Rapid review of patient-ventilator dyssynchrony

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Abstract

Patient-Ventilator Dyssynchrony (PVD) is often described as a patient "fighting" the ventilator. In fact, there are many forms of dyssynchrony some of which can very subtle. If unrecognized early, dyssynchrony can evoke patient discomfort, increase incidence of lung injury, lead to oversedation, and lengthen duration of mechanical ventilation. Since start of the COVID-19 pandemic, many clinicians without critical care experience have been compelled to manage patients requiring mechanical ventilation. Many academic centers, hospital systems, and physician groups have attempted to provide educational material in efforts to prepare clinicians on how to operate a ventilator. During this frenzied time, very few resources have been made available to clinicians to rapidly recognize ventilator dyssynchrony as it occurs when taking care of these patients. The figures presented in this article depict dyssynchrony in Volume Control Ventilation (VCV) with a decelerating ramp of flow and are hand drawn. While they may not perfectly represent waveforms seen on ventilators, the patterns shown and described below will be similar.

Keywords: Patient-Ventilator dysynchronies, VCV

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Introduction

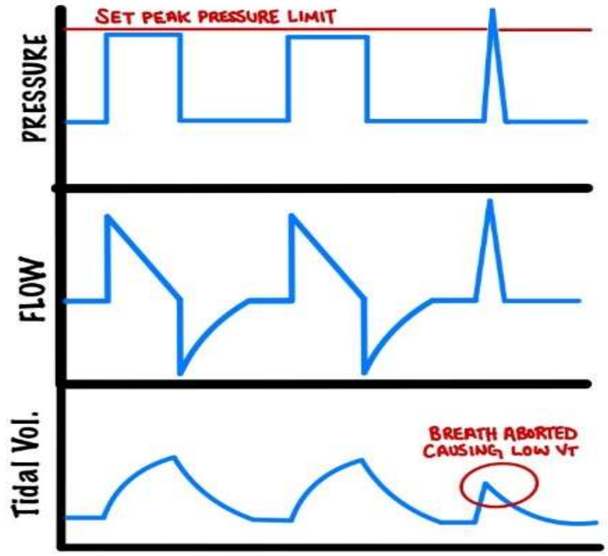
Mechanical ventilation is a commonly used intervention in the ICU. The primary intent of Mechanical Ventilation is to decrease work of breathing and maintain adequate levels of gas exchange. [1] This is often continued while waiting for the condition that was the indication for mechanical ventilation to resolve or improve.

Patient-Ventilator Dyssynchrony (PVD) can be defined as a failure of synchronize the provided breath support from a ventilator with the patient's spontaneous effort. Estimated occurrence of PVD is reported to range from 10% to 85%.[1,2] However, the incidence of PVD can be difficult to determine due to various definitions of PVD, methods used for detection, ventilator modes, and duration of observation during studies.[3]

Dyssynchrony may occur when inappropriate timing or delivery parameters are assigned to the ventilator. While advanced ventilator modes are available which may reduce the incidence of dyssynchrony through improved trigger sensitivity, target, and cycling. The recognition of dyssynchronies remains an important skill for all clinicians involved in ventilator management. If recognition is delayed, dyssynchrony can evoke patient discomfort, lead to oversedation, increase incidence of lung injury, lengthen duration of mechanical ventilation, and thereby stymie clinical improvement. [4, 5, 6] It is the purpose of this article to explore several types of PVD, its recognition, and possible interventions to improve patient-ventilator interactions.

Peak Pressure Apnea

Description: Peak Pressure (Ppeak) is described as the amount of airway pressure delivered by the ventilator to initially overcome the resistance of Endotracheal tube (ETT), airway, and alveoli. In general, an accepted maximum Ppeak is 40 cmH_2O. Peak Pressure Apnea is type of dyssynchrony is often seen in Volume Control Ventilation (VCV) and occurs when the patient peak pressure is elevated (i.e., > 40 cmH_2O). This causes the ventilator delivered breath to be prematurely aborted before the full tidal volume can be delivered. [6]



Recognition: Pressure waveform rises above max Ppeak value which causes discontinuation of given tidal volume as described above.

