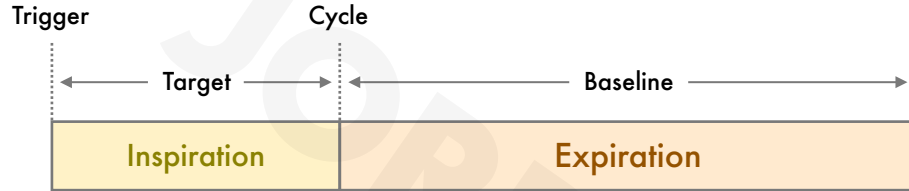# MECHANICAL VENTILATION

Trigger - What initiates inspiration?
- <u>Controlled</u> breath → Vent trigger: Time
- <u>Assisted</u> breath → Patient trigger: Pressure or Flow

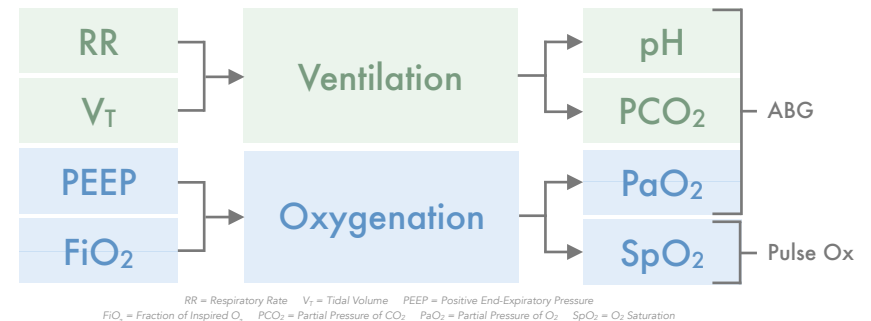### Target - how breath is delivered during inspiration
- Pressure target, PCV; Flow = dependent variable, varies
- Flow target, VCV; Pressure = dependent variable, varies

Cycle - What ends inspiration?
- Volume-cycle = inspiration continues until set volume delivered
- Time-cycle = until set time has elapsed
- Pressure-cycle = high pressure reach (safety)
- Flow-cycle = terminates breath until flow reaches certain percentage of peak inspiratory flow

Baseline - Airway pressure during expiration

Limit - What stops a breath early?

RR = Respiratory Rate V_T = Tidal Volume   PEEP = Positive End-Expiratory Pressure
FiO_2 = Fraction of Inspired O_2 PCO_2 = Partial Pressure of CO_2 PaO_2 = Partial Pressure of O_2 SpO_2 = O_2 Saturation

↑RR, ↑V_T → ↑pH, ↓PCO_2
If PCO_2 is high, then ↑ RR and/or V_T
If PCO_2 is low, then ↓ RR and/or V_T

↑PEEP, ↑FiO_2 → ↑PaO_2, ↑SpO_2
If PaO_2 is low, then ↑ FiO_2 and/or PEEP
If PaO_2 is high, then ↓ and/or PEEP

Ventilator-Induced Lung Injury (VILI)
- **Volutrauma:** Over-distention of alveoli due to high V_T
- **Barotrauma:** Injury from high $P_{PLATEAU}$ (highest risk > 35)
- **Atelectrauma:** Shear forces from cyclic alveolar recruitment and de-recruitment
- **Biotrauma:** Cytokine release from lung epithelium → multi-organ dysfunction
- **Oxytrauma:** ↑ FiO_2 → free radical production → lung injury

Dynamic Hyperinflation (Auto-PEEP)
Incomplete alveolar emptying during expiration; measured during expiratory hold
- **Diagnosis**: End-expiratory flow >0 (residual pressure)
- **Risk factors**: Vent strategy causing hyperinflation (high RR, ↓ expiratory time) or obstructive disease (asthma, COPD, CF)
- **Consequences**: HoTN (due to ↓ venous return), Alveolar over-dissension (→ volu/barotrauma), ↑ effort for patient to trigger vent-assisted breath
- **Treatment**: Allow longer exhalation (↑ expiratory time, ↓ RR), Bronchodilators for obstruction
- If severe hemodynamic or respiratory compromise, transiently *disconnect patient from ventilator* and manually bag ventilate to allow deflation

