CRITCARE BITES
VENTILATOR DYSSYNCHRONY

Clare Fong
Alexandra Hospital, National University Hospital

SICM
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SINGAPORE

MAD FOR MEDICINE

INTRODUCTION

- The ventilator needs to be told
  - When to start the breath (Trigger)
  - What it needs to achieve with each breath (Limit)
  - When to stop the breath (Cycle)

- Patient ventilator dyssynchrony (PVD) is the uncoupling of a mechanically delivered breath from patient's own intrinsic neural breath

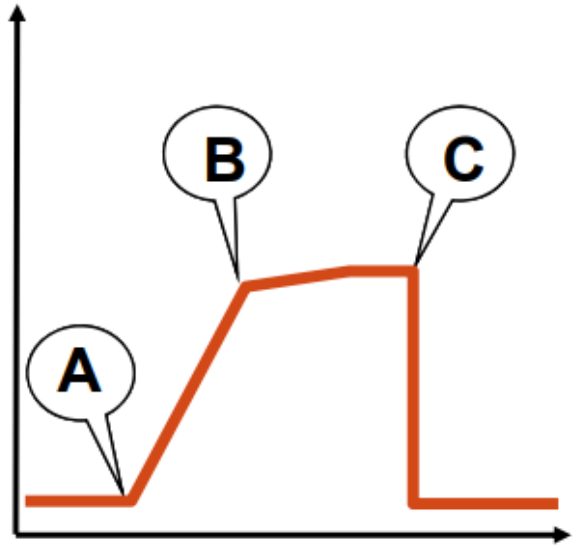
CONSEQUENCES

- **Ventilator induced lung injury** (VILI)
- **Patient self inflicted lung injury** (P-SILI)
- **Increases work of breathing**, increases **oxygen demand**, causes **patient distress and discomfort**, increases ICP
- **Increases length of ventilation and ICU stay** (possibly even mortality)

- Can occur because of high respiratory drive (flow starvation, premature cycling) or low respiratory drive (ineffective triggering, delayed cycling, reverse triggering)

PATIENT VENTILATORY DYSSYNCHRONY

- **Trigger** Dyssynchrony
  - Ineffective triggering
  - Auto triggering
  - Reverse trigger
- **Flow** Dyssynchrony
  - Inadequate flow (flow starvation)
- **Cycle** Dyssynchrony
  - Premature cycling > with resultant double triggering
  - Delayed cycling



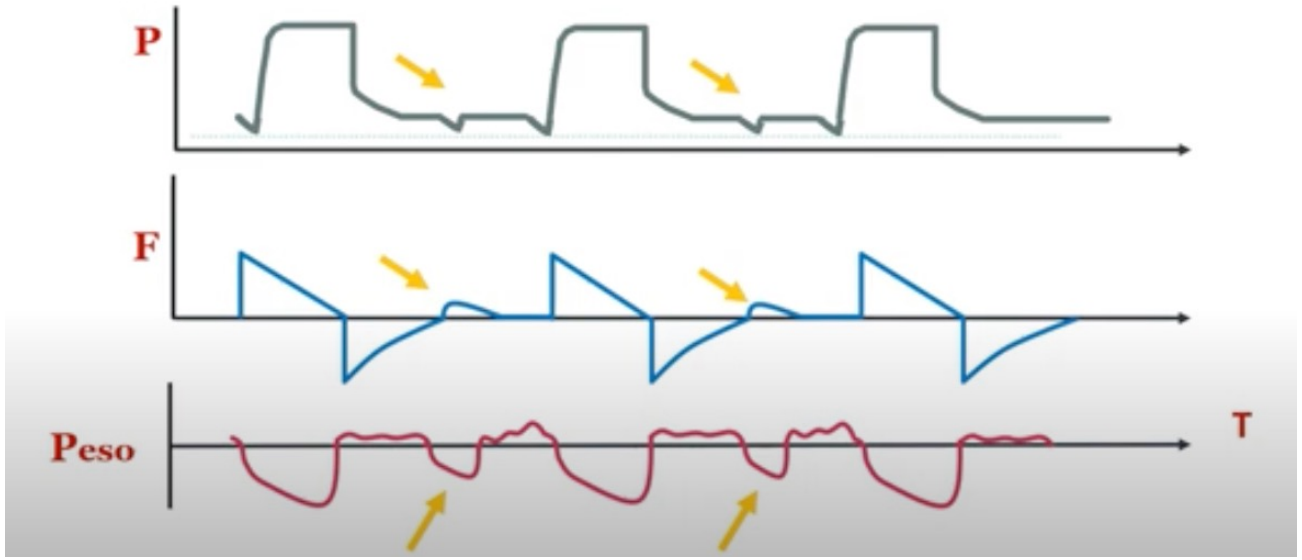
A = Trigger

B = Limit

C = Cycle

INEFFECTIVE TRIGGER

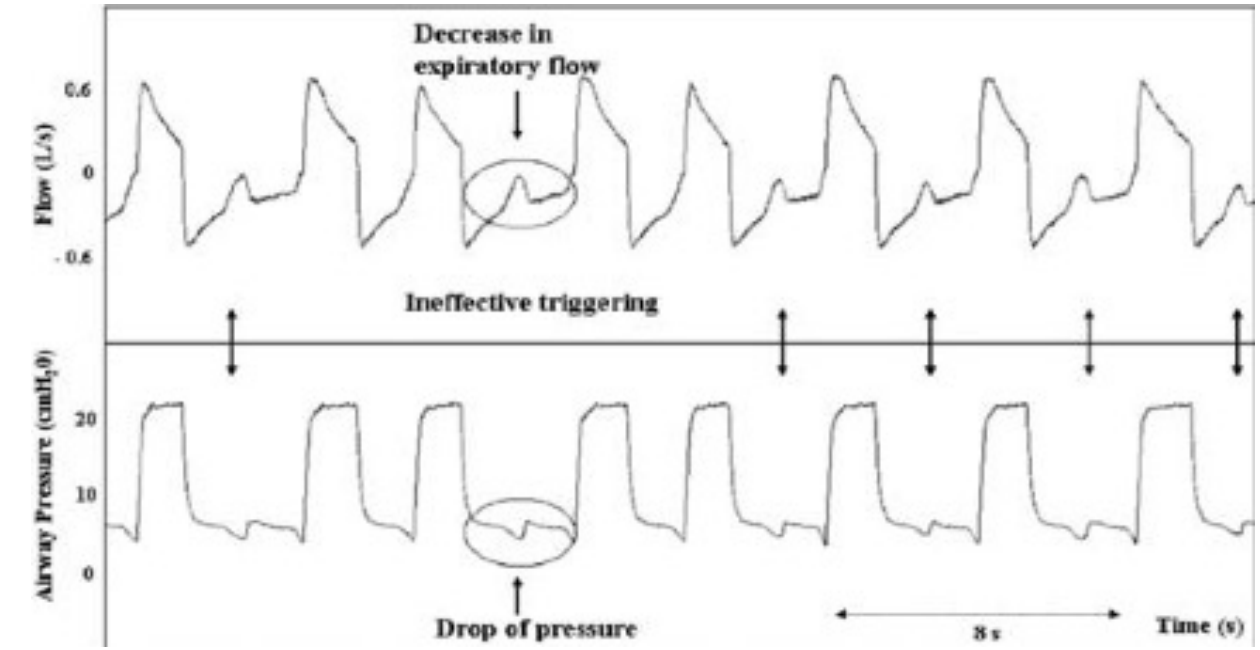
- Patient effort does not trigger breath
- More easily diagnosed with esophageal pressure monitoring