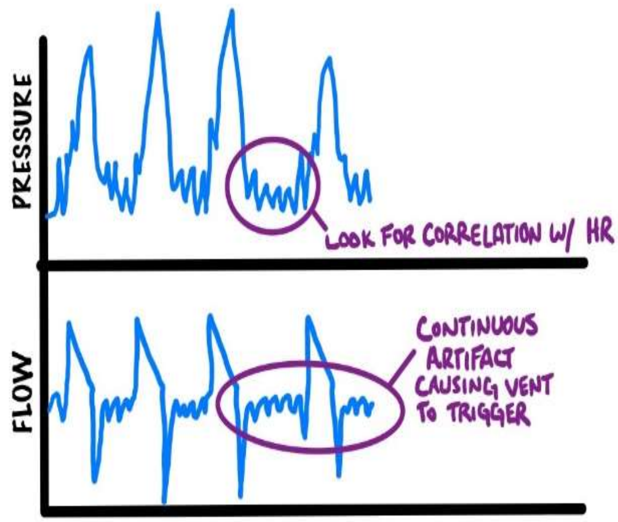
Implications: Persistent low tidal volumes due to the aborted breath can cause patient discomfort and decrease minute ventilation overall. [6] This is often a sign of underlying airway resistance or compliance problem.

Causes of Peak Pressure Apnea	Corrective Measures
Resistance Problem: Mucus plugging, bronchospasm, biting on ETT, kinking, or fluid accumulation in circuit. Compliance Problem: Pulmonary edema, pleural effusion, abdominal distention, pneumothorax, pneumonia, ARDS	Increase peak pressure alarm settings Determine plateau pressure Address underlying cause

Trigger Dyssynchrony

Autotriggering

Description: Autotriggering is a form of trigger dyssynchrony which occurs when unwanted breaths are repeatedly delivered due to a false activation of the ventilator. This type of dyssynchrony can be more commonly observed in flow sensed triggers as they can be more sensitive. [5,6]



Recognition: Continuous baseline artifact seen in the setting of rapid respiratory rate

Implications: Rapid respiratory rates can cause respiratory alkalosis, failed spontaneous breathing trials leading to increased sedation, and prolonged course of mechanical ventilation. [5,6]

Causes of Autotriggering	Corrective Measures
Cardiac oscillations Air leak Fluid in circuit Breath trigger too sensitive	Eliminate source: remove leaks and excess fluid Switch from flow to pressure sensor Decrease sensitivity of trigger

Reverse Triggering

Description: Reverse triggering is a special cause of Autotriggering in which the machine delivered breath elicits a spontaneous patient effort. In other words, it is a type of dyssynchrony that occurs when a patient appears to be triggering a breath following a non-patient triggered breath. [7] It appears typically in patients that are in a comatose state or if heavily sedated and transitioning to a more awakened state. It is thought that stimulation of vagal pathways and mediated through stretch receptors on the diaphragm [6] with cortical and subcortical influences.[2] However, the cause reverse triggering is complex and only partially understood.

Recognition: The lack of patient effort on the initial breath can help distinguish between early and reverse triggering. Other means of detecting reverse triggering varies between modes of ventilation:

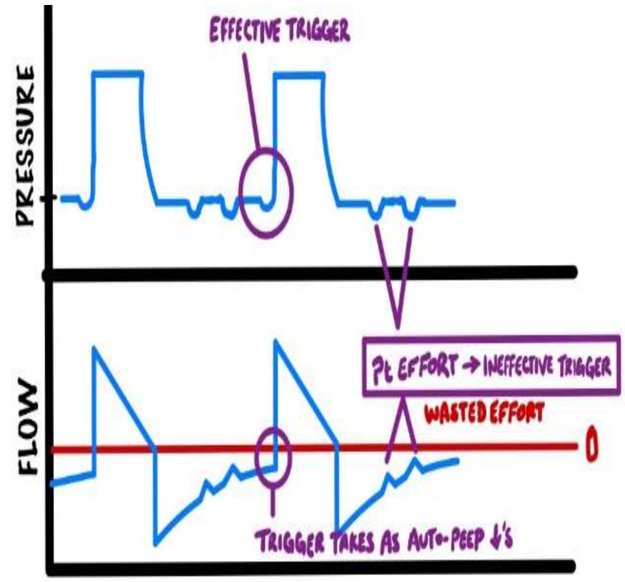
- Pressure Control: Detection of patient effort which is triggered by a controlled breath shows up as a change in flow early in the inspiratory phase
- Volume Control: Effort shows up when looking at pressure tracing and is described as a loss of plateau after inspiratory pause is performed. This may also be seen as a positive deflection (bump) in the expiratory waveform.

Implications: Carries similar risk as Autotriggering. Reverse triggering can also confound a neurological examination (e.g., brain-death) as it can be misinterpreted as a spontaneous patient-triggered breath.

