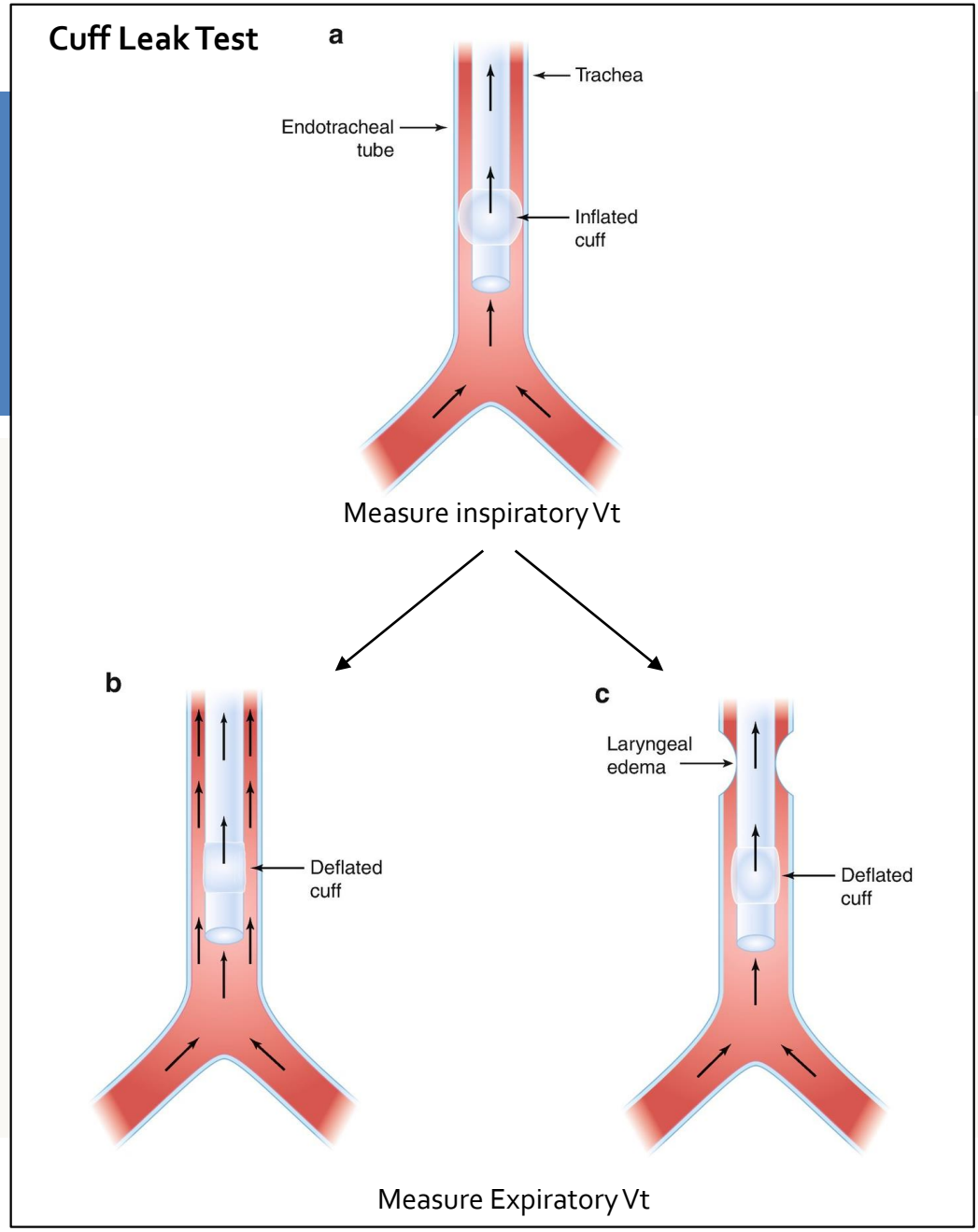


Image source: <https://link.springer.com/chapter/10.1007/978-3-319-89981-7_9>

Cuff Leak Test

Positive	Negative
Potential identification of LE and PES prior to extubation Potential to minimize postextubation risk	Potential delay in extubation may lead to increased risks associated with prolonged duration MV Indirect assessment of LE (just surrogate) Variable sensitivity/specificity

Pluijms, W., et al. "Postextubation laryngeal edema and stridor resulting in respiratory failure in critically ill adult patients: updated review." Critical Care. 2015; 19: 295-314.