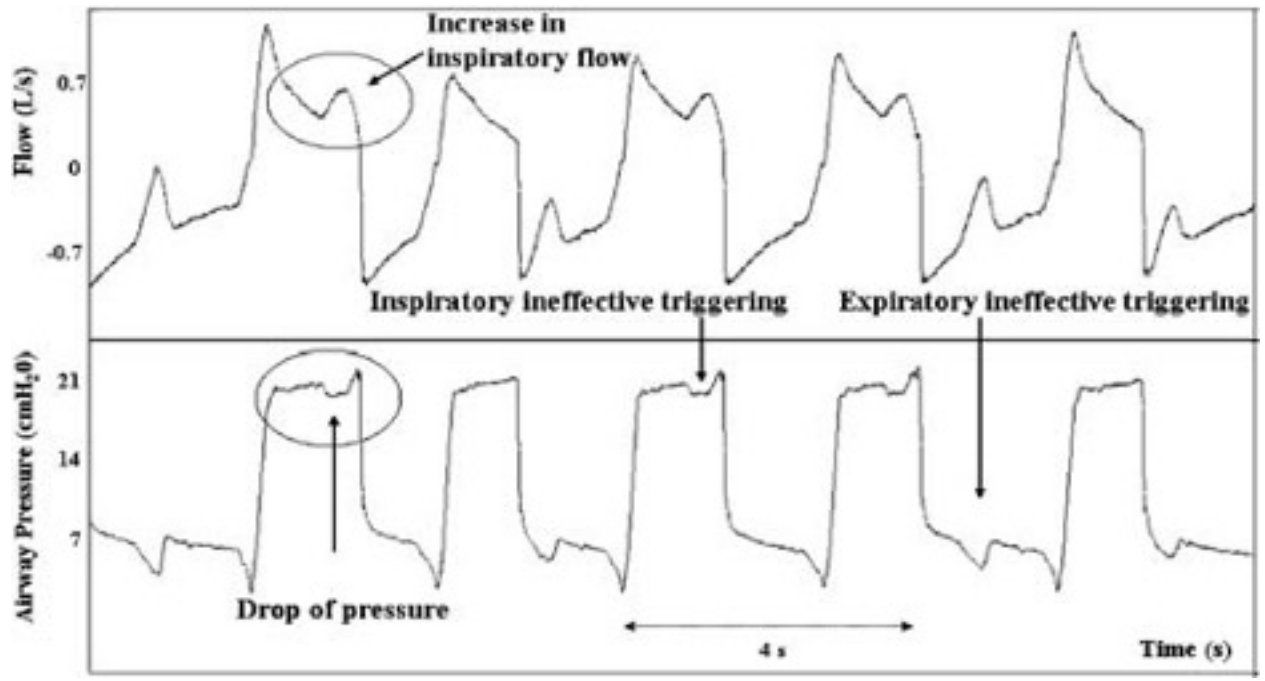


INEFFECTIVE TRIGGER: CAUSES

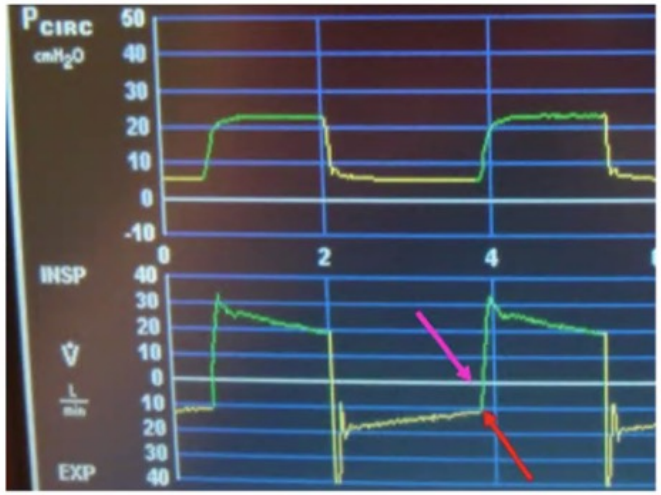
- **Dynamic hyperinflation**
- Neuromuscular weakness
- Reduced respiratory drive (over sedation)
- Flow trigger too insensitive (rarely the case)

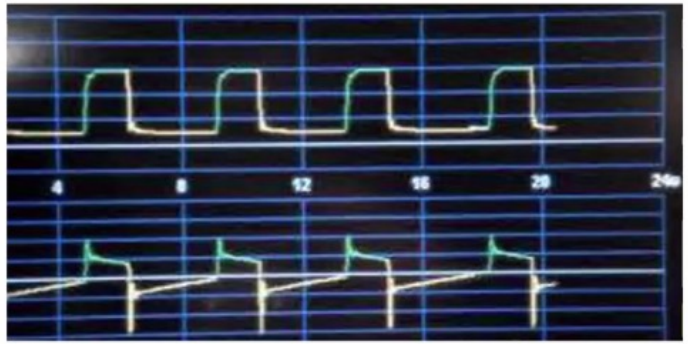
- **Consequences**
  - Increases work of breathing
  - Uncomfortable for the patient
  - Prolonged weaning


Decrease in
expiratory flow
Flow (L/s)
0.6
0
-0.6
Ineffective triggering
Airway Pressure (cmH2O)
20
10
0
Drop of pressure
8 s
Time (s)

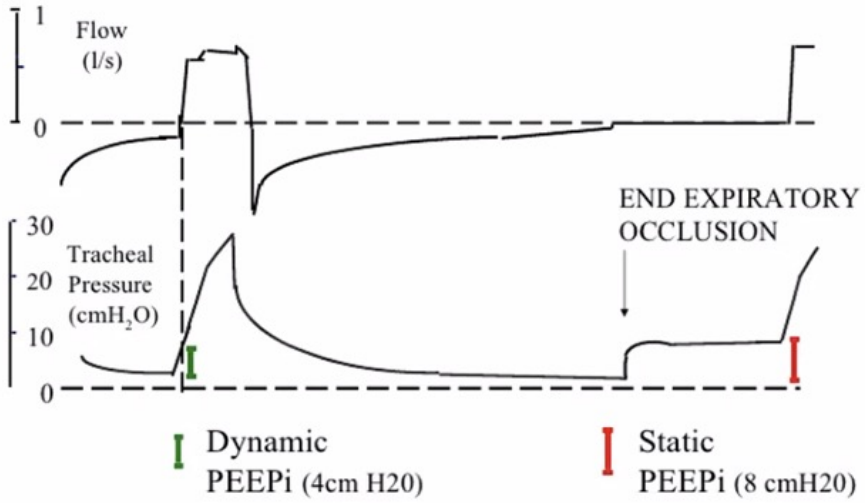

Increase in
inspiratory flow
Flow (L/s)
0.7
0
-0.7
Inspiratory ineffective triggering
Expiratory ineffective triggering
Airway Pressure (cmH2O)
21
14
7
Drop of pressure
4 s
Time (s)

DETECTING DYNAMIC HYPERINFLATION





Assessing for AutoPeep



1) Failure of the expiratory flow waveform to return to baseline

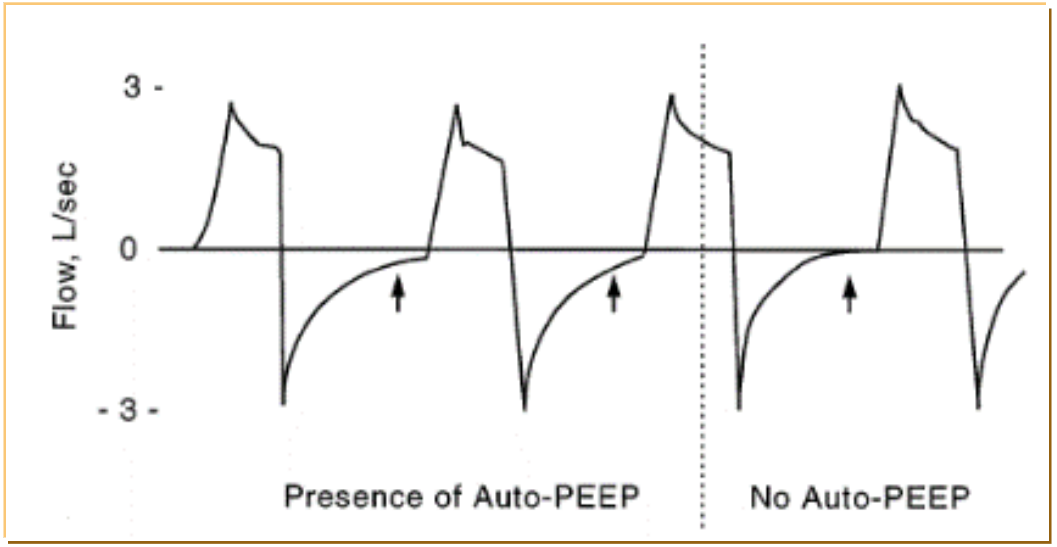
2) Expiratory pause

3) Area under the curve of the flow-time waveform (inspiratory = delivered Vt > expiratory = exhaled Vt)

