Mechanical Ventilation

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Mechanical Ventilation

Mechanical Ventilation

Common indications for mechanical ventilation

- **Bradypnea or apnea with respiratory arrest**
- **ALI/ARDS**
- **Tachypnea**
- **Vital capacity less than 15 mL/kg**
- **Minute ventilation greater than 10 L/min**
- **PaO2 with a supplemental fraction of inspired oxygen (FIO2) of less than 55 mm Hg**
- **Alveolar-arterial gradient of oxygen tension (A-a DO2) with 100% oxygenation of greater than 450 mm Hg**
- **Respiratory muscle fatigue**
- **Obtundation or coma**
- **Hypotension**
- **Neuromuscular disease**
- *The trend of these values should influence clinical judgment*.

Mechanical Ventilation

Background

The Drinker and Shaw tank-type ventilator of 1929 was one of the first negative-pressure machines

- metal cylinder completely engulfed the patient up to the neck.
- A vacuum pump created negative pressure in the chamber, which resulted in expansion of the patient's chest.
- When the vacuum was terminated, the negative pressure applied to the chest dropped to zero, and the elastic recoil of the chest and lungs permitted passive exhalation

Mechanical Ventilation

Negative Pressure

- No intubation
- limited access to the patient
- Because the negative pressure created in the chamber was exerted on the abdomen the cardiac output tended to decrease.

Mechanical Ventilation

- Intensive use of positive-pressure mechanical ventilation gained momentum during the polio epidemic in Scandinavia and the United States in the early 1950s.

Mechanical Ventilation

- In Copenhagen, the patient with polio and respiratory paralysis who was supported by manually forcing 50% oxygen through a tracheostomy had a reduced mortality rate.
- 1400 medical students recruited from the universities.

Mechanical Ventilation

Definitions:

Pressure Ventilation: Pre-set Inspiratory pressure will be delivered to the patient.

Volume Ventilation: Pre-set Tidal volume will be delivered to the patient.

Mandatory breaths: Breaths that the ventilator delivers at a set frequency, volume, flow.

Spontaneous breaths: Patient initiated breath.

Mechanical Ventilation

Definitions:

Triggering: The sensitivity of the ventilator to the patient's respiratory effort.

Flow or pressure setting that allows the ventilator to detect the patient's inspiratory effort.

Mechanical Ventilation

Positive-pressure ventilation

- Means that airway pressure is applied at the patient's airway through an endotracheal or tracheostomy tube.

- The positive nature of the pressure causes the gas to flow into the lungs.

- As the airway pressure drops to zero, elastic recoil of the chest accomplishes passive exhalation by pushing the tidal volume out.

Mechanical Ventilation

Classifications of Positive-Pressure Ventilators

- Classified by their method of cycling from the inspiratory phase to the expiratory phase.

- The signals are
  - preset volume (for a volume-cycled ventilator)
  - preset pressure limit (for a pressure-cycled ventilator)
  - preset time factor (for a time-cycled ventilator).

Mechanical Ventilation

- Volume-cycled ventilation is the most common form
- Termination of the delivered breath is signaled when a set volume leaves the ventilator.

Mechanical Ventilation

Initial Ventilator Settings

- Mode: SIMV / PSV
- VT : 8-10 ml/kg (600-700 mls on average)
- RR: 12 bpm
- FiO2: 0.5
- PEEP: 5 cmH20
- PSV: 10 cmH20
- (I:E) Ratio: (1: ≥2)
- Flowrate 40-60 lpm

Assist-Control

Initial Ventilator Settings

Mode of ventilation: Assist-control mode (tidal volume and rate are preset and guaranteed)

- The patient can affect the frequency and timing of the breaths.
- If the patient makes an inspiratory effort, the ventilator senses a decrease in the circuit pressure and delivers the preset tidal volume.

Assist-Control

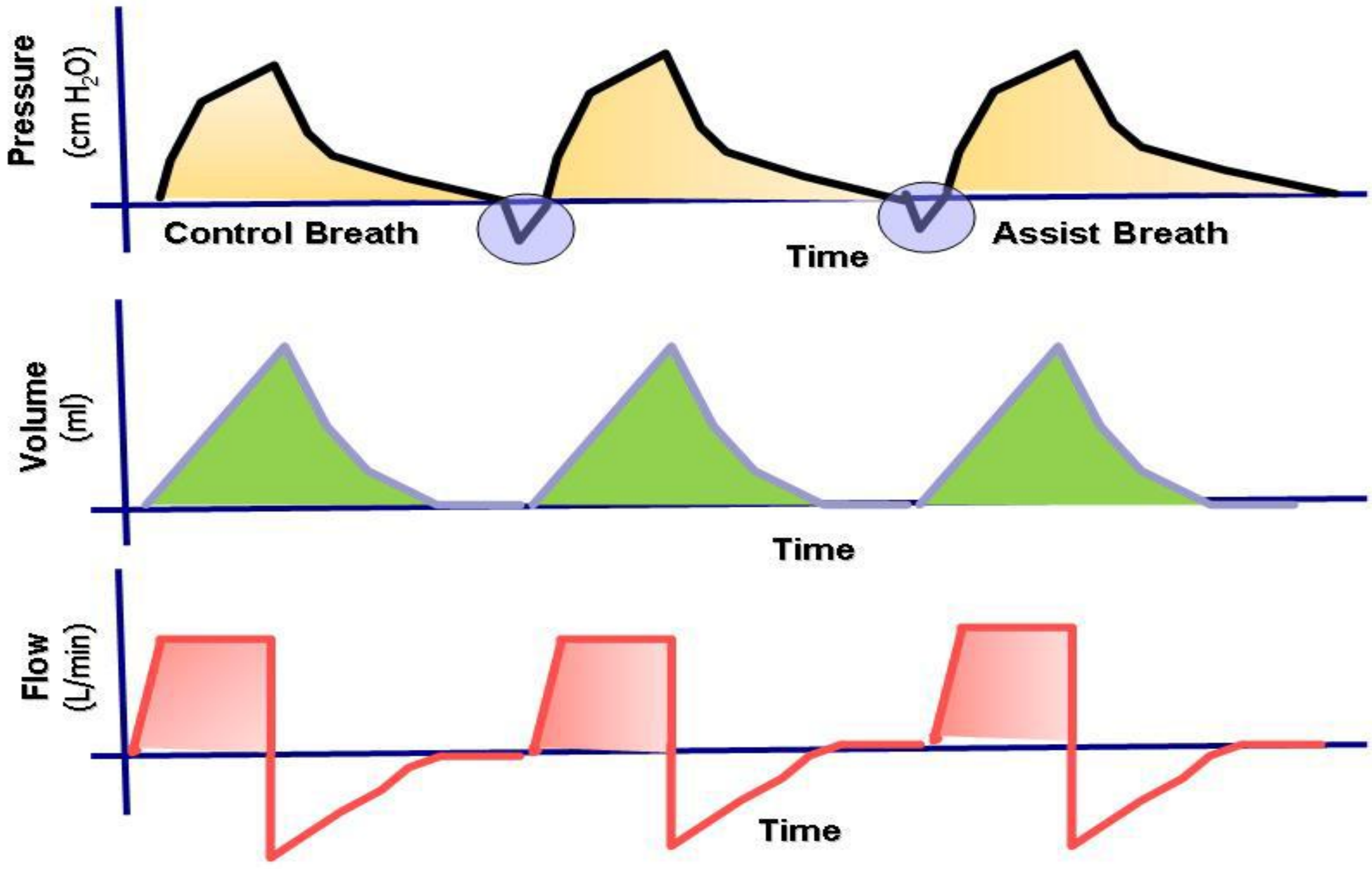
- Initial choice for mechanical ventilation.
- The patient can trigger the ventilator to deliver a breath and, thereby, adjust their minute ventilation.

Assist-Control

- The work of breathing is reduced to the amount of inspiration needed to trigger the inspiratory cycle of the machine.

- This trigger is adjusted by setting the sensitivity of the machine

Assisted Mode (Volume-Targeted Ventilation)



The pressure, volume, and flow to time waveforms for assist-control ventilation.

Assist-Control

Advantage

- Rest of respiratory muscles.
- Patient can achieve the required minute ventilation by triggering additional breaths above the set back-up rate
- Prevents atrophy of the respiratory muscles.

Assist-Control

Disadvantage

Respiratory Alkalosis

Patients with a potential for alveolar hyperventilation and hypocapnia in the include:

- end-stage liver disease
- hyperventilatory stage of sepsis
- head trauma.

Decrease global cardiac output

serial preset positive-pressure breathes retard venous return to the right side of heart and to affect global COP.