- How often do you use a cuff leak test prior to liberation from mechanical ventilation at your institution?

Time to participate!

PES Prevention

- 3 RCTs of steroid vs placebo for patients who failed cuff leak test pooled data demonstrate:
  - Decreased PES (10.8 vs 31.9%, RR 0.35, 95%CI 0.20 – 0.63)
  - Decreased reintubation (5.8 vs 17.0%, RR 0.32, 95%CI 0.14 – 0.76)
- RCT of methylprednisolone (20mg x4 over 12hr) vs placebo before extubation for all patients (no cuff leak performed)
  - Steroids reduced PES, reintubation, and reintubation due to PES

ATS/CHEST recommendations.

- For adults who have failed a cuff leak test but are otherwise ready for extubation, we suggest administering systemic steroids at least 4 hours before extubation, (conditional recommendation, moderate certainty in the evidence).

Girard, T., et al. "An Official ATS/ACCP Clinical Practice Guideline: Liberation from Mechanical Ventilation in Critically Ill Adults. AJRCCM. 2017; 195: 120-133.

Explaining other answers…

(A) Only patients at high risk for extubation failure should have a spontaneous breathing trial (SBT) before extubation	→ All patients receiving mechanical ventilation should have a daily SBT paired with SAT.
(B) Using non-invasive ventilation (NIV) immediately after extubation for patients at high risk for extubation failure does not impact mortality	→ NIV used immediately after extubation for high risk patients is associated with a mortality benefit.
(C) Patients who fail a cuff leak test but are otherwise ready for extubation should have extubation delayed by at least 48 hours	→ There is no evidence to support this. In fact, delay of extubation is a concern related to routine cuff leak testing.
(D) Patients who fail a cuff leak test but are otherwise ready for extubation should receive systemic steroids prior to extubation	→ Correct answer!
(E) Men are at higher risk than women for developing post-extubation stridor	→ Women are at increased risk for developing post-extubation stridor.

Learning Objectives: Ventilator Liberation

- Performing a **daily SAT and SBT for all mechanically ventilated patients in the ICU** decreases the duration of MV and improves mortality
- Using **NIV immediately following extubation for patients at high risk for extubation failure** improves mortality
- Giving **systemic steroids prior to extubation to patients who fail a cuff leak test** can improve ventilator liberation outcomes.
  - Less likely to develop postextubation stridor
  - Less likely to require re-intubation

Question 3

- A 73-year-old man with a history of prostate cancer collapses while boarding a bus in a crowded urban bus terminal.
- Bystander CPR is begun, a transit policeman arrives, attaches an AED which recommends “shock” and discharges with return of spontaneous circulation.

Image source: <https://www.cprconsultants.com/a-hero-saves-two-lives-in-one-day-with-cpr-in-charlotte-nc/>

Question 3

- The patient is brought to the closest hospital; he remains unconscious but with a stable blood pressure.
- Upon arrival, he is emergently taken to the cath lab; a suspicious, non-obstructing plaque is found in the circumflex artery.
- He is transferred to the ICU. His BMP, CBC, and coagulation panel are normal.

Question 3

What is the best next step to improve the outcome for this patient?

(A) STAT head CT to rule out CNS catastrophe.

(B) Refer for hyperbaric oxygen for possible hypoxic brain injury.

(C) Begin external cooling of patient to 32° C for 12 hours

(D) Activate protocol for targeted temperature management of patient.

(E) Hold a family meeting to relay his poor neurologic prognosis and discuss withdrawal of care.

Question 3

What is the best next step to improve the outcome for this patient?

(A) STAT head CT to rule out CNS catastrophe.

(B) Refer for hyperbaric oxygen for possible hypoxic brain injury.

(C) Begin external cooling of patient to 32° C for 12 hours

(D) Activate protocol for targeted temperature management of patient.

(E) Hold a family meeting to relay his poor neurologic prognosis and discuss withdrawal of care.

Targeted Temperature Management (TTM)

- **Indication:**
  - AHA 2020 guidelines class 1 (strong) recommendation
  - TTM with goal temp 32-36°C for at least 24 hours once target temp reached for adults who do not follow commands with ROSC after:
    - out of hospital cardiac arrest with any initial rhythm
    - in hospital cardiac arrest with initial non-shockable rhythm
    - In-hospital cardiac arrest with initial shockable rhythm*

*based on non-randomized trials

- What temperature does your institution target when doing targeted temperature management?