4) Increasing Pplat

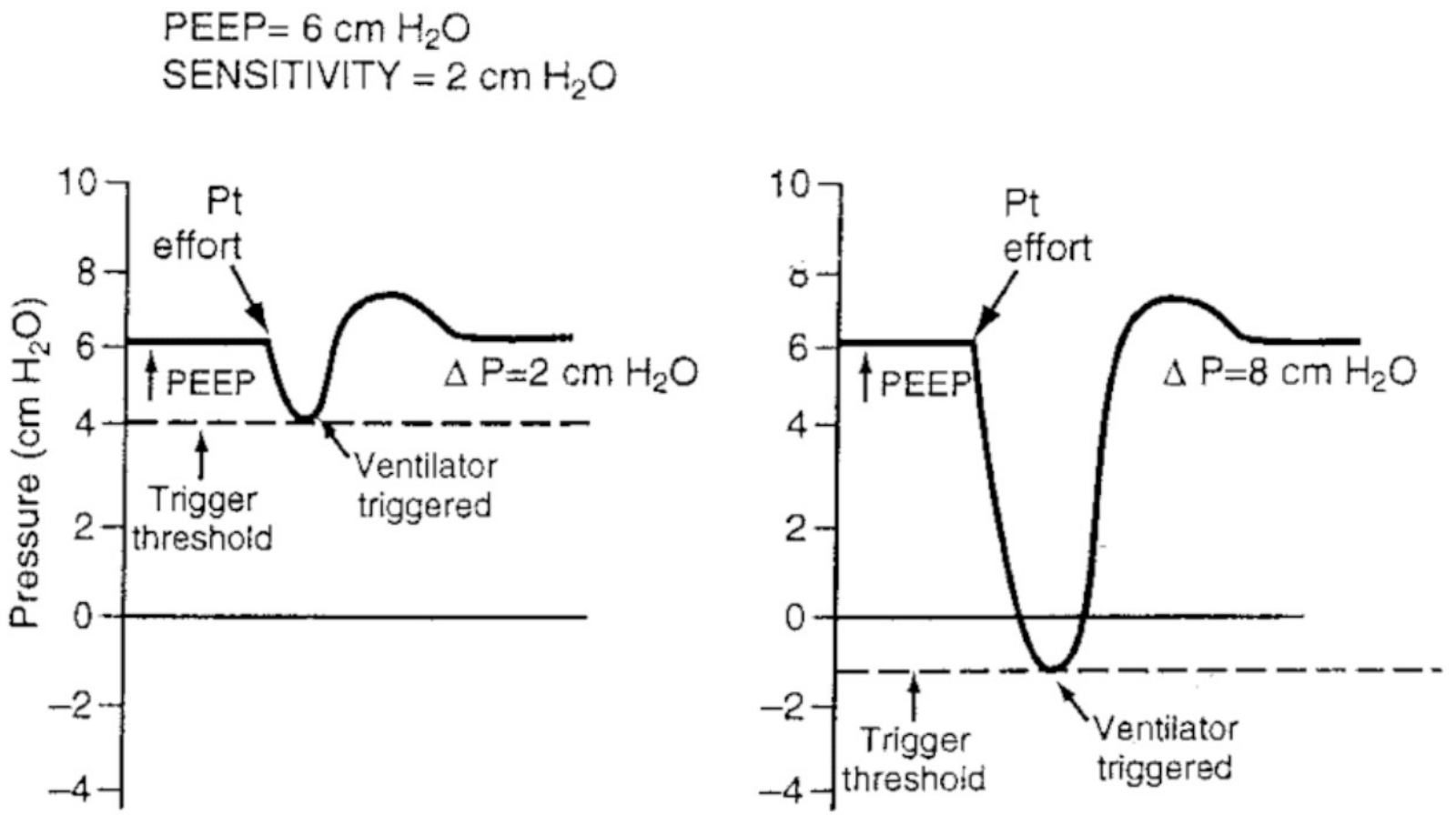
INEFFECTIVE TRIGGER AUTO-PEEP: SOLUTION

- Obstructive airways disease results in **dynamic hyperinflation**



- **Decrease auto-PEEP**: reduce RR, increase expiratory time, reduce VT, bronchodilators
- **Apply external PEEP**

Nava et al, Intensive Care Med 1995
Thille et al, Intensive Care Med 2008



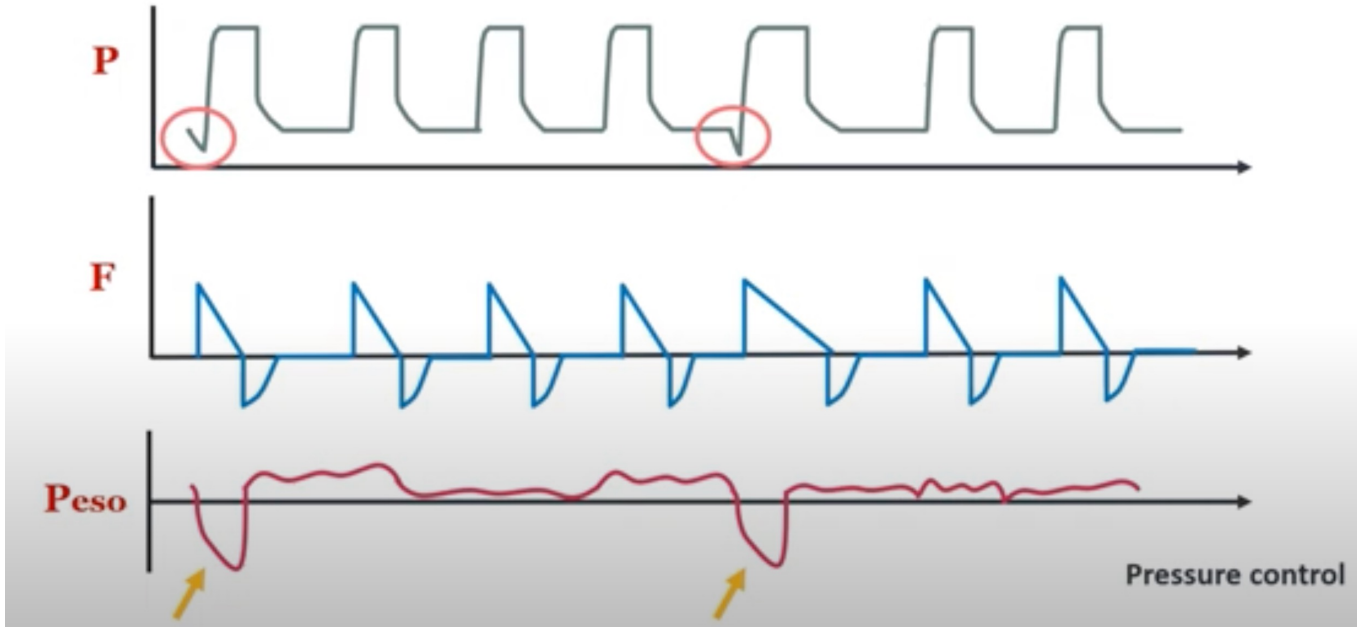
- **Apply external PEEP**
  - Applied PEEP 50-80% of intrinsic PEEP → reduces inspiratory effort required to trigger the ventilator
  - As long as applied PEEP is less than intrinsic PEEP, will not worsen iPEEP (waterfall theory)

INEFFECTIVE TRIGGER: SOLUTION

- Reduce sedation if over-sedated
- Increase trigger sensitivity
  - Flow
  - Pressure

AUTO TRIGGER

- Ventilator delivers a breath even though patient is not making an inspiratory effort

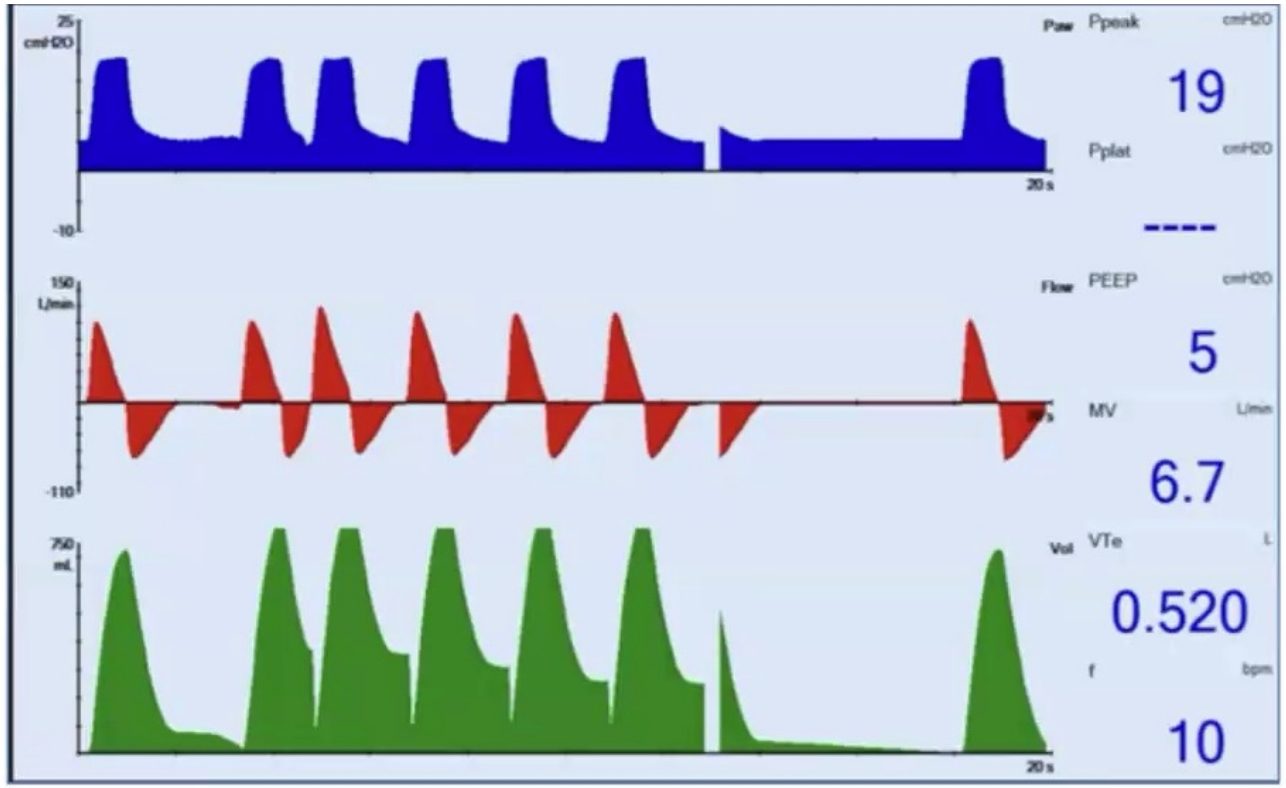


AUTO TRIGGER: CAUSES

- Air leak
- Secretions
- Cardiac oscillations
- Hiccups
- Diaphragm myoclonus
- Nebulizer treatment

