The Basics of Mechanical Ventilation

Terrence Shenfield MS, RRT-ACCS, RPFT, NPS, AE-C


0.55
400
0.35
40
4
14
3
0.3

Objectives

- Describe the role of mechanical ventilation
- Describe the settings involved with setting up a mechanical ventilation
- Describe the different pressures related to mechanical ventilation regarding lung mechanics
- Describe different modes of ventilation
- Describe the ventilator alarms and how to set them
- Describe how to wean the patient from mechanical ventilation

What is a mechanical ventilator?

- Ventilators are inspiratory assist devices that integrate volume, pressure, time, and flow (each as dependent or independent variables) to deliver a tidal breath under positive pressure
- They differ from spontaneous breathing

Why do we need to have mechanical ventilators?

- To deliver high concentrations of oxygen into the lungs.
- To help get rid of carbon dioxide.
- To decrease the amount of energy a patient uses on breathing so their body can concentrate on fighting infection or recovering.
- Patients under general anesthesia.
- Patients who are not breathing because of injury to the nervous system, like the brain or spinal cord, or who has very weak muscles.
- To breathe for a patient who is unconscious because of a severe infection, build up of toxins, or drug overdose.

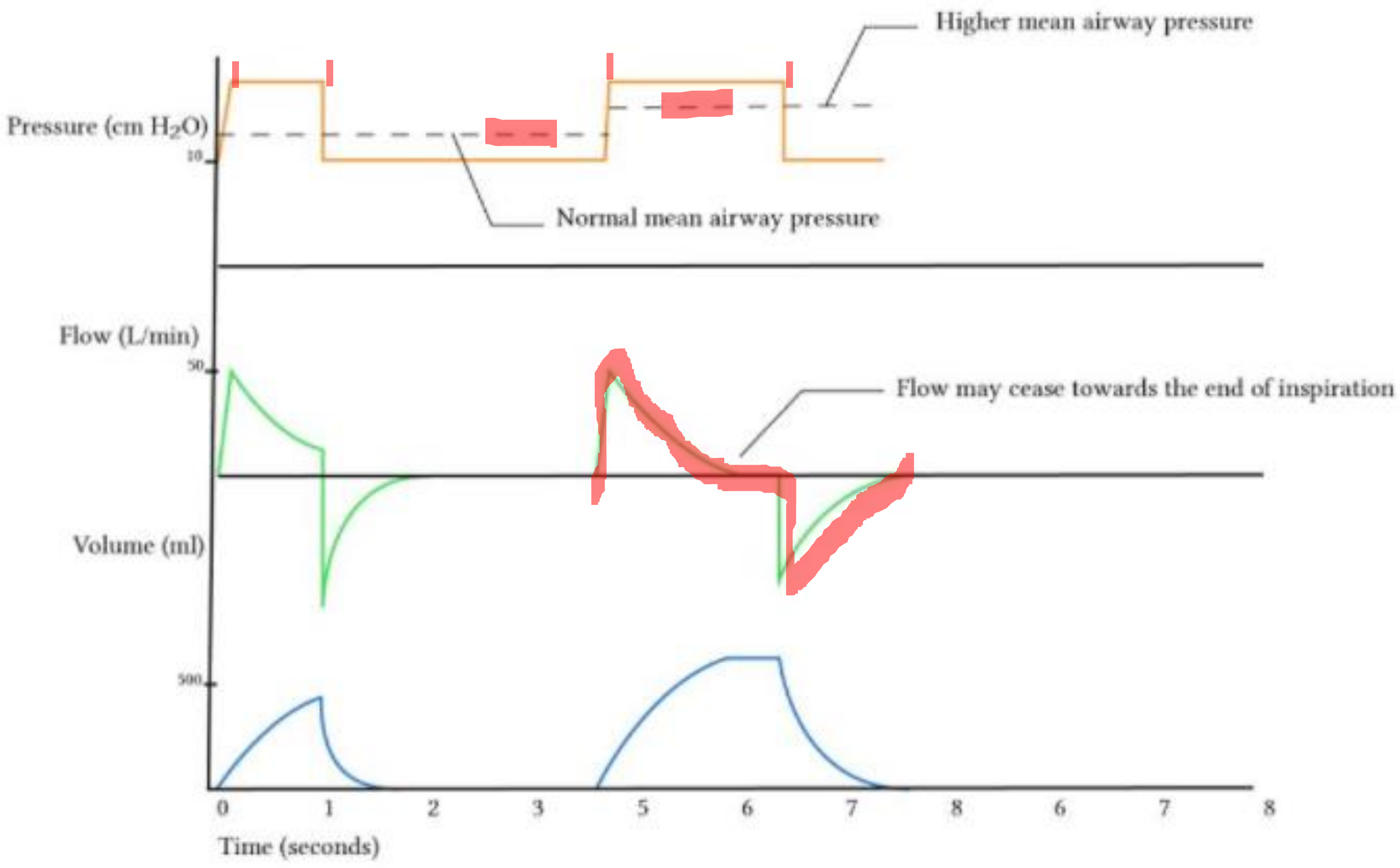
What is tidal volume?

- Tidal volume during normal spontaneous breathing equals 5 ml/kg
- Preferred tidal volume = 7-8 ml/kg
- ARDS patients is 4-6 ml/kg
- Determining Ideal or Predicted Body Weight
- The ideal body weight is based on height as lung volume does not change based on gaining or losing weight
- Male: 50 + (0.91) [height (cm) – 152.4] or 50 + 2.3[height (inches) – 60]
- Female: 45.5 + (0.91) [height (cm) – 152.4] or 45.5 + 2.3[height (inches) – 60]

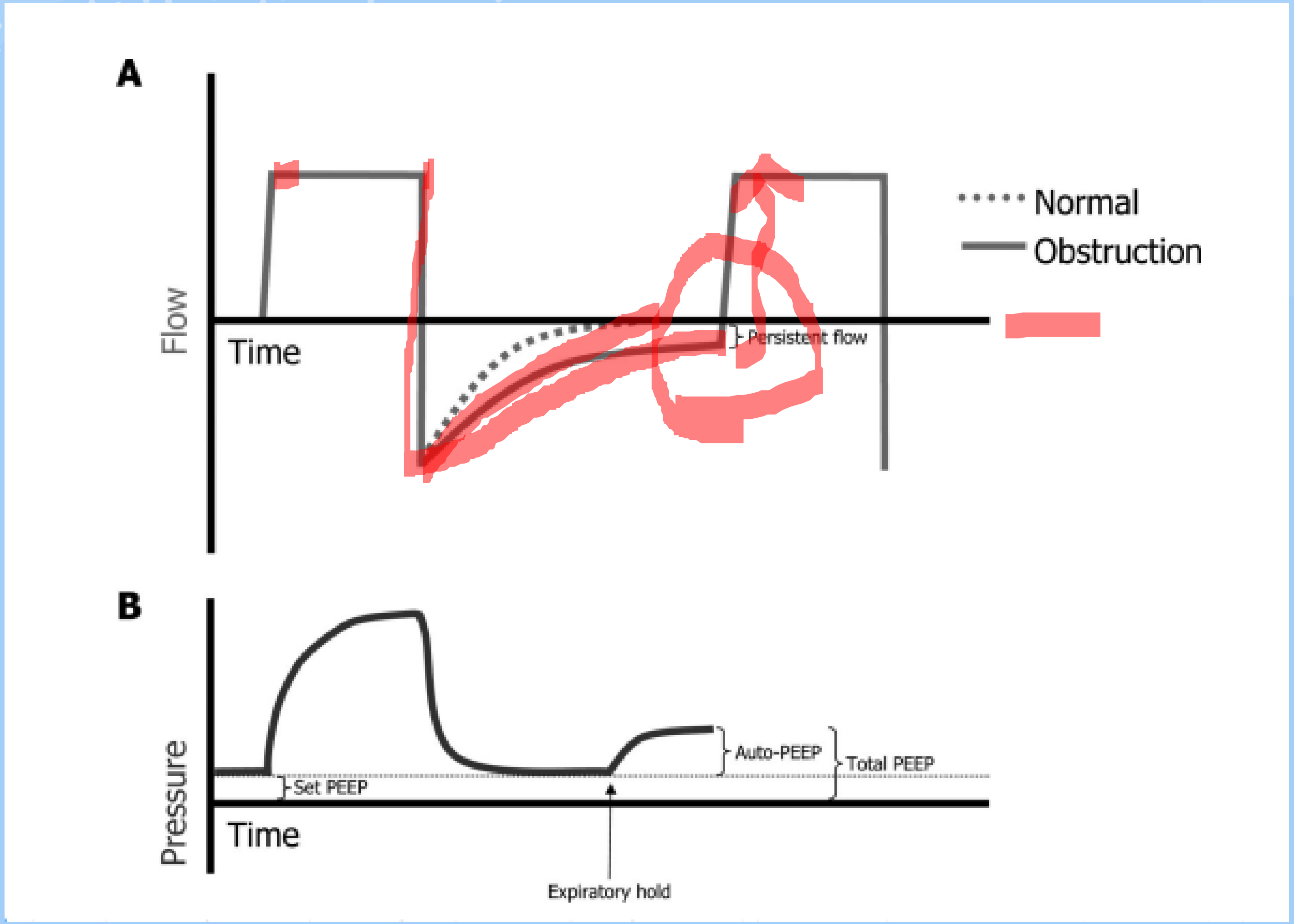
Respiratory rate

- A respiratory rate (RR) of 8-12 breaths per minute is recommended for patients not requiring hyperventilation for the treatment of toxic or metabolic acidosis, or intracranial injury.
- Obese patients tend to have higher respiratory rates and lower tidal volumes
- Respiratory rate times tidal volume is minute ventilation
- Normal minute ventilations is 5 to 8 LPM

Inspiratory time
1-1.5 seconds
Make it shorter in cases of air trapping



Auto-PEEP



A
Flow
Time
Normal
Obstruction
Persistent flow
B
Pressure
Time
Set PEEP
Auto-PEEP
Total PEEP
Expiratory hold

Inspiratory Flow

- Spontaneous breathing patients breathe about 20 to 30 liters per minute
- Patients on mechanical ventilation are typically set to an inspiratory flow of approximately 60 liters per minute in most cases
- Volume cycled modes typically have a set inspiratory flow except for PRVC, VC+, or autoflow
- Pressure control ventilation has a variable flow based upon inspiratory needs

PEEP

- 5-8 cm H_2O for healthy lungs
- Increase as needed to achieve adequate oxygenation in "sick" lungs or if there is bronchomalacia and a need to "stent" the airways
- Can sometimes be detrimental if there is significant air trapping.
- This can be checked via end expiratory hold, giving a measure of AUTO PEEP (Intrinsic PEEP).
- This will be elevated with air trapping or significant airway resistance.
- Generally, set PEEP 1-2 below Auto PEEP or Intrinsic PEEP

FIO2

- The FiO2, or fraction of inspired oxygen, is the concentration of oxygen that is being inhaled by the patient.
- 30% in healthy lungs, goal to maintain <50-60% to avoid oxygen toxicity
- For patient with severe hypoxemia, an FiO2 of 100% may be required when mechanical ventilation is initiated.
- But your goal should be to wean the FiO2 down to the lowest possible level that provides adequate oxygenation.
- If a patient receives an FiO2 > 60% for a prolonged period, it increases their chances of oxygen toxicity.

$$\text{Raw} = \frac{\text{Peak airway pressure} - \text{Plateau pressure}}{\text{Flow in L/sec}}$$

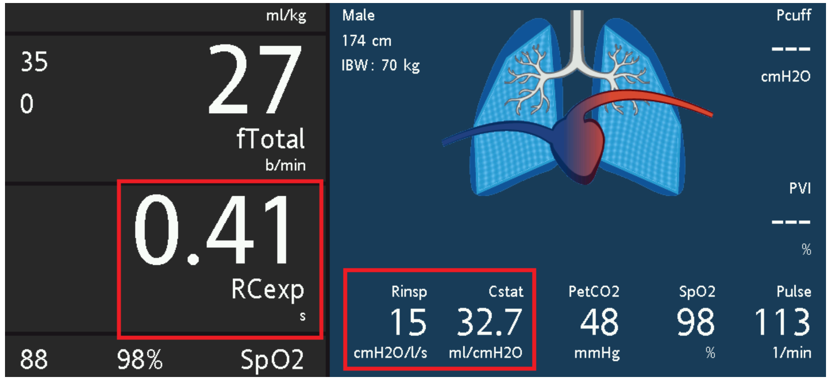
$$\text{Raw} = \frac{30\ \text{cm}\ H_2O - 20\ \text{cm}\ H_2O}{1\ \text{L/sec}} = 10\ \text{cm}\ H_2O/\text{L/sec}$$

$$\text{Compliance} = \frac{\Delta\ \text{Volume}}{\Delta\ \text{Pressure}}$$

$$\text{Compliance} = \frac{\Delta\ \text{Volume/time}}{\Delta\ \text{Pressure/time}}$$

Therefore:

$$\text{Compliance} = \frac{\dot{V}}{\Delta\ \text{Pressure/time}}$$



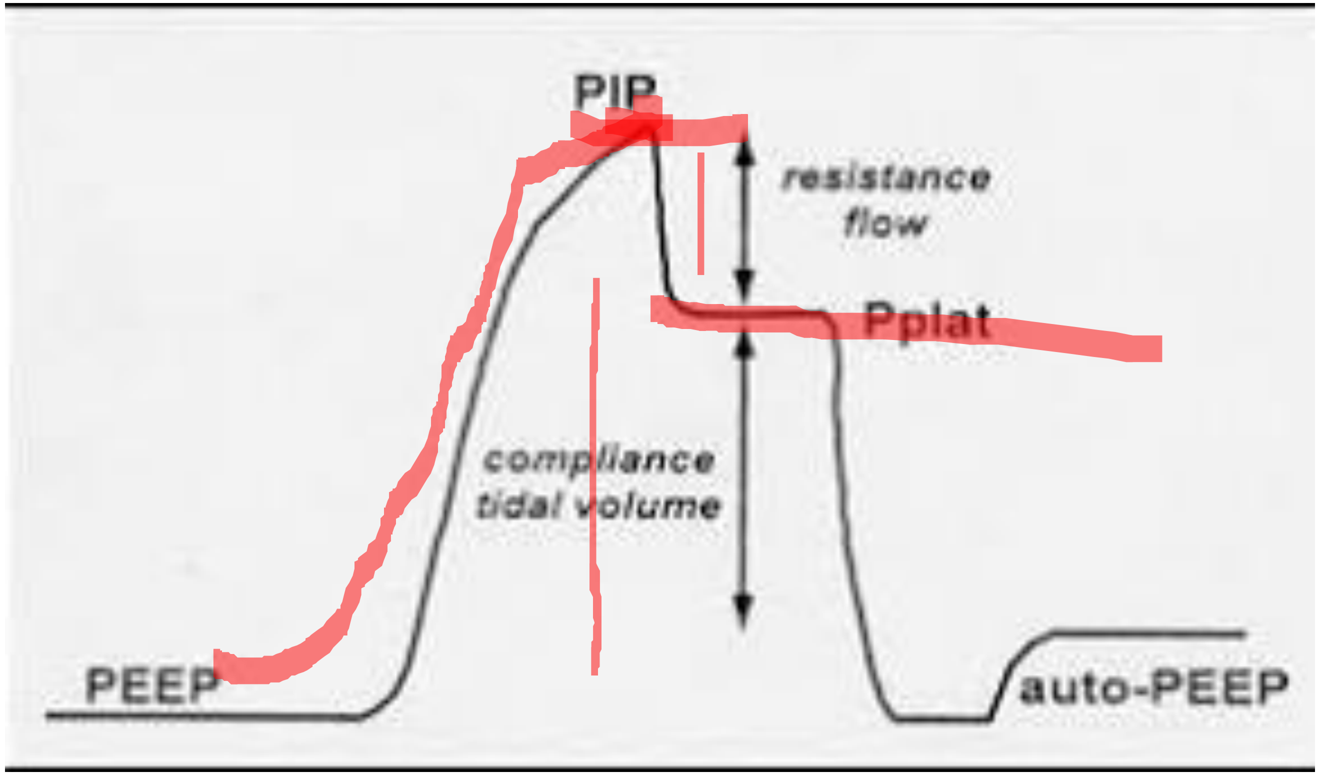
Compliance and Resistance

- Change in volume divided by change in pressure.
- In respiratory physiology, total compliance is a mix of lung and chest wall compliance
- These two factors cannot be separated in a patient unless you conduct esophageal pressure monitoring.
- Trend these values on your ventilator
- Resistance for COPD and Asthma
- Compliance for ARDS

Transpulmonary pressure

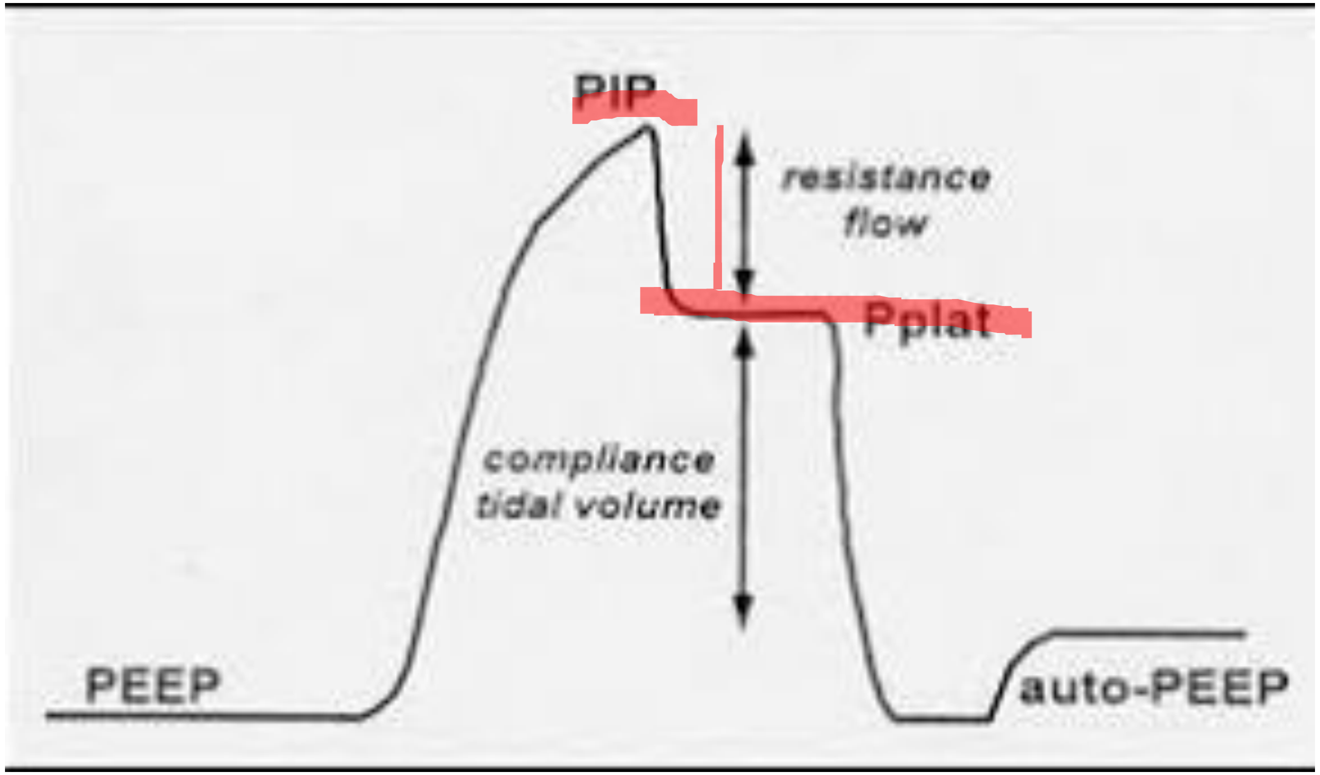
- Transpulmonary pressure, the pressure across the lung that gives rise to pulmonary ventilation, is central to our understanding of respiratory mechanics.
- It does not include chest wall mechanics such as obese patients or restrictive disorders.
- Measuring esophageal pressure can be estimated transpulmonary pressure and used to make clinical decisions (PEEP).
- Measuring transpulmonary pressure in ventilated patients allows positive end-expiratory pressure (PEEP) to be adjusted to compensate for chest wall mechanics.

Peak Inspiratory Pressure



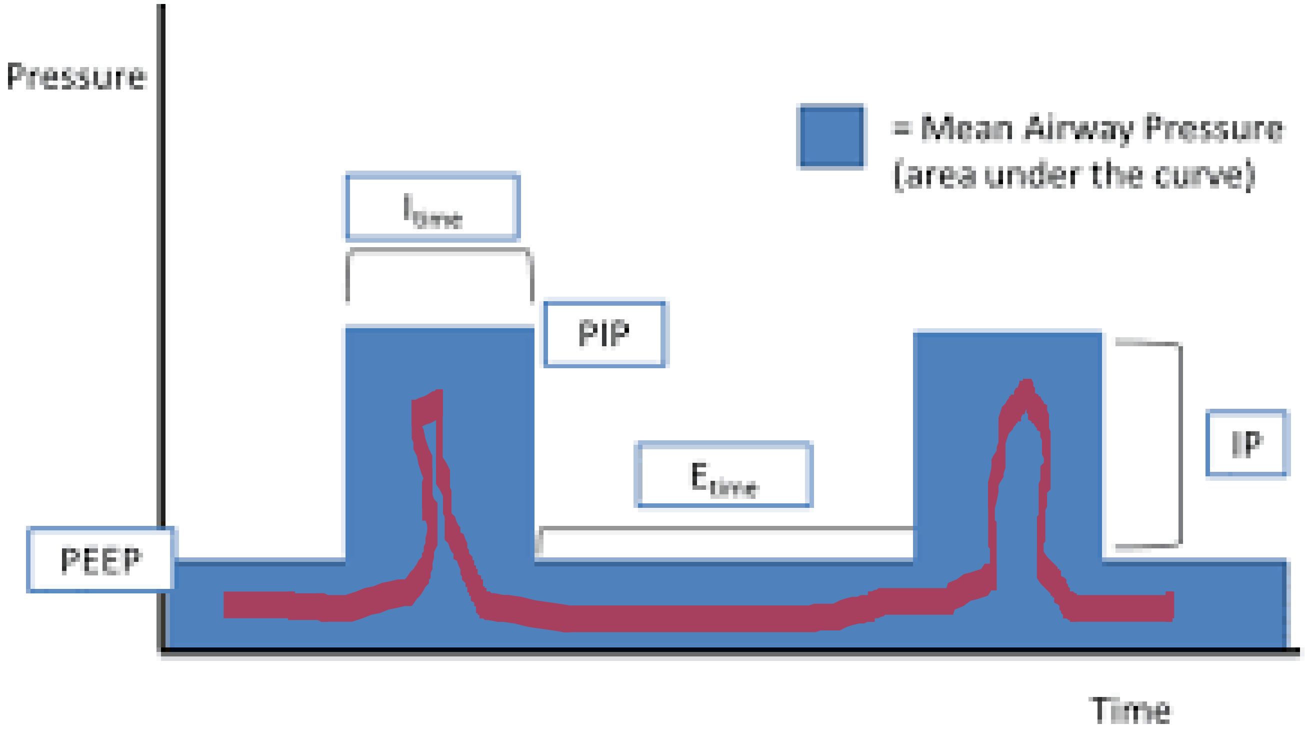
- Peak inspiratory pressure (PIP) is the highest level of pressure applied to the lungs during inhalation.
- Peak pressure reflects resistance to airflow and lung compliance and is measured during inspiration.
- The difference between Ppeak and Pplat divided by the airflow is the airway resistance.
- In normal subjects, airway resistance values do not exceed 15–20 cmH2O/L/s under controlled mechanical ventilation

Plateau pressure



- Plateau pressure can be measured during an inspiratory pause when the respiratory muscles are relaxed and is equal to alveolar pressure when airflow is zero.
- In ARDS patients, Pplat <30 cmH_2O was associated with lower mortality

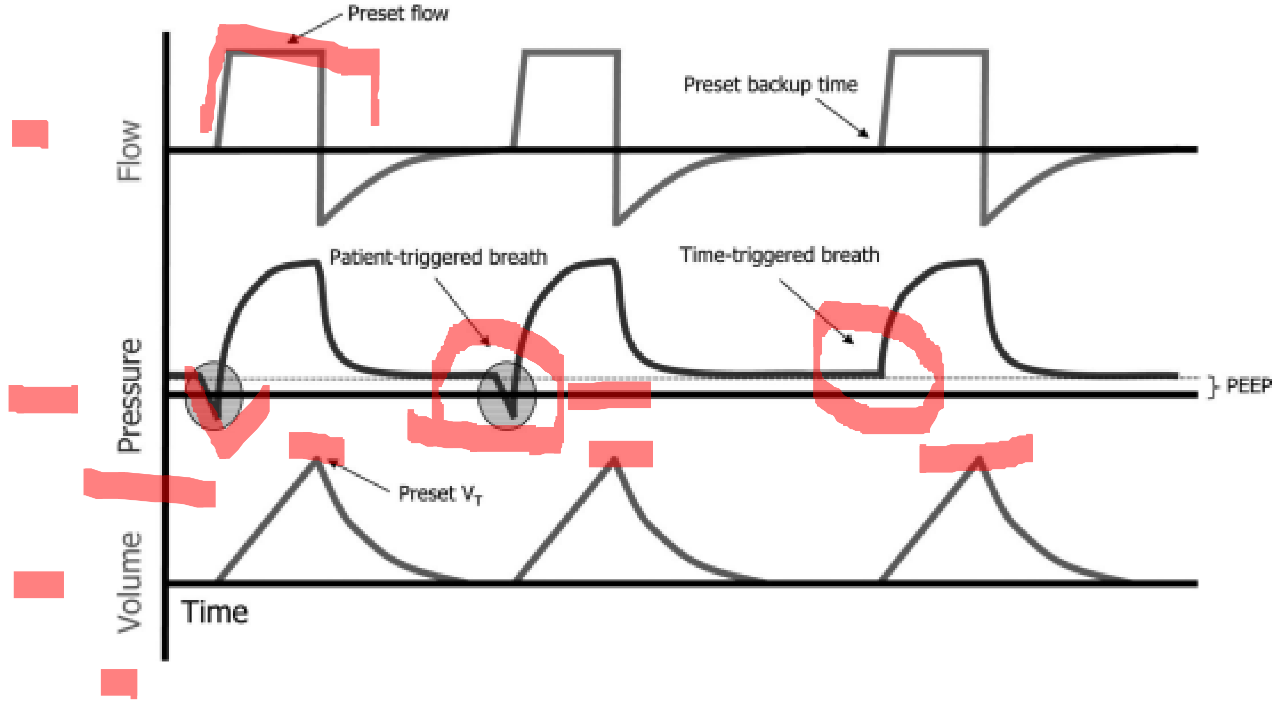
Mean airway pressure



- The average pressure your lung is exposed to during mechanical ventilation both during inspiration and expiration
- Increasing I-time, PIP, PEEP all increase MAP
- MAP is linked to oxygenation

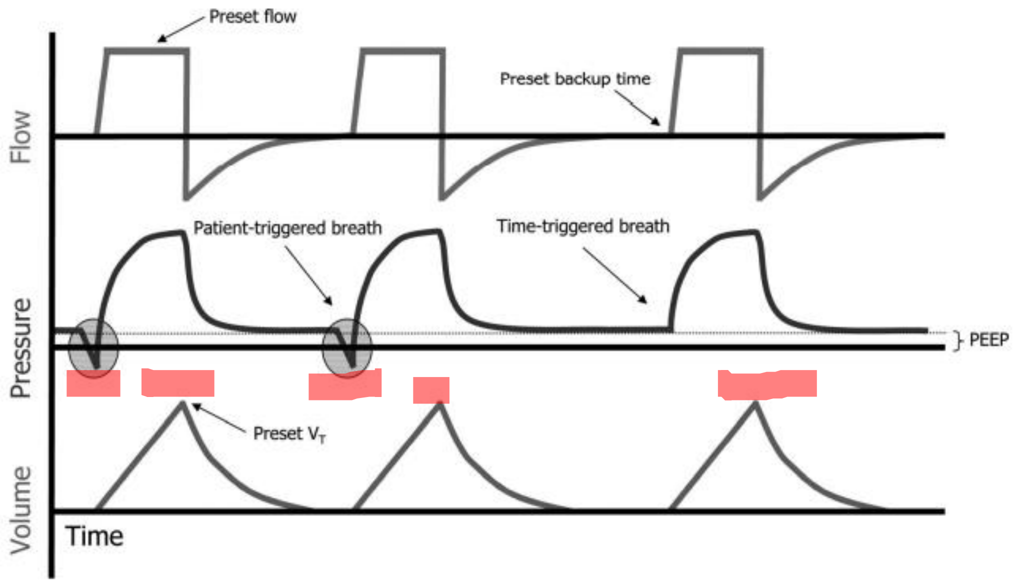
Assist control

- Assist-control is a patient- or time-triggered, flow limited, and volume-cycled mode of mechanical ventilation.
- A key concept in the AC mode is that the tidal volume (VT) of each delivered breath is the same, regardless of whether it was triggered by the patient or the ventilator.



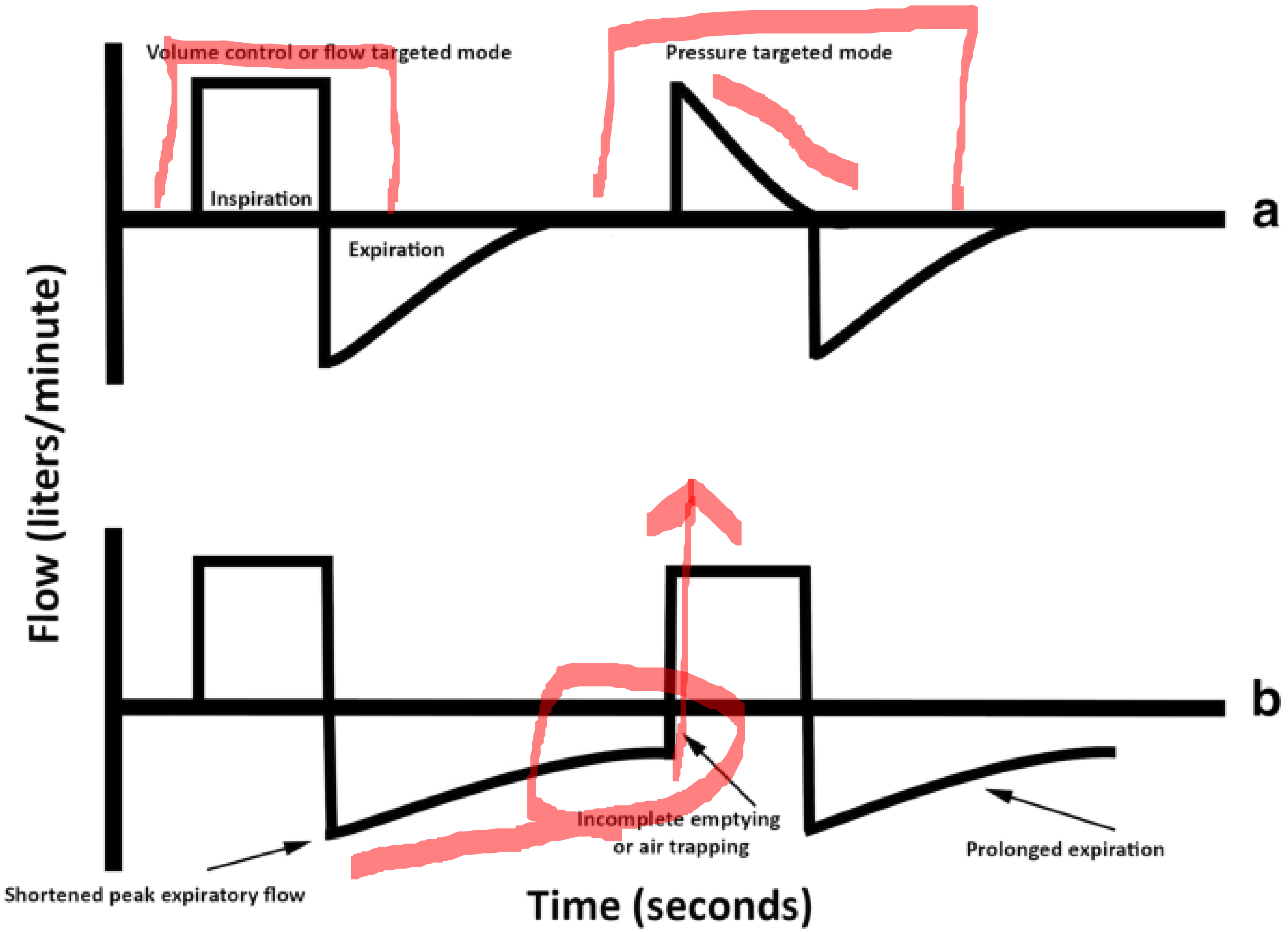
AC-VC

- Assist-control is a patient- or time-triggered, flow limited, and volume-cycled mode of mechanical ventilation.
- A key concept in the AC mode is that the tidal volume (VT) of each delivered breath is the same, regardless of whether it was triggered by the patient or the ventilator
- The pressure or flow threshold needed to trigger a breath is generally set by the respiratory therapist and is termed the trigger sensitivity



AC-PC

- Inspiration is pressure targeted
- Time cycled ventilation
- Decelerating flow pattern
- tidal volume is variable

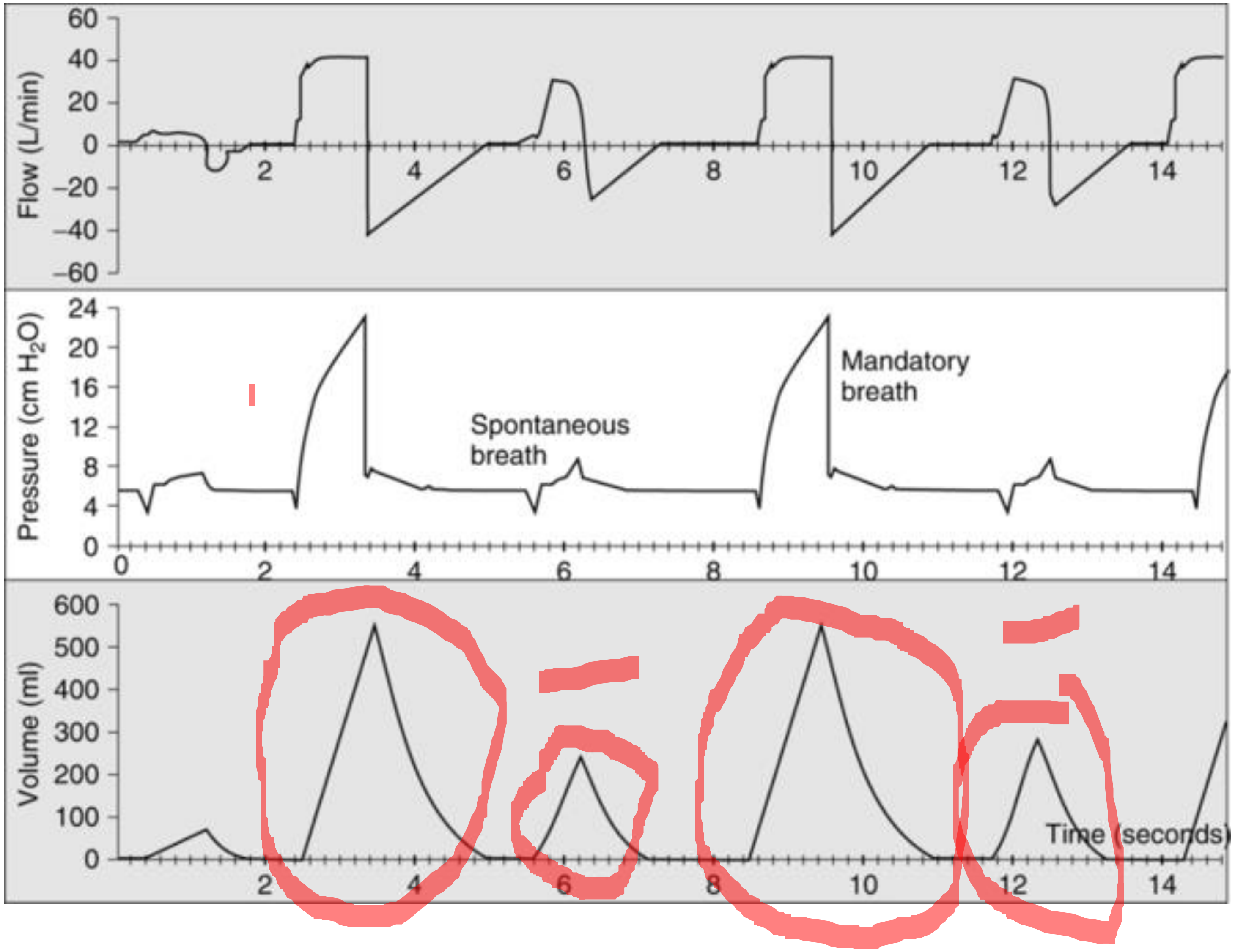


PRVC, VC+, Auto-flow, Adaptive pressure ventilation

- Ti and a goal VT are set by the clinician
- The ventilator delivers a constant inspiratory pressure with decelerating flow for the duration of the Ti , after which the breath is cycled off.
- This mode is therefore patient or time triggered, pressure targeted, and time cycled as in AC-PC
- Ventilator adjusts inspiratory pressure to correct discrepancies between the delivered and goal VT

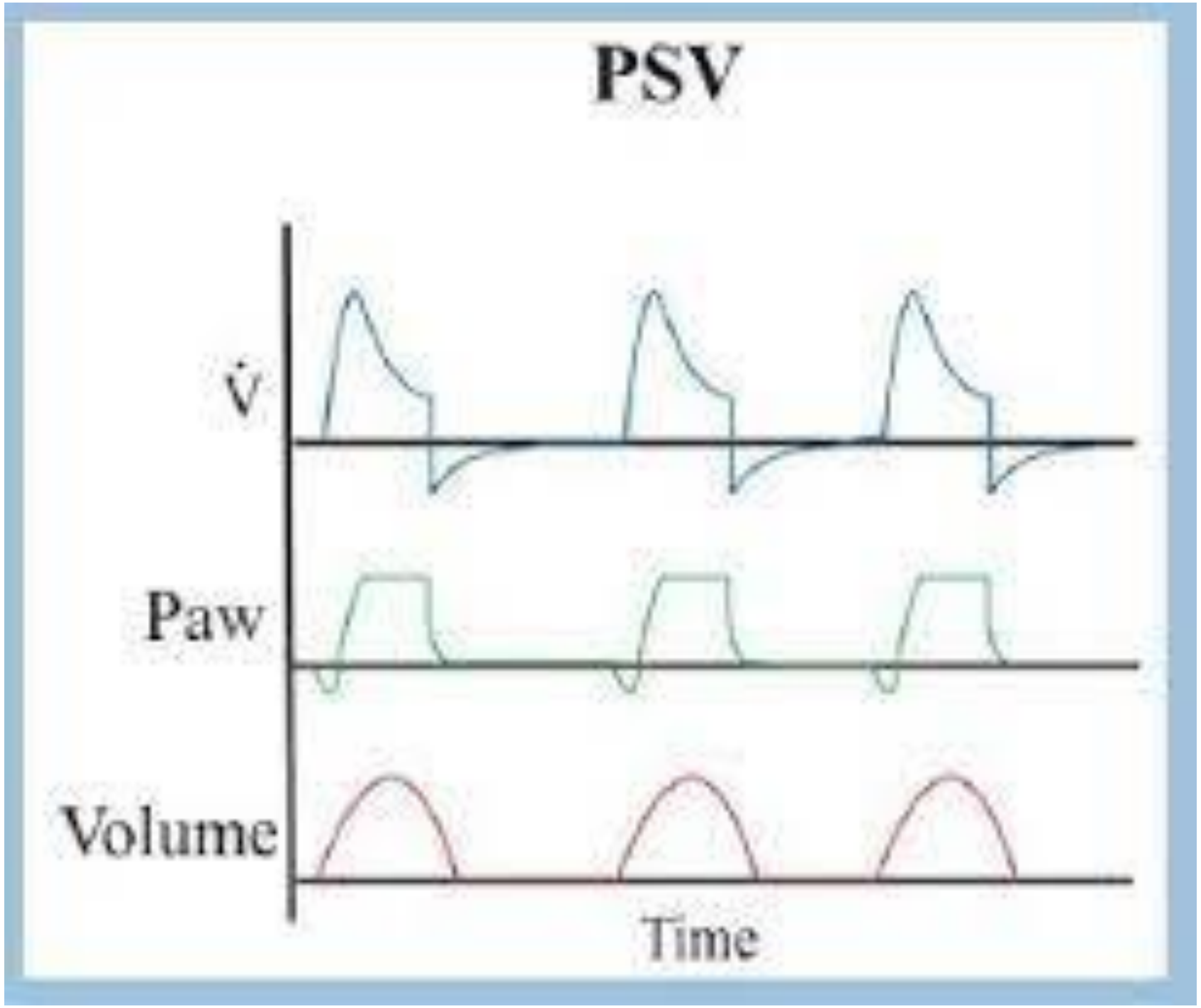
Synchronized Intermittent Mandatory Ventilation (SIMV)

- Synchronized intermittent mandatory ventilation is similar to assist-control mode except that breaths taken by the patient beyond those delivered by the ventilator are not supported; pressure support may be added to these breaths to augment their volumes.



Pressure Support Ventilation

- PSV mode is patient-triggered, pressure-limited, and flow-cycled. With this strategy, breaths are assisted by a set inspiratory pressure that is delivered until inspiratory flow drops below a set threshold.



Ventilator complications

- Infection
  - VAP
- Lung damage
  - VILI
    - VILI remains ventilation with low tidal volumes (4–8 mL/kg predicted body weight) and low inspiratory pressures (plateau pressure <30 cmH_2O)
  - Alectatrauma
    - Over distension of alveolar and stress tears
  - Biotrauma
    - Tears lead to inflammatory mediators

Initial settings

- Mode AC or SIMV
- FIO2 depends (60% to 100%)
- Tidal volume 7-8 mL/kg
- RR 10-12 BPM
- Inspiratory flow depends (60 lpm) OR flow cycled
- PEEP 5-8 cmH_2O
- Sensitivity

Alarm settings

- **Common Ventilator Alarms Include:**
- High Pressure
- Low Pressure
- Low Expired Volume
- High Frequency
- Apnea
- High PEEP
- Low PEEP

Weaning from mechanical ventilation

- Why they were intubated in the first place
- Are they awake and conscious
- Able to protect their airway
- Cough and gag intact
- GCS >8
- Respiratory drive intact
- RSBI
- Cuff leak

Summary

- Know The terminology of mechanical ventilation
- Know how pressures and volume can cause injury to the lung
- Understand your basic settings
- Understand your alarms
- Understand how to wean the patient from mechanical ventilation

References

- Abdelrahim, M. E., Saeed, H., Harb, H. S., & Madney, Y. M. (2021). Types of Mechanical Ventilation. In *Essentials of Aerosol Therapy in Critically ill Patients* (pp. 27-43). Springer, Cham.
- Hickey, S., & Giwa, A. (2022). Mechanical Ventilation. *StatPearls*.
- Park, S., & Suh, E. S. (2020). Home mechanical ventilation: back to basics. *Acute and critical care*, *35*(3), 131.
- Walter, J. M., Corbridge, T. C., & Singer, B. D. (2018). Invasive mechanical ventilation. *Southern medical journal*, *111*(12), 746.