Time to participate!

Targeted Temperature Management (TTM)

- **Contraindications**:
  - Active non-compressive bleeding (relative, increased bleeding risk with lower temps)
  - Pregnancy (relative, increased bleeding risk)
  - Hemodynamically unstable (relative, increased bleeding risk)

TTM: External Cooling Device

- Key component for TTM device is a continuous feedback mechanism
  - Requires ability to measure and monitor core temperature (e.g. via bladder probe)

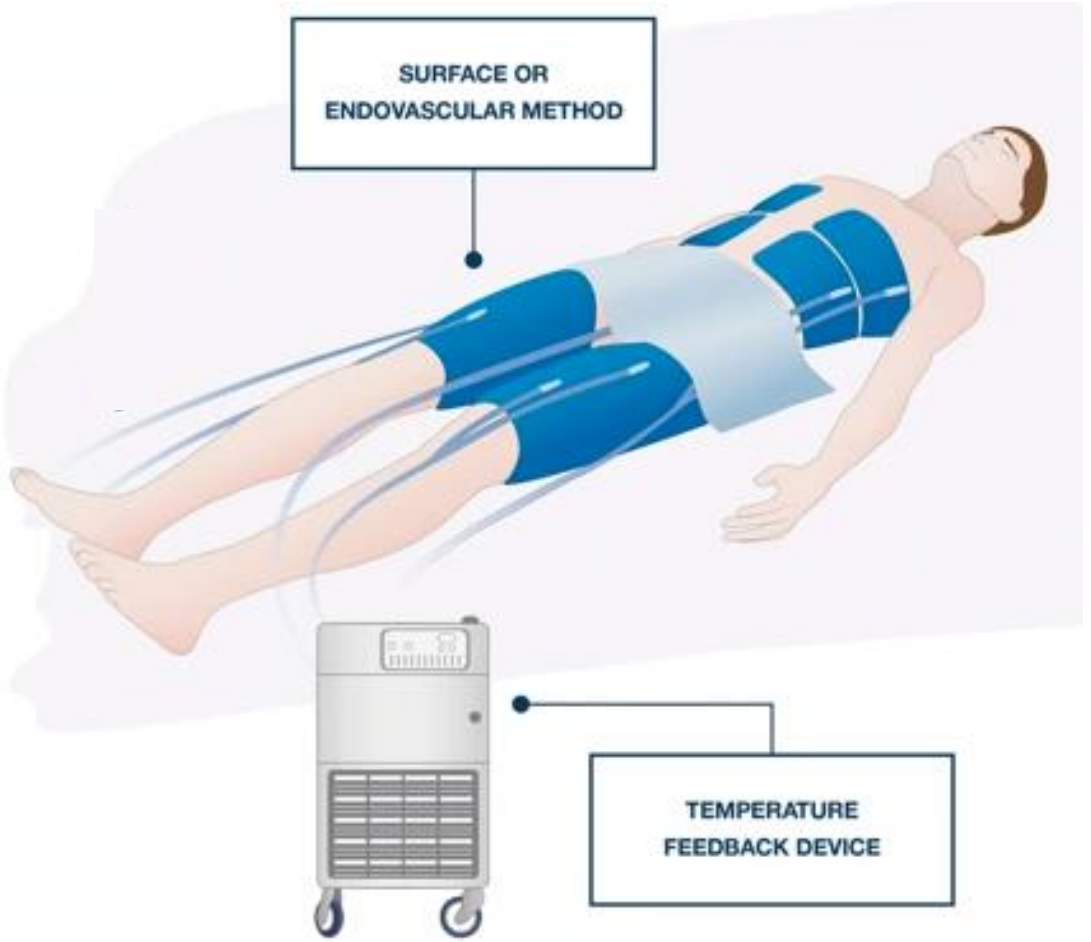


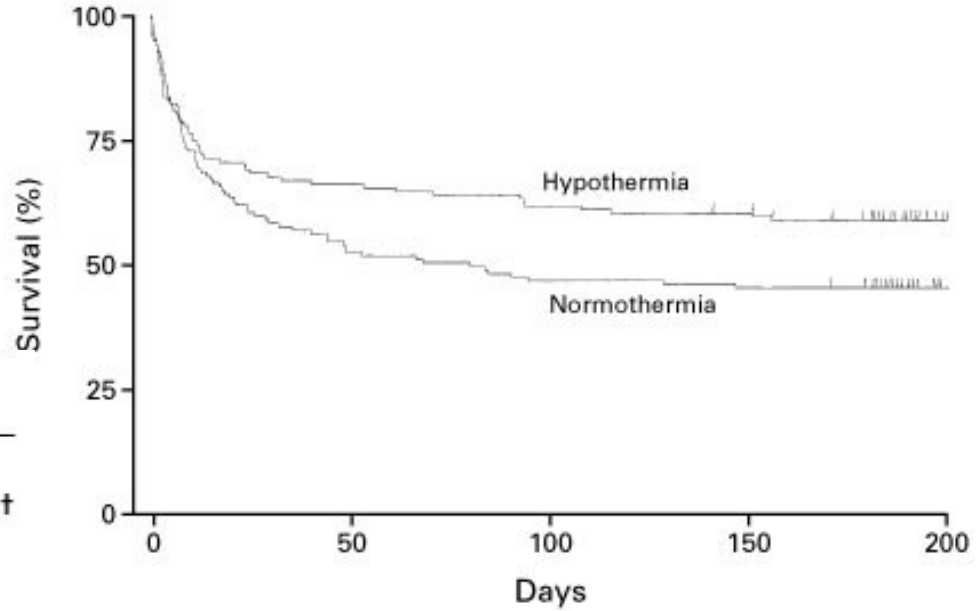
Image source: <https://ccforum.biomedcentral.com/articles/10.1186/s13054-019-2721-1>