Causes of Reverse Triggering (Entrainment)	Corrective Measures
Reflexive diaphragmatic stimulation Deep Sedation Comatose states	Switch to pressure support mode Decrease sedation Decrease respiratory rate Paralytic (if refractory/harmful)

Trigger Failure

Description: Trigger Failure is the most common form of ventilator dyssynchrony and usually occurs because of the patient's insufficient respiratory effort to trigger the ventilator, resulting in a wasted effort from ventilator. Depending on the severity, one can see a delayed or absent breath in response to patient effort. Many instances of trigger failure occur in response to elevated intrinsic PEEP (Auto PEEP). [6]



Recognition: Intrinsic PEEP manifests itself in the expiratory flow not returning to zero before the next breath is delivered.

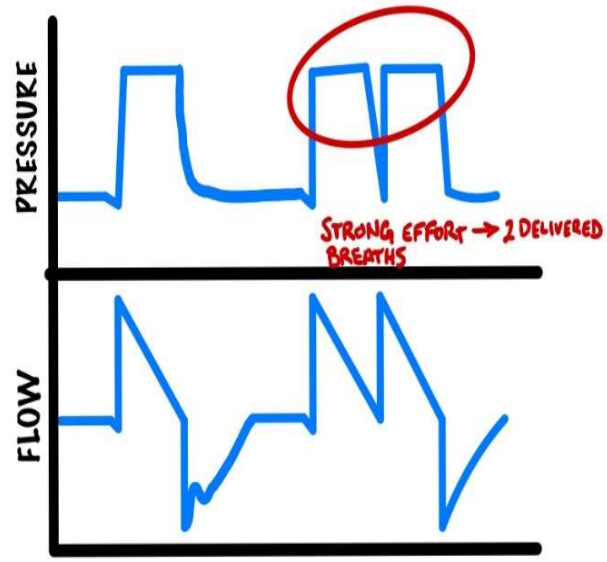
Implications: Increased patient effort, respiratory muscle fatigue, dynamic hyperinflation, reduced venous return, and cardiovascular collapse.

Causes of Trigger Failure	Corrective Measures
Intrinsic PEEP (Auto-PEEP): Most common cause of trigger failure: - Obstructive lung diseases - Large tidal volumes - Rapid respiratory rates Inappropriate Trigger settings: - Flow Trigger - Pressure Trigger Respiratory muscle weakness Decreased neural drive	Decreasing Intrinsic PEEP - Reduce respiratory rate - Decrease inspiratory time - Address cause Reduce work of triggering ventilator - Increase extrinsic PEEP Increase trigger sensitivity Consider removal or reduction of sedation, neuromuscular blockade, and neural drive depressants (ex. benzodiazepines, opioids, barbiturates)

Cycle Dyssynchrony

Premature Cycling

Description: Also known as breath stacking or double triggering, this form of dyssynchrony occurs due to an imbalance between the ventilator I-time, tidal volume, or flow being less than that of the patient. [5,6]



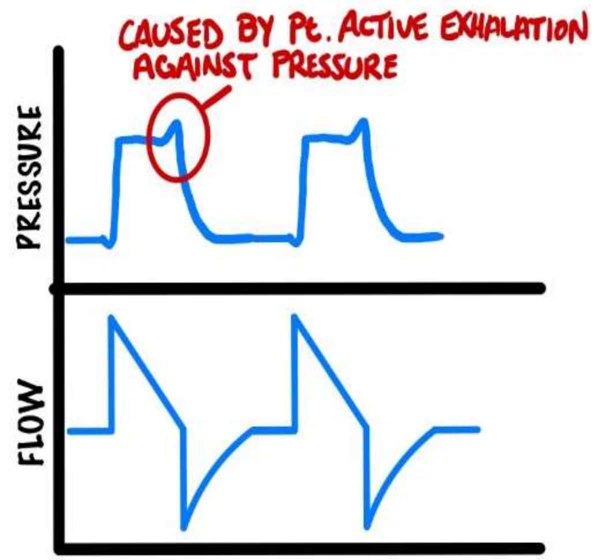
Recognition: On exam, the patient may be tachypneic and by placing a hand near the diaphragm, the clinician can feel a strong contraction of the diaphragm. On a single breath an upward deflection on the flow scalar denotes that the patient I-time is longer than the machine's I-time. If continued effort is strong enough then this can trigger the ventilator to deliver an untimely second breath.

Implications: Patient discomfort, oversedation, large tidal volumes, and potential lung injury.

