Assessment, Management trouble shooting of Patient-ventilator dyssynchrony

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A daily scenario in ICU…..

Synchronous ventilator support match with patient demands

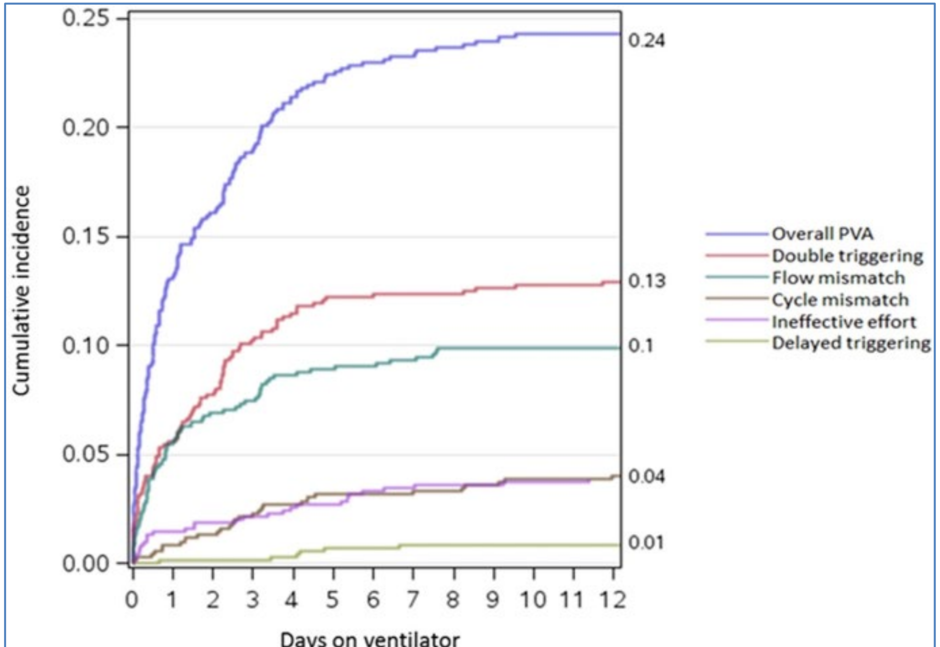
Asynchronies during mechanical ventilation are associated with mortality

- *Intensive Care Med* **41,** 633–641 (2015).

Ventilator Dyssynchrony

- Dyssynchrony = Asynchronies
  - Mismatch between the inspiratory and expiratory times of patient and ventilator
  - Failure to provide ventilated patients with optimal assistance.
- Result in
  - prolonged mechanical ventilation, difficult weaning, patient discomfort, increased diaphragmatic damage
  - Potential increase in morbidity and mortality

Incidence of patient–ventilator asynchrony in critically-ill patients



Cumulative incidence of asynchrony over the first 12 days of mechanical ventilation.

- PVA: ineffective triggering, double-triggering, short-cycle breaths, and long-cycle breaths

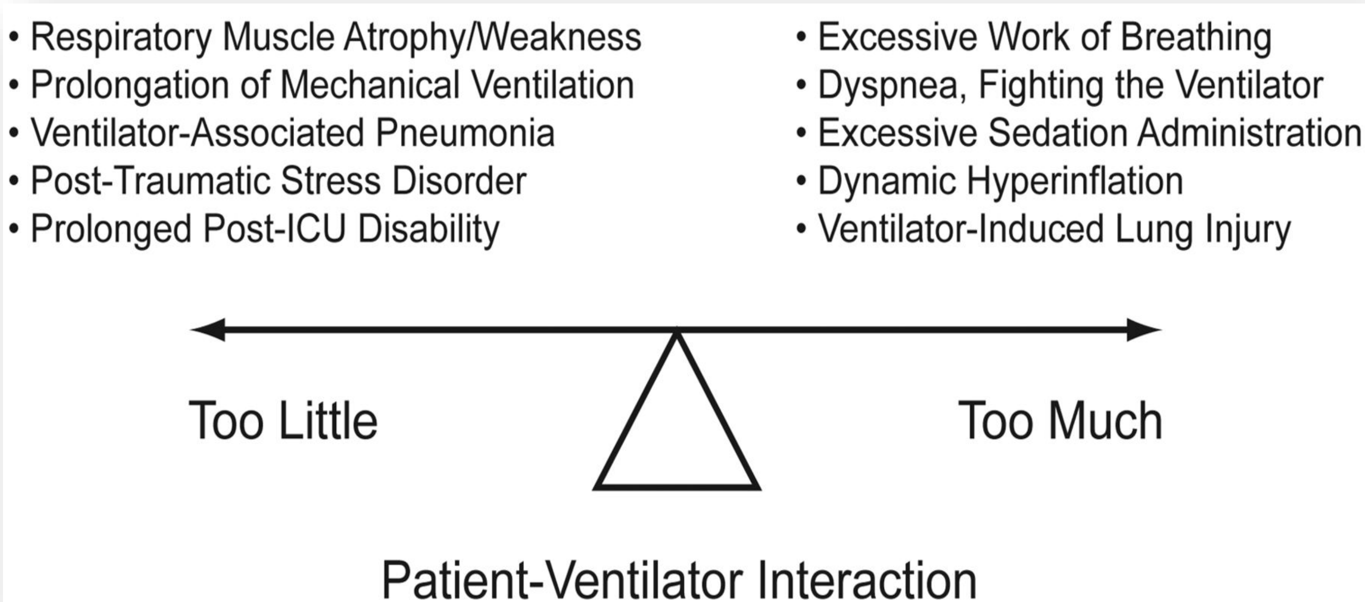
- Asynchrony index (AI)
  - number of PVA events/total respiratory rate × 100)

  ->10% was not associated with adverse clinical outcome !

-*Respir. Care*. 58(11), 1847–1855 (2013).

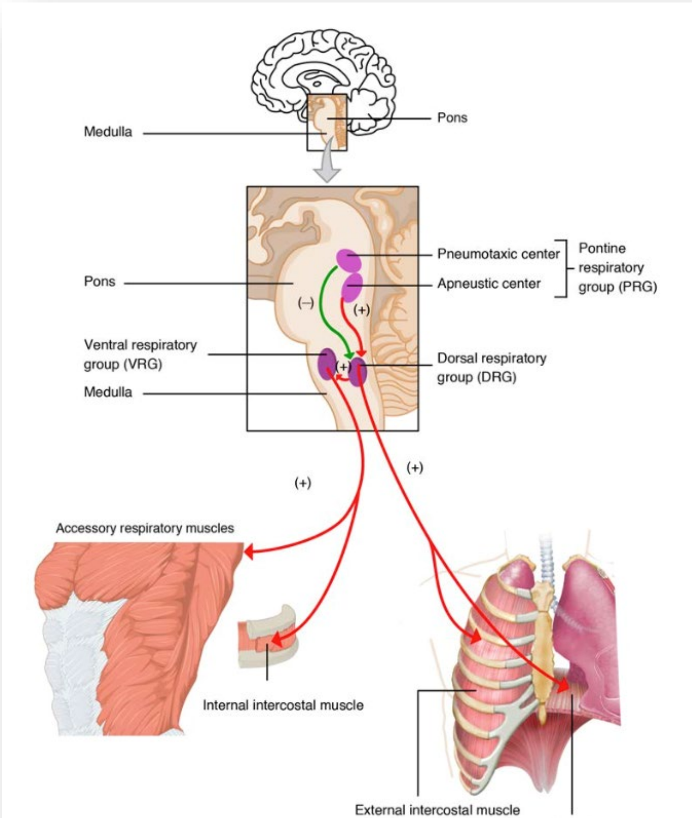
- Zhou, Y. et al *Sci Rep* 11, 12390 (2021).

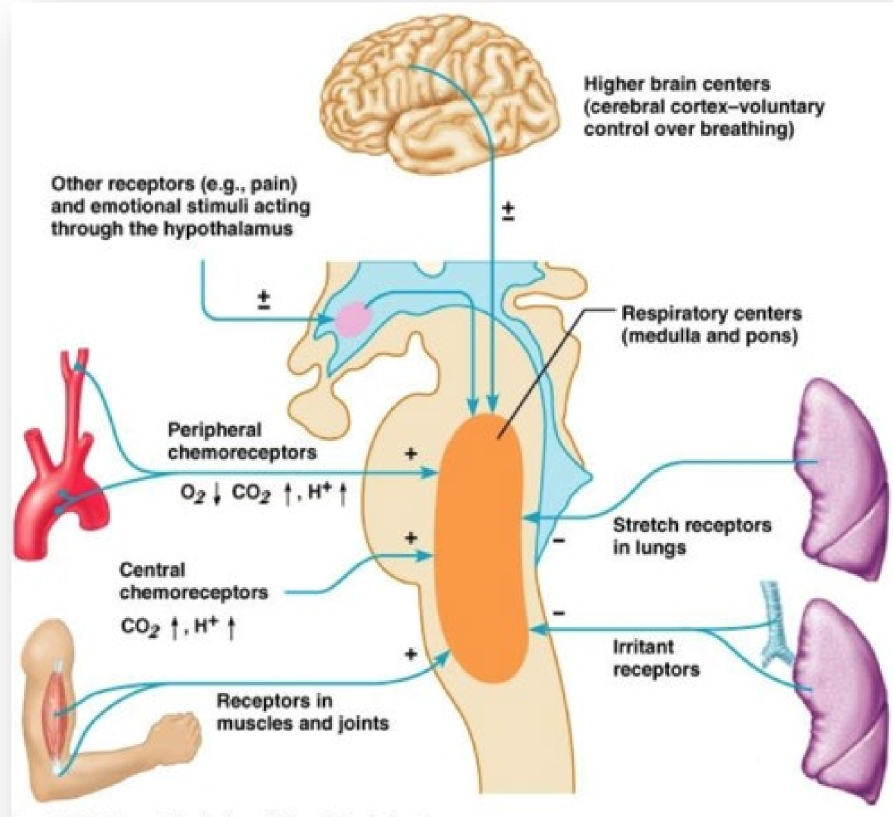
Achieve the right balance between patient-ventilator interaction



- David J Pierson Respir Care 2011;56:214-228

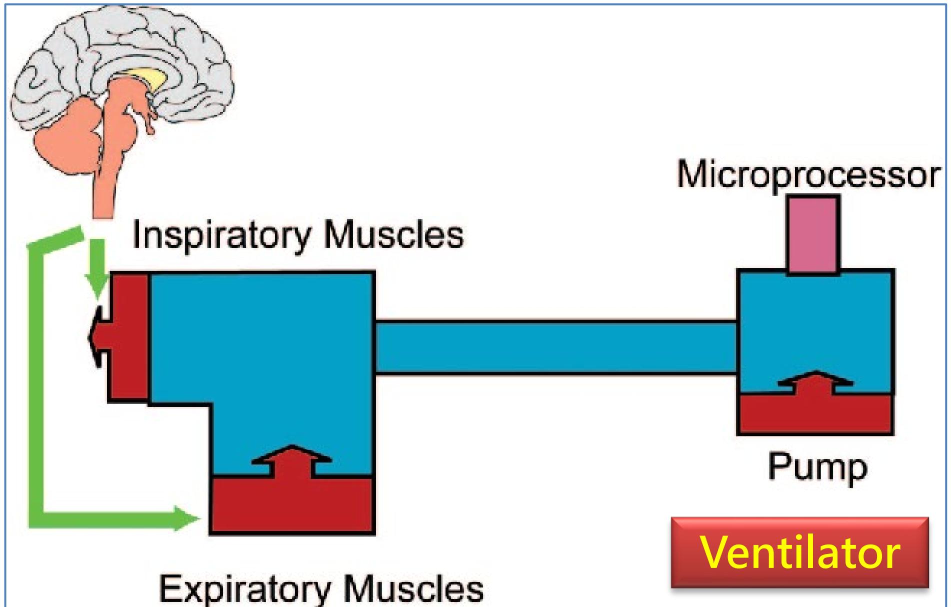
Ventilation regulation

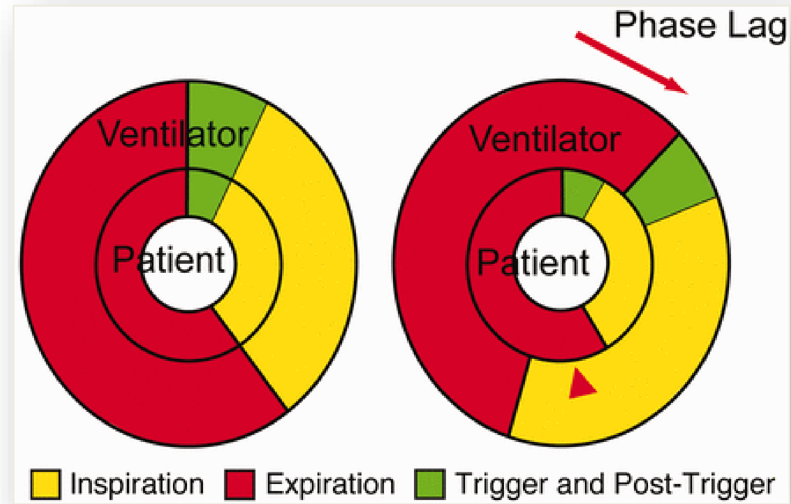




Complex feedback-based respiratory neural controller in humans

Control of Breathing During Mechanical Ventilation: Who Is the Boss?