AUTO TRIGGER: AIR LEAK

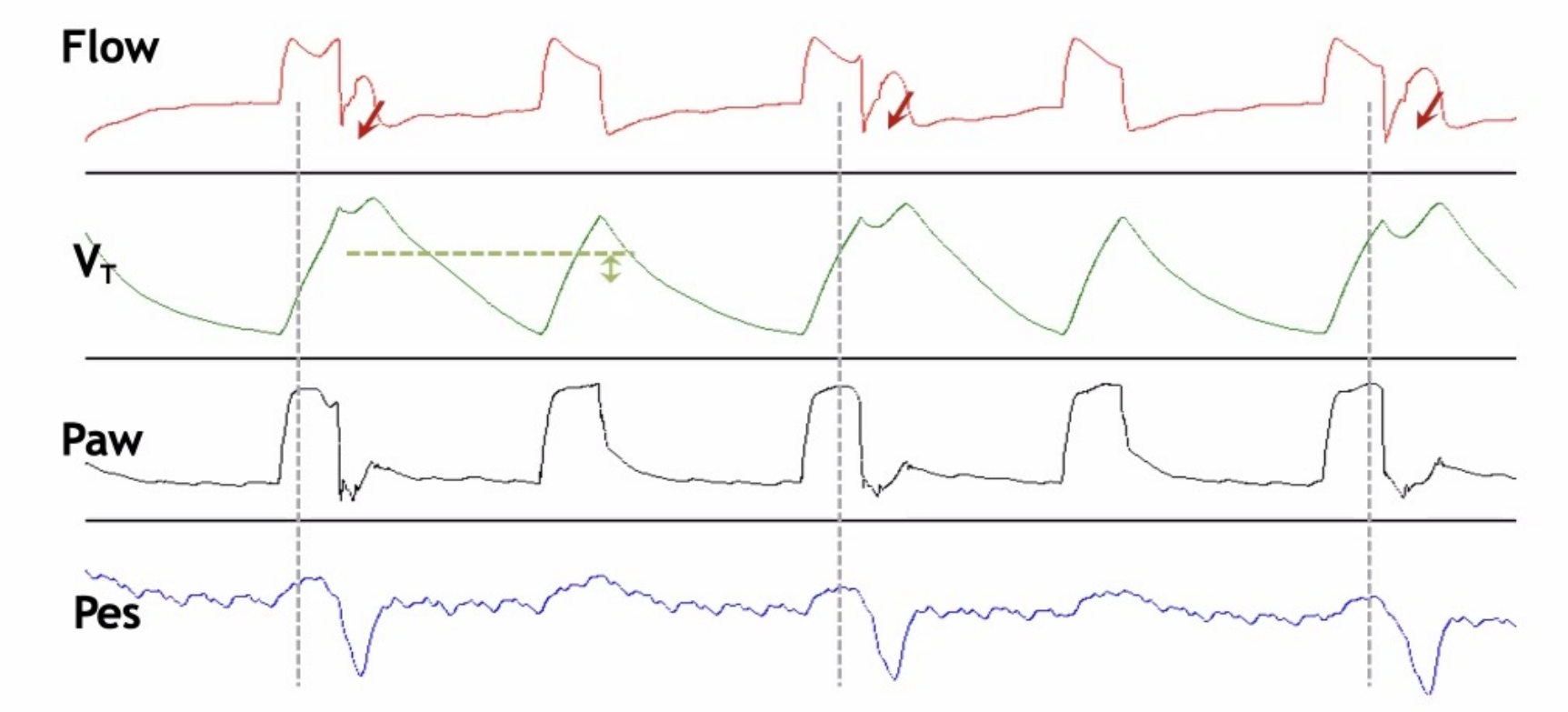
- Suspect air leak because the volume time curve does not return to baseline
- Auto trigger only in flow triggered mode



REVERSE TRIGGER

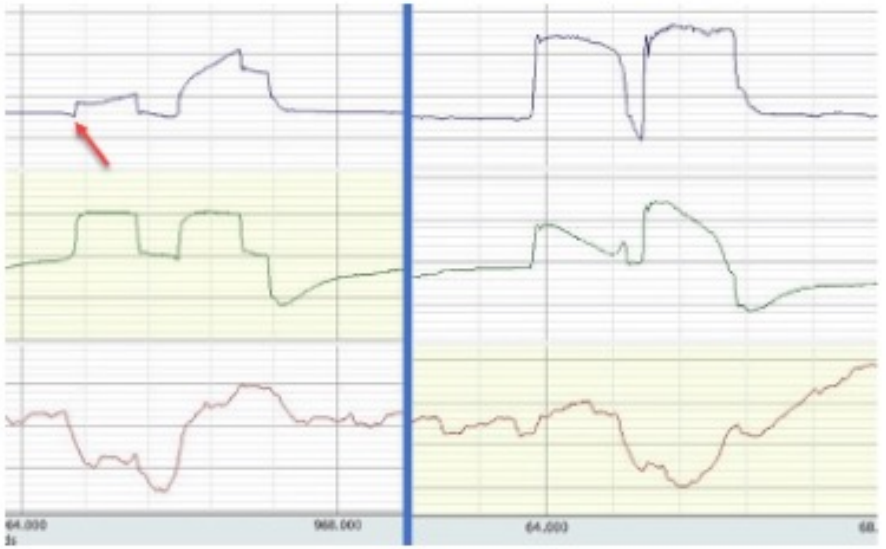
- Ventilator triggered breath followed by patient triggered breath
- Associated with deep sedation
- Postulated mechanisms
  - Brainstem respiratory centres synchronise with mechanical breaths delivered by ventilator
  - Machine delivered breath stretches chest wall, triggers Hering-Breuer stretch reflex mediated breath
- Management: reduce sedation, neuromuscular blockade, increase set RR

REVERSE TRIGGER



REVERSE TRIGGER

Double triggering or Reverse triggering



Pressure

Flow

Oesophageal pressure

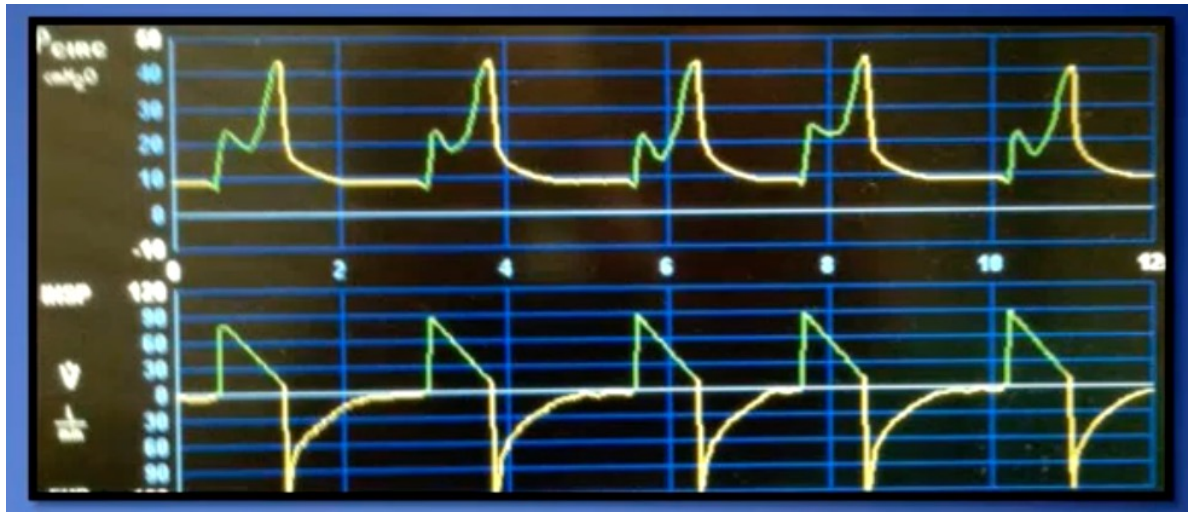
Patient-initiated breath
May not be deeply sedated