Peak Inspiratory Pressure: Reflection of airway resistance + lung compliance

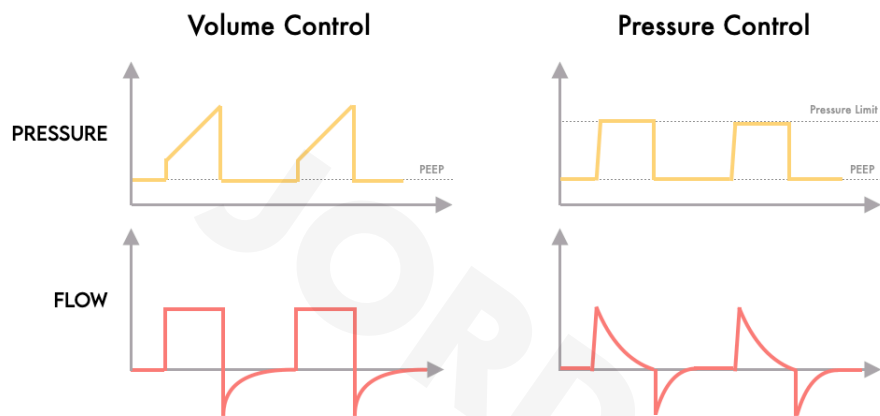**Plateau Pressure:** Reflection of lung compliance
Applies when there is no airflow in the circuit; occurs when inspiration is complete (inspiratory hold)

P_{PEAK} - $P_{PLATEAU}$ > 10 = Resistance problem
- Small ET tube
- Kinking/biting/obstructed ET tube
- High flow rate or V_T
- Ventilator asynchrony
- Mucus plug, blood clot
- Bronchospasm

P_{PEAK} - $P_{PLATEAU}$ < 10 = Compliance problem
- ARDS, edema, atelectasis
- Pneumothorax, effusion
- Air trapping (auto PEEP)
- Right mainstem intubation
- Fibrosis, Interstitial lung disease
- Obesity
- Abdominal compartment syndrome

Volume Control

Pressure Control

MODE	DESCRIPTION	PROS	CONS	EXAMPLES & EXPLANATION	
VC Volume Control	Preset **tidal volume (V_T)**; pressures vary • Trigger = Time • Target = Flow • Cycle = Volume • Limit = Volume	• Good general-purpose mode • Ensures V_M is achieved • Good for Lung Protective Ventilation (LPV) - fixed TV prevents volutrauma	• Must monitor pressures (P_{PEAK}, $P_{PLATEAU}$) to avoid barotrauma • Fixed inspiratory flow regardless of effort → ↑ patient-vent dyssynchrony	RR ..... 10 bpm TV ..... 500 cc PEEP ..... +8 FiO₂ 60%	Ventilator will deliver a breath with the preset TV of 500 cc 10 times a minute
PC Pressure Control	Preset **inspiratory pressure (IP)**; volumes vary • Trigger = Flow • Target = Pressure • Cycle = Time • Limit = Pressure	• Good for limiting pressure • Variable flow & TV may be more comfortable → ↓ dyssynchrony • Good for Lung Protective Ventilation (LPV) - fixed IP prevents barotrauma	• Must monitor volumes (V_T, MV) to avoid volutrauma or hypoventilation, as compliance changes	RR ..... 10 bpm IP ..... 20 cmH₂O I:E ratio ..... 1:2 PEEP ..... +5 FiO₂ 60%	Ventilator will deliver a breath with preset IP of 20 cmH₂O 10 times a minute
PRVC Pressure Regulated Volume Control	*Hybrid* PC mode that dynamically changes inspiratory pressure to deliver a desired volume • Trigger = Flow • Target = Pressure • Cycle = Time • Limit = Volume	• Guarentees TV • Delivers pressure controlled breaths		RR ..... 10 bpm TV ..... 500 cc I:E ratio ..... 1:2 P_MAX ..... 30 cmH₂O PEEP ..... +8 FiO₂ 60%	Ventilator will deliver the preset TV of 500 cc 10 times a minute; if the patients RR > 10, each breath will also be 500 cc
SIMV Synchronous Intermittent Mandatory Ventilation	Delivers mandatory number of breaths with a fixed volume, while at the same time allowing spontaneous breaths • Trigger = Time • Target = Variable • Cycle = Volume • Limit = Volume		• Seldom used • Not effective for weaning • Must monitor pressures (P_{PEAK}, $P_{PLATEAU}$) to avoid barotrauma	RR ..... 10 bpm TV ..... 500 cc PS ..... +5 PEEP ..... +5 FiO₂ 60%	Ventilator will deliver 10 bpm with TV 500 cc; if the patient's RR > 10, those non mandatory breaths will receive inspiratory pressure support to peak pressure 5 cmH₂O above the PEEP of 5 cmH₂O
PS Pressure Support	All breaths/ventilation are patient initiated No backup rate • Trigger = Pressure/Flow • Target = Pressure • Cycle = Flow • Limit = Pressure	• Ideal weaning mode • Most comfortable as it allows patient to control ventilation	• Does not guarantee a rate • Need to monitor volumes (V_T, MV) to ensure adequate ventilation	PS ..... +10 PEEP ..... +5 FiO₂ ..... 40% Note that PS is above PEEP, so "Ten over Five" PIP = 15 cmH₂O	Patient must be breathing spontaneously; each breath will receive inspiratory pressure support to peak pressure 10 cmH₂O above the PEEP of 5 cmH₂O