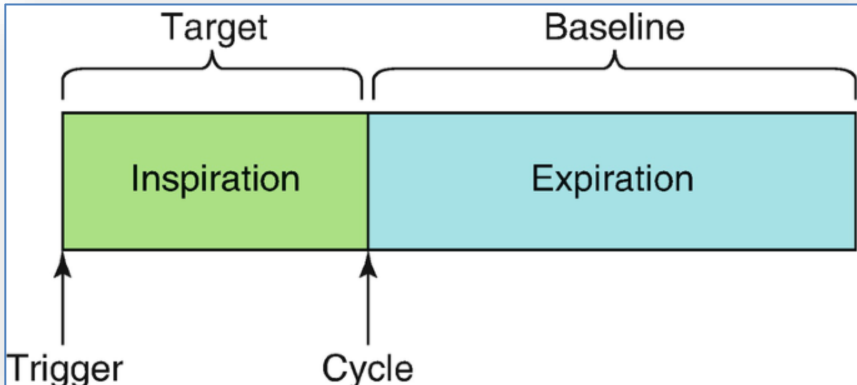




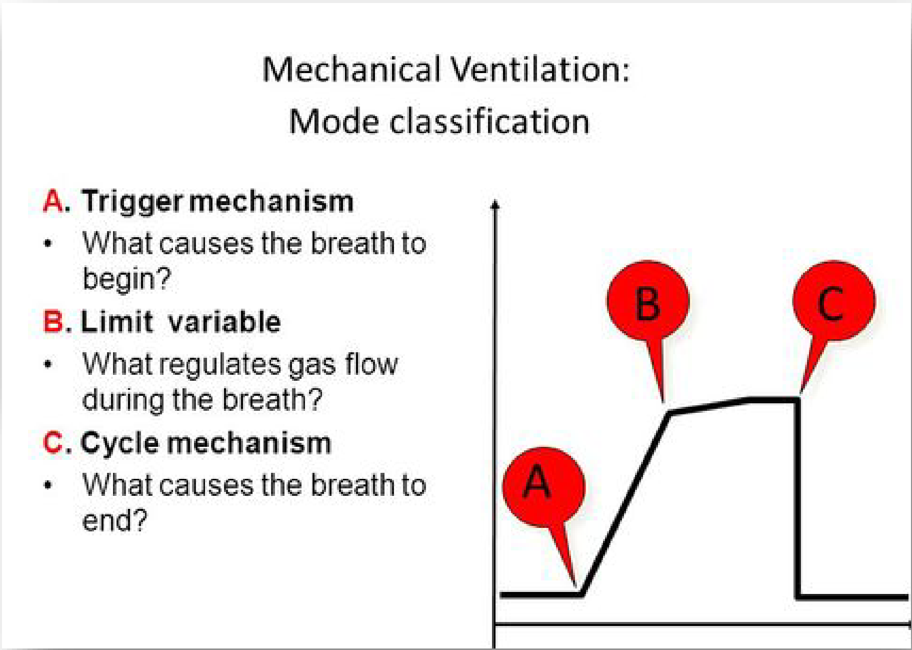
Synchrony between the two system !

- Respir Care. 2011 Feb; 56(2): 127–139

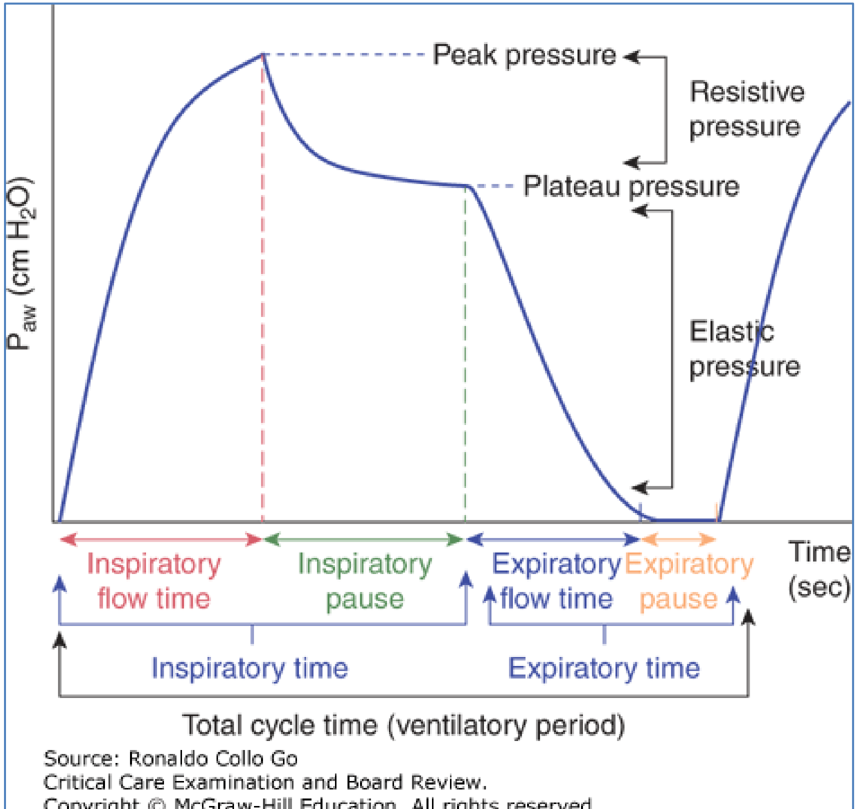
Patient–Ventilator Interactions

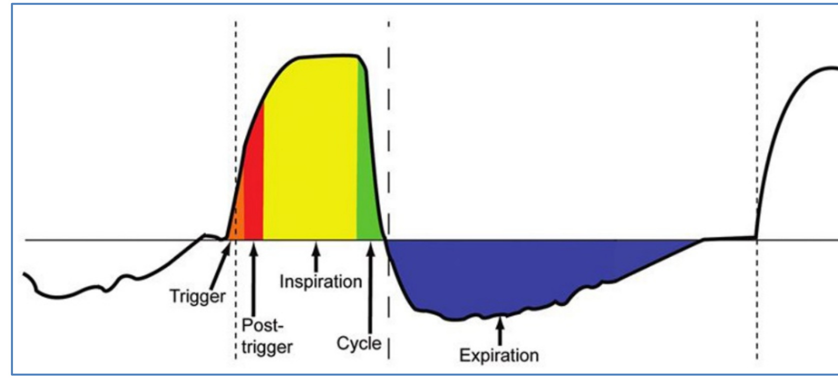


- From control to A/C mode.
- Three phases of breath delivery:
  『trigger, target, and cycle. 』



Ventilatory phases





With problems in

- Timing of inspiration
- Adequate inspiratory flow
- Duration of inspiration
- Timing switch to expiration

Common ventilator modes and parameters

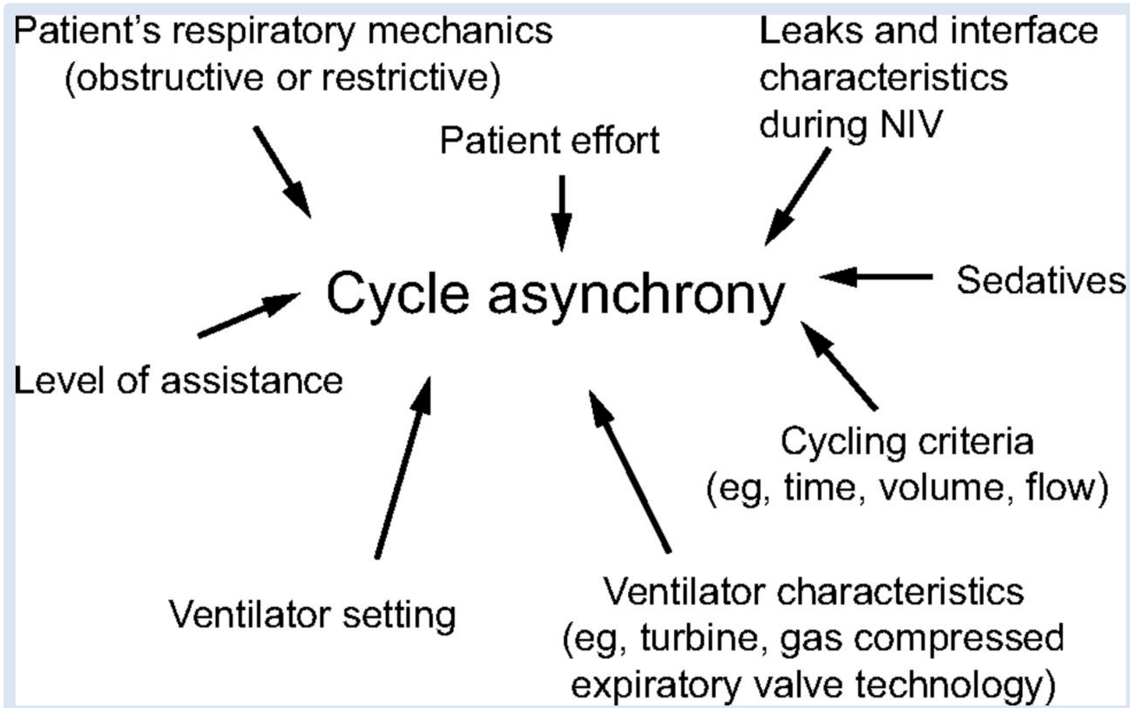
	Assist control ventilation		
	Volume control ventilation	Pressure control ventilation	Pressure support ventilation
Trigger	**Time** (vent-initiated breath) or Negative flow/pressure[a] (patient-initiated breath)	**Time** (vent-initiated breath) or Negative **flow/pressure**[a] (patient-initiated breath)	Negative **flow/pressure**[a]
Target/limit	Inspiratory **volume**	Inspiratory **pressure**	Inspiratory **pressure**
Cycle	Inspiratory **time**[b]	Inspiratory **time**	Inspiratory **flow decay**[c]

[a]Determining flow versus pressure triggering is usually clinician-configurable.
[b]Ventilators in volume control ventilation (VCV) modes appear to cycle the breath after the inspiratory volume is reached, but in fact are usually cycling after the inspiratory time predicted for the set volume and flow. As flow in VCV is fixed, this has the same result.
[c]Pressure support ventilation cycling is most often defined by a fraction of the peak inspiratory flow; e.g. a breath ends when the flow decays to 25% (or some user-defined value) of the highest flow reached during the breath. On other ventilators, this cycling value may instead be set as a non-relative figure, such as 5 l/min.