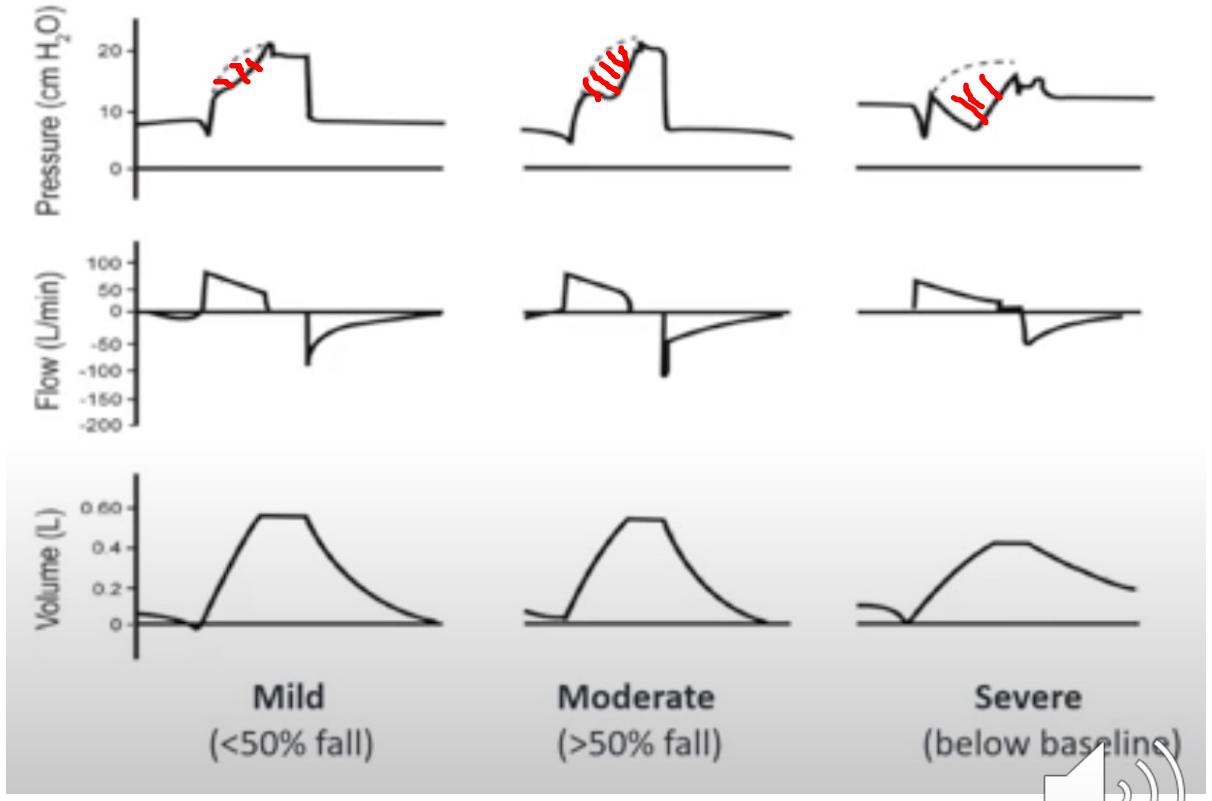
Machine-initiated breath
Usually deeply sedated

FLOW STARVATION

- Flow starvation occurs when the ventilator fails to meet patient's flow demand; usually in volume control mode
- Demonstrated by a drop in airway pressure
- Causes: High respiratory drive or low ventilatory settings
- Pathophysiology: Pendelluft effect with high volumes of air movement from non-dependent to dependent parts of lungs (P-SILI)

FLOW STARVATION





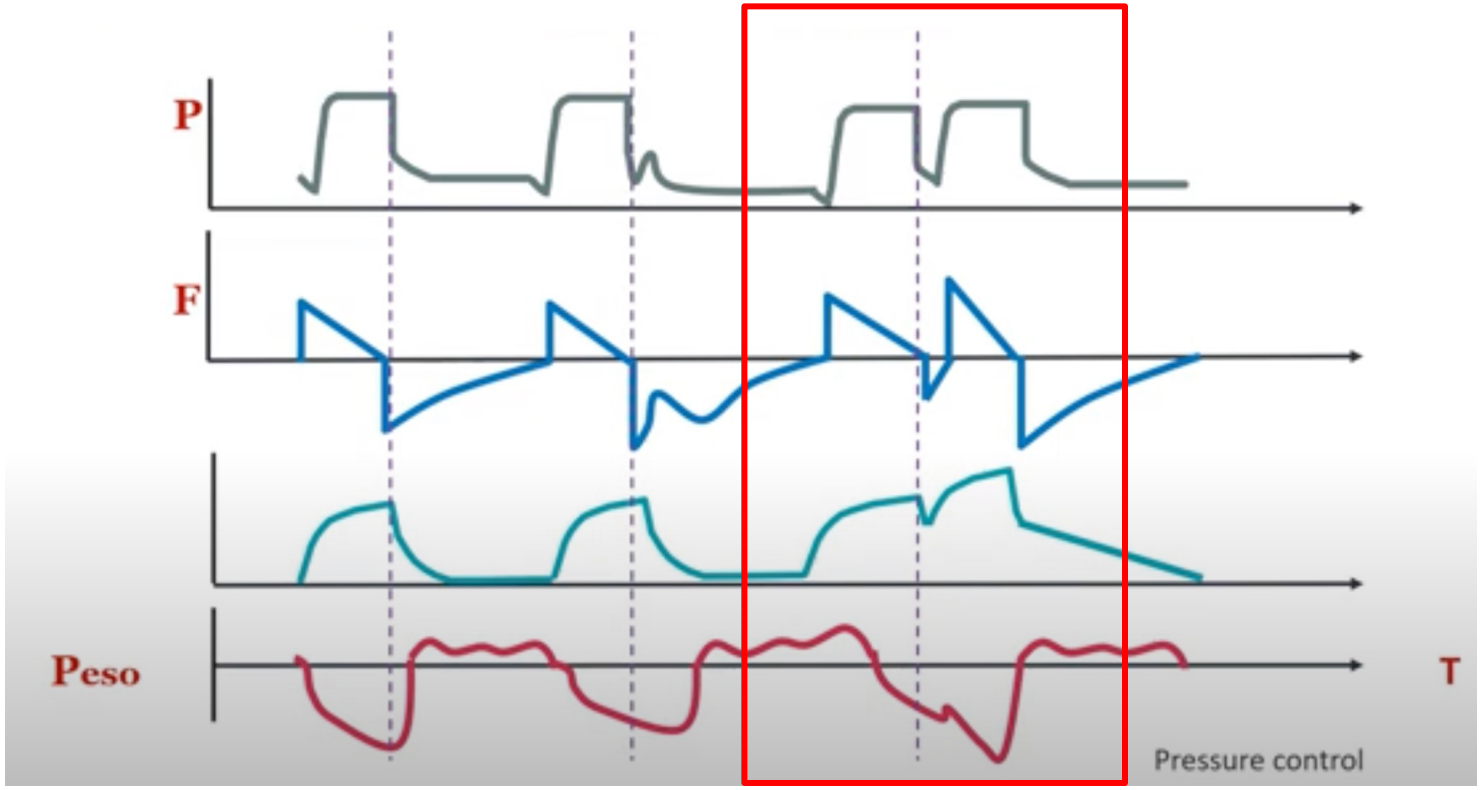
FLOW STARVATION: SOLUTION

- Change to Pressure Control
- Increase TV
- Increase flow (or reduce Ti)
- Assess analgesia and sedation
- Paralysis as a last resort

DOUBLE TRIGGERING

- Two inspiratory cycles separated by a very short expiratory time (less than one-half of the mean inspiratory time)
- Mechanical Ti < neural Ti
- Leads to larger tidal volumes and breath stacking