Why do TTM?

- Two landmark trials in 2002 published in NEJM showed that cooling:
  - Improves survival
    - NNT = 7 (to prevent 1 death)
  - Improves neurologic outcome

TABLE 2. NEUROLOGIC OUTCOME AND MORTALITY AT SIX MONTHS.

OUTCOME	NORMOTHERMIA	HYPOTHERMIA	RISK RATIO (95% CI)*	P VALUE†
	no./total no. (%)			
Favorable neurologic outcome‡	54/137 (39)	75/136 (55)	1.40 (1.08–1.81)	0.009
Death	76/138 (55)	56/137 (41)	0.74 (0.58–0.95)	0.02

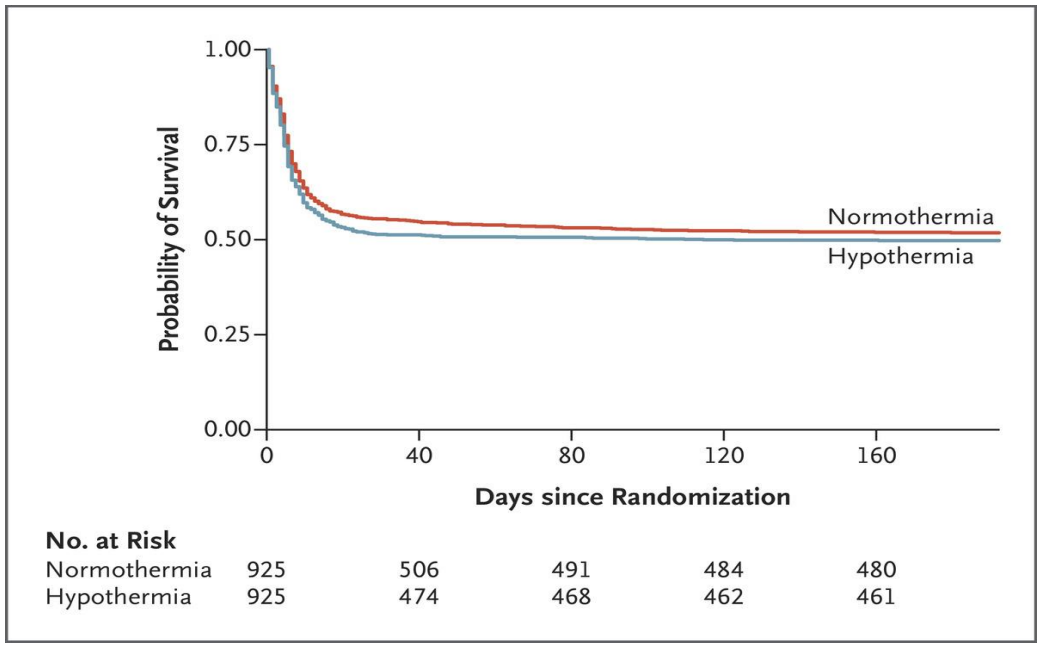


"Mild Therapeutic Hypothermia to Improve the Neurologic Outcome after Cardiac Arrest." NEJM 2002; 346: 549-556.