Causes of Patient-Ventilator dyssynchronized

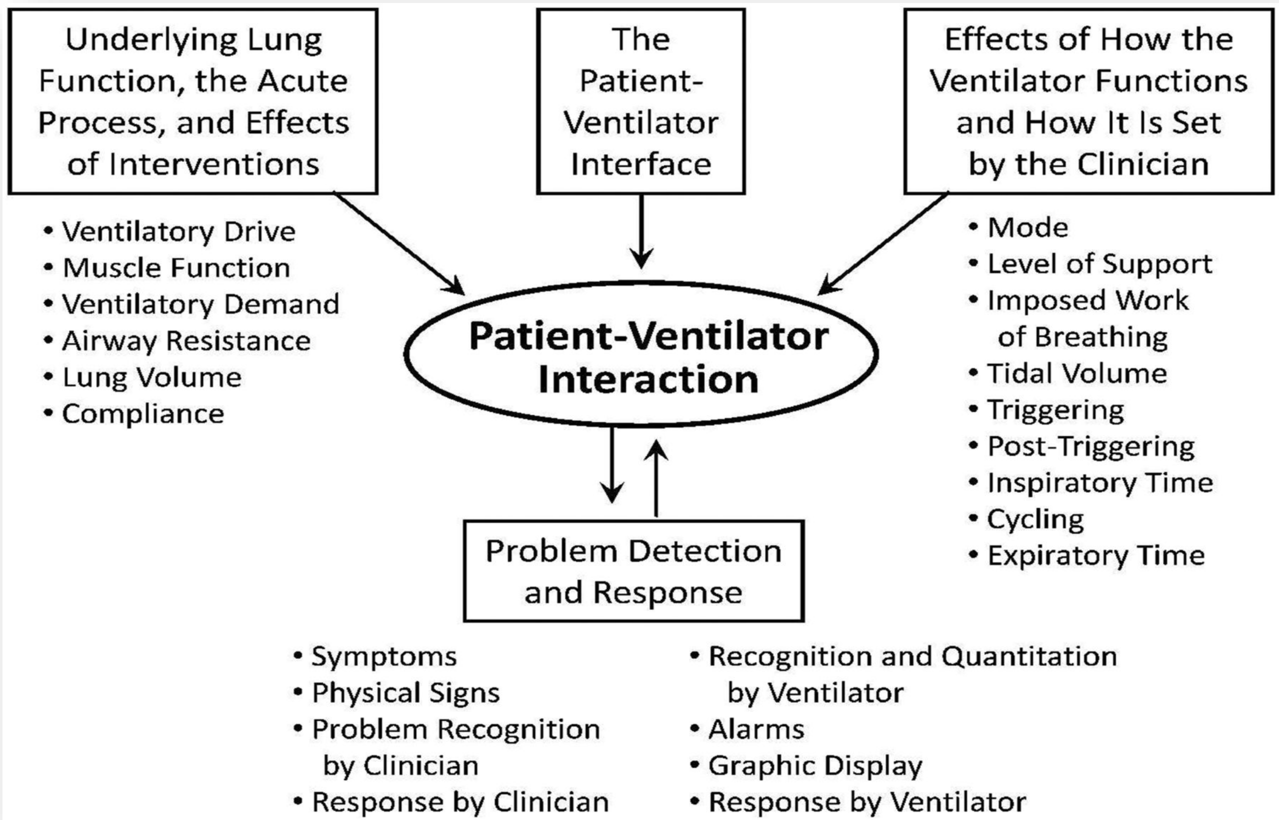
Patient factors	Ventilator factors
• Underlying disease – Acute processing distress • Ventilatory drive – High or low • Ventilatory requirements – flow and volume demand	• inspiratory trigger – flow, volume or pressure • delivery mechanism – flow, volume or pressure • cycling criteria – time to ventilator stops assisting inspiration – allows passive exhalation

Factors may cause asynchrony



Lucia Mirabella et al. Respir Care 2020;65:1751-1766

Factors that influence patient-ventilator interaction.



David J Pierson Respir Care 2011;56:214-228

Classifications of patient-ventilator asynchronies

Types of Asynchronies

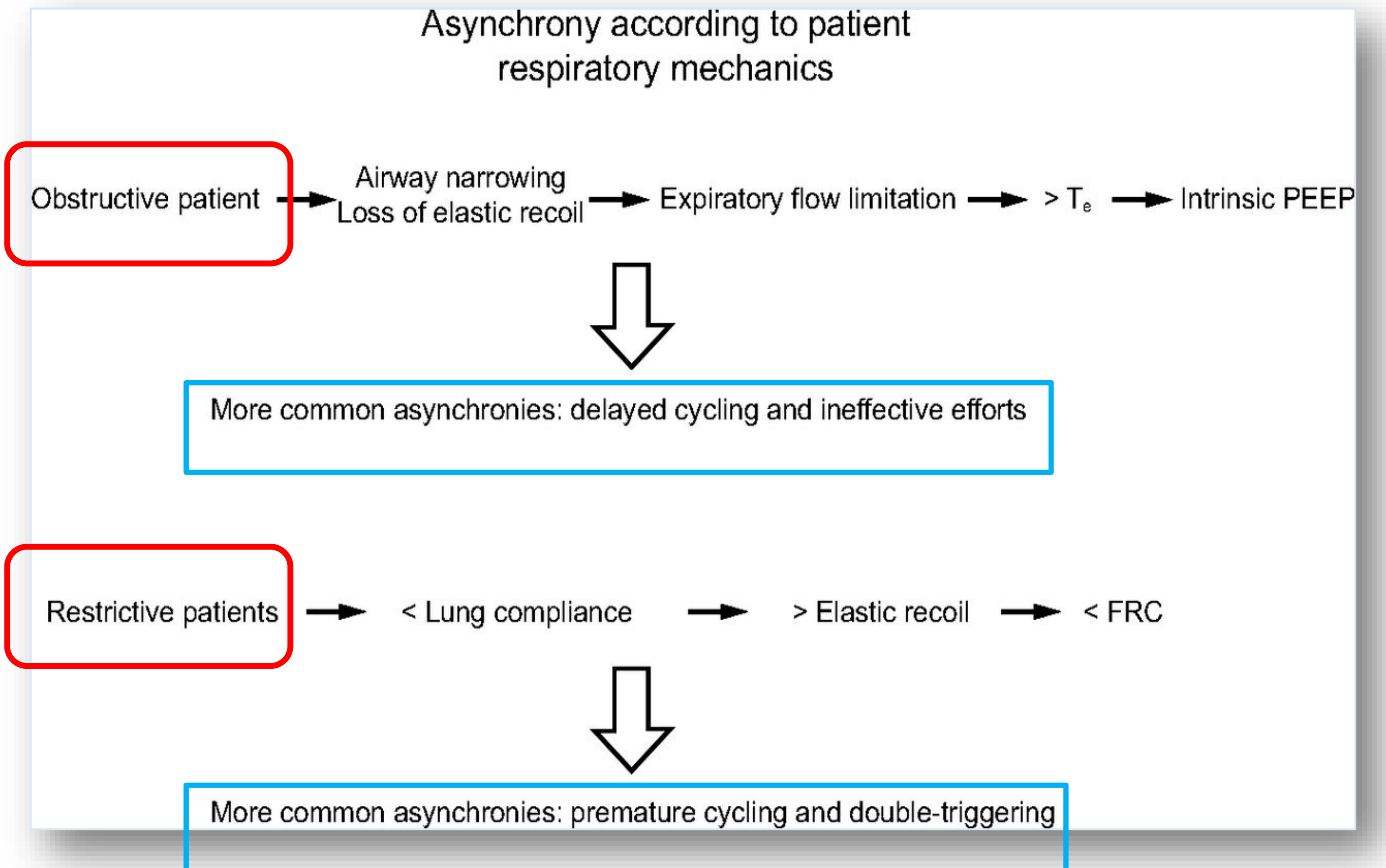
- Major
  - ineffective triggering, auto-triggering, double-triggering
- Minor
  - premature or short cycling, prolonged or delayed cycling, triggering delay

- ERJ Open Res 2017;3(4):00075-2017

Classification of PVA

- Phase classification
  - Inspiratory : delayed triggering, ineffective efforts, auto-triggering
  - Expiratory : late and early cycling, double-triggering. •
- Etiology classification
  - Low respiratory drive ± too much ventilator assistance:
    - ineffective efforts, delayed cycling, auto-triggering, reverse triggering.
  - High respiratory drive and low ventilator support:
    - early cycling, double-triggering.

Underlying respiratory mechanics generate different types of asynchronies.



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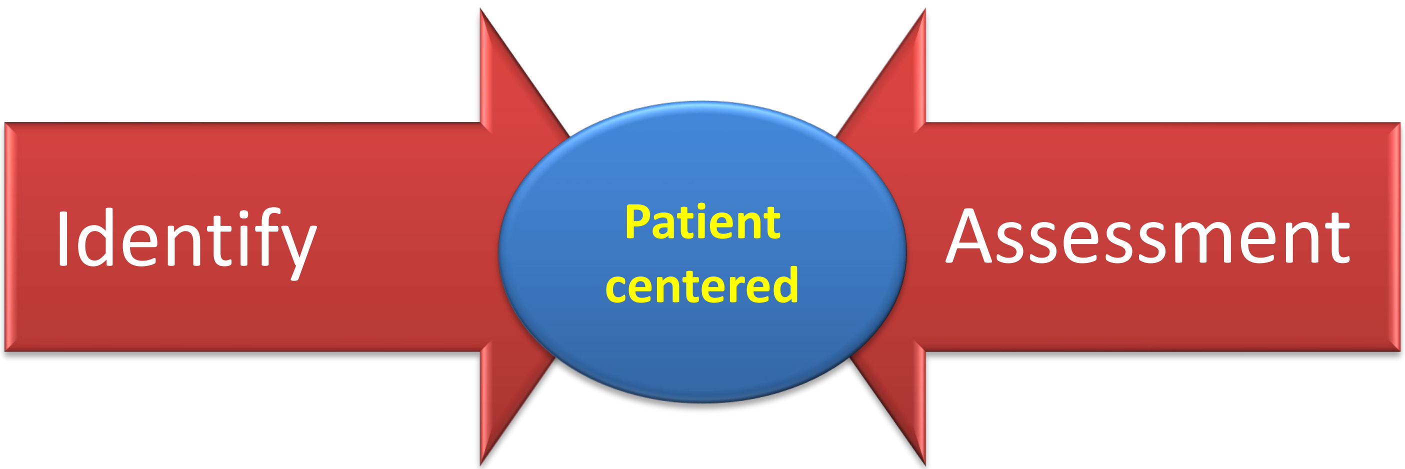
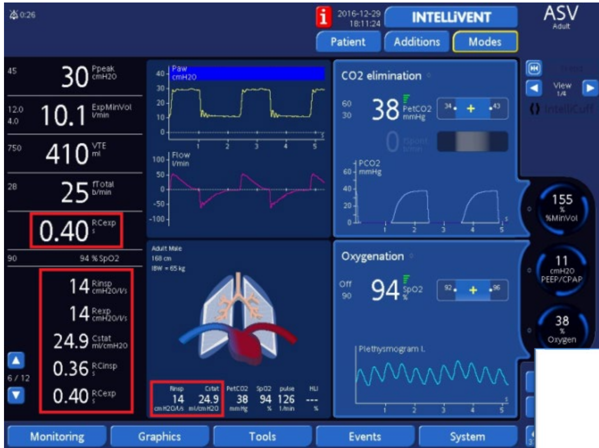
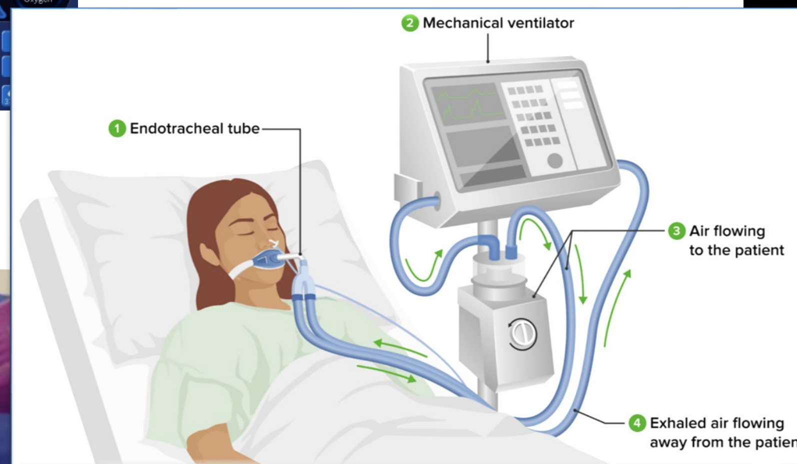
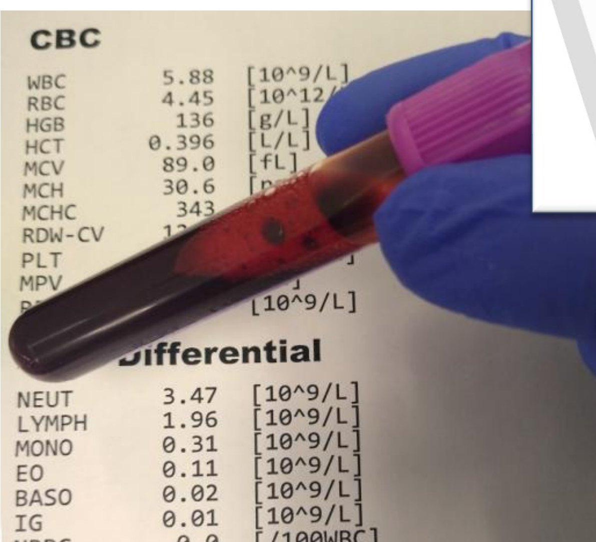
How to improve patient-ventilator synchrony