DOUBLE TRIGGERING

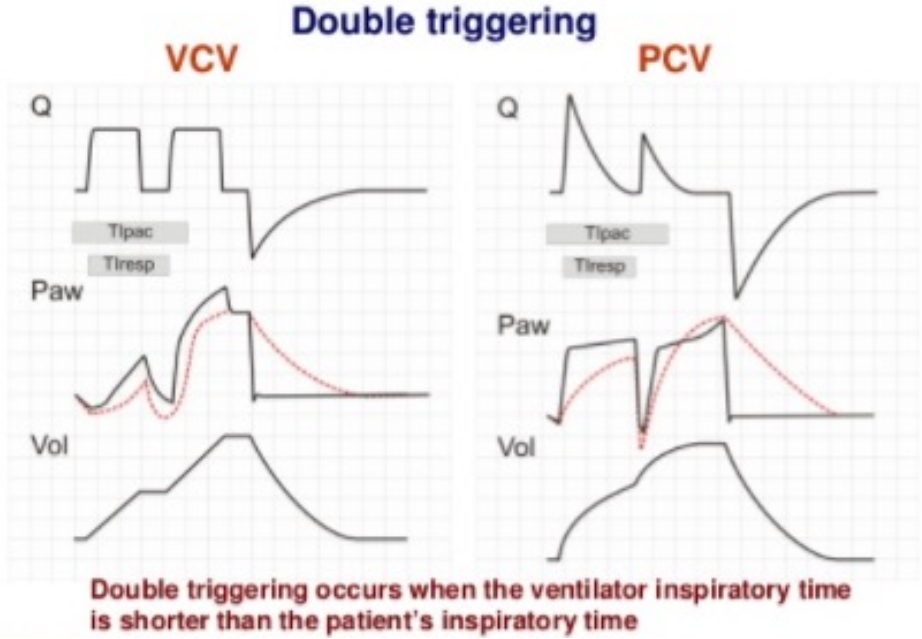


DOUBLE TRIGGERING: SOLUTION

- **Increase mechanical Ti**

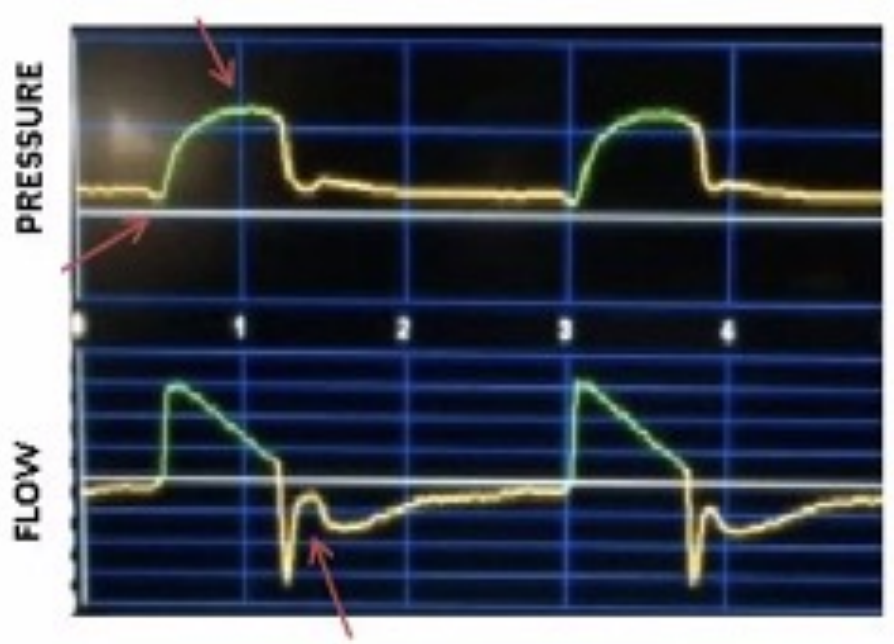
- PCV
  - Increase Ti
- VCV
  - Increase VT
  - Reduce flow (recall: Ti = volume/ flow)
- PS
  - Lower cycle threshold
  - Increase PS
  - Slower rise time

- **Reduce neural Ti**
  - Sedation



PREMATURE CYCLING

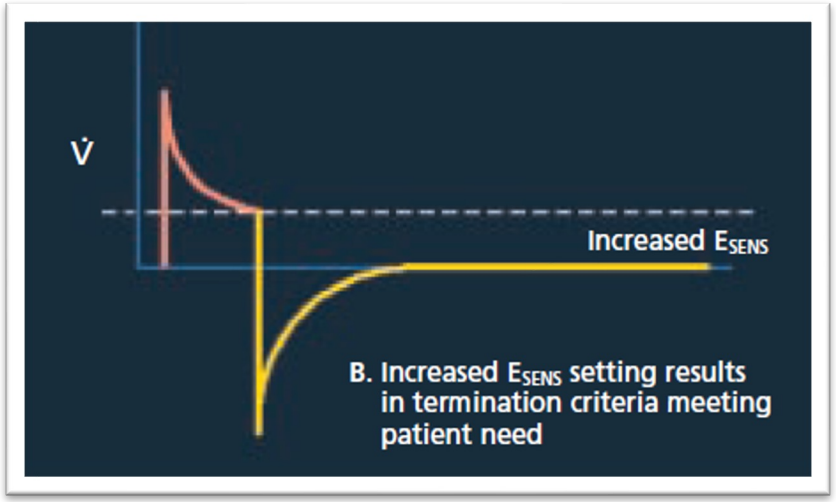
- Mechanical Ti < neural Ti
- Patient factors
  - Unusually high ventilatory demand
- Ventilator risk factors
  - Low tidal volume
  - Ventilator Ti set too short
  - Pressure support

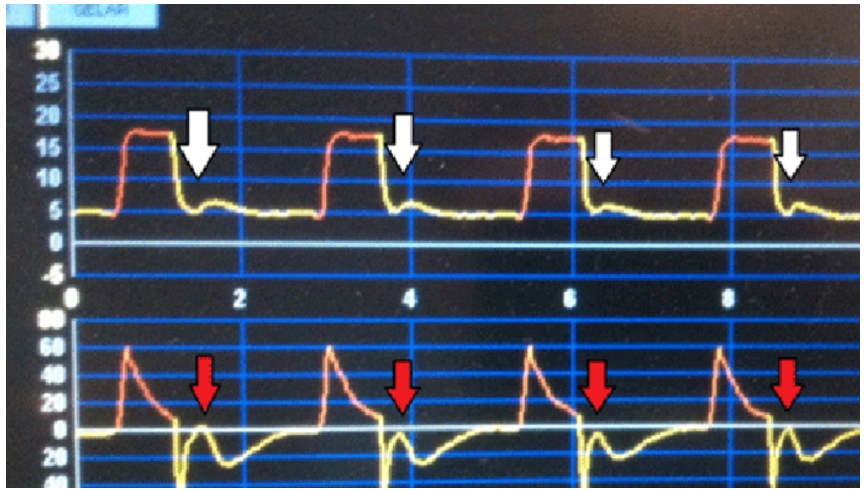


Positive deflection in expiratory flow:
Patient wants to continue inspiration but machine is already in expiration

PREMATURE CYCLING: PS

- Breath normally cycles off in PS when flow is 25% of the peak flow rate
- Premature termination of the breath may occur if set threshold (ESENS) is too high or there is a decrease in lung compliance





DOI:10.15226/2374-8362/4/4/00147

PREMATURE CYCLING: SOLUTIONS

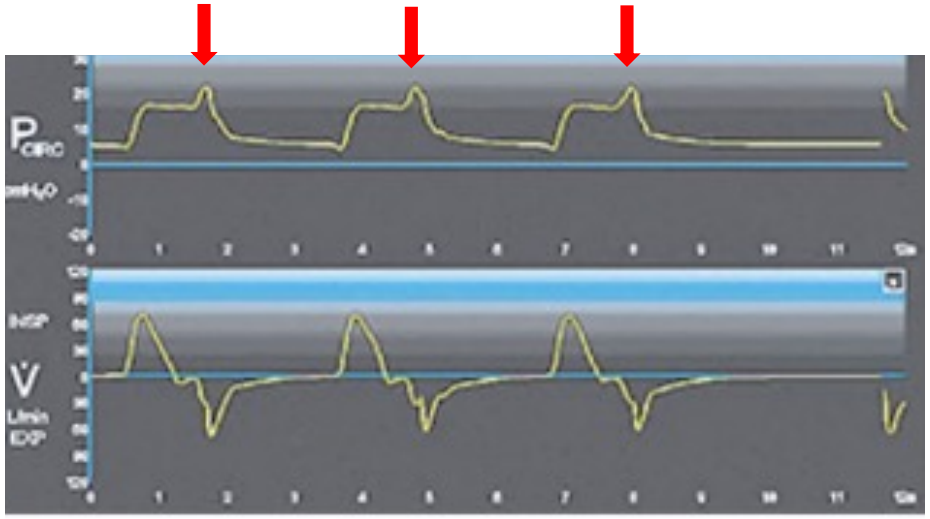
- **Increase mechanical Ti**

Mode	Solution
PCV	Increase Ti
VCV	Increase VT Reduce flow (recall: Ti = volume/ flow)
PS	Lower cycle threshold Increase PS Slower rise time Lowering PEEP: alters respiratory system compliance and slope of inspiratory flow