Causes of Premature Cycling	Corrective Measures
The ventilator I-Time is shorter than the patients intrinsic I-Time. Prolonged patient effort is sensed by the ventilator as a new breath Low tidal volume in VCV	VCV - Increase tidal volume - Decrease flow Pressure Modes - Increase set I-Time

Delayed Cycling

Description: Delaying cycling is essentially the opposite of premature cycling in that the machine's I-time is longer than the patients natural I-time. [8]



Recognition: The flow scalar is typically unchanged in delayed cycling. However, end inspiratory pressure spikes are observed denoting patient effort to exhale prematurely.

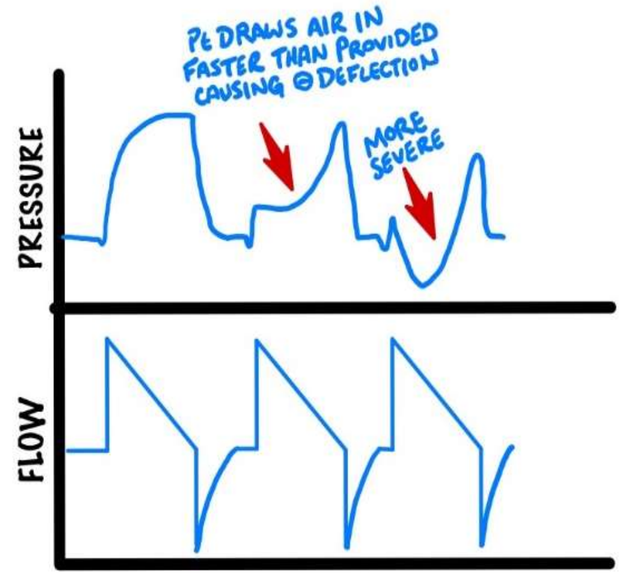
Implications: Auto PEEP can develop due to longer than needed I-times. It can increase patient discomfort and predispose to lung injury.

Causes of Delayed Cycling	Corrective Measures
The ventilator I-Time is more than the patients intrinsic I-Time. Large tidal volumes in VCV Long set I-time in PCV	VCV - Decrease tidal volume - Increase flow Pressure Modes - Decrease set I-Time

Flow Dyssynchrony

Description: Inadequate flow (flow hunger) occurs when the patients flow demand is more that the ventilator is set up to provide. Often seen in VCV and older machine without an "autoflow" setting. [4]

Recognition: Pulled down or scooped out appearance on pressure scaler

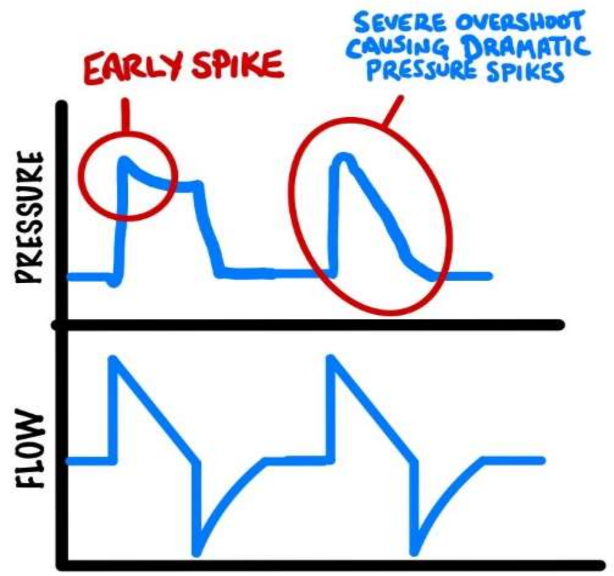


Implications: Breathing hard against the ventilator represents a failure to shift the work of breathing from the patient to the ventilator. This also causes increased respiratory fatigue and oxygen consumption. Flow dyssynchrony can lead to an increase in transpulmonary pressure and predispose the patient to developing lung injury.

Causes of Inadequate Flow	Corrective Measures
Inadequate flow settings on ventilator - Fixed flow targeted breaths Acute respiratory failure Increased respiratory drive Fever Pain	VCV - Increase inspiratory flow - Switch to pressure modes as flow varies with patient effort Pressure Modes - Shorten rise time Address underlying cause - Pain, fever, etc.

Flow Overshoot

Description: Flow overshoot can occur more commonly during an initial ventilator set-up as the ventilator is set to deliver a breath faster than the patient desires.



Recognition: An early spike in the pressure scalar is observed during the inspiratory phase. If severe, this can cause a more dramatic spike.