Patient monitoring during mechanical ventilation







How to improve patient-ventilator synchrony

- Ventilator factor
  - Waveform analysis
  - Optimization of ventilator settings

- Patient factor
  - Solve patient pathological condition
  - Treat underlying disease and best supportive care

    ex: sepsis control, organs support, PADIS problem etc.

ASSESSMENT

- Examination
  - work of breathing
  - respiratory pattern
  - audible sounds (e.g. cuff leak, stridor, wheeze)
  - chest findings (e.g. hyperexpansion, dullness, crackles)

- Monitor
  - vital signs
  - ETCO2
  - SpO2
- Ventilator
  - waveforms
  - alarms
- Chest x-ray

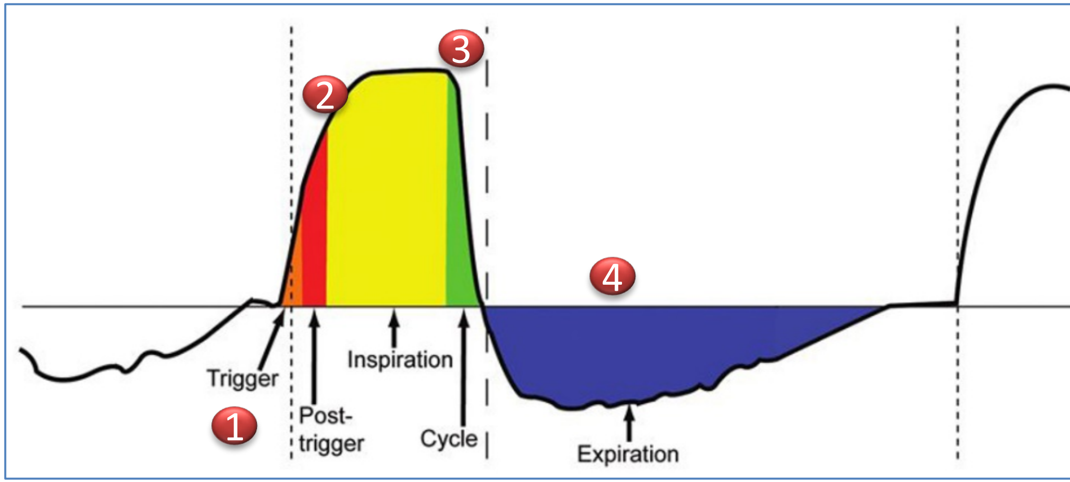
MANAGEMENT

- Resuscitation
  - address life threats
  - disconnect patient from ventilator and replace with BVM if required
- Address patient factors
  - treat patients respiratory pathology affecting resistance and/ or compliance (e.g. sputum, bronchospasm, chest wall eschar, pneumothorax)
  - treat other patient factors (e.g. hunger, pain, weakness, sleep ,sedation, nutrition, physiotherapy)

Management principles

- Correct problems associated with ventilator
  - choose appropriate ventilator
  - choose appropriate mode
  - ensure sensitivity is not too low or high
  - choose appropriate ventilator rate
  - set appropriate flow rate
  - check that patient isn’t auto-triggering
    - cardiogenic oscillations, high sensitivity, circuit leaks, water condensation in the circuit
  - sedate patient to reduce agitation
  - taking over ventilation if fatigue is apparent

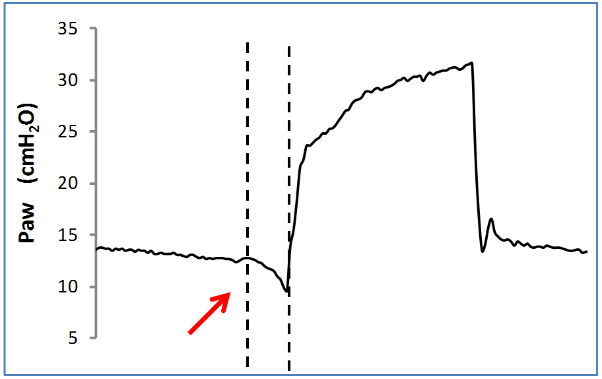
Respiratory cycle 4 phases approach

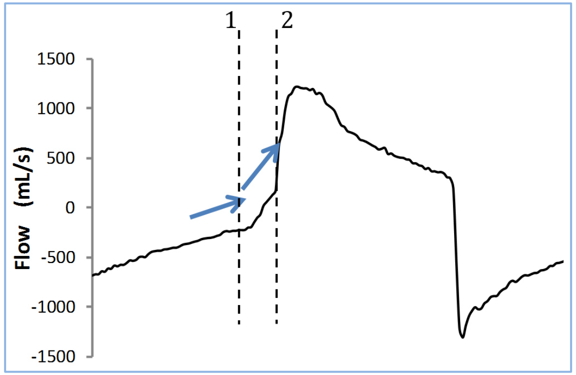


phase 1: 初始吸氣，要克服設定的壓力閾值才能驅動呼吸器打開吸氣瓣膜。
phase 2: 評估在吸氣週期間病人吸氣氣流是否足夠。
phase 3: 吸氣期結束時，取決於吐氣設定靈敏度。PSV決定吸氣的長短主要取決於吐氣啟的設定；當吸氣氣流下降到設定值時，就會吸轉吐。
phase 4: 為吐氣週期部分，主要用來觀察有無存在auto-PEEP。

Asynchrony type: Trigger delay

Cause of Asynchrony	Solutions
1. Low trigger sensitivity 2. Low respiratory drive 3. Presence of threshold load such as intrinsic PEEP 4. Presence of partially obstructed ETT or HME 5. Type of NIV interface - eg, mask vs helmet	• Adjust trigger sensitivity, • Increase PEEP to counter intrinsic PEEP • Replace HME or ETT • Change NIV interface HME:heat-and-moisture exchange



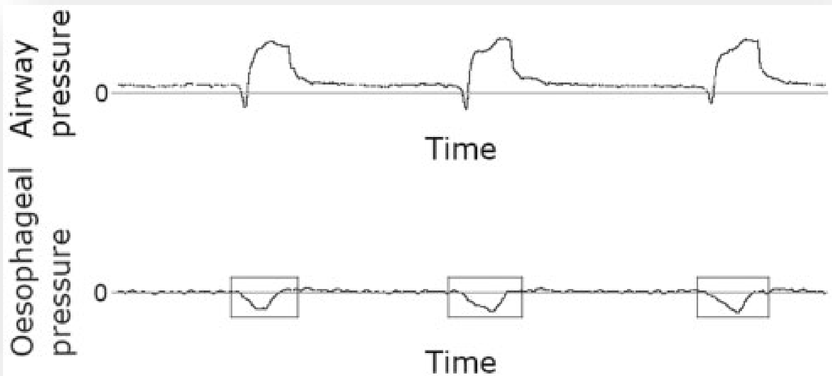


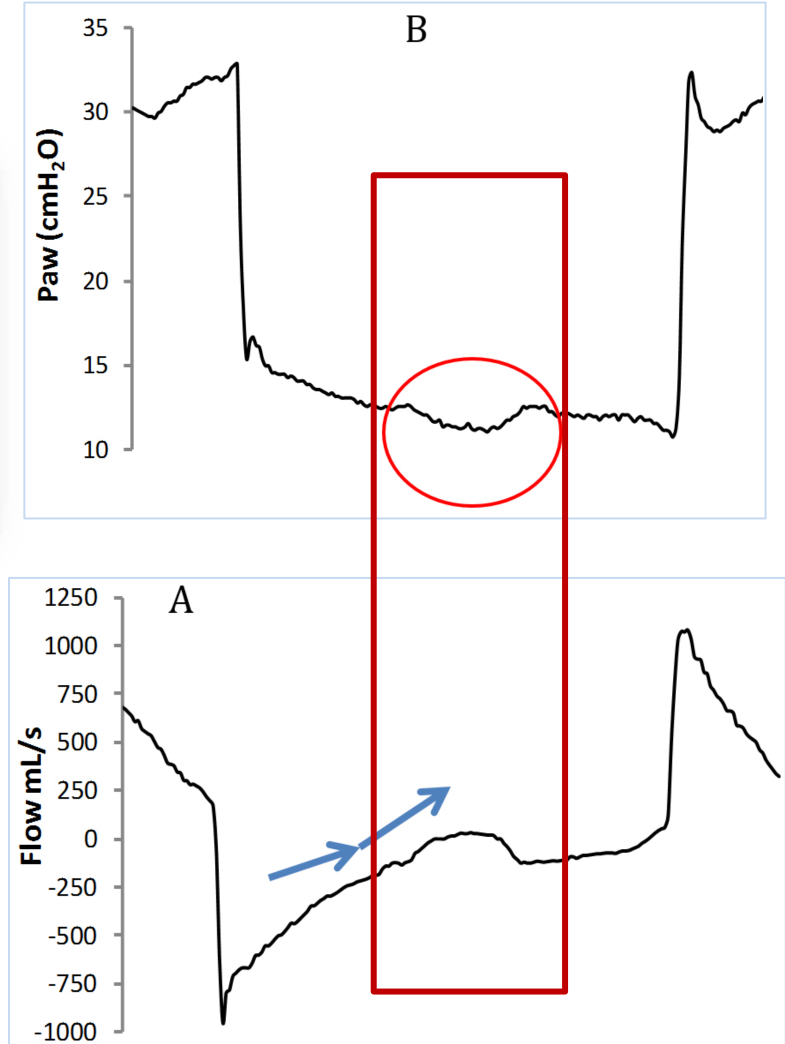
1. the beginning of the patient's inspiratory effort
2. the delayed ventilator support (inspiratory delay)