- **Reduce neural Ti**
  - Sedation

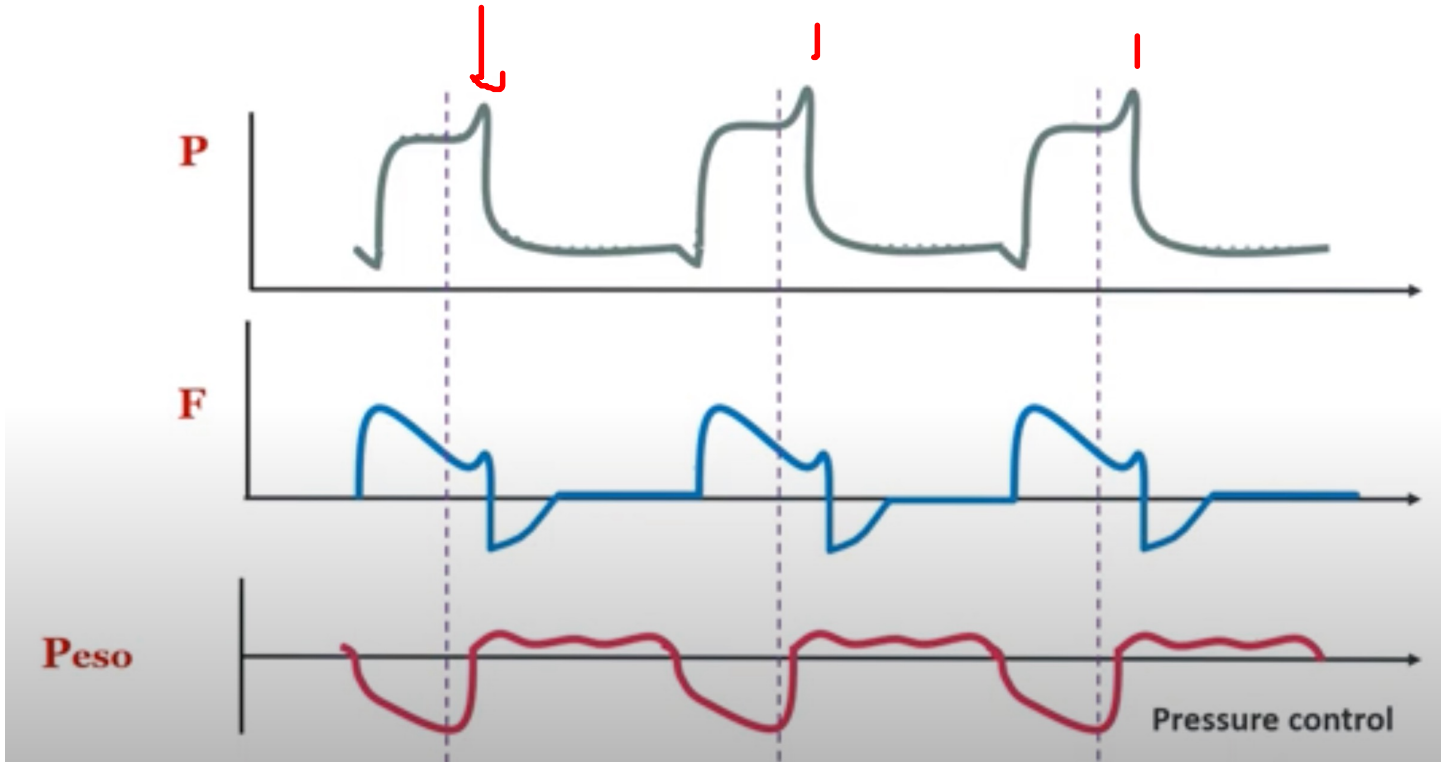
DELAYED CYCLING

- Mechanical Ti > neural Ti
- Ventilator continues inspiration when patient has started to expire – **usually in pressure support**
- Causes: Leaks, COPD (increased resistance and compliance)
- Can result in dynamic hyperinflation



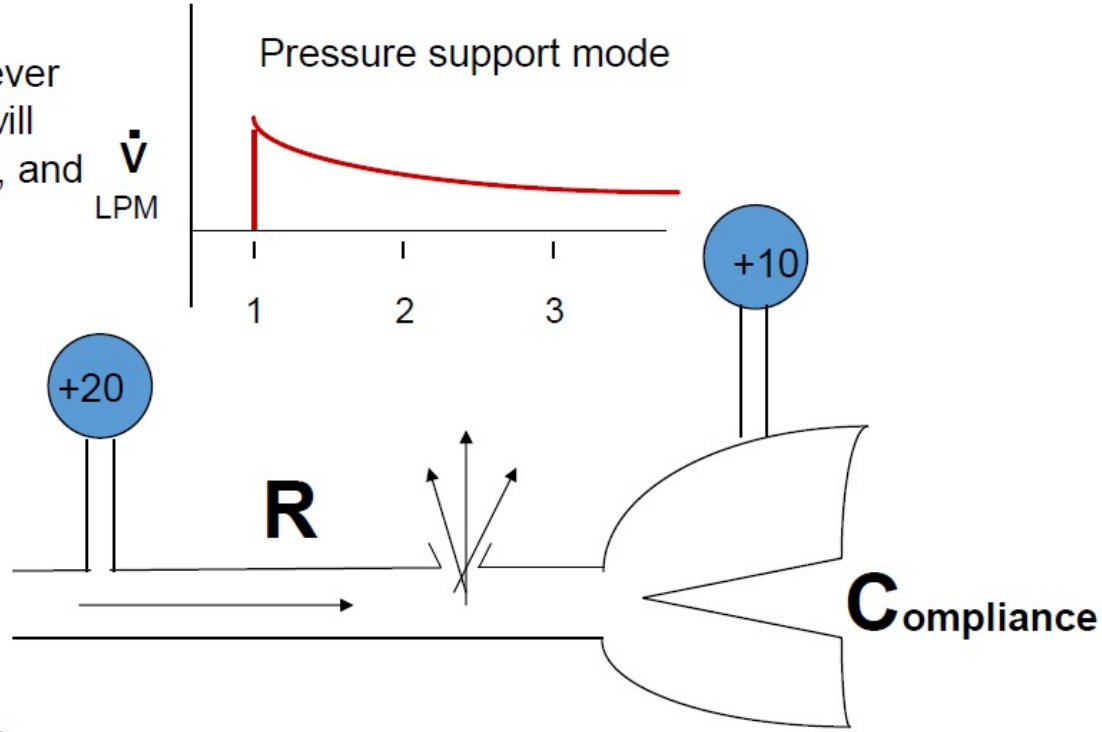
Patient is trying to exhale but ventilator is still delivering the breath

DELAYED CYCLING

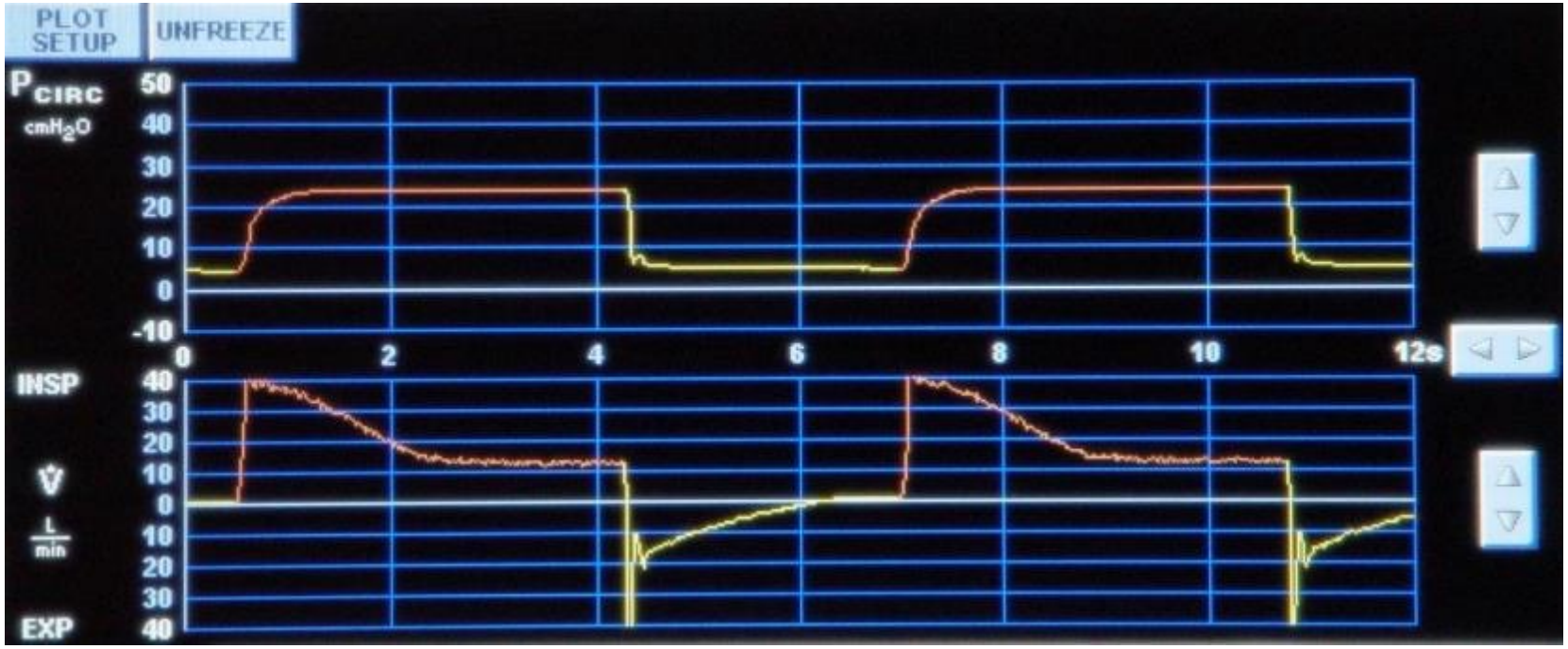


DELAYED CYCLING: LEAK

If there is a leak in the system, the pressures can never be equal. Flow will not come to zero, and the breath will continue forever.



