Troubleshooting the Ventilator

Dr zeinab Naderpour

Assistant professor of Tehran University of Medical Science

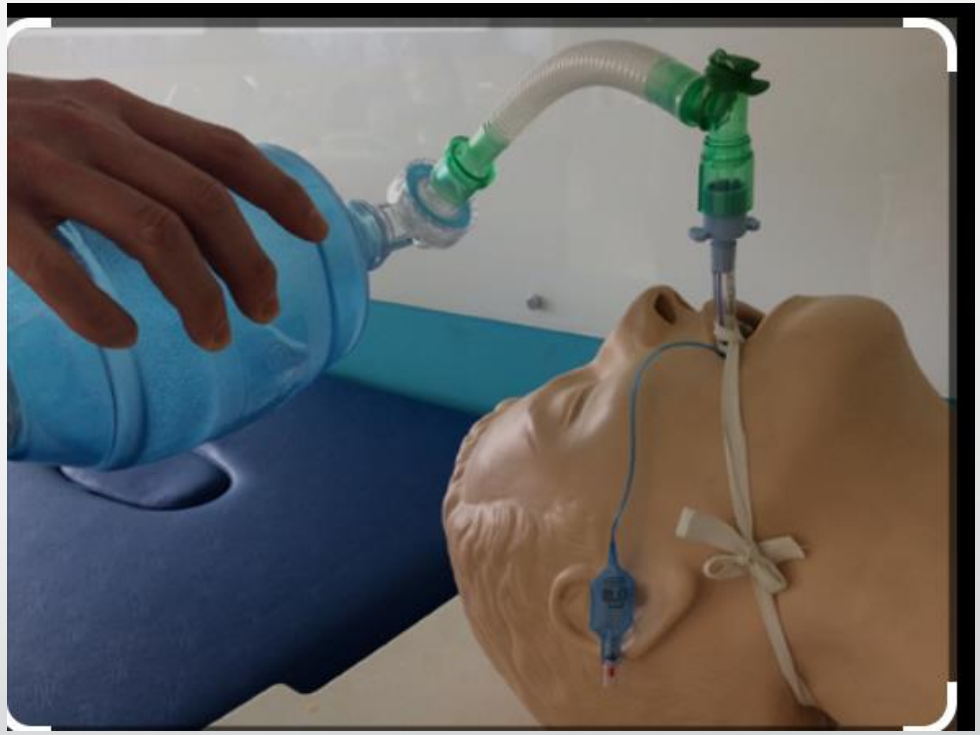
Distressed patients on mechanical ventilation

- A 65 year-old man was admitted to the ICU with pneumonia and was intubated when he developed progressive hypoxemia. He has been on the ventilator for 5 days and has generally been tolerating this therapy well. The nurse calls you because he has all of a sudden become severely agitated and appears to be fighting the ventilator.
- She asks if she can increase the infusion rates on his midazolam and fentanyl drips for sedation.
- **What should you do next?**

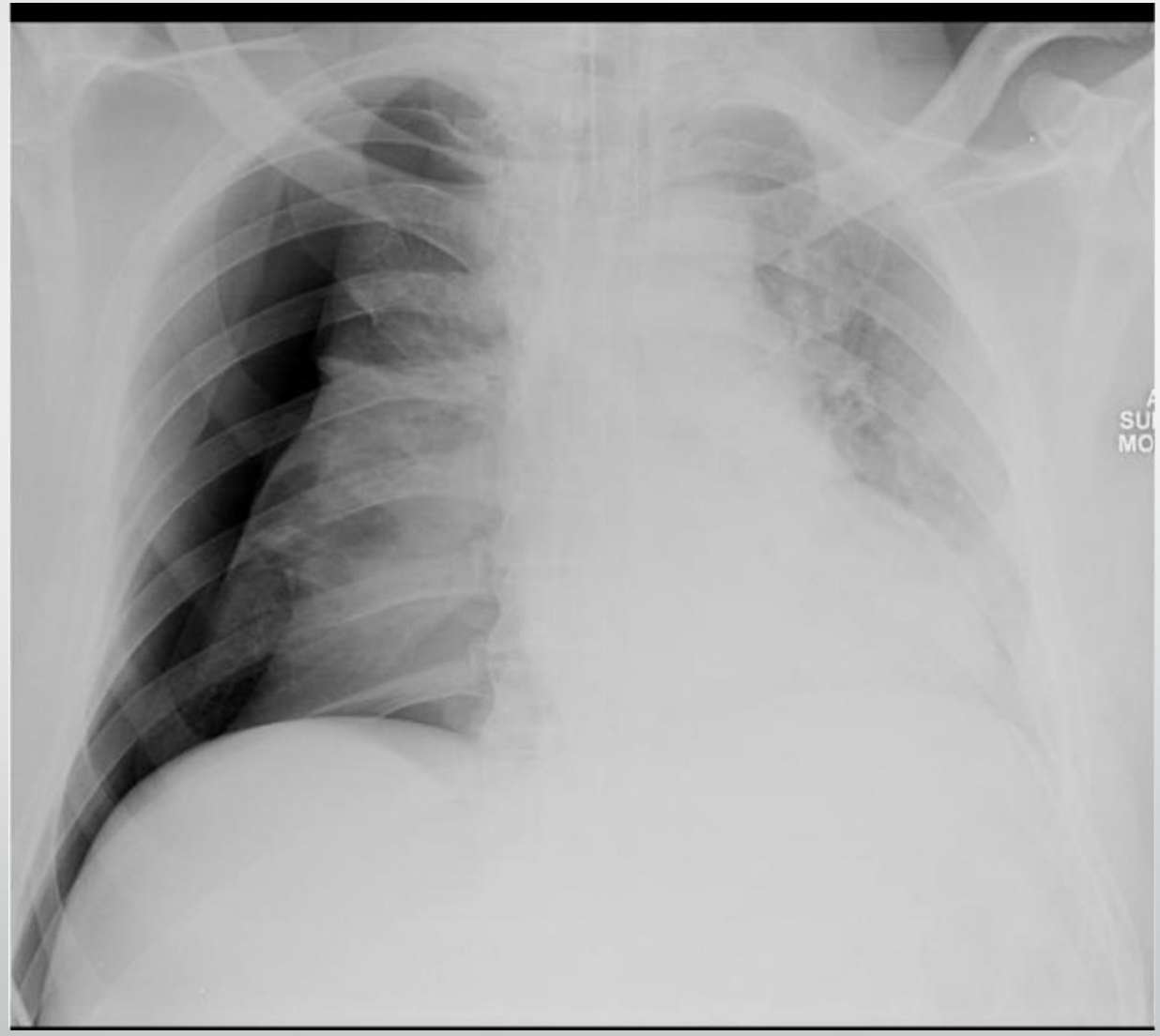
The first step in evaluating the ventilated patient who has a change in clinical status:

assess vital signs

Patients with acute, severe hemodynamic compromise, such as profound hypotension or cardiac arrest, should be removed from the ventilator and bagged manually on 100% oxygen.



While the patient is bagged, the chest should be examined to ensure bilateral breath sounds. Changes in breath sounds may indicate a pneumothorax or migration of the endotracheal tube.



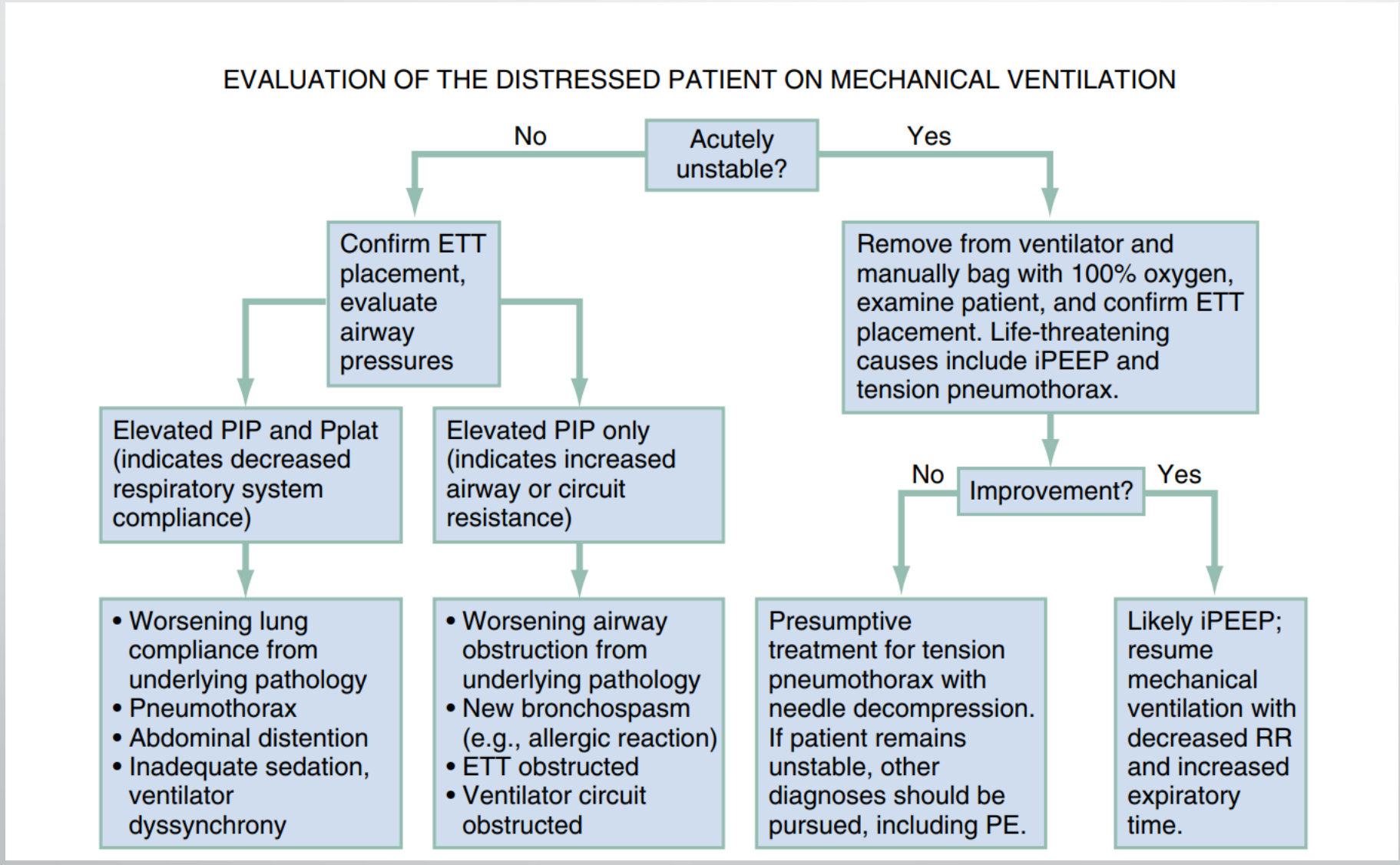
Distressed patients on mechanical ventilation

- Tension pneumothorax, increased iPEEP, and accidental extubation are the most life-threatening concerns in this situation and must be expeditiously addressed.

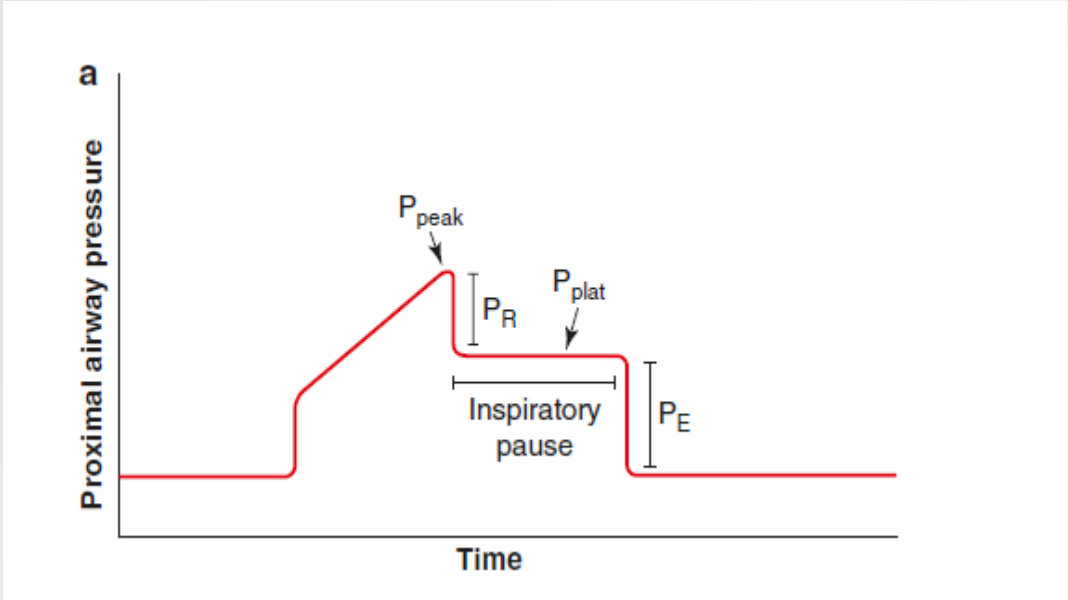
- Clinical examination, oxygen saturation, correlation between set and exhaled tidal volumes, and ETco2 monitoring can be used to assess tube placement, but suspicion of inadvertent extubation should prompt immediate laryngoscopy or endoscopic evaluation of the location of the endotracheal tube.

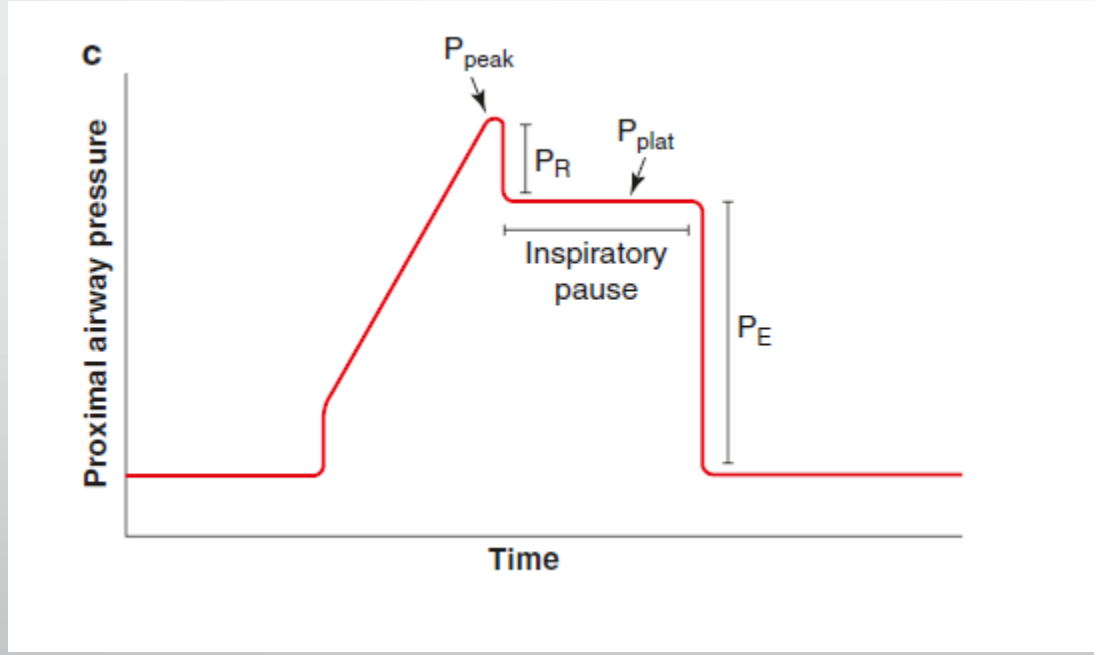
TABLE 2.4 Troubleshooting the Ventilator: Potential Causes of Acute Respiratory Distress

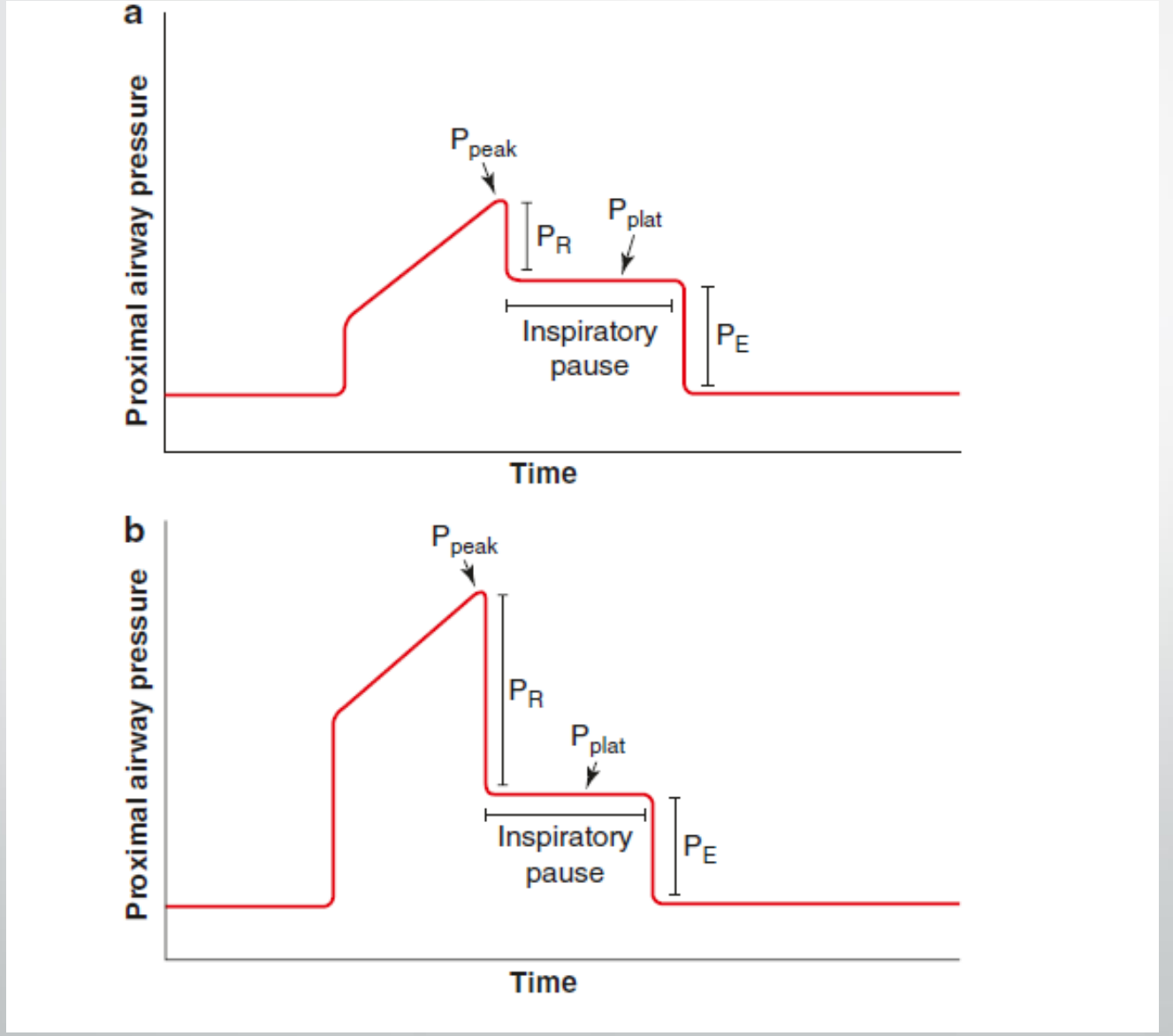
With Hemodynamic Compromise: Immediately Discontinue Mechanical Ventilation and Manually Bag with 100% Oxygen	
Increased intrinsic positive end-expiratory pressure (iPEEP)	
Tension pneumothorax	
Massive pulmonary embolus	
Without Hemodynamic Compromise: Search for Underlying Cause	
Mechanical	Physiologic
Endotracheal tube migration into bronchus	Worsening lung compliance
Endotracheal tube obstruction	Worsening airway obstruction
Endotracheal tube cuff leak	Abdominal distention
Inadvertent extubation	Pulmonary embolus
Discontinuity in ventilator circuit	Pain or inadequate sedation


EVALUATION OF THE DISTRESSED PATIENT ON MECHANICAL VENTILATION
Acutely unstable?
No
Yes
Confirm ETT placement, evaluate airway pressures
Remove from ventilator and manually bag with 100% oxygen, examine patient, and confirm ETT placement. Life-threatening causes include iPEEP and tension pneumothorax.
Elevated PIP and Pplat (indicates decreased respiratory system compliance)
Elevated PIP only (indicates increased airway or circuit resistance)
Improvement?
No
Yes
• Worsening lung compliance from underlying pathology
• Pneumothorax
• Abdominal distention
• Inadequate sedation, ventilator dyssynchrony
• Worsening airway obstruction from underlying pathology
• New bronchospasm (e.g., allergic reaction)
• ETT obstructed
• Ventilator circuit obstructed
Presumptive treatment for tension pneumothorax with needle decompression. If patient remains unstable, other diagnoses should be pursued, including PE.
Likely iPEEP; resume mechanical ventilation with decreased RR and increased expiratory time.

When a patient's condition suddenly deteriorates during mechanical ventilation, a systematic approach should be applied to assess for life-threatening conditions.

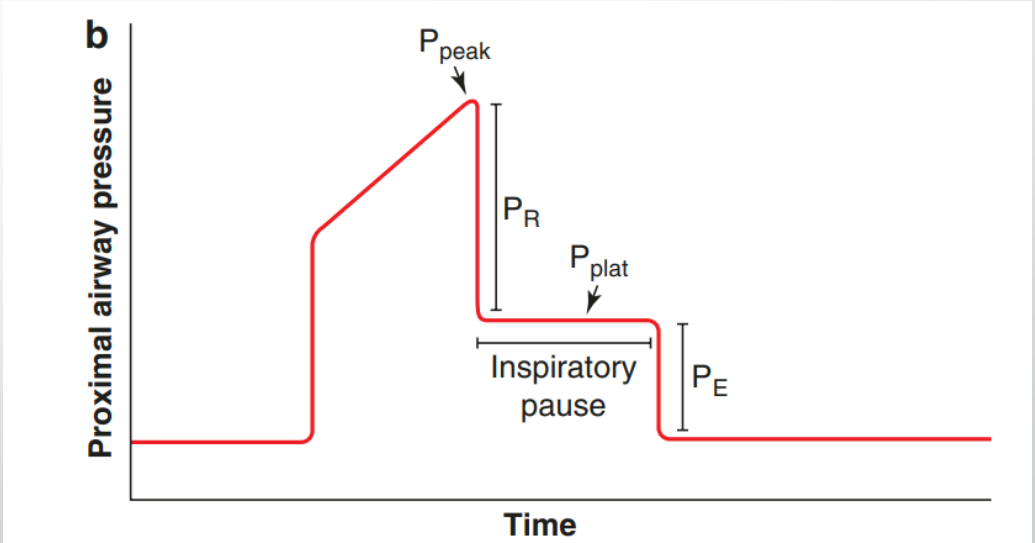

a
Proximal airway pressure
P_{peak}
P_R
P_{plat}
Inspiratory pause
P_E
Time


c
Proximal airway pressure
P_{peak}
P_R
P_{plat}
Inspiratory pause
P_E
Time


a
Proximal airway pressure
P_{peak}
P_R
P_{plat}
Inspiratory pause
P_E
Time
b
Proximal airway pressure
P_{peak}
P_R
P_{plat}
Inspiratory pause
P_E
Time

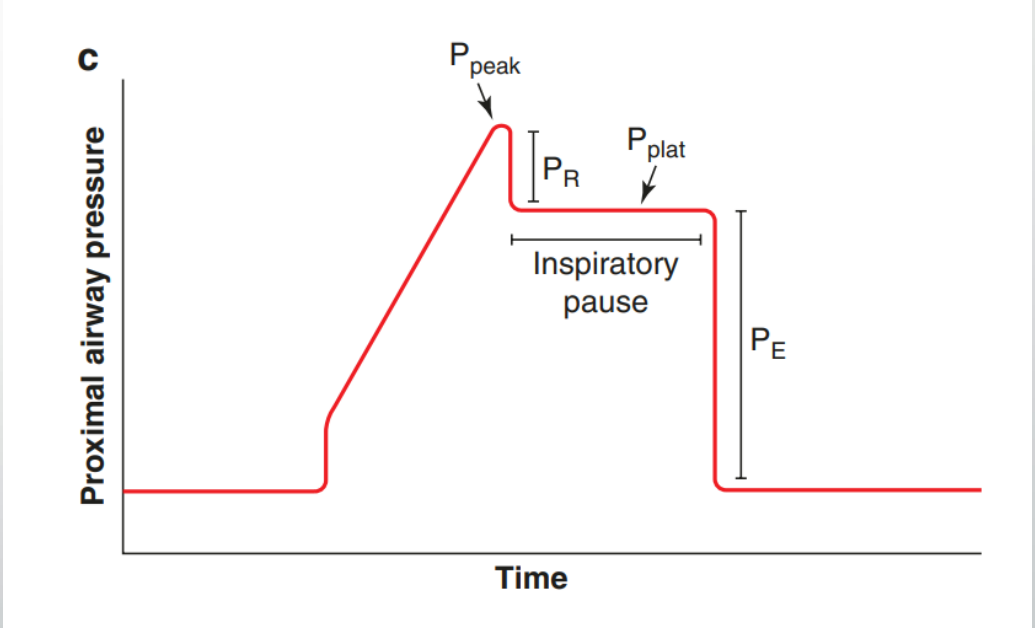
Causes of increased airway resistance

- Biting of endotracheal tube
- Airway secretions
- Bronchoconstriction



Causes of decreased respiratory system compliance:

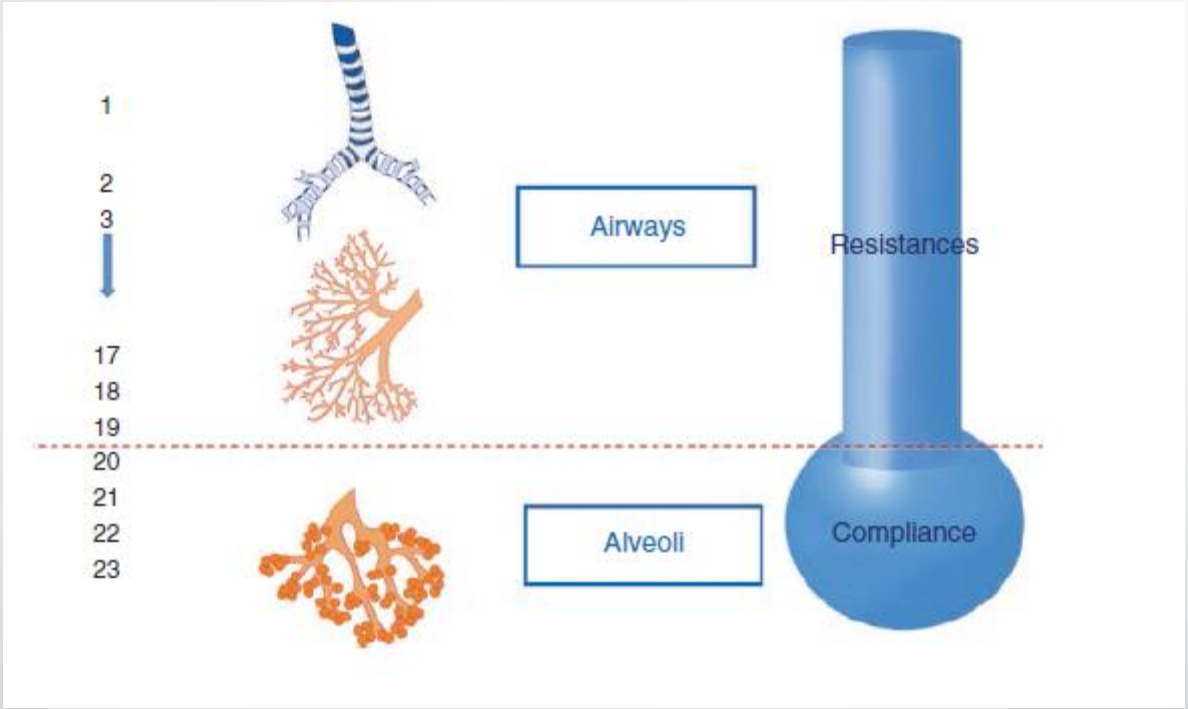
- Pulmonary edema
- Pulmonary fibrosis
- Pneumothorax
- Atelectasis
- Gas trapping
- Ascites
- Obesity
- Pregnancy

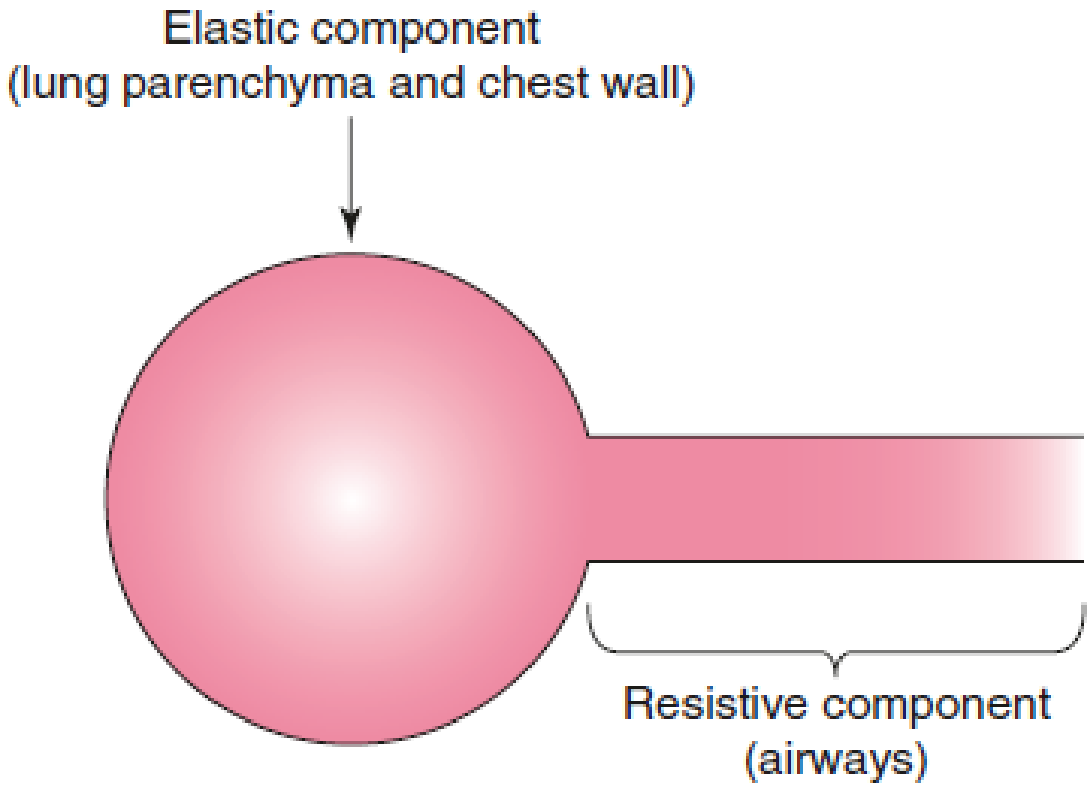


Monitoring respiratory mechanics

Two-Component Model

- break down the respiratory system into two components: the **resistive component** and the **elastic component**.
- The ***resistive component*** is determined by the airways, which are comprised of the endotracheal tube and the patient's own airways.
- The ***elastic component*** is determined by the lung parenchyma and the chest wall.


1
2
3
17
18
19
20
21
22
23
Airways
Alveoli
Resistances
Compliance



$$P_{air} = P_R + P_E$$

FIGURE 4.1 Two-component model of the respiratory system. The respiratory system is composed of a resistive component (airways) and an elastic component (lung parenchyma and chest wall). P_{air} proximal airway pressure; P_E elastic component of proximal airway pressure; P_R resistive component of proximal airway pressure

- To ventilate such a system, there are two main forces that oppose inflation of the balloon:

  1. The impedance to flow, which represents resistance of the airways:

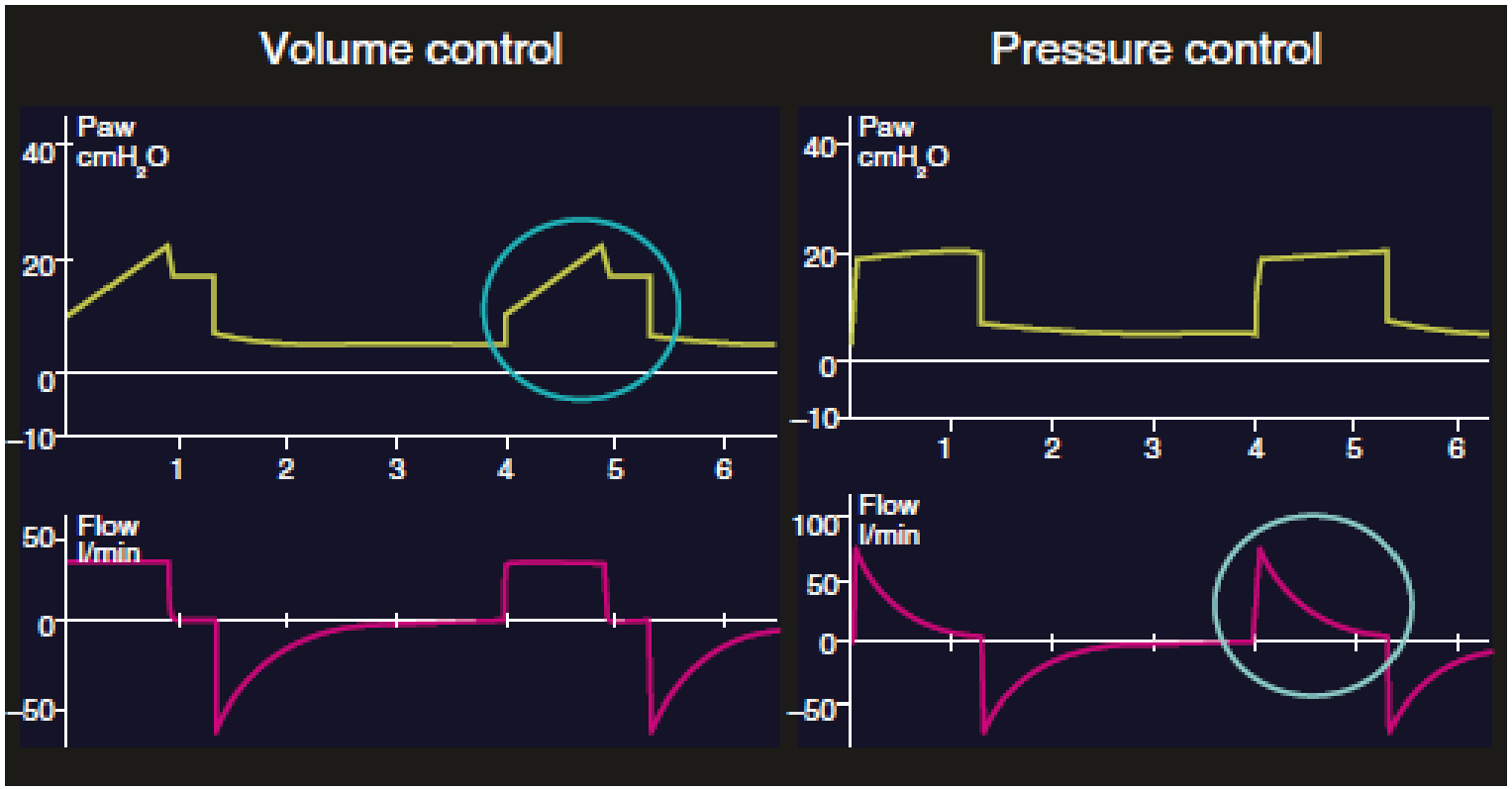
  • Resistance = Δ pressure/flow

  2. The impedance to volumetric expansion, which represents compliance of the lung and chest wall:

  • Compliance = Δ volume/Δ pressure

  • Elastance = Δ pressure/Δ volume

Which Curves Should Be Monitored During Inspiration ?



- The ventilator must provide adequate airway pressure to push air through the resistive component (creating flow), an action analogous to blowing air through a tube.
- The ventilator must also provide adequate airway pressure to inflate the elastic component (filling with volume), an action analogous to inflating a balloon.

Key Concept #1

Two-component model of the respiratory system:

- Resistive component = airways
- Elastic component = lung parenchyma and chest wall

$$P_R = Q \times R$$

$$P_E = \frac{V}{C}$$

$$P_{air} = Q \times R + \frac{V}{C}$$

Compliance is the reciprocal of elastance

Airway Pressures

- Proximal airway pressure will depend on resistance of the airways and compliance of the lung parenchyma and chest wall.
- For a given flow rate and tidal volume, ***peak airway pressure will be elevated in the setting of increased resistance or decreased compliance.***

- **Peak airway pressure** is the maximum proximal airway pressure during the respiratory cycle. For a given flow rate and tidal volume, peak airway pressure will be elevated in the setting of increased resistance or decreased compliance.

plateau pressure

- Proximal airway pressure measured at the end of the inspiratory pause maneuver is known as **plateau pressure**. Plateau pressure will increase with increased tidal volume or decreased respiratory system compliance.

$$\text{Resistance} = (P_{PEAK} - P_{PLAT})/\text{flow}$$

$$C_{STAT} = VT/(P_{PLAT} - PEEP_{TOT})$$

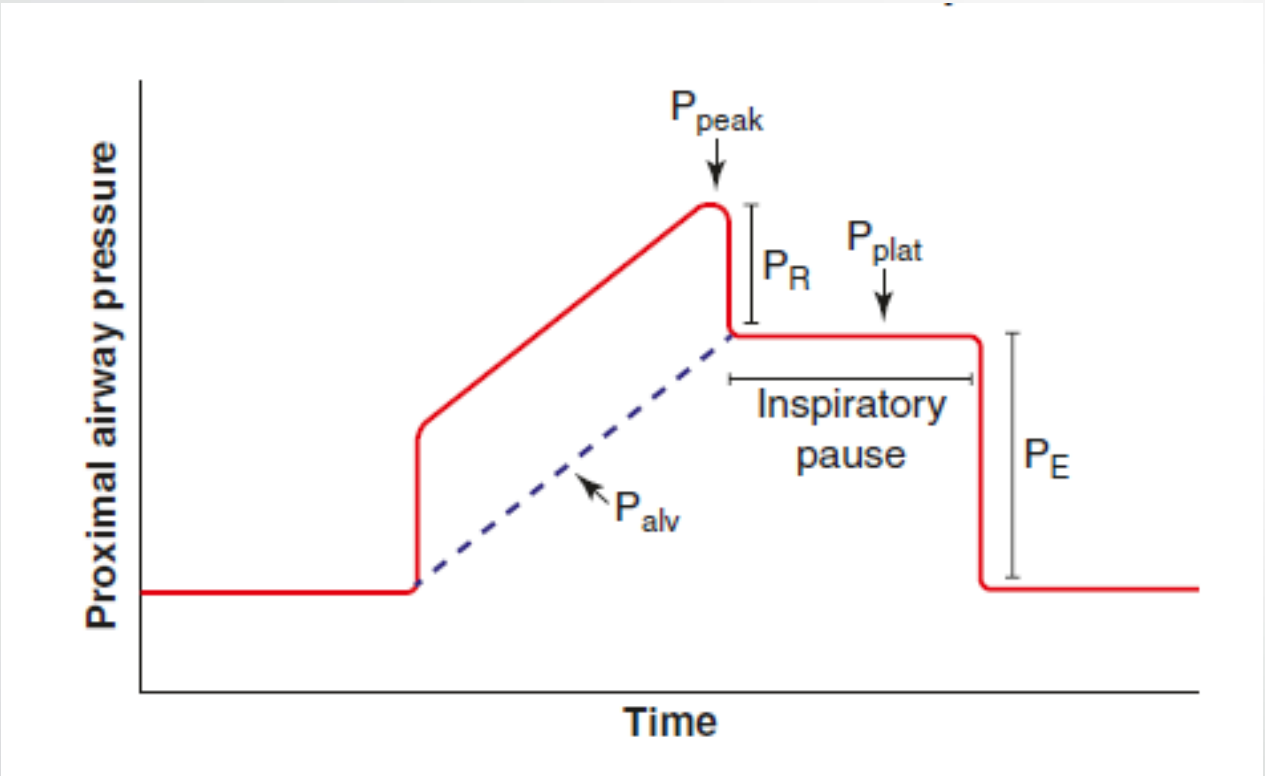
EXAMPLE

- ACV
- VT=500ml flow=60L/min RR=12/min

PEEP=5 cm H_2O

- Ppk=25 cm H_2O
- Ppl=15 cm H_2O
- Resistance= (25−15)/1L/S R=10 cm H2O/L/s
- CSTAT = 500/(15 − 5) C=50 mL/cm H2O

	Normal lung	ARDS	COPD
C_{STAT} (ml/cm H_2O)	45–65	< 45	50–80
R_{INS} (cm H_2O s/l)	10–15	10–15	16–33



Peak and plateau pressures, as measured during VCV, can provide information about a patient's respiratory mechanics

Key Concept #3

Plateau pressure:

- Measure of maximum alveolar pressure during respiratory cycle
- Measured by **inspiratory pause maneuver**
- Higher with increased tidal volume and decreased respiratory system compliance

EXAMPLE

- ACV
- VT=500ml flow=60L/min RR=12/min

PEEP=5 cm H_2O

- Ppk=45 cm H_2O
- Ppl=15 cm H_2O
- Resistance= (45−15)/1L/S R=30 cm H2O/L/s
- CSTAT = 500/(15 − 5) C=50 mL/cm H2O

Key Concept #4

Causes of increased airway resistance:

- Biting of endotracheal tube
- Airway secretions
- Bronchoconstriction

EXAMPLE

- ACV
- VT=500ml flow=60L/min RR=12/min

PEEP=5 cm H_2O

- Ppk=40 cm H_2O
- Ppl=30 cm H_2O
- Resistance= (40−30)/1L/S R=10 cm H2O/L/s
- C_{STAT} = 500/(30 − 5) C=20 mL/cm H2O

Key Concept #5

Causes of decreased respiratory system compliance:

- Pulmonary edema
- Pulmonary fibrosis
- Pneumothorax
- Atelectasis
- Gas trapping
- Ascites
- Obesity
- Pregnancy