Asynchrony type: Ineffective efforts/trigger

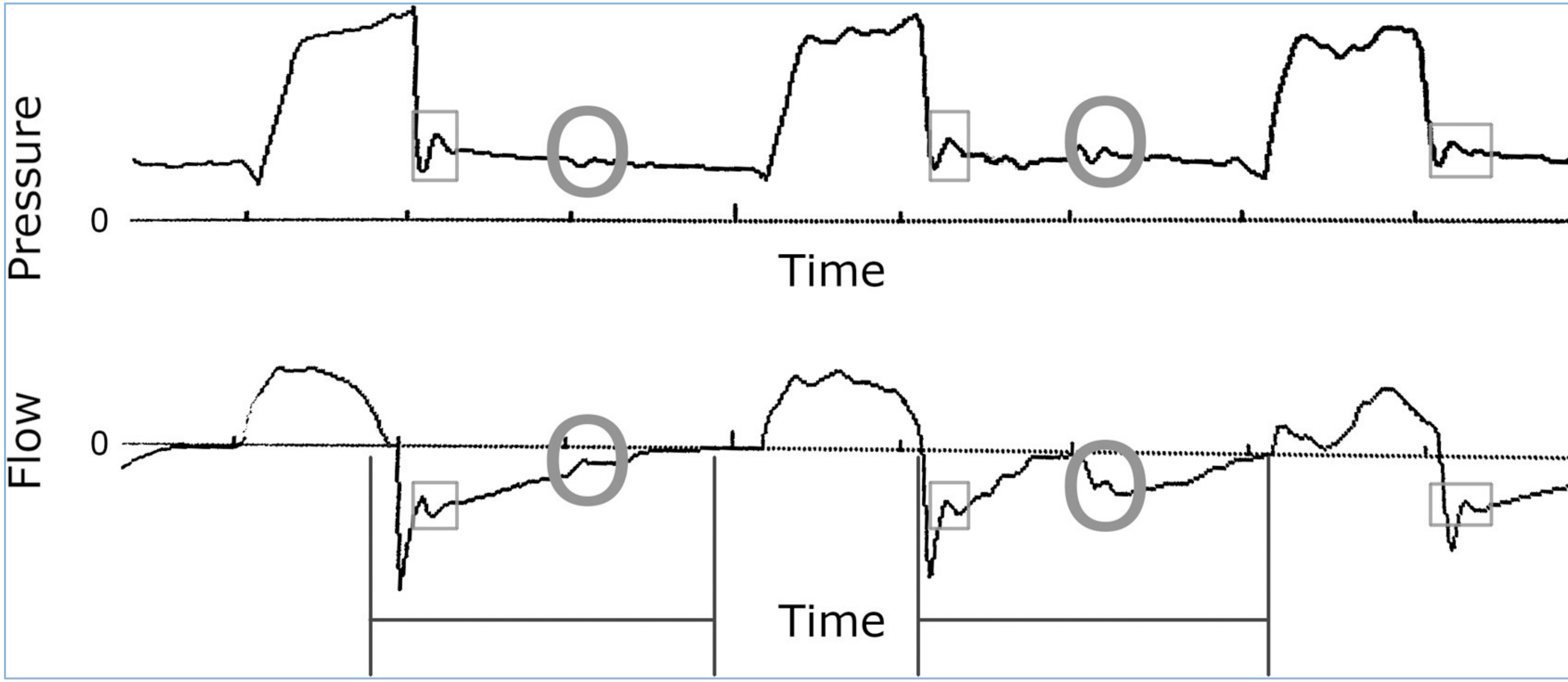
Cause of Asynchrony	Solutions
1. Low trigger sensitivity 2. Weak respiratory drive or weak effort - due to heavy sedation - excessive respiratory support - diaphragm dysfunction 3. Presence high threshold load such as intrinsic PEEP 4. Delayed cycling - especially in PSV mode or obstructive condition (Fig. 2), - during NIV in presence of intentional leak in a ventilator unable to compensate for them 5. Inspiratory time too long in a time-cycled breath	• Adjust trigger sensitivity • Reduce sedation or use drugs with no effect on the respiratory drive • Reduce support • Correct metabolic alkalosis • Increase PEEP to counter intrinsic PEEP • Shorten inspiratory time • Adjust EET criteria in an obstructive condition (eg, COPD), • Use appropriate NIV software • consider a neural trigger if the problem persists

Patient neural inspiratory time and the ventilator cycling variable.

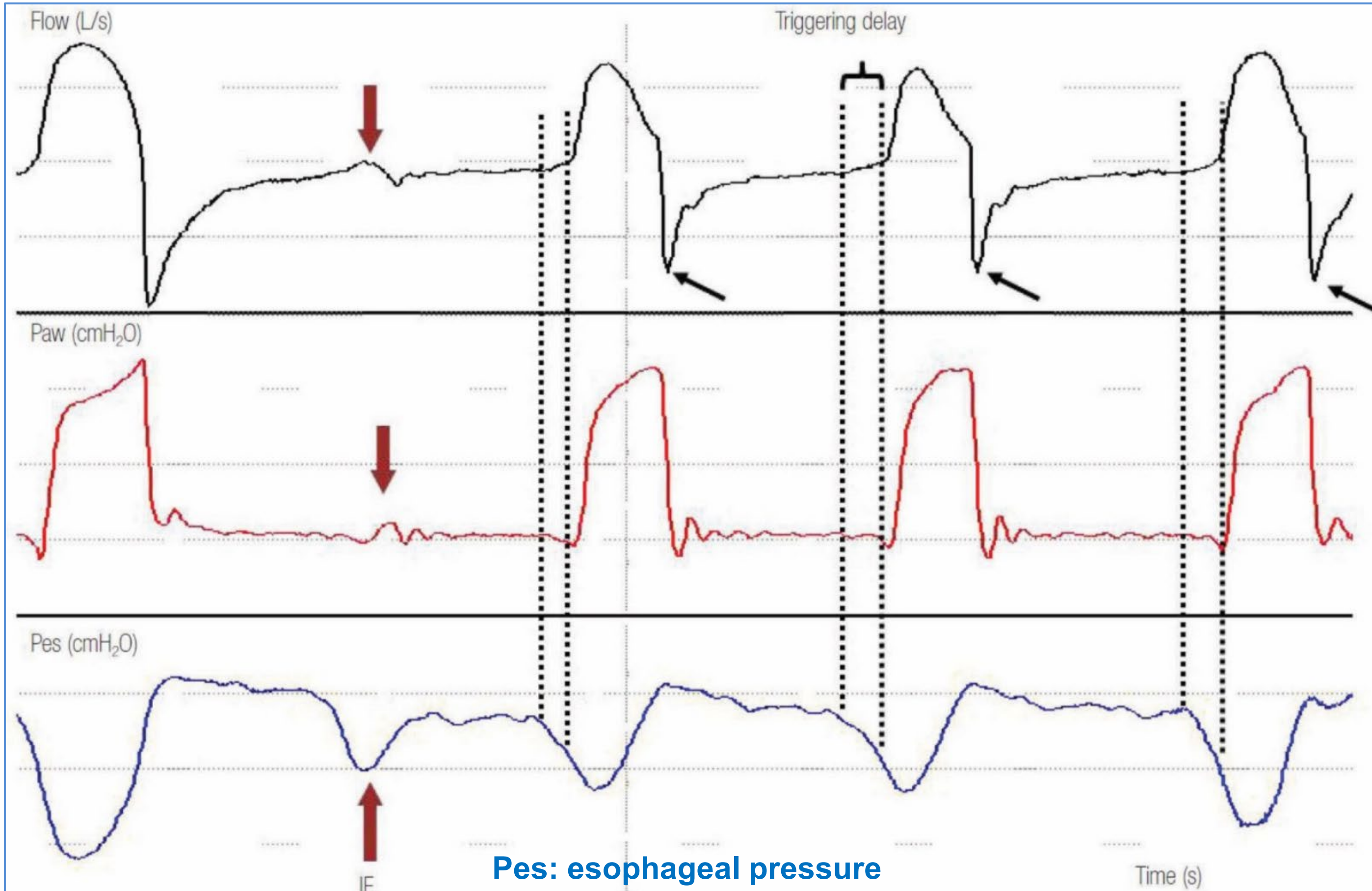




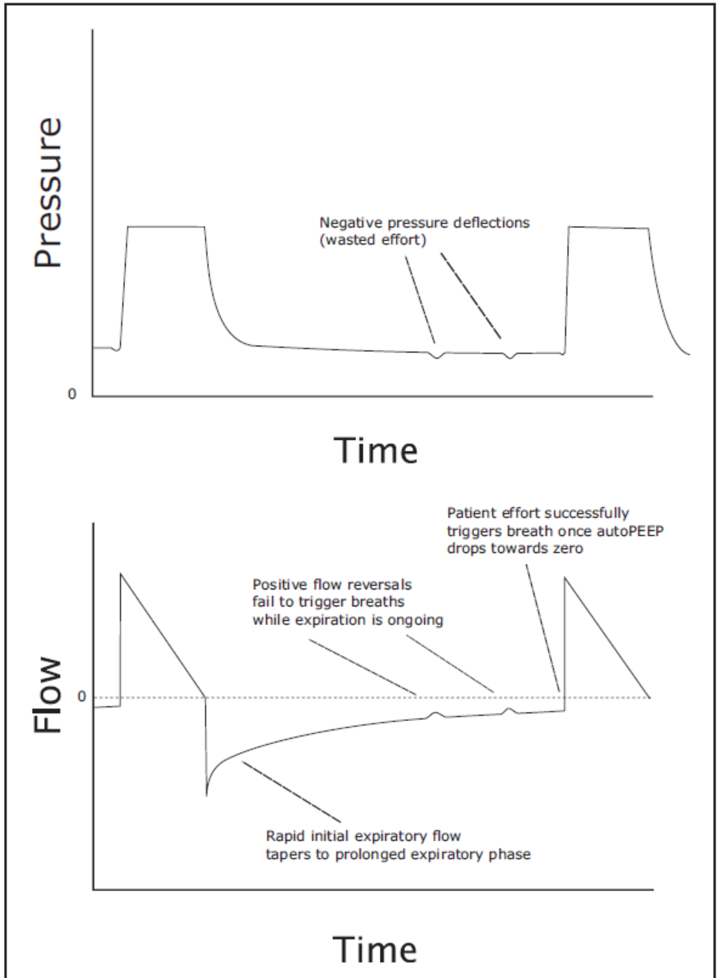
Patient inspiratory activity without ventilator assistance