Initial Ventilator Settings

Tidal volume and rate

- TV of 6-12 mL/Kg
- Rate12 times a minute

For (COPD)

- TV and rate are slightly reduced to prevent overinflation and hyperventilation.
- TV 10 mL/kg
- Rate 10 times a minute

Initial Ventilator Settings

Tidal volume and rate

(ARDS)

- low TV of 6-8 mL/kg.
- These lowered volumes may lead to slight hypercarbia.

Initial Ventilator Settings

(Permissive Hypercapnia)

- An elevated PCO2 is typically recognized and accepted without correction
- allowable pH not less than 7.25.
- The RR of the ventilator may need to be adjusted upward to increase the minute ventilation lost by using smaller tidal volumes.

Initial Ventilator Settings

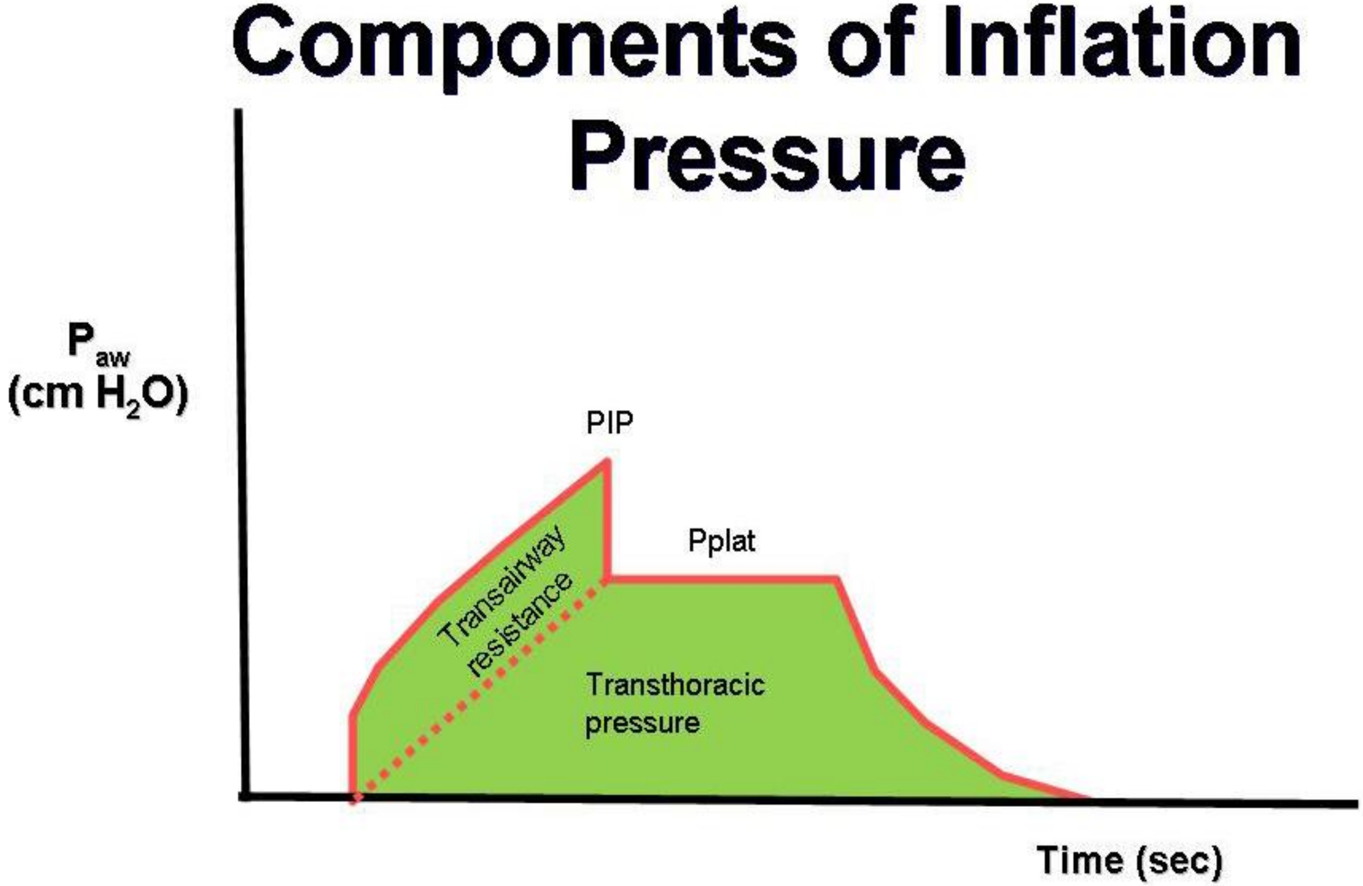
Double-checking the selected tidal volume

Peak airway pressure

As the tidal volume increases, so does the pressure required to force that volume into the lung.

Double-checking the selected tidal volume

The TV need to be decreased to keep the peak airway pressure less than 45 cm water



Initial Ventilator Settings

Double-checking the selected tidal volume

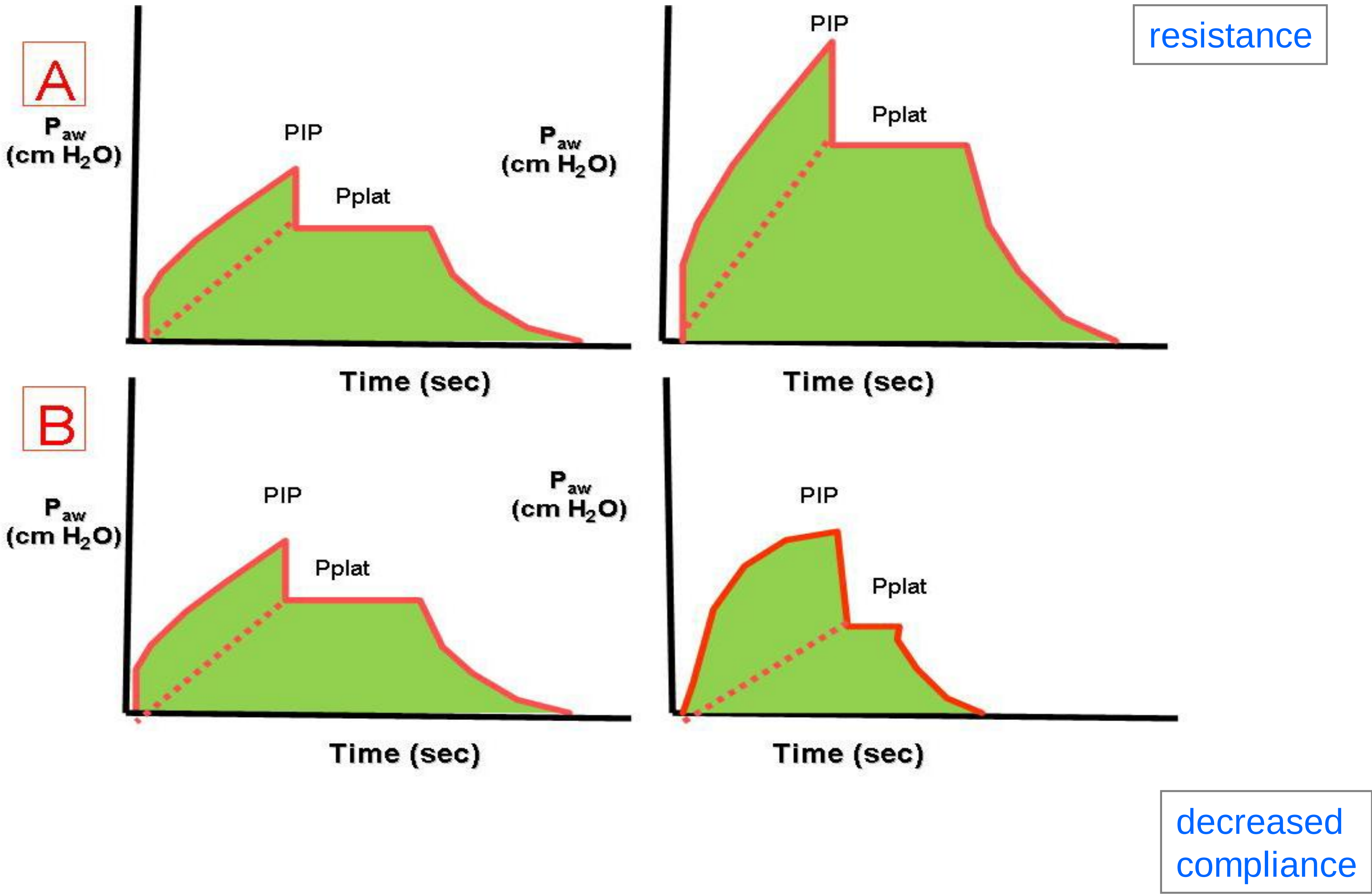
Plateau pressures

- Should be monitored as a means to prevent barotrauma in the patient with ARDS.