Implications: While this dyssynchrony will cause patient discomfort, delivering the breath too fast also artificially shortens the breath and increases the respiratory rate, promoting dyspnea.

Causes of Flow Overshoot	Corrective Measures
Ventilator flow exceeds what patient wants - Volume Modes: Flow set too high - Pressure Modes: I-Time too fast or Inspiratory pressure too high.	VCV - Decrease flow Pressure Modes - Lengthen rise time

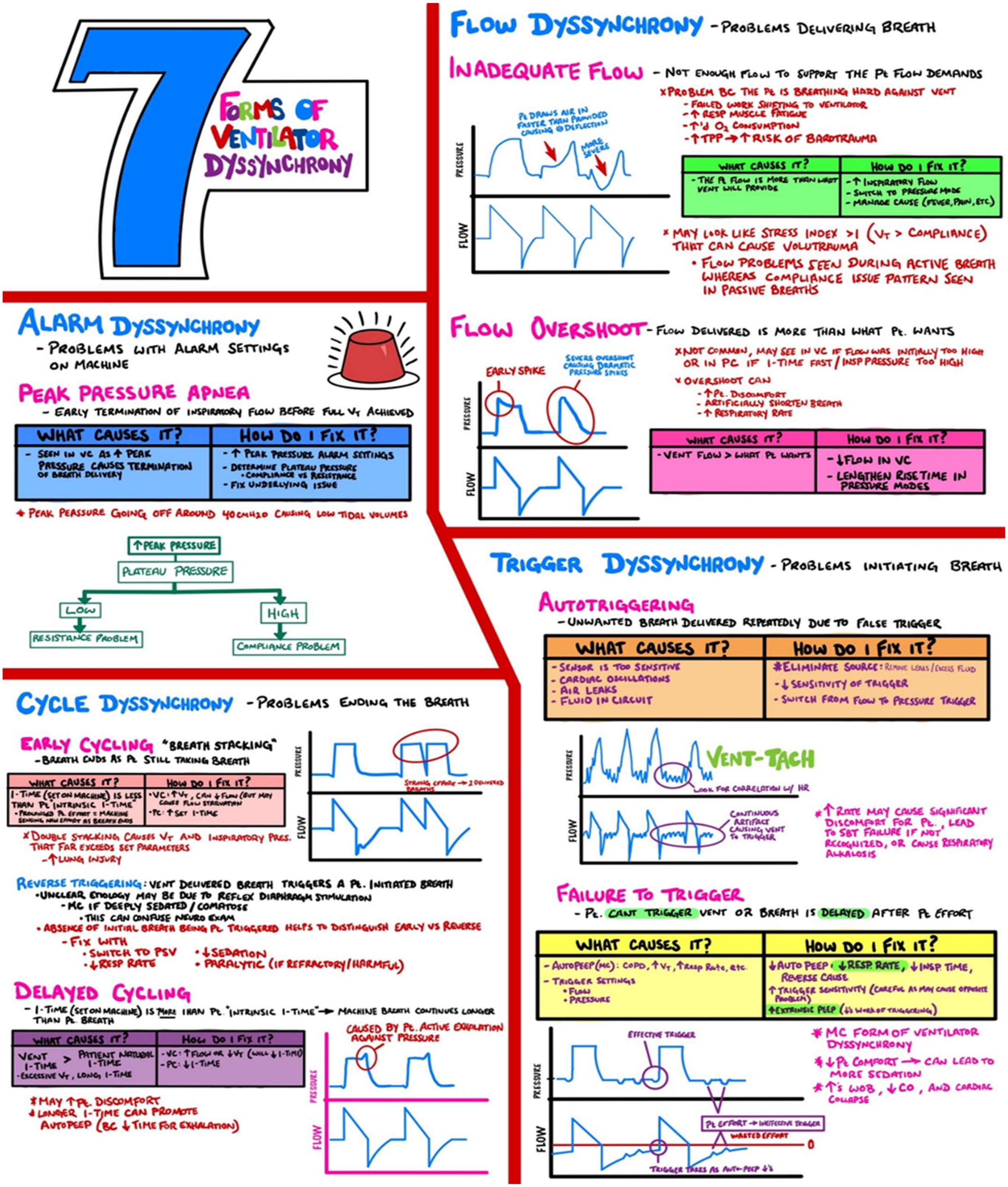


Figure 1: A quick review of ventilator dyssynchrony. All the flow scalars depicted here are from VCV with a decelerating ramp of flow. However, key features in other modes will be similar. A more in-depth review of ventilator dyssynchrony can be found in reference 5.

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