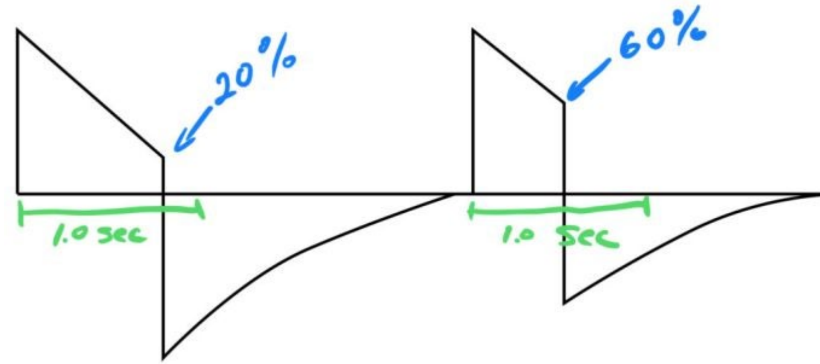


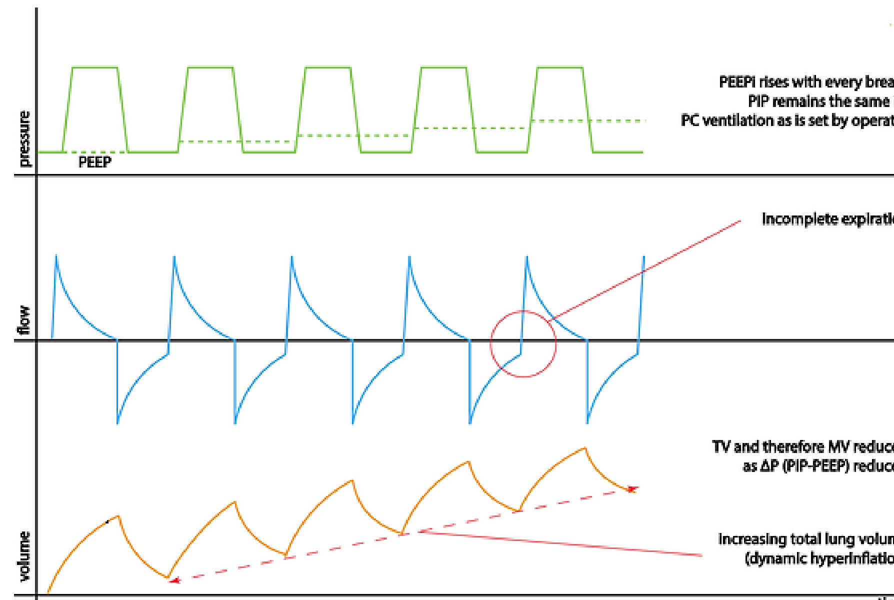
- Ineffective triggering, result in flow starvation delayed triggering



IE: ineffective effort


Pressure
0
Negative pressure deflections
(wasted effort)
Time
Flow
0
Patient effort successfully
triggers breath once autoPEEP
drops towards zero
Positive flow reversals
fail to trigger breaths
while expiration is ongoing
Rapid initial expiratory flow
tapers to prolonged expiratory phase
Time

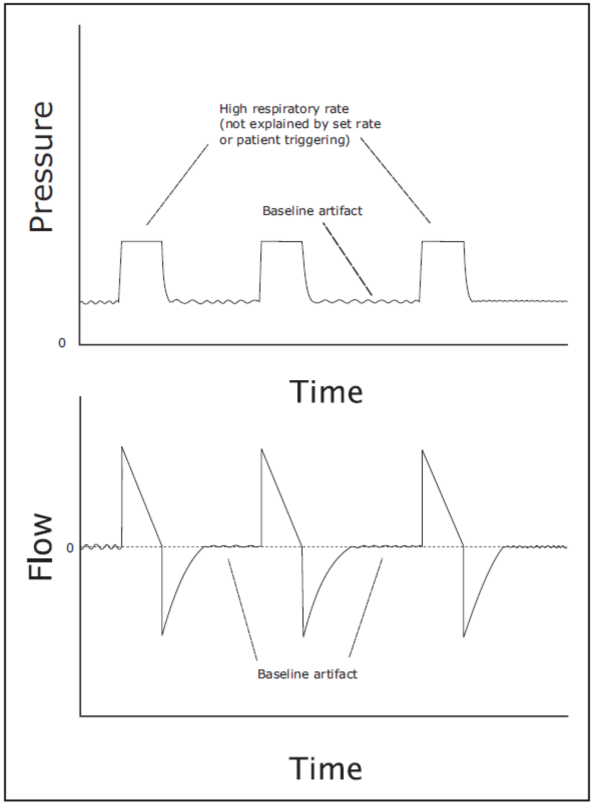

20%
60%
1.0 sec
1.0 sec

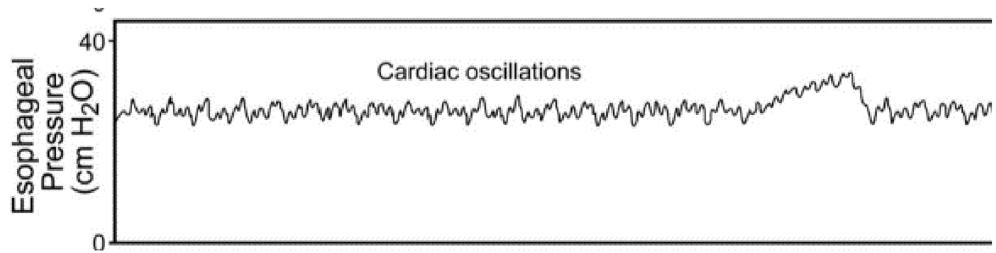

pressure
PEEP
PEEPi rises with every breath
PIP remains the same in
PC ventilation as is set by operator
flow
Incomplete expiration
volume
TV and therefore MV reduced
as ΔP (PIP-PEEP) reduced
Increasing total lung volume
(dynamic hyperinflation)
time

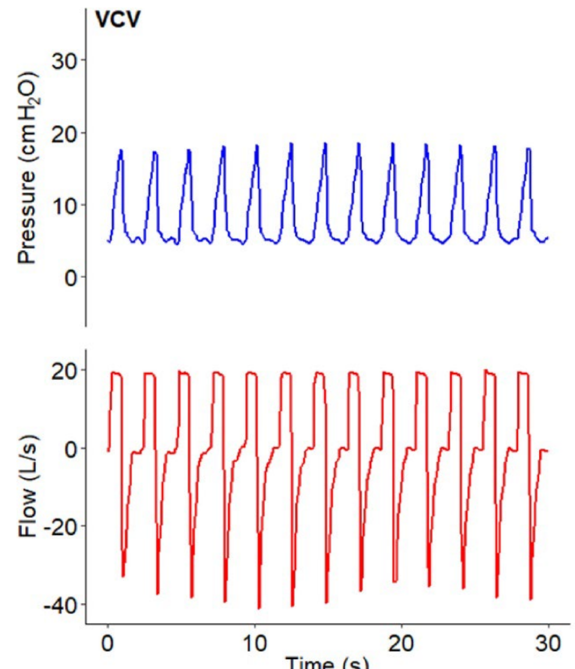
Asynchrony type: Auto-triggering

Cause of Asynchrony	Solutions
1. High trigger sensitivity 2. Leaks of circuit induced 3. Random noise in the circuit - cardiac oscillations - condensed water in the circuit - copious tracheobronchial secretions	• Adjust trigger sensitivity • Reduce noise • Remove leak, • Use appropriate NIV software

Cardiac oscillation

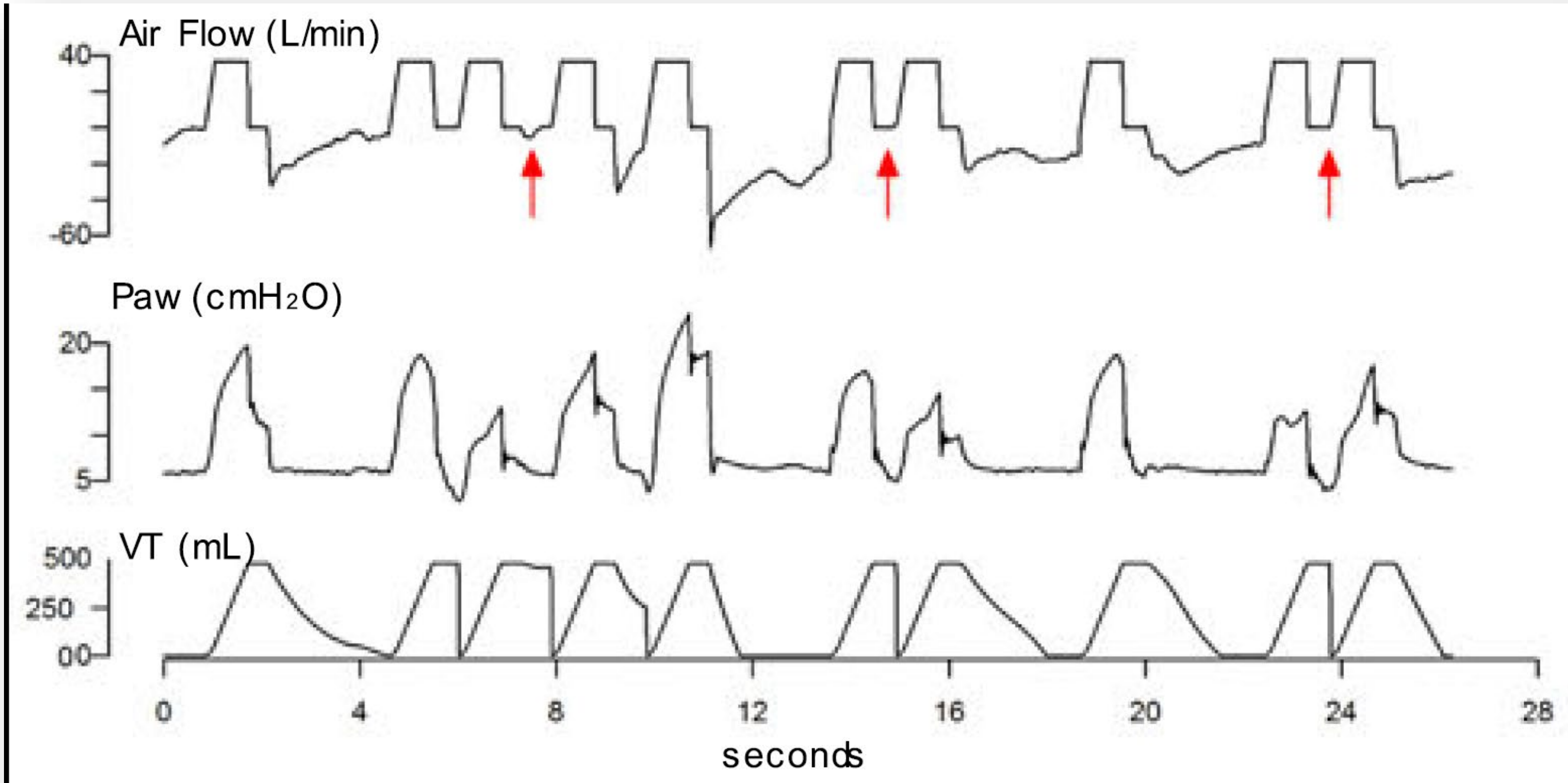






Asynchrony type: Double-triggering

Cause of Asynchrony	Solutions
1. Short cycling due to insufficient assistance - fixed flow or lower tidal volumes in patient with high inspiratory flow demand in A/C mode 2. Short cycling due to high expiratory trigger threshold - premature cycling, PSV mode in patients with low respiratory-system compliance and high respiratory drive (Fig. 2) 3. Promote by reverse-triggering	• Increase inspiratory time in a time-cycled breath, • increase inspiratory flow, • adjust EET in PSV mode, • optimize pressure rise time in PSV mode, • remove the cause of reverse-triggering