Initial Ventilator Settings

Plateau pressures

- Measured at the end of the inspiratory phase.
- The ventilator is programmed not to allow expiratory airflow at the end of the inspiration for a set time, typically half a second.
- Barotrauma is minimized when less than 30-35 cm water


A
P_{aw} (cm H_2O)
PIP
Pplat
Time (sec)
P_{aw} (cm H_2O)
PIP
Pplat
Time (sec)
resistance
B
P_{aw} (cm H_2O)
PIP
Pplat
Time (sec)
P_{aw} (cm H_2O)
PIP
Pplat
Time (sec)
decreased compliance

Initial Ventilator Settings

Sighs

- Sighs 6-8/h normaly

- At present, accounting for sighs is not recommended if the patient is receiving TV of 10-12 mL/kg or if PEEP.

- When a low TV is used, sighs are preset at 1.5-2 times the tidal volume and delivered 6-8 times an hour if the peak and plateau pressures are within acceptable limits.

Initial Ventilator Settings

Initial FIO2

- FIO2 should always be set at 100% until adequate arterial oxygenation is documented.
- A short period with an FIO2 of 100% is not dangerous.

Initial Ventilator Settings

Initial FIO2

Inadequate oxygenation despite of 100%

- mainstem intubation
- positive-pressure breathing (pneumothorax).

- If not present, PEEP is needed to treat the intrapulmonary shunt pathology.

Potential source of hypoxemia :

- Alveolar collapse - Major atelectasis
- Lobar pneumonia
- Water and protein - ARDS
- Water - Congestive heart failure
- Blood - Hemorrhage

Initial Ventilator Settings

PEEP

- maintains the patient's airway pressure above the atmospheric level.
- achieved by maintaining a positive pressure flow at the end of exhalation.
- measured in centimeters of water.

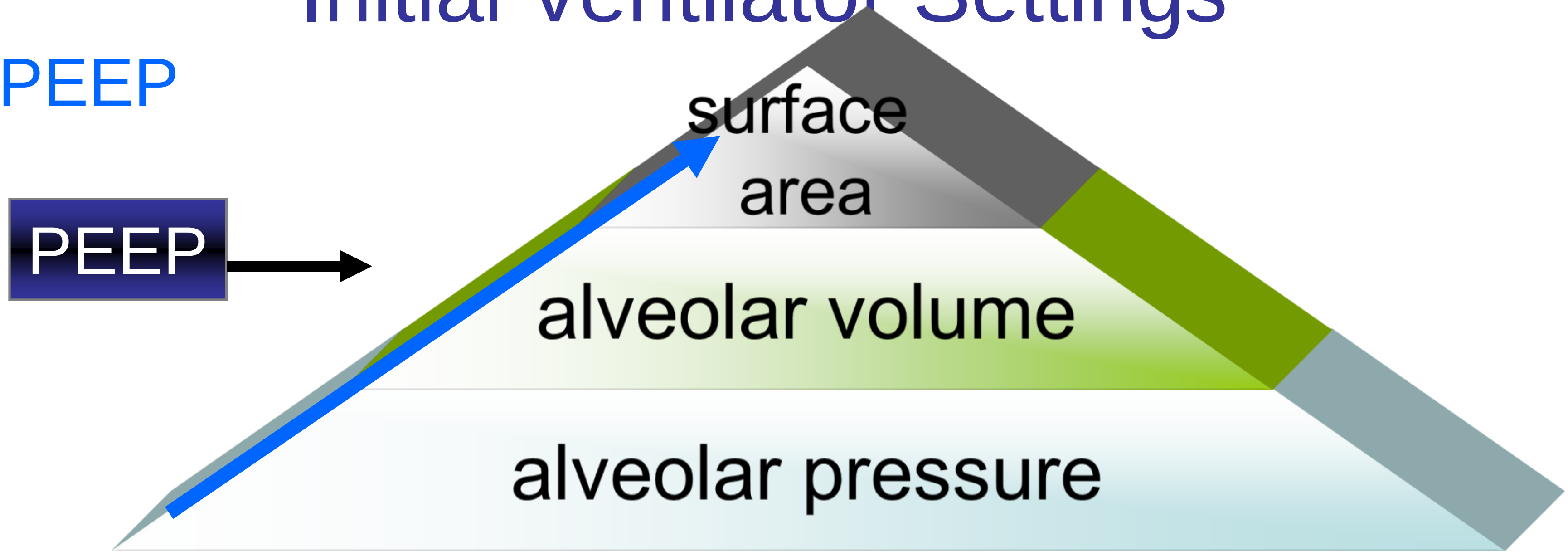
Initial Ventilator Settings

PEEP

- Collapse of the unstable alveoli decreases lung volume & surface area available for gas exchange and results in intrapulmonary shunting (unoxygenated blood returning to the left side of the heart).
- TTT……………..PEEP

Initial Ventilator Settings

PEEP



reopening and stabilizing collapsed or unstable alveoli

improves the ventilation-perfusion match & reduce the shunt effect.

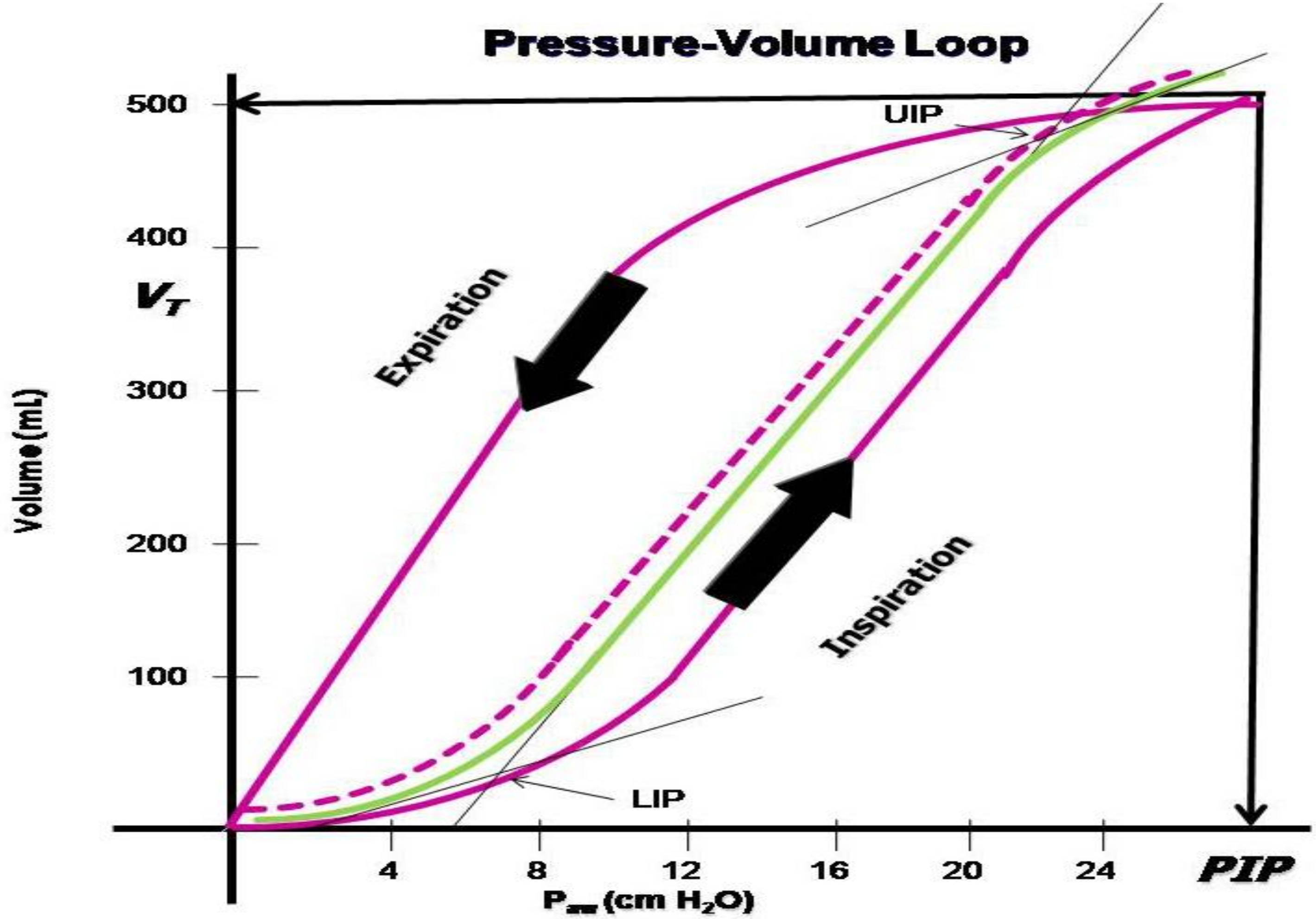
lowered oxygen can be used

Initial Ventilator Settings

PEEP

- The most important benefit of the use of PEEP is that it enables the patient to maintain an adequate PaO2 at a low and safe concentration
- The addition of external PEEP is typically justified when a PaO2 of 60 mm Hg cannot be achieved with an FIO2 of 60%

Positive end-expiratory pressure



Determination of the lower inflection point to estimate the best (optimal) PEEP from the pressure-volume hysteresis curve.