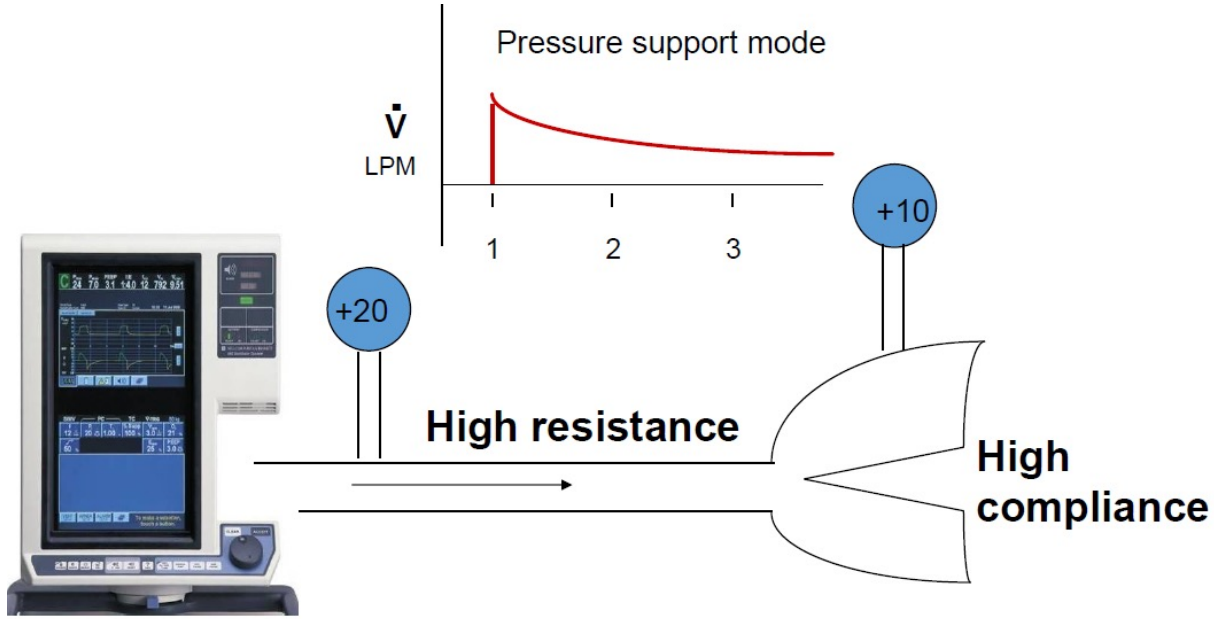
DELAYED CYCLING: LEAK

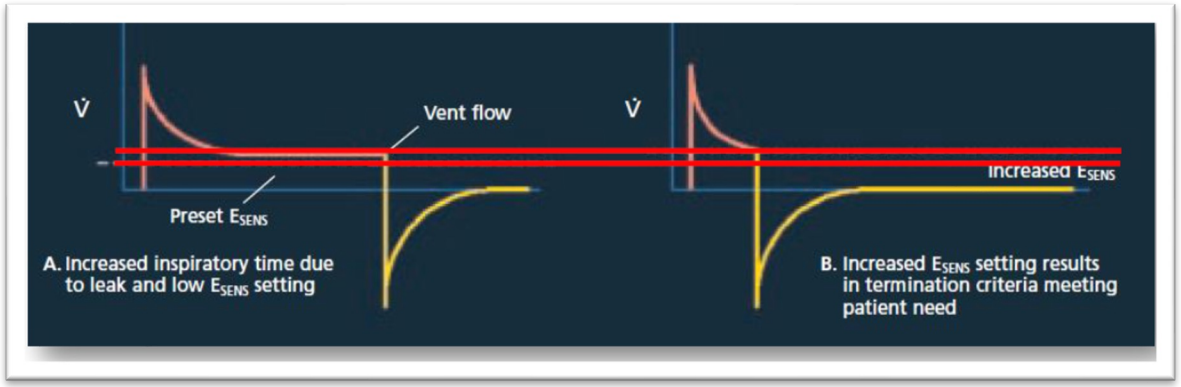


Delayed cycling due to leak

Delayed cycling due to leak

DELAYED CYCLING: COPD

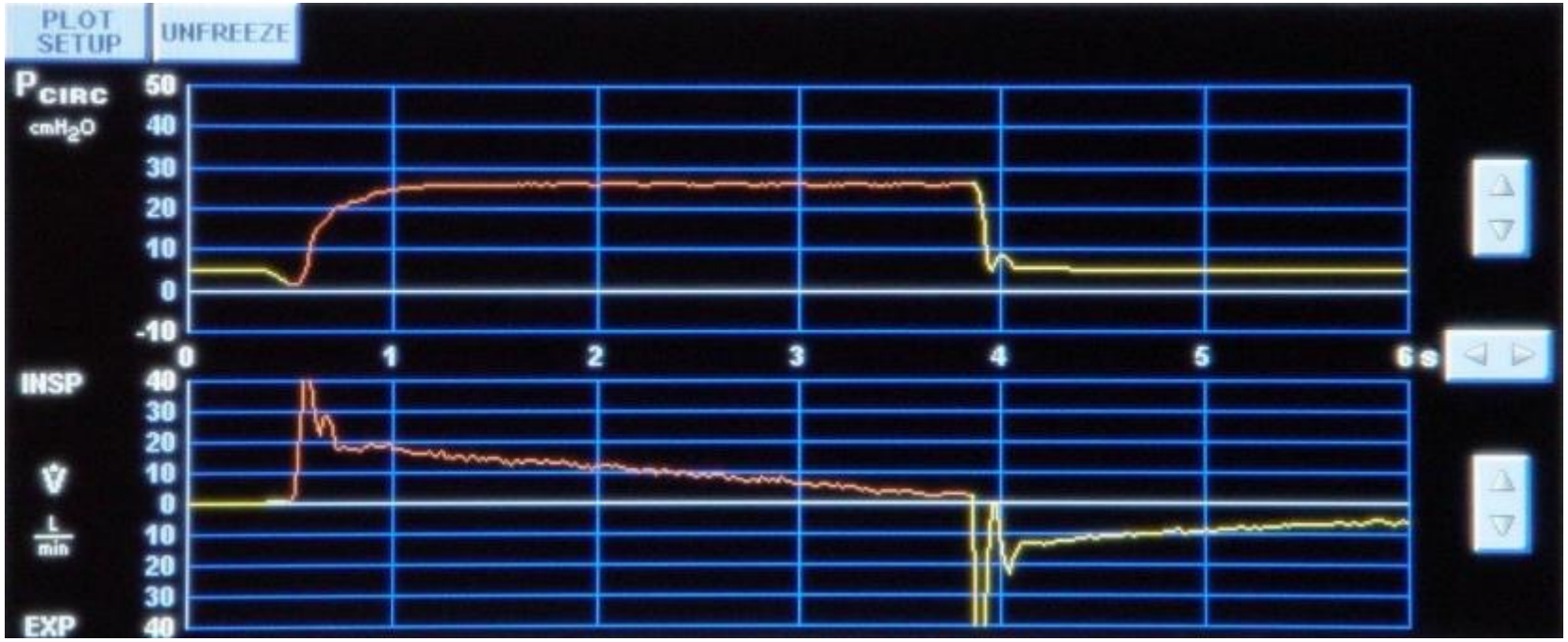




- In COPD, there is high airways resistance
- Peak flows are very slow
- A long period must pass before flow drops to 25% of peak inspiratory flow

- Solution
  - Increase ESENS
  - Pre-set cycle time

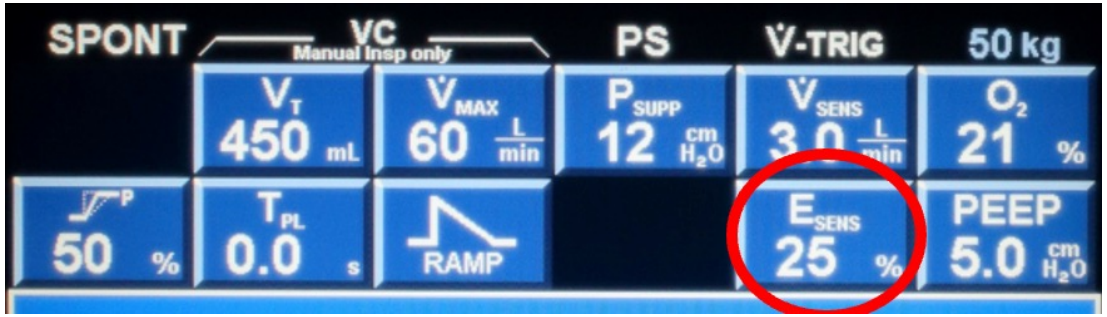
DELAYED CYCLING: COPD



Delayed cycling in COPD due to high compliance and resistance

DELAYED CYCLING: SOLUTIONS

- **Decrease mechanical Ti**
  - PCV: decrease Ti
  - VCV: decrease VT
  - PS
    - Increase cycling threshold
- **Address underlying cause**
  - Leaks
  - COPD



FURTHER READING

Concise Clinical Review

Patient–Ventilator Interactions
Implications for Clinical Management

Daniel Gilstrap[1] and Neil MacIntyre[1]

[1]Department of Medicine, Duke University, Durham, North Carolina

Respiratory Mechanics in Mechanically Ventilated Patients

Dean R Hess PhD RRT FAARC

Credit to Dr Jason Phua, Dr Addy Tan for some of the graphics