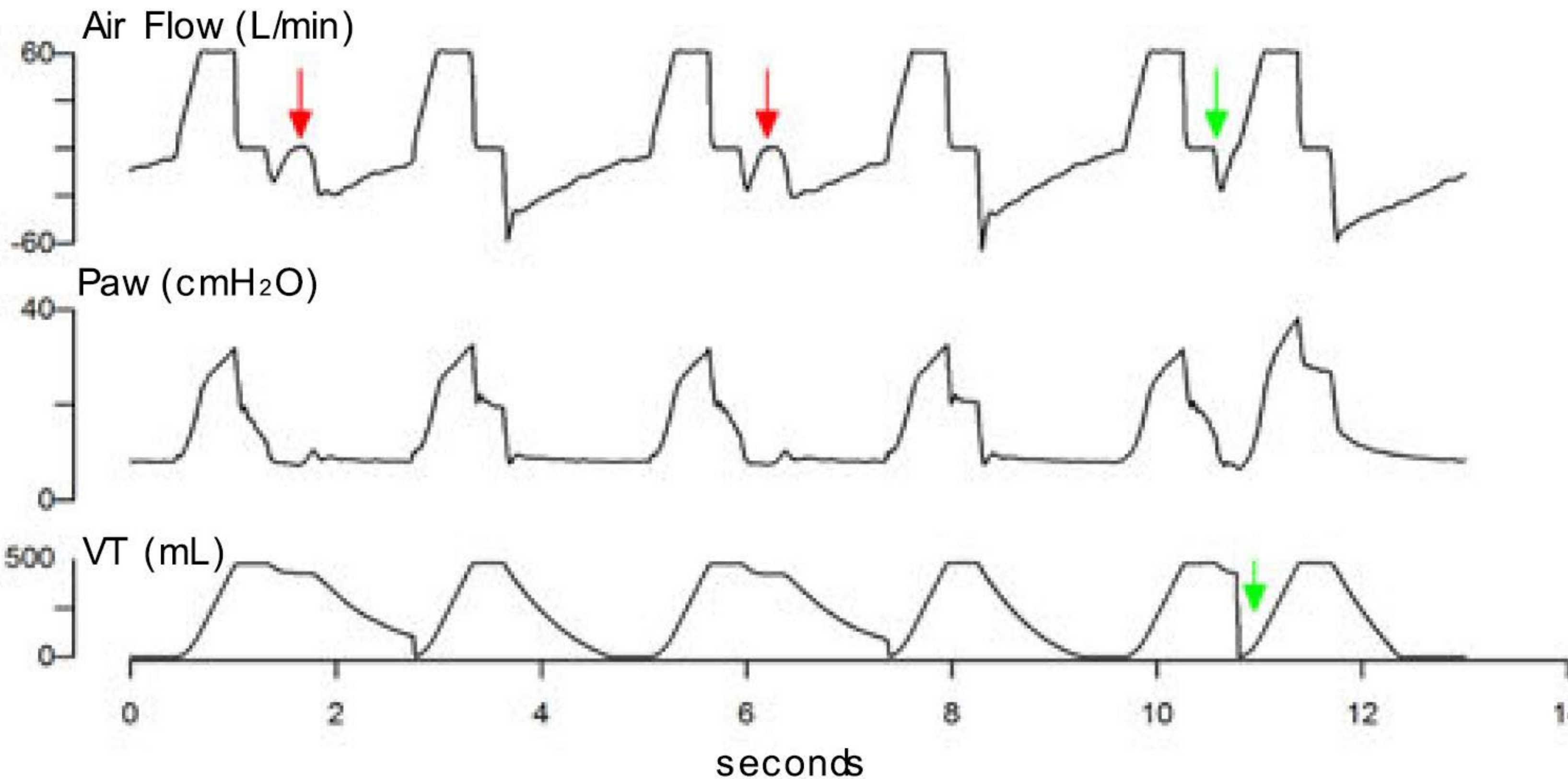
- Insp. effort continued beyond ventilator Tinsp.

Asynchrony type: Reverse-triggering

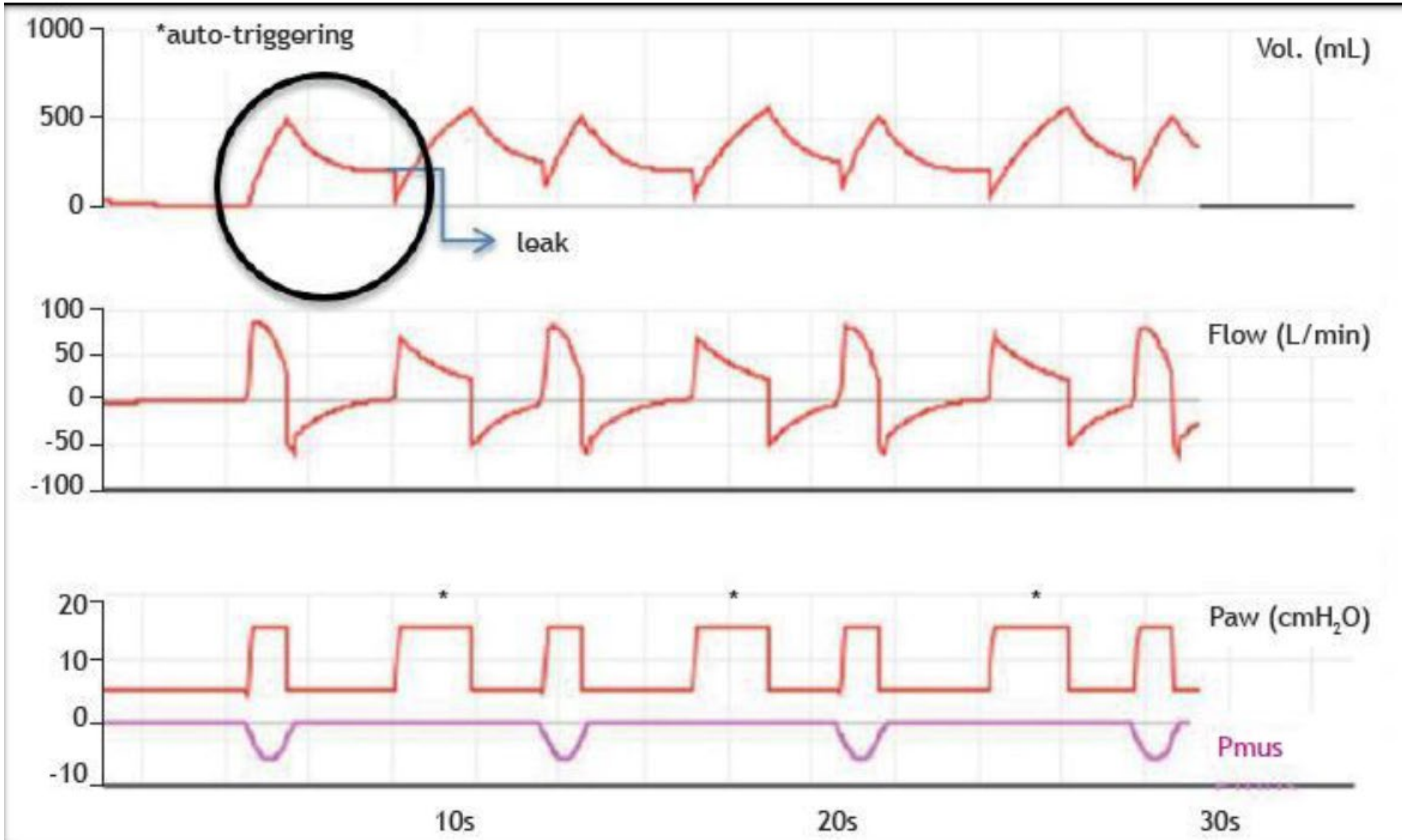
Cause of Asynchrony	Solutions
1. Over assistance 2. Deep sedation	• Reduce assistance • Reduce sedatives • Muscle paralysis if necessary

Asynchrony type: Cycling asynchrony

Cause of Asynchrony	Solutions
1. Neural time > ventilator inspiratory time - premature cycling 2. Neural time < ventilator inspiratory time - delayed cycling	• Adjust inspiratory time and EET criteria in PSV mode, • check for excessive assistance • reduce leaks or use an appropriate NIV software • use proportional modes

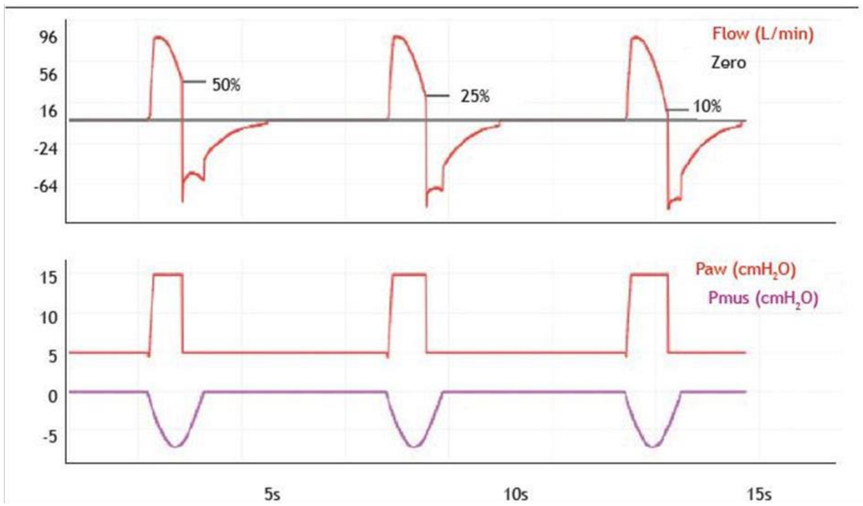


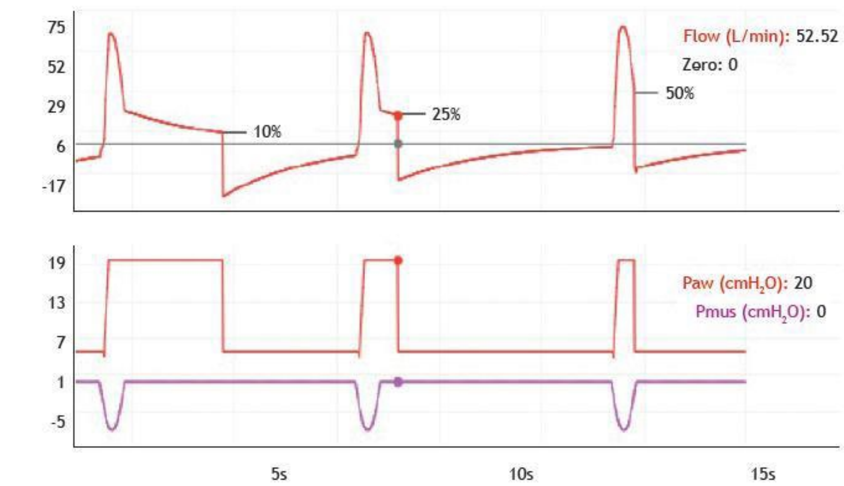
Reverse triggering: neuro-mechanical coupling



auto-triggering by air leak

Delay Cycling VS Premature cycling





Asynchrony type: Flow asynchrony

Cause of Asynchrony	Solutions
1. Low gas flow ring assisted volume control ventilation 2. Pressure rise time too low in pressure control mode	• Increase gas flow or adjust inspiratory flow, • decrease respiratory drive with an appropriate drug • increase pressure rise in pressure control mode