Bernard, S. et al. "Treatment of Comatose Survivors of Out-of-Hospital Cardiac Arrest with Induced Hypothermia." NEJM 2002; 346: 557-563.

2021 Update

- TTM-2 Trial (June 2021)
  - 1900 patients with OHCA enrolled, 1861 randomized
  - Targeted hypothermia (33°C) vs Targeted normothermia (<37.8 °C)
  - Primary outcome = death @6 months → no difference
  - Secondary outcome = functional status @ 6 months → no difference



Dankiewicz, J et al. "Hypothermia versus Normothermia After Out-of-Hospital Cardiac Arrest." NEJM 2021; 346: 2283-2294.

TTM-2 Controversies

- The trial did not include a group without TTM – does the trial simple demonstrate the benefit of using a protocolized approach to temperature management and/or avoidance of large temperature swings?
- The patient population in this trial (OHCA, s/p bystander CPR, no shock) is different than that of prior TTM trials that have shown benefit – does the trial indicate that we have yet to identify the subgroup of patients who benefit most from TTM?
- Still unclear how the findings from TTM-2 will be incorporated into practice guidelines – will recommendations change?

Taccone, F. et al. "Targeted temperature management and cardiac arrest after the TTM-2 study." Critical Care 2021, 275.

- Has your practice with targeted temperature management changed after the TTM-2 trial?

Time to participate!

Explaining other answers…

(A) STAT head CT to rule out CNS catastrophe.	→ With no focal neuro deficits, likely low yield.
(B) Refer for hyperbaric oxygen for possible hypoxic brain injury.	→ Hypoxic brain injury is not an indication for hyperbaric oxygen.
(C) Begin external cooling of patient to 32° C for 12 hours	→ TTM is recommended for at least 24 hours.
(D) Activate protocol for targeted temperature management of patient.	→ Correct answer!
(E) Hold a family meeting to relay his poor prognosis and discuss withdrawal of care.	→ In patients who are candidates for TTM, neuro-prognostication should occur 72 hrs after the patient returns to normothermia.

Prognosis after arrest

- Poor neurologic outcome associated with:

Clinical Finding	Time after cardiac arrest
Absence of pupillary light reflex	72 hours
Presence of status myoclonus	During first 72 hours
Absence of N20 somatosensory evoked potential cortical wave	24-72 hours
Marked reduction in gray-white ratio on Brain CT	Within 2 hours
Extensive restriction of diffusion on brain MRI	2-6 days
Persistent absence of EEG reactivity to external stimuli	72 hours
Persistent burst suppression or intractable status epilepticus	After rewarming

Neumar, R. et al. "2015 AHA Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care." Circulation 2015; 132: S315-S367.

Prognosis after arrest

- Neurologic prognostication **can not** occur when a patient is cooled
  - Wait 72 hrs after normothermia is achieved to examine and assess
  - Multiple modalities of testing and examination should be used together to predict neurologic outcome

Donnino, M. et al. "Temperature Management After Cardiac Arrest" Circulation. 2015; 132: 2448-2456.

Learning Objectives: Targeted Temperature Management (TTM)

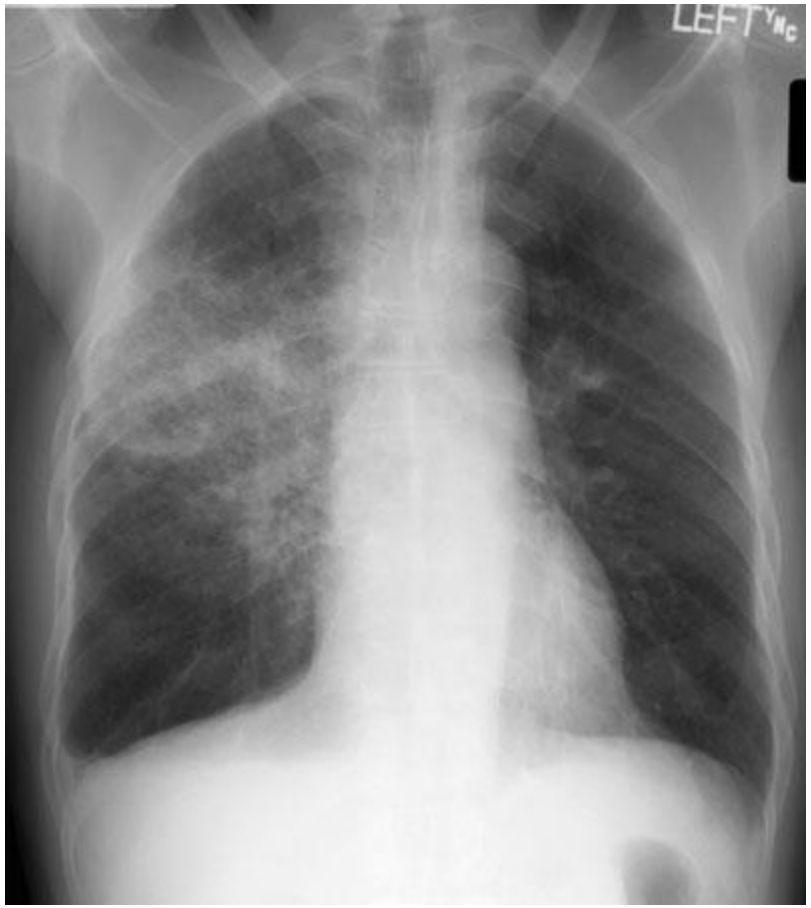
- TTM **improved outcomes** in patients who remain unconscious with ROSC after out of hospital cardiac arrest
  - Improvement in survival and neurologic function
- TTM with a goal temperature of 33°C does not confer benefit compared to 36°C (NEJM 2013) or >37.8 °C (NEJM 2021)
- Neuro-prognostication can not be performed when a patient is hypothermic
  - Though there are clinical markers of poor prognosis earlier, wait 72 hours after the patient is normothermic to formally assess and prognosticate

Dankiewicz, J et al. "Hypothermia versus Normothermia After Out-of-Hospital Cardiac Arrest." NEJM 2021; 346: 2283-2294.

Nielsen, N. et al "Targeted Temperature Management at 33C versus 36C after Cardiac Arrest." NEJM 2013; 369:2197-2206.

Question 4:

- An 81-year-old man with a past medical history of HTN, DM2, and mild emphysema is admitted with pneumonia.
- Vital signs:
  - BP 100/60 (baseline 140/80)
  - HR 110 bpm
  - SpO2 92% on 10L
  - Temp 101.8 F
- Labs:
  - WBC 15K
  - Cr 1.2 (baseline 1)
  - Electrolytes normal
  - Glucose 220



Question 4:

- Before transfer out of the ED, the patient was given 1L of normal saline, blood cultures were drawn, and empiric broad spectrum antibiotics started.
- He became progressively altered and was ultimately intubated for acute hypoxemic and hypercarbic respiratory failure prior to transfer to the ICU.
    - Blood pressure remains low
    - Urine output 10cc in the last hour
    - Lactate is elevated

Question 4:

Which of the following is true regarding fluids for this patient with septic shock?

(A) Compared to crystalloids, resuscitation with colloids cause less renal dysfunction but increased mortality.

(B) Resuscitation with hydroxyethyl starch is associated with decreased mortality.

(C) Resuscitation with balanced crystalloids may cause less renal dysfunction than unbalanced crystalloids.

(D) Normal saline is the most commonly used balanced crystalloid resuscitation fluid.

(E) Resuscitation with crystalloids combined with albumin is associated with a mortality benefit.

Question 4:

Which of the following is true regarding fluids for this patient with septic shock?

(A) Compared to crystalloids, resuscitation with colloids cause less renal dysfunction but increased mortality.

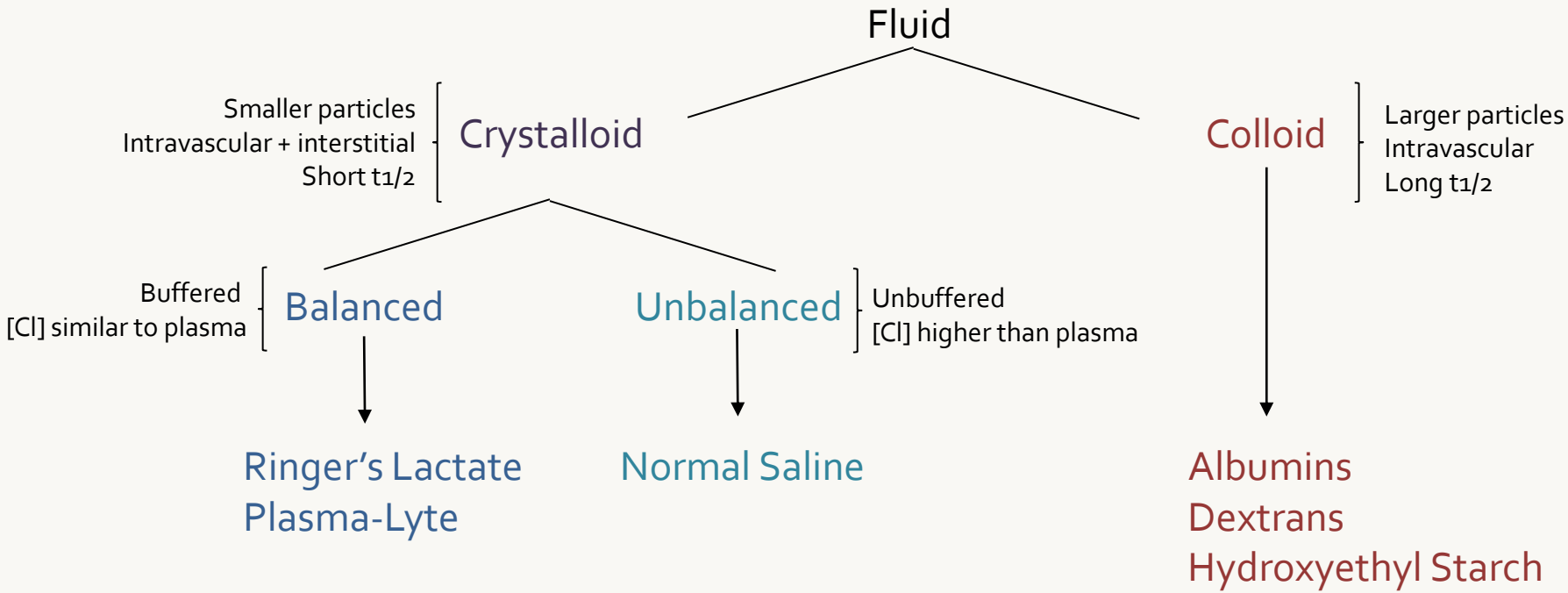
(B) Resuscitation with hydroxyethyl starch is associated with decreased mortality.

(C) Resuscitation with balanced crystalloids may cause less renal dysfunction than unbalanced crystalloids.

(D) Normal saline is the most commonly used balanced crystalloid resuscitation fluid.

(E) Resuscitation with crystalloids combined with albumin is associated with a mortality benefit.

Fluid Resuscitation: Types of Fluid



Fluid for Resuscitation in Sepsis

- Colloid vs Crystalloid?
  - **Point:** Colloid may be protective of renal function given its tendency to remain intravascular as this could help the kidney maintain an adequate GFR.
  - **Counterpoint**: With the capillary dysfunction that occurs with sepsis, the potential benefit of colloid fluid remaining intravascular may be minimal or non-existent.

Fluid for Resuscitation in Sepsis

- Colloid vs Crystalloid?
  - SAFE 2004 (NEJM): albumin vs. saline
    - no difference in new organ failure, need for RRT, volume of fluid needed
  - CRISTAL 2013 (JAMA): colloid (albumin, dextran, HES, etc.) vs. crystalloid (NS, LR etc.)
    - no difference mortality or need for RRT
  - ALBIOS 2014 (NEJM): crystalloid + albumin vs. crystalloid alone
    - no diff mortality, renal injury, need for RRT
  - Meta-analysis of 9 studies with HES vs. crystalloids or albumin
    - Higher risk mortality and dose dependent effect causing AKI and need for RRT

Finfer, S. et al. "A comparison of albumin and saline for fluid resuscitation in the intensive care unit". NEJM. 2004. 350:2247-2256.

Annane D, et al. "Effects of fluid resuscitation with colloids vs. crystalloids on mortality in critically ill patients presenting with hypovolemic shock" JAMA. 2013. 310: 1809-1817.

Caironi P, et al. "Albumin replacement in patients with severe sepsis or septic shock". NEJM. 2014. 370(15):1412-1421.

Rhodes, A., et al. "Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock 2016." Intensive Care Medicine. 2017. 43: 304-377.

Fluid for Resuscitation in Sepsis

- Colloid vs Crystalloid?
  - No difference in outcomes aside from hydroxyethyl starches
    - Guidelines recommend <u>against</u> use of hydroxyethyl starches
  - **Guidelines recommend use of crystalloids for resuscitation** over colloids
    - Given similar outcomes and lower cost in most of the world

Rhodes, A., et al. "Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock 2016." Intensive Care Medicine. 2017. 43: 304-377.

- Do you use colloids for resuscitation of septic shock in any particular scenarios?

Time to participate!

Fluid for Resuscitation in Sepsis

- Balanced vs unbalanced crystalloids?
  - **Point**: Fluids with [Cl] > plasma chloride may cause GFR to fall by offsetting natural compensatory mechanism of kidney to maintain GFR via sensing at the macula densa
  - **Counterpoint**: Unclear if this natural compensatory mechanism, and the impact of high [Cl] fluids, is altered in patients with septic physiology.

Fluid for Resuscitation in Sepsis

- Balanced vs unbalanced crystalloids?
  - Yunos et al., JAMA 2012: pre/post study, chloride-rich vs chloride-poor IVF
    - Balanced fluids associated with less AKI and less need for RRT
    - Limited by pre/post design + changing standard of care re. timing of initiating RRT
  - SPLIT, JAMA 2015: multicenter RCT of balanced vs unbalanced fluid, med/surg ICUs
    - No difference AKI or need for RRT
  - SALT-ED, NEJM 2018: open-label single center RCT (LR/PL vs. NS), ED patients
    - No difference in median hospital-free days (to day 28)
    - Balanced fluids better on composite outcome (death, new RRT, persistent renal dysfunction)
  - SMART, NEJM 2018: open-label single center RCT (LR/PL vs NS) med/surg ICUs
    - Balanced fluid better on composite outcome (death, new RRT, persistent renal dysfunction)

Yunos, N., et al. "Association Between a Chloride-Liberal vs Chloride-Restrictive Intravenous Fluid Administration Strategy and Kidney Injury in Critically Ill Adults." JAMA. 2012; 308: 1566-1572.

Young, P., et al. "Effect of a Buffered Crystalloid Solution vs Saline on Acute Kidney Injury Among Patients in the ICU." JAMA. 2015. 314: 1701-1710.

Self W, et al. "Balanced crystalloids versus saline in noncritically ill adults". NEJM. 2018. 378(10):819-828.

Semler MW, et al. "Balanced Crystalloids versus Saline in Critically Ill Adults". NEJM. 2018. 378(9):829-839.

Fluid for Resuscitation in Sepsis

- Balanced vs unbalanced crystalloids?
  - 2021 surviving sepsis campaign has changed recommendation from 'either balanced crystalloids or saline' and now suggests using balanced crystalloids instead of normal saline for resuscitation
    - Though the recommendation is weak and with low quality of evidence, given the conflicting studies and major limitations to the existing studies

Evans, L, et al. "Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock 2021." Critical Care Medicine. Nov 2021. 49: p e1063-e1143.

Explaining other answers…

(A) Compared to crystalloids, resuscitation with colloids cause less renal dysfunction but increased mortality. → There is no difference in renal dysfunction or mortality associated with use of crystalloids or colloids for resuscitation.

(B) Resuscitation with hydroxyethyl starch is associated with decreased mortality. → Hydroxyethyl starch is associated with renal dysfunction, not decreased mortality.

(C) Resuscitation with balanced crystalloids may cause less renal dysfunction than unbalanced crystalloids. → Correct answer!

(D) Normal saline is the most commonly used balanced crystalloid resuscitation fluid. → Normal saline is an unbalanced crystalloid fluid.

(E) Resuscitation with crystalloids combined with albumin is associated with a mortality benefit. → There is no mortality benefit to resuscitation with crystalloids with albumin compared to crystalloids alone.

Learning Objectives: Fluid Resuscitation

- Type of fluid for resuscitation in septic shock seems to impact outcomes
  - Crystalloids are recommended over colloid for initial resuscitation because there is no clear benefit (regarding renal dysfunction or mortality) to using colloids and colloids often cost more
  - Hydroxyethyl starches should be avoided for resuscitation, they cause renal dysfunction in a dose-responsive pattern
  - Data suggests balanced crystalloids may be associated with improved outcomes (renal dysfunction and mortality)

Questions?

Thank you for your time and participation!