You have just admitted a 28 year-old male with an asthma exacerbation. He was intubated in the ED for labored breathing and his initial vitals after intubation were fine. He’s now hypotensive with BP 82/50, HR 130, RR 32. He looks uncomfortable and his breath sounds are diminished. Vent settings include AC, Vt 500, RR 12, 100% FiO2, 5 PEEP Peak pressures = 50, Plateau pressures = 32, Auto-PEEP = 15

What is the most likely cause for his hypotension?
A. Tension pneumothorax
B. Hypovolemia
C. Auto-PEEP with breath stacking
D. Septic shock

Peak Inspiratory Pressure

- Maximum airway pressure measured - almost always occurs at the end of inspiration
- "Dynamic" - measured during flow
- Increases with flow rates, airway resistance, patient-ventilator dysynchrony
**Inspiratory Plateau Pressure**

- Airway pressure measured at end of inspiration with no gas flow present (during breath hold)
- Estimates alveolar pressure at end-inspiration
- Indirect indicator of alveolar distension

**Inspiratory Plateau Pressure**

- Increased with:
  - States that decrease lung compliance
  - ARDS, pulmonary fibrosis, obesity, large pleural effusions, abdominal compartment syndrome

- High inspiratory plateau pressure can lead to:
  - Barotrauma, volutrauma
    - Pneumothorax at IPP > 30 cm H₂O
  - Impaired venous return to the right heart
  - Decreased cardiac output

**Inspiratory Plateau Pressure (IPP)**

Methods to decrease IPP:
1. Correct underlying states if present
   - Drain effusions, tap ascites, etc
2. Decrease PEEP
3. Decrease tidal volume
Auto-PEEP

- Auto-PEEP is the pressure in the airways at end expiration
- Can be measured on most ventilators
- Increases peak, plateau, and mean airway pressures
- Potential harmful physiologic effects

Auto-PEEP

- Reduce auto-PEEP by shortening inspiratory time
  - Decrease respiratory rate
  - Decrease tidal volume
  - Increase gas flow rate

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A. Tension pneumothorax
B. Hypovolemia
C. Auto-PEEP with breath stacking
D. Septic shock
Case 2

Continued

A 28 year-old male with an asthma exacerbation has just been admitted to the ICU. He is on mechanical ventilation and is hypotensive. He is uncomfortable with a RR of 34. You diagnose breath stacking with auto-PEEP = 15 cm H$_2$O.

Vent settings include AC, Vt 600, RR 16, 100% FiO2, 5 PEEP
Peak pressures = 50, Plateau pressures = 35, Insp time = 1sec

What is the next best step to reduce auto-PEEP?

A. Reduce ventilator rate to 12
B. Increase inspiratory time to 2 seconds
C. Reduce tidal volume to 400 cc
D. Give sedation / analgesia to reduce patients respiratory rate
E. C and D
Inspiratory Time: Expiratory Time (I:E ratio)

- Spontaneous breathing I:E = 1:2
- Determinants of inspiratory time
  - Tidal volume
  - Gas flow rate
  - Respiratory rate
  - Inspiratory pause
- Expiratory time passively determined

Examples

- Vent 1
  - Assist control, Vt 600, RR 10
  - Insp time = 1 second
  - Exp time = 5 seconds
Inspiratory Time: Expiratory Time Examples

• Vent 1
  – Assist control, VT 600, RR 10
  – Insp time = 1 second
  – Exp time = 5 seconds

• Vent 2
  – Assist control, VT 600, RR 20
  – Insp time = 1 second
  – Exp time = 7

I:E Ratio During Mechanical Ventilation

• Problems can arise when the expiratory time is too short to permit full exhalation
  – Breath stacking
  – Auto-PEEP

• Increased intrathoracic pressure can result in:
  – Decreased venous return
  – Decreased cardiac output
  – Tachycardia, hypotension, hypoxemia

• The way to fix auto-PEEP is to allow the lungs to fully empty
Return to the case

• Vent: AC, Vt 600, RR 16, 100% FiO2, 5 PEEP, Insp time = 1 sec
• Peak pressure 50 cm H2O, IPP 35 cm H2O, auto-PEEP 15
• Total rate 30 breaths/min
• I:E ratio = 1:1
• pH 7.20, PaCO2 60 torr, PaO2 215 torr, SpO2 100%
• BP 90/60 mm Hg, heart rate 130–140 beats/min

Analysis

• Hypercapnia
• High peak airway pressure
• Wide peak-plateau pressure difference
• High auto-PEEP
• High minute ventilation, increased PaCO2
• Hypotension and tachycardia (from auto-PEEP)
How to Fix the Vent

- The patient has breath stacking and Auto-PEEP
- We need to increase his expiratory time
  - Decrease respiratory rate
  - Increase inspiratory flow rate (decrease inspiratory time to 0.5 seconds)
- Need to decrease inspiratory tidal volume
- Give bronchodilators
- These interventions will increase expiratory time from 1 second to 5.5 seconds

How to Fix the Vent

- The patient has breath stacking and Auto-PEEP
- We need to increase his expiratory time
  - Decrease respiratory rate
    - Add sedatives
  - Increase inspiratory flow rate (decrease inspiratory time to 0.5 seconds)
- Need to decrease inspiratory tidal volume
- Give bronchodilators
- These interventions will increase expiratory time from 1 second to 5.5 seconds

How to Fix the Vent to Improve Auto-PEEP

- The patient has breath stacking and Auto-PEEP
- We need to increase his expiratory time
  - Decrease respiratory rate
    - Reduce ventilator rate from 16 to 10
  - Increase inspiratory flow rate (decrease inspiratory time to 0.5 seconds)
- Need to decrease inspiratory tidal volume
- Give bronchodilators
- These interventions will increase expiratory time from 1 second to 5.5 seconds
A 28 year-old male with an asthma exacerbation has just been admitted to the ICU. He is on mechanical ventilation and is hypotensive. He is uncomfortable with a RR of 34. You believe that he has breath stacking with auto-PEEP.

Vent settings include AC, Vt 600, RR 16, 100% FiO2, 5 PEEP.
Peak pressures = 50, Plateau pressures = 35, Insp time = 1sec.

What is the next best step to reduce auto-PEEP?

A. Reduce ventilator rate to 12
B. Increase inspiratory time to 2 seconds
C. Reduce tidal volume to 400 cc
D. Give sedation / analgesia to reduce patients respiratory rate
E. C and D

Case 3

A 42-yr old female is admitted after a drug overdose complicated by emesis and aspiration. Intubation, mechanical ventilation, and neuromuscular blockade are initiated in the emergency department:
AC, Vt 680, RR 10, FiO2 100%, PEEP 5. She weighs 68kg.
Vent mechanics include: PPk 52, IPP 48, Auto-PEEP 0, SpO2 86%.
ABG pH 7.38, PaCO2 36, PaO2 54, SpO2 86%.

What is the next best step to optimize the vent?
A. Increase PEEP to 10
B. Reduce tidal volume to 400 cc (6cc/kg)
C. Increase respiratory rate
D. All of the above
**Analysis of Ventilator-Patient Interaction**

- High inspiratory plateau pressure
  - IPP 48 cm H$_2$O
- Hypoxemia despite FiO$_2$ at 1.0
  - SpO$_2$ 86%, P$_{aO_2}$ 54 torr
- Adequate ventilation
  - pH 7.38, PaCO$_2$ 36 torr
- Sedation/neuromuscular blockade

**Fixing the PaO$_2$**

- Hypoxemia despite FiO$_2$ at 1.0
  - SpO$_2$ 86%, P$_{aO_2}$ 54 torr
  - Vent = AC Vt 680, RR 10, FiO2 100%, 5 PEEP
- Solution = ?
- Consequences = ?

**Fixing the PaO$_2$**

- Hypoxemia despite FiO$_2$ at 1.0
  - SpO$_2$ 86%, P$_{aO_2}$ 54 torr
  - Vent = AC Vt 680, RR 10, FiO2 100%, 5 PEEP
- Solution = Increase PEEP
- Consequences = increased airway pressures
Fixing the Plateau Pressure

- IPP = 48 cm H2O (Peak = 52)
  - Vent = AC Vt 680, RR 10, FIO2 100%, 5 PEEP
  - Solution = ?

Fixing the Plateau Pressure

- IPP = 48 cm H2O (Peak = 52)
  - Vent = AC Vt 680, RR 10, FIO2 100%, 5 PEEP
  - Solution = Decrease Vt
  - Goal = 6 cc/kg BW (~ 360 cc)
  - Consequences = ?

Fixing the Plateau Pressure

- IPP = 48 cm H2O (Peak = 52)
  - Vent = AC Vt 680, RR 10, FIO2 100%, 5 PEEP
  - Solution = Decrease Vt
  - Goal = 6 cc/kg BW (~ 300 cc)
  - Consequences = drop in minute ventilation
    - Initial MV = .680 x 10 = 6.8 L
    - After change = .360 x 10 = 3.6 L
    - PaCO2 will rise, pH will fall
Fixing the Plateau Pressure

- IPP = 48 cm H₂O (Peak = 52)
  - Vent = AC Vt 680, RR 10, FIO₂ 100%, 5 PEEP
- Solution = Decrease Vt
  - Goal = 6 cc/kg IBW (~ 360 cc)
- Consequences = drop in minute ventilation
  - Initial MV = .680 x 10 = 6.8 L
  - After change = .360 x 10 = 3.6 L
  - PaCO₂ will rise, pH will fall
  - Need to increase the respiratory rate

Patient J.T. - Fixing the IPP

- IPP = 48 cm H₂O (Peak = 52)
  - Vent = AC Vt 680, RR 10, FIO₂ 100%, 5 PEEP
- Solution = Decrease Vt
  - Goal = 6 cc/kg IBW (~ 360 cc)
- Consequences = drop in minute ventilation
  - Initial MV = .680 x 10 = 6.8 L
  - After change = .360 x 10 = 3.6 L
  - Need to increase respiratory rate

Acute Lung Injury - Summary

- Decreased lung compliance results in high airway pressures
- Low tidal volume often needed
- Maintain IPP ≤ 30 cm H₂O
- PEEP to improve oxygenation
A 42-yr old female is admitted after a drug overdose complicated by emesis and aspiration. Intubation, mechanical ventilation, and neuromuscular blockade are initiated in the emergency department:

AC, VT 680, RR 10, FiO2 100%, PEEP 5. She weighs 68kg
Vent mechanics include: PIP 52, IPP 48, Auto-PEEP 0, SpO2 86%
ABG pH 7.38, PaCO2 36, Paco2 54, SpO2 86%

What is the next best step to optimize the vent?
A. Increase PEEP to 10
B. Reduce tidal volume to 400 cc (6cc/kg)
C. Increase respiratory rate
D. All of the above