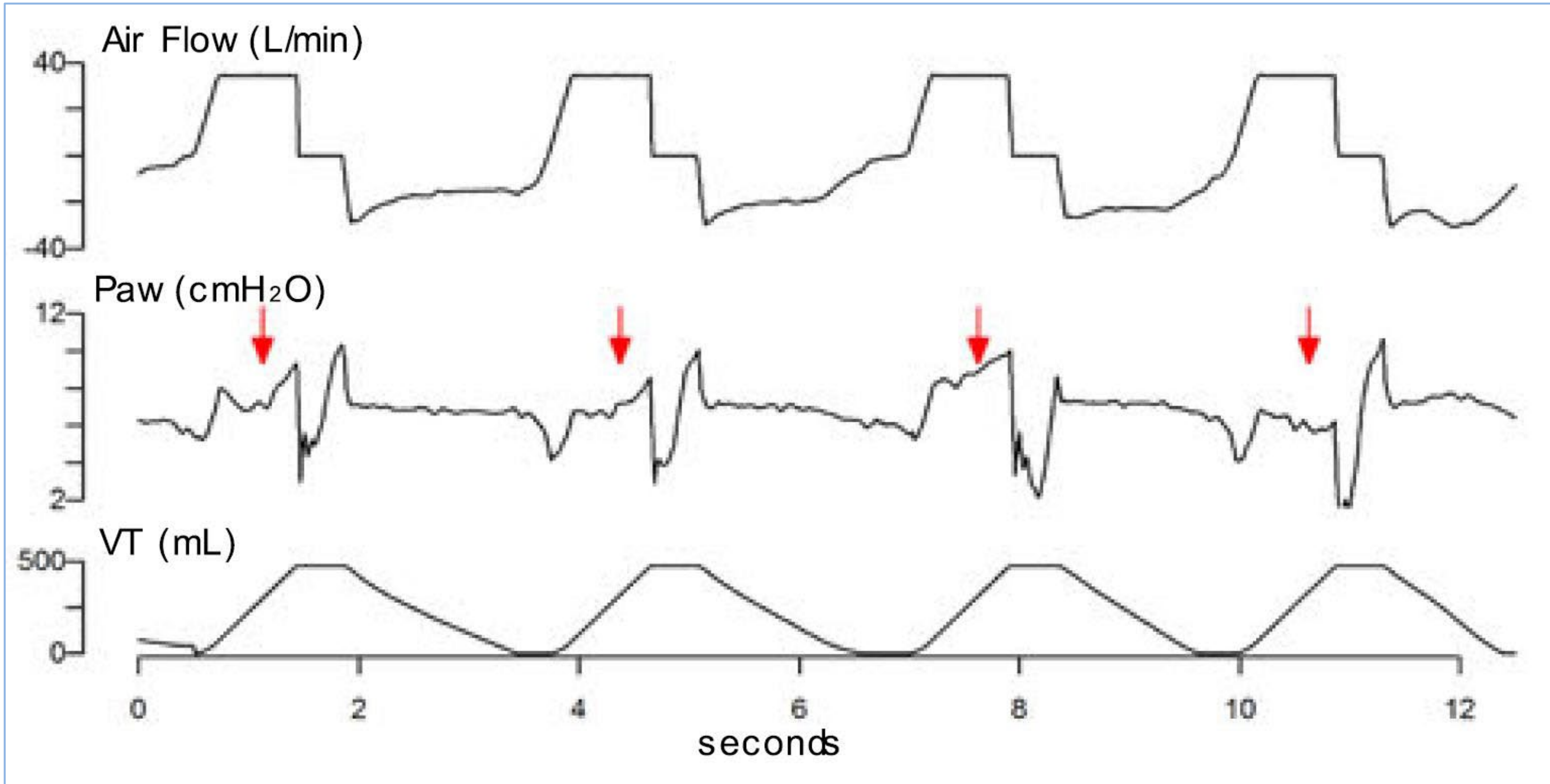
Flow dyssynchrony (too fast or too slow)

Autotriggering (important to distinguish from ineffective triggering)

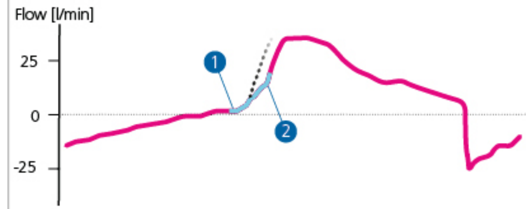
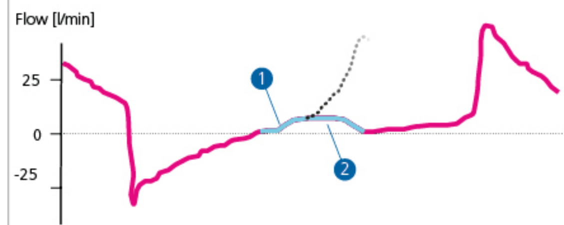
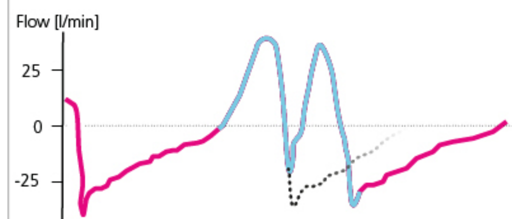
- hiccups
- coughing
- cardiac oscillations
- shivering
- seizures
- ‘rain out’ (condensation in ventilator circuit)
- trigger sensitivity set too low

Flow dyssynchrony (too fast or too slow)

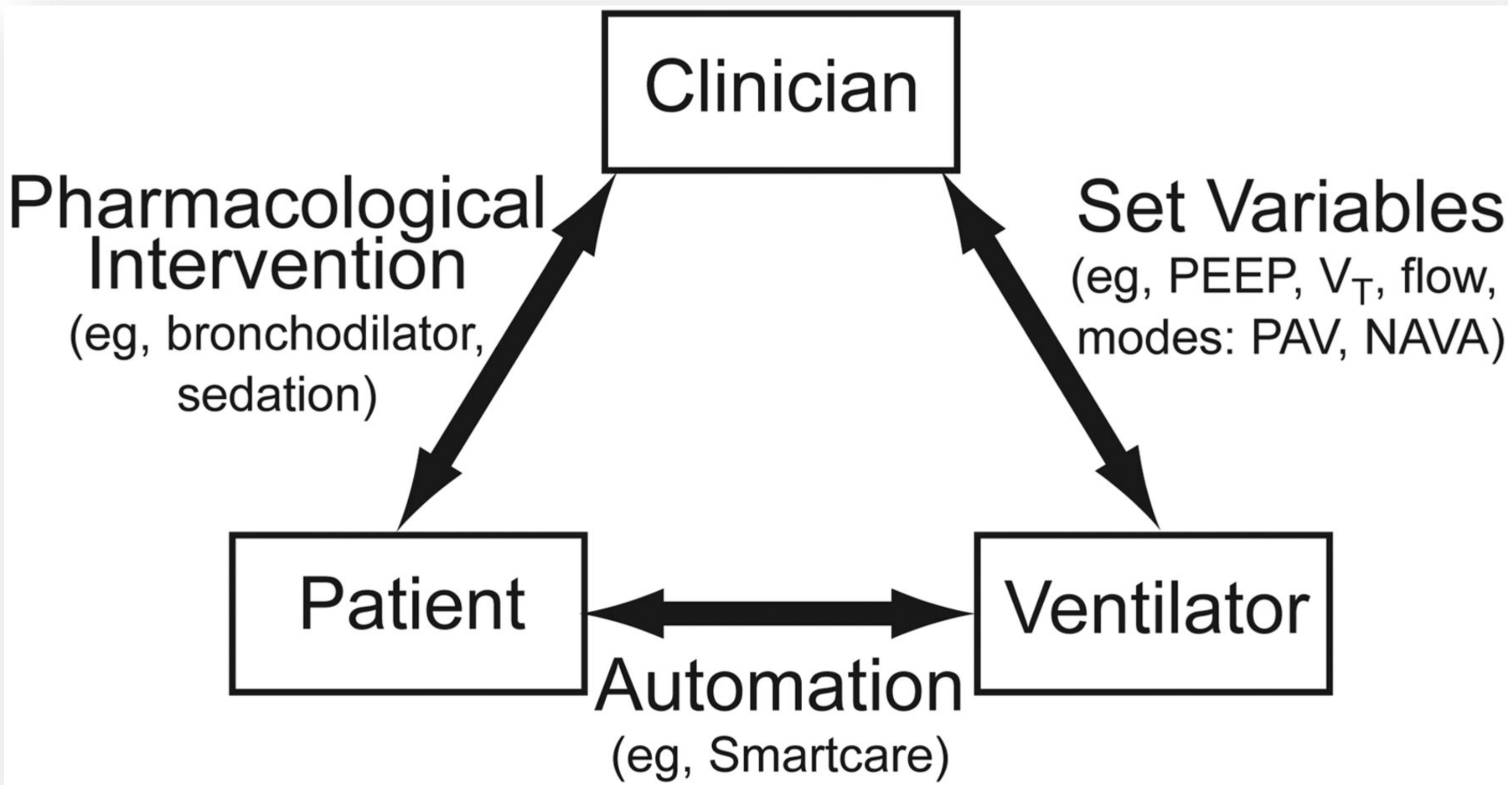
- too slow: ‘pull down’ on pressure curve upstroke during inspiration
- too fast : e.g. discomfort from rise time too short



Strong inspiratory effort due to insufficient airflow in patient under Asisted VCV (**concave in P tracing**)

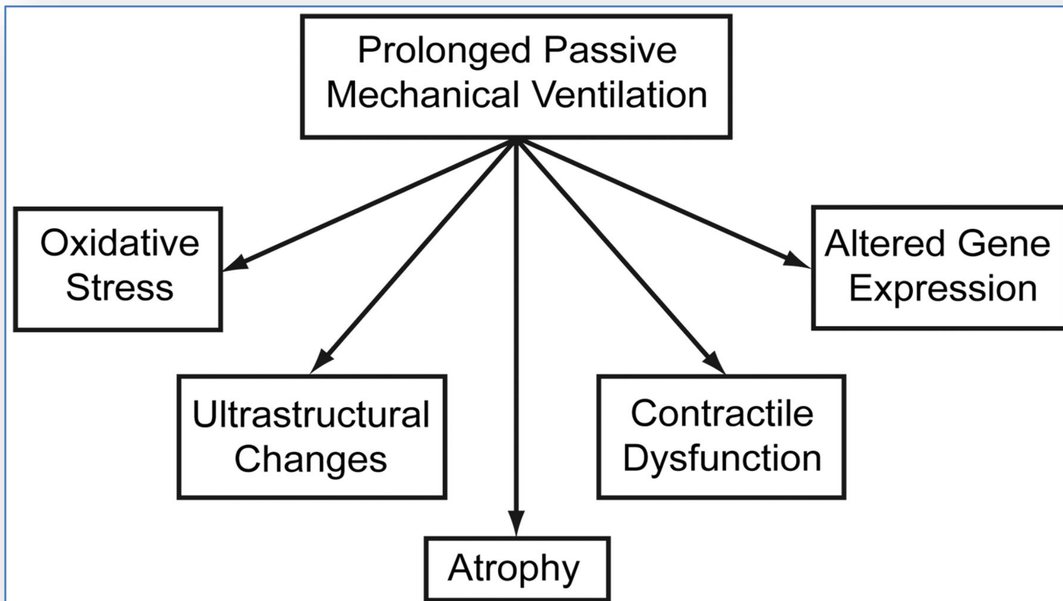
Asynchrony	Description	On the waveform	Waveform example	Common possible causes
Trigger asynchronies - during the beginning of inspiration				
Delayed triggering	The time interval between the patient's inspiratory effort and the delivery of a mechanical breath is increased	**Flow** waveform: look for a longer-than-normal time interval between the positive deflection in flow 1 and the delivery of ventilatory support 2		Trigger threshold set too high Ventilator pneumatics Presence of AutoPEEP Low respiratory drive Weak inspiratory effort
Ineffective effort	The patient's inspiratory effort fails to trigger the delivery of a mechanical breath	**Flow** waveform: look for an abrupt change in the steepness of the waveform 1 (decrease in expiratory flow or increase in inspiratory flow) that is not followed by ventilatory support 2		Trigger threshold set too high Pressure support too high Set frequency and/or inspirato high (in controlled modes) Tidal volume set too high Presence of AutoPEEP Low respiratory drive Weak inspiratory effort Sedation
Double triggering	Two (or more) mechanical breaths are delivered during one single inspiratory effort	**Flow** waveform: look for two assisted breaths without expiration between them or with an expiration interval of less than half of the mean inspiratory time (often visually displayed as a waveform with two inspiratory peaks)		Cycling criteria (ETS) set too h Pressure support too high P-ramp too short Flow starvation High respiratory drive Time constant too short
			Paw [cmH$_2$0]	

Avoid Patient – clinician Dyssynchrony !



Effects of prolonged passive mechanical ventilation

Controlled ventilation in a passive patient: often requires heavy sedation or even neuromuscular blockade to silence ventilatory muscle activity.



David J Pierson Respir Care 2011;56:214-228

THANKS