

## **Obtaining Optimal Patient-Ventilator Synchrony**

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### **Introduction:**

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There are a few terms that should be removed from the vocabulary of respiratory care practitioners (RCPs). Topping the list is “vent check”, followed closely by “check, drain, and maintain” and the cynical title of “knob turner”. The critical care RCP of today should be conducting true patient-ventilator assessments – assessing the patient, the ventilator and their relationship. This means the constant evaluation of patient-ventilator interactions during the resolution of the patient’s underlying disease. The RCP must possess the ability to recognize abnormal patient-ventilator interactions and the knowledge and skills to utilize the tools available today to accomplish optimal synchrony.

When a patient is first placed on a mechanical ventilator, a control mode of ventilation is commonly used to provide adequate gas exchange and unload fatigued respiratory muscles. The patient usually requires sedation to all but obliterate spontaneous breathing efforts in the initial phases of acute respiratory failure (ARF). The ventilator does the majority, if not all, of the work. Asynchrony is not usually a problem at this stage. As the patient’s respiratory status improves, the clinician switches the patient to an interactive mode of ventilation. Interactive modes allow spontaneous ventilatory activity. This activity could be as little as triggering an assisted machine breath or as much as determining the timing of the breath cycle during a pressure-supported breath. It is this range of patient activity along with the ventilator’s capabilities and set parameters that determine patient-ventilator interaction.

There is increasing data that supports the use of some spontaneous breathing through interactive modes of ventilation at the onset of ARF. The advantages of spontaneous breathing during mechanical ventilation include fewer negative hemodynamic effects and better gas exchange, providing there is proper patient-ventilator synchrony. The new generation of microprocessor-driven ventilators has given RCPs the tools to achieve this goal. When transitioning to an interactive mode, ventilating airway pressures will decrease and less sedation should be required as long as optimal synchrony is attained.

When patient-ventilator asynchrony occurs, it will result in impaired gas exchange, an increased load to the respiratory muscles and increased intrathoracic pressures. Discontinuation from ventilatory support could be delayed, resulting in more complications, which will potentially increase morbidity, mortality and overall healthcare cost.

This article will focus on the systematic recognition of patient-ventilator asynchrony and utilization of breath types, modes and other ventilator parameters to optimize the patient-ventilator synchronization.

Patient-ventilator interaction can be simplified to three distinct phases: patient triggering, ventilator breath delivery, and the process of cycling the ventilator from inspiration to expiration. Problems with synchrony in one phase could well affect the other phases. A RCP must have a firm understanding of ventilator operation and graphics and knowledge of respiratory system mechanics to achieve patient-ventilator synchrony.

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## Trigger Asynchrony: Recognition, Causes and Interventions

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There are three different ways a machine breath can be initiated by the ventilator: time-triggered, manual-triggered or patient-triggered. When the patient attempts to trigger the mechanical ventilator, there is a myriad of problems that can cause the patient and the ventilator to be out-of-sync.

For all practical purposes, when a patient initiates a breath, there are two types of patient-triggering systems available on most ventilators today: pressure or flow. With pressure-triggering, a breath is initiated when the patient inspires, causing a drop below the level of the end-expiratory pressure. Flow-triggering delivers a patient-initiated breath after sensing a difference between the continuous bias flow circulating in the inspiratory and expiratory limbs of the ventilator circuit. Studies suggest that flow-triggering decreases response time and patient work of breathing (WOB), making it superior to pressure-triggering.

If the patient's efforts are not matched with the initiation of flow from the ventilator, the result will be increased muscle loading, wasted oxygen consumption and general agitation. Due to uncontrollable factors with the patient and ventilator, there is a slight delay in ventilator response time, defined as the amount of time it takes for the ventilator to respond to the patient's initial effort. This will cause trigger asynchrony, even in an ideal situation. The normal inherent delay is < 150ms. This is indicative of only a small amount of WOB during the triggering phase. It is the responsibility of the RCP to ensure that the ventilator responds to the patient's breath initiation as optimally as possible.