Initial Ventilator Settings

PEEP

- less than 10 cm water rarely causes hemodynamic problems in the absence of intravascular volume depletion.
- The cardiodepressant effects of PEEP are often minimized volume and inotropic support.
- Hypotension is related to the mean airway pressure that may decrease venous return to the heart or decrease right ventricular function.

Initial Ventilator Settings

Withdrawal of PEEP

- FIO2 of 40% or less.
- Reduce the PEEP in 3- to 5-cm of water decrements while the oxygen saturations are monitored.

Initial Ventilator Settings

Inspiration/expiration ratio

- The normal inspiration/expiration (I/E) ratio to start is 1:2.
- This is reduced to 1:4 or 1:5 in the presence of obstructive airway disease in order to avoid air-trapping (breath stacking) and auto-PEEP or intrinsic PEEP (iPEEP).

Initial Ventilator Settings

Inspiratory flow rates

- Inspiratory flow rates are a function of the TV, I/E ratio, and RR and may be controlled internally by the ventilator via these other settings.
- 60 L/min is typically utilized.
- may increase to 100 L/min to deliver TVs quickly and allow for prolonged expiration in the presence of obstructive airway disease

Initial Ventilator Settings

Sensitivity

- With assisted ventilation, the sensitivity typically is set at -1 to -2 cm H_2O.

Summary of initial ventilator setup

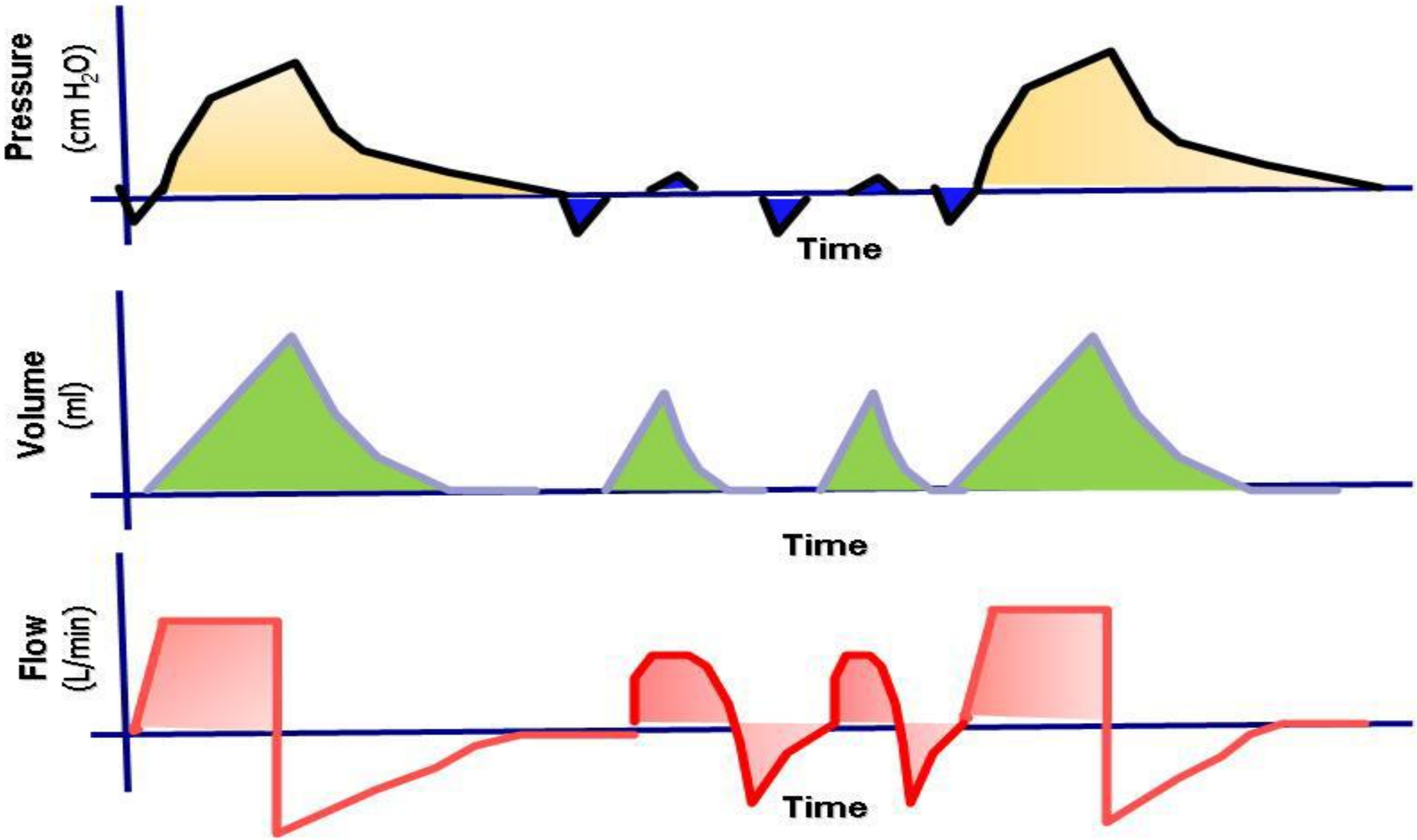
Assist-control mode

- Tidal volume
  - Normal = 12 mL/kg ideal body weight
  - COPD = 10 mL/kg ideal body weight
  - ARDS = 6-8 mL/kg ideal body weight
- Rate of 10-12 breaths per minute
- FIO2 of 100%
- PEEP
  - Inability to oxygenate with an FIO2 less than 60%

Synchronized Intermittent Mandatory Ventilation (with/without Pressure support) SIMV / PS

- The vent allow the patient to trigger a breath spontaneously
- otherwise mandatory breath will be delivered.
- The mandatory rate is guaranteed.

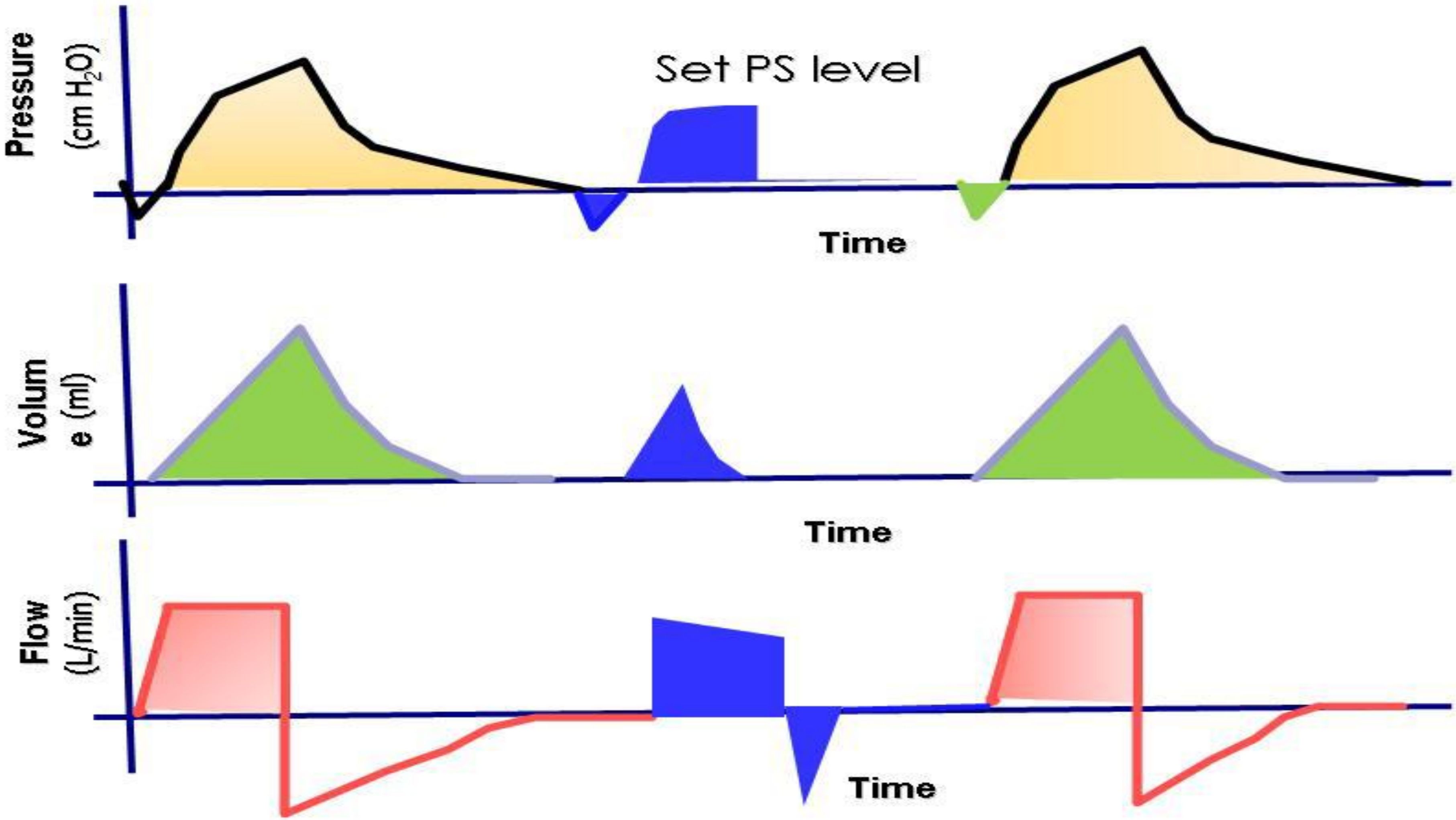
SIMV
(Volume-Targeted Ventilation)



Synchronized Intermittent Mandatory Ventilation (with/without Pressure support) SIMV / PS

- Spontaneous breaths greater then the rate set can be supported with a pressure support to decrease the work of breathing
- TV of these extra breaths is dependent on the patient's inspiratory effort

SIMV+ PS
(Volume-Targeted Ventilation)



Synchronized Intermittent Mandatory Ventilation (with/without Pressure support) SIMV / PS

Disadvantages:

- respiratory fatigue if set rate is too low
- high respiratory rate
- rising pCO_2
- air trapping can occur

Pressure Support Ventilation PSV

Initial settings:

- not a volume-cycled mode
- PS at the pressure required to generate VT of 8-10 ml/kg

usually be about the same as the plateau pressure

- VT is variable, dependant on PS level set above PEEP, patient effort, chest compliance, resistance to flow.

Pressure Control Ventilation PCV

Either SIMV or A/C

- PC (Inspiratory pressure above PEEP)

Background:

- The breath is pressure limited rather than volume limited

Pressure Control Ventilation PCV

Disadvantages:

- no guaranteed TV
- air trapping
- CO_2 retention frequently occurs
- patients must be heavily sedated

Alternative Modes of Mechanical Ventilation

Dual-control ventilation modes

Advantages

volume-control (guaranteed minute ventilation) + pressure-control ventilation (limited peak airway pressure).

- Increase the safety and comfort of mechanical ventilation.
- No RCT indicate improved patient outcomes (including mortality).

Alternative Modes of Mechanical Ventilation

Pressure-**R**egulated **V**olume-**C**ontrol (PRVC)

- This mode is under the dual control of pressure and volume.

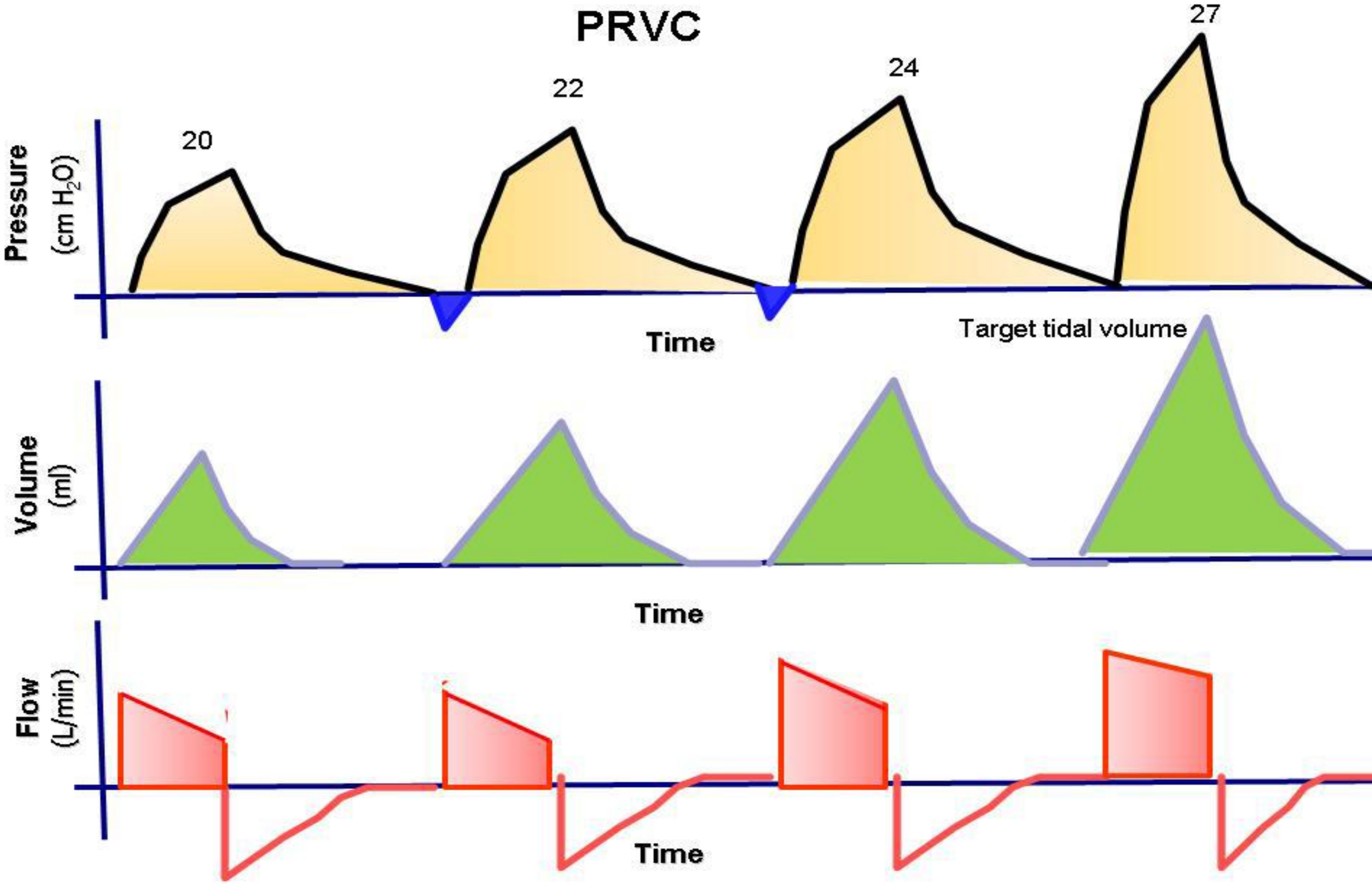
- The physician presets a desired TV, and the ventilator delivers a pressure-limited (controlled) breath until that preset TV is achieved.

- The breath is essentially like a conventional pressure-controlled ventilation breath, but the ventilator can guarantee a predetermined minute ventilation.

Alternative Modes of Mechanical Ventilation

Pressure-**R**egulated **V**olume-**C**ontrol (PRVC)

- Breath to breath, the inspiratory pressure is automatically adjusted down or up to deliver a preset TV.
- If the delivered volume is too low, it increases the inspiratory pressure on the next breath.
- If it is too high, it decreases the inspiratory pressure.
- This adjustment gives the patient the lowest peak inspiratory pressure needed to achieve a preset TV.
- Advantage…..deliver minimum minute ventilation at the lowest peak airway pressures possible



The pressure, volume, and flow to time waveforms for pressure-regulated volume-controlled ventilation

Alternative Modes of Mechanical Ventilation

Dual-control breath-to-breath, pressure-limited, flow-cycled ventilation

- volume-support ventilation (VSV) or variable-pressure-support.
- Combination of PSV and volume-control ventilation.
- Like PSV, the patient triggers every breath, controlling his or her own respiratory frequency and inspiratory time.
- This mode delivers a breath exactly like conventional PSV, but the machine can guarantee minute ventilation.
- The pressure support is automatically adjusted up or down to deliver a preset TV.

Alternative Modes of Mechanical Ventilation

Volume-support ventilation (VSV) or Variable-pressure-support

- it is flow cycled, which means that the patient determines the respiratory rate and inspiratory time.
- The mode cannot be used in a patient who lacks spontaneous breathing effort.

☺ Volume support has also been marketed as a self-weaning mode.

Alternative Modes of Mechanical Ventilation

Volume-support ventilation (VSV) or Variable-pressure-support

Potential Problems

- If the patient's metabolic demand increases, raising the tidal volume, the pressure support decreases to provide less ventilatory support when the patient needs it most result in hypoxemia.
- TV must be correctly set to the patient's metabolic needs.
- If the tidal volume is set too high, weaning is delayed. If it is set too low, the work of breathing increase

Alternative Modes of Mechanical Ventilation

3--Automode and variable support or variable-pressure control

- This mode is basically the combination of the 2 modes described above.
- If the patient has no spontaneous breaths, the ventilator is set up in the PRVC mode.
- When the patient takes 2 consecutive breaths, the mode is switched to Volume-support ventilation VSV.

Alternative Modes of Mechanical Ventilation

3--Automode and variable support or variable-pressure control

- Designed for automatic weaning from pressure control to pressure support depending on the patient's effort.
- no randomized trials have been conducted to show this type of weaning is more effective than conventional weaning.

Alternative Modes of Mechanical Ventilation

Dual control within a breath

- This mode has been called volume-assured pressure support or pressure augmentation.

- This mode can switch from pressure control to volume control within a single specific breath cycle. After a breath is triggered, rapid and variable flow creates pressure to reach the set level of pressure support.

Alternative Modes of Mechanical Ventilation

Dual control within a breath

- TV is monitored.
- If it equals the minimum set TV, the patient receives a typical pressure-supported breath
- if the TV is less than the set one, the ventilator switches to a volume-controlled breath with constant flow rate until the set tidal volume is reached.

Alternative Modes of Mechanical Ventilation

Dual control within a breath

One study compared volume-assured pressure support with simple assist-control volume support and showed a 50% reduction in the work of breathing, lowered airway resistance, and lowered intrinsic PEEP.

Alternative Modes of Mechanical Ventilation

Automatic tube compensation

- Specifically for weaning
- Designed to overcome the resistance of the endotracheal tube by means of continuous calculations.
- These calculations allow the ventilator to supply the appropriate pressure needed to overcome this resistance
- no studies so fare

Alternative Modes of Mechanical Ventilation

Proportional assist ventilation

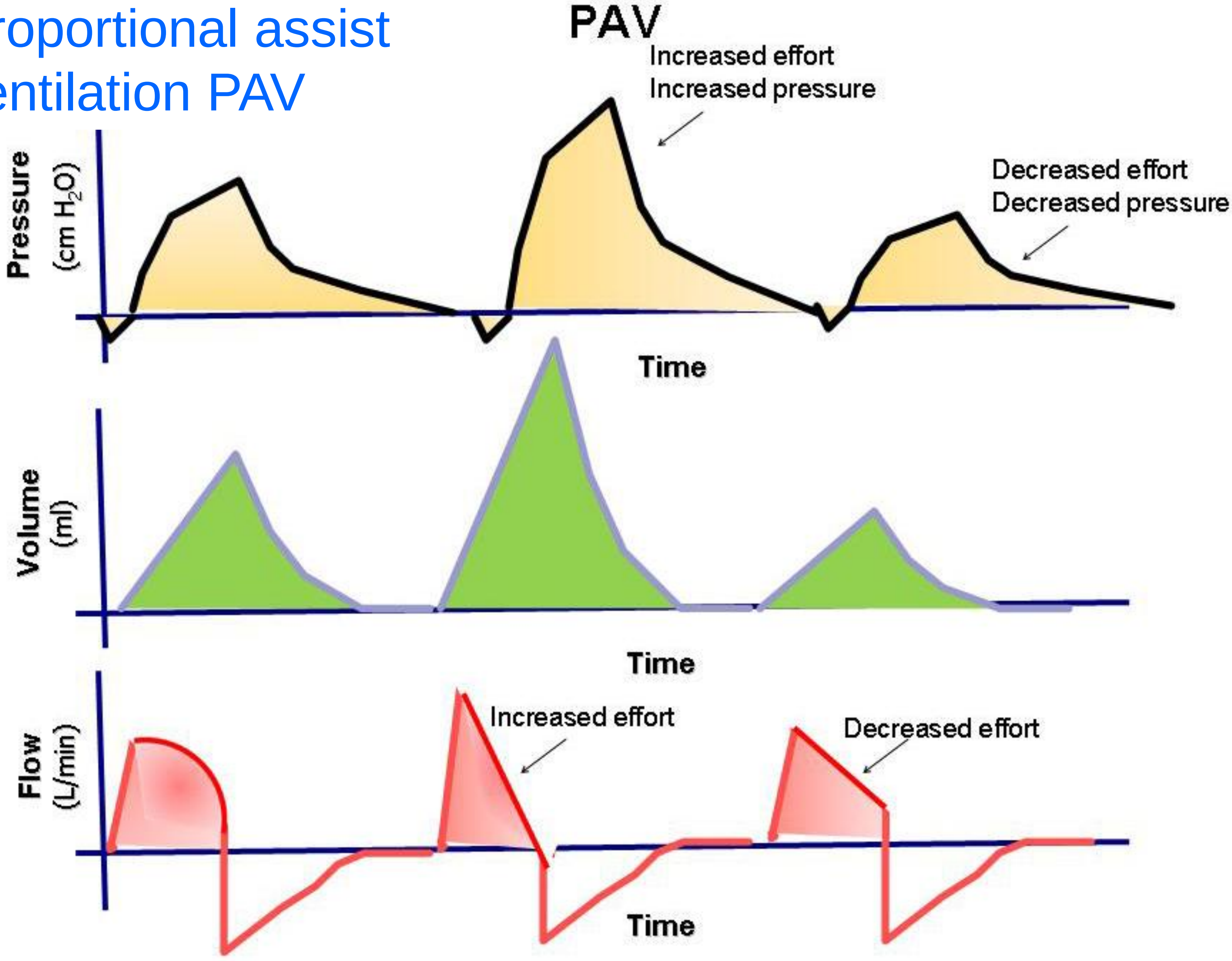
- Decrease the work of breathing.
- The mode adjusts airway pressure in proportion to the patient's effort.
- lets the patient determine the inspired volume and the flow rate.
- The support given is a proportion of the patient's effort and is normally set at 80%.
- .

Alternative Modes of Mechanical Ventilation

Proportional assist ventilation

- This support is always changing according to patient's effort and lung dynamics.
- The patient's work of breathing remains constant regardless of his or her changing effort or demand
- This mode can be used only in patients with spontaneous respiratory efforts.
- Not approved by FDA

Proportional assist ventilation PAV



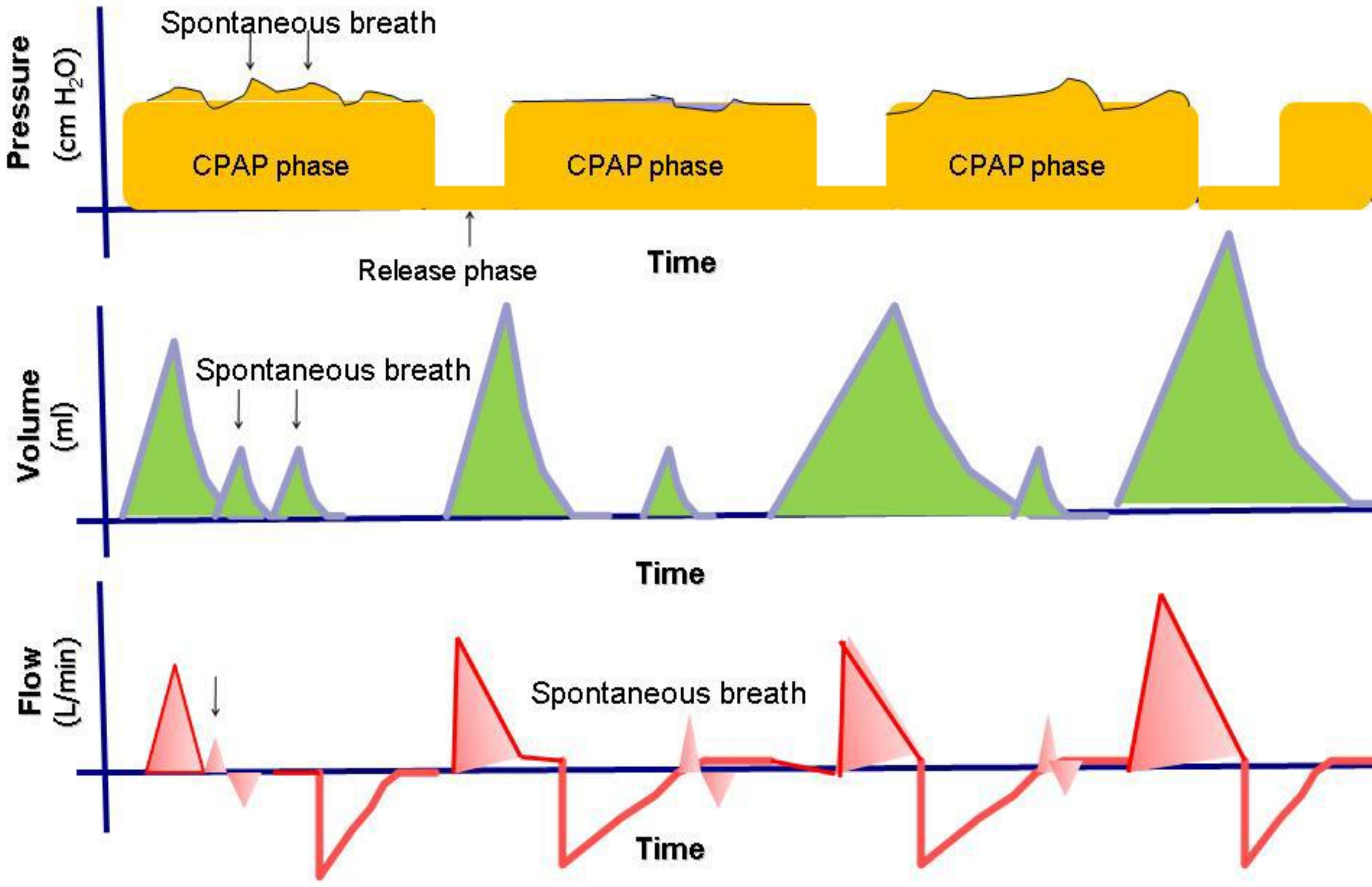
Alternative Modes of Mechanical Ventilation

Airway pressure–release ventilation

- Bilevel, or biphasic, ventilation
- new mode.
- The ventilator is set at 2 pressures

  high CPAP & low CPAP both levels are time cycled.

APRV



Spontaneous breath
Pressure
(cm H_2O)
CPAP phase
CPAP phase
CPAP phase
Release phase
Time
Volume
(ml)
Spontaneous breath
Time
Flow
(L/min)
Spontaneous breath
Time

Alternative Modes of Mechanical Ventilation

Airway pressure–release ventilation

- The high pressure is maintained for most of the time, while the low pressure is maintained for short intervals of usually less than 1 second to allow exhalation and gas exchange to occur.
- The patient can breathe spontaneously during high or low pressure

Alternative Modes of Mechanical Ventilation

Airway pressure–release ventilation

- Has benefit of alveolar recruitment.
- Its disadvantage is that the tidal volume is variable.
- The clinician must be constantly aware of the patient's minute ventilation to prevent severe hypercapnia or hypocapnia.

Complications of Mechanical Ventilation

Complications of intubation

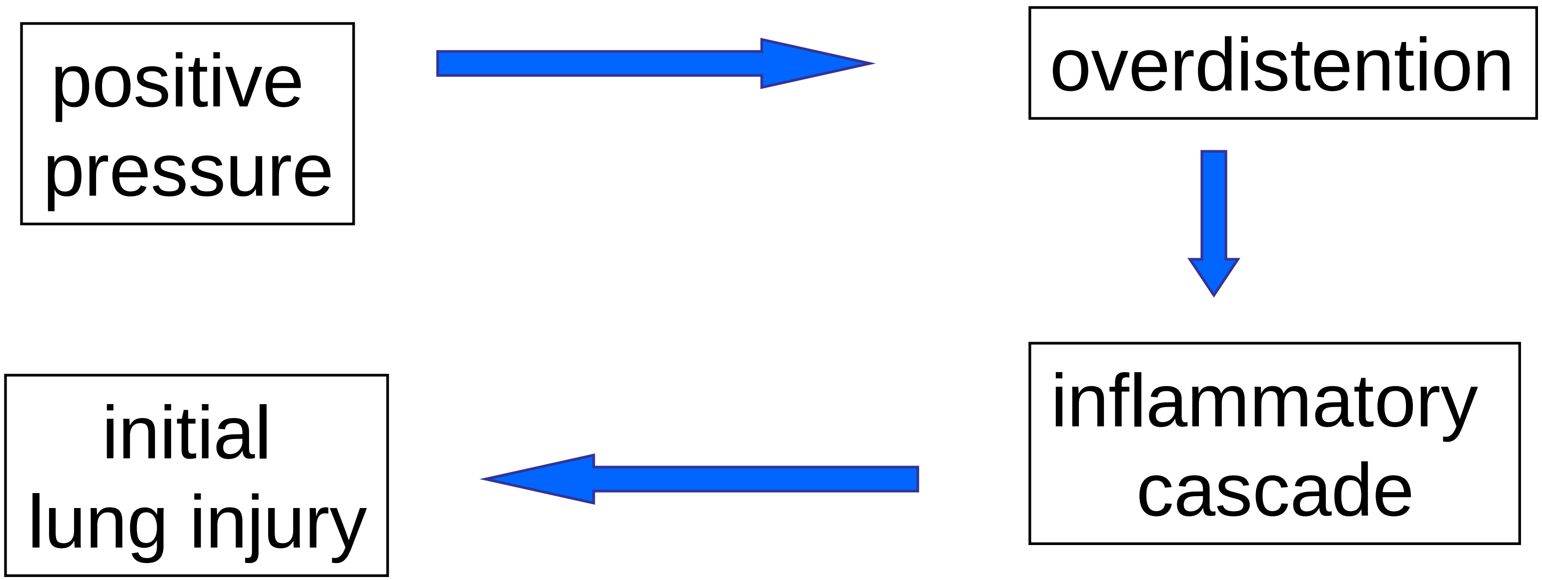
Ventilator-induced lung injury

- Barotrauma, Prevalence of 6-25%.
  - Pneumothorax
  - Pneumomediastinum
  - Risk factors
  - Large tidal volumes
  - elevated peak inspiratory pressures
  - elevated plateau pressures

    PIP of less than 45 mm Hg and Plat P. of less than 30-35 mm Hg are recommended.
  - underlying lung pathology (better indicator)

Complications of Mechanical Ventilation

Volutrauma



PEEP prevents the alveoli from totally collapsing at the end of exhalation and may be beneficial in preventing this type of injury.

Complications of Mechanical Ventilation

Oxygen toxicity

- increased FIO2 and its duration of use.
- due to the production of oxygen free radicals, such as superoxide anion, hydroxyl radical, and hydrogen peroxide.
  - Tracheobronchitis
  - absorptive atelectasis
  - hypercarbia to diffuse alveolar damage that is indistinguishable from ARDS.
- level of FIO2 required to cause oxygen toxicity????

Complications of Mechanical Ventilation

Ventilator-associated pneumonia (VAP)

new infection of the lung parenchyma that develops within 48 hours after intubation.

- mortality 33-50%.
- Incidence 10-25%.
- highest immediately after intubation.
- frequently in trauma, neurosurgical, or burn units

Complications of Mechanical Ventilation

Ventilator-associated pneumonia (VAP)

- 48 hours after intubation are flora of the upper airway
  - *Haemophilus influenza*
  - *Streptococcus pneumonia.*
- After 48, gram-negative bacilli such as
  - *Pseudomonas aeruginosa*
  - *Escherichia coli*
  - *Acinetobacter*
  - *Proteus*
  - *Klebsiella*
  - MRSA typically after 7 days.

TTT

- Most of the medical literature recommends initial therapy with broad-spectrum antibiotics that cover pathogens resistant to multiple drugs

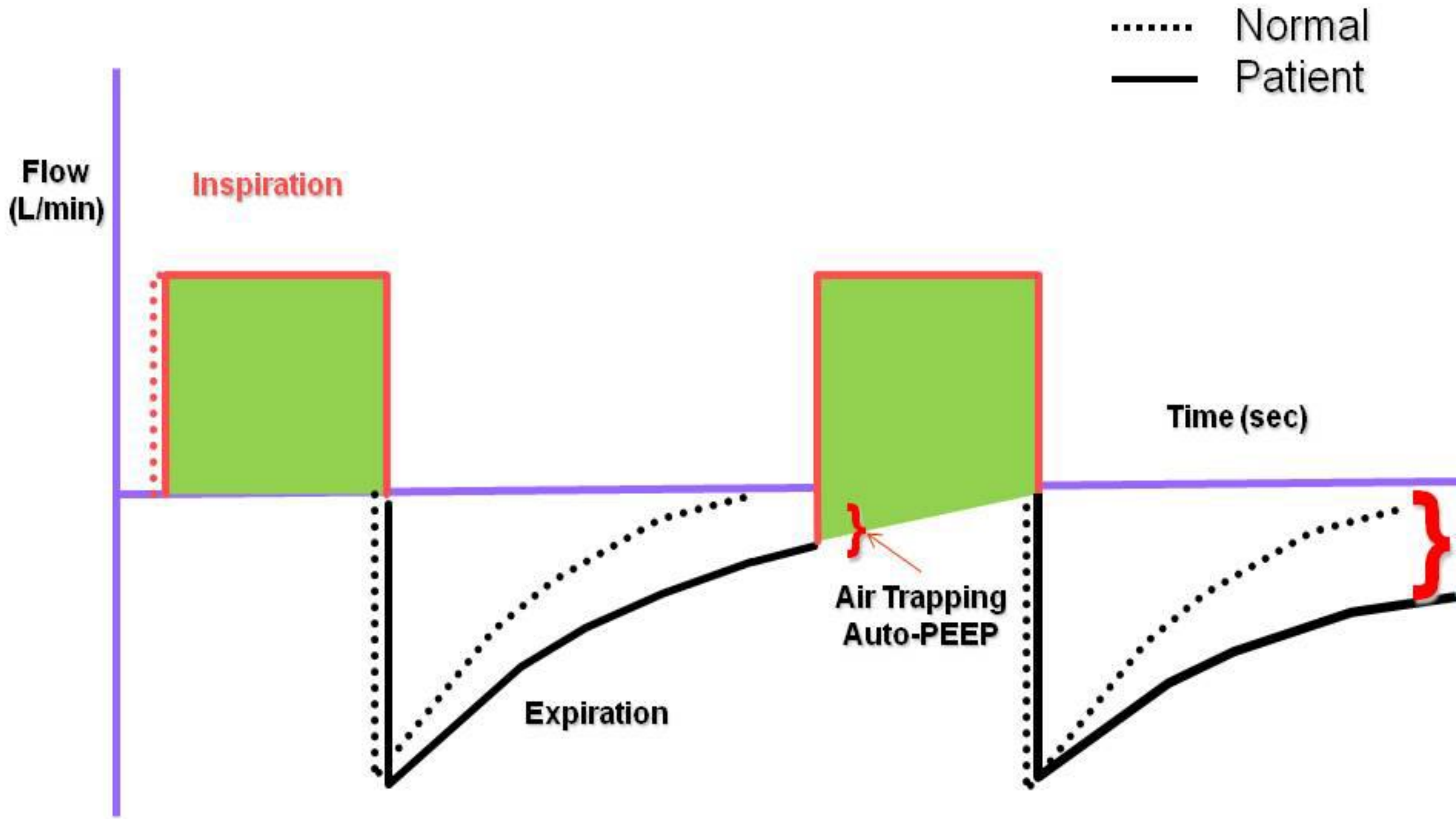
Complications of Mechanical Ventilation

Intrinsic PEEP, or auto-PEEP

- With COPD and/or asthma
- Breath stacking

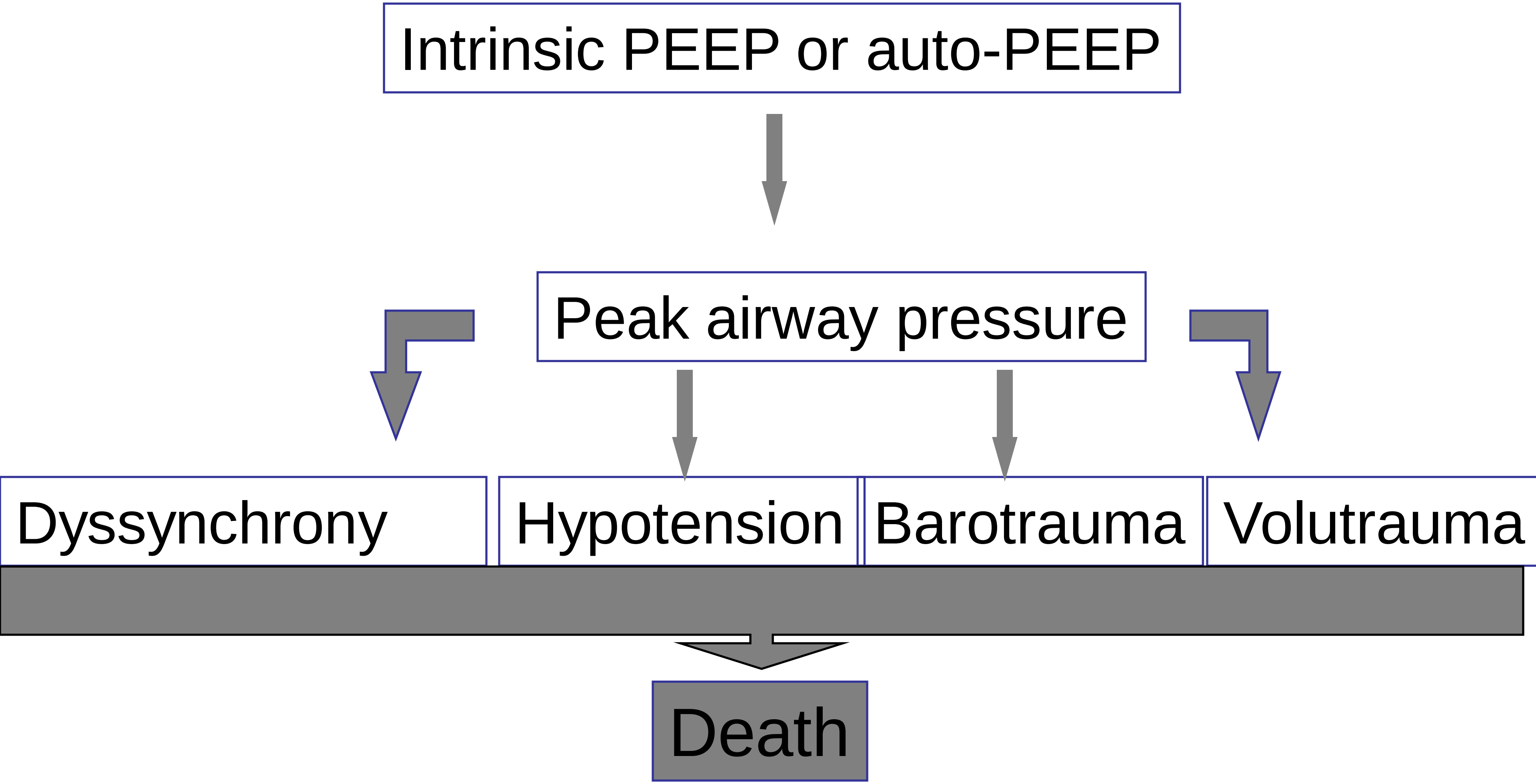
(difficulty in totally exhaling the ventilator-delivered tidal volume before the next machine breath is delivered. a portion of each subsequent tidal volume may be retained in the patient's lungs)

Air Trapping



The flow to time waveform demonstrating auto–positive end-expiratory pressure (auto-PEEP).

Complications of Mechanical Ventilation



Complications of Mechanical Ventilation

Intrinsic PEEP, or auto-PEEP

- Manometry performed by using an esophageal balloon to record changes in pleural pressure is the most accurate

TTT

- temporarily dc mechanical ventilation to allow for full expiration.
- short inspiration by
  - decreasing the set tidal volume or
  - increasing the inspiratory flow rate.

Complications of Mechanical Ventilation

Cardiovascular effects

Positive-pressure ventilation can

- Decrease preload
- Decrease stroke volume
- Decrease cardiac output.
- Decrease renal blood flow and function, resulting in gradual fluid retention.
- Decrease venous return from the head, increasing ICP lead to
  - Agitation
  - Delirium
  - Sleep deprivation.