An inappropriately set sensitivity level (pressure or flow-triggering) could cause severe asynchrony. If the level is set too sensitive, auto-triggering may occur. If this occurs suddenly, the cause could be signal noise due to water in the ventilator circuit, leaks in the patient-ventilator system or patient movement. The degree of discomfort and complications to the patient from auto-triggering depends on the mode and breath type utilized. If auto-triggering occurs, the sensitivity level should be adjusted until it ceases. If the sensitivity level is not set sensitive enough, WOB will be increased, as the patient struggles to initiate a breath. In some cases the patient may not even be able to trigger the desired breath at all. Setting the patient on a more sensitive setting or switching to a more advanced flow-triggering ventilator would be the first step in correcting ineffective patient triggering. The next step is to search for another cause for the lack of ventilator response to the patient's breath initiation. The RCP must combine patient assessment and ventilator graphics interpretation skills to diagnose alterations in the pressure-time and flow-time scalars.

Another possible cause for trigger asynchrony is dynamic hyperinflation and its resultant auto-PEEP. When minute volume is high and expiratory time ( $T_E$ ) is too short, auto-PEEP may occur. A positive lung recoil pressure at the end of expiration defines dynamic hyperinflation, which is transmitted to the alveoli. A patient with auto-PEEP has to generate a greater effort to overcome the positive alveolar pressure. This is particularly difficult in patients who are weak and/or have COPD. These patients may not have the muscle strength to initiate a breath.

Patients with COPD have flow limitations due to early small airway collapse, which causes dynamic hyperinflation. Efforts should be made to decrease the level of auto-PEEP to reduce this form of trigger asynchrony. These actions include setting the sensitivity at the most sensitive level, maximizing bronchodilator therapy, and decreasing minute volume. The minute volume can be decreased by lowering the pressure support level, tidal volume, respiratory rate, or by increasing  $T_E$ .  $T_E$  is lengthened by increasing the inspiratory flow in volume ventilation or by decreasing the inspiratory time ( $T_I$ ) in pressure ventilation. These airways may need to be stented open with an increased applied PEEP, up to 85% of the actual auto-PEEP level. This will allow the patient to trigger the ventilator when the alveolar pressure falls below the level of the applied PEEP, rather than below zero. Caution should be used to monitor hemodynamics when increasing the applied PEEP. Under a physician's order, the RCP should increase the applied PEEP by 1 cm H<sub>2</sub>O at a time until the patient successfully triggers the ventilator with each breath. If applied PEEP has to be increased by more than 6 cm H<sub>2</sub>O, sedation should be increased to decrease patient effort. This maneuver should only be done in patients with auto-PEEP caused by COPD (early small airway collapse with flow limitation). If it is used with auto-PEEP caused by any other process, it could worsen the respiratory mechanics and cause hyperventilation, resulting in hemodynamic instability and worsening of patient-ventilator asynchrony.

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### **Breath Delivery Asynchrony: Recognition, Causes and Interventions**

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For optimal breath delivery synchrony, several parameters need to be met. The ventilator must deliver a sufficient amount of flow to consistently match or exceed the spontaneously breathing patient's inspiratory demand, deliver an adequate Tidal Volume ( $V_T$ ), and an adequate rise-to-pressure time should be set (in pressure breaths only). The use of ventilator graphics and proficient patient assessment skills are paramount to achieving this sometimes-difficult phase of the breath delivery synchronization. Patient sedation requirements should be minimal if breath delivery synchrony is optimal.

Flow starvation is a common cause for breath delivery asynchrony in volume ventilation. If patients do not have enough inspiratory flow to meet their demands they will pull against their own impedance as well as the ventilator's. This will increase the WOB substantially, sometimes greater than that of unassisted spontaneous breaths. It will not only be obvious on the ventilator graphics, but in most cases it will be clearly visible during the patient assessment. This is more of an issue in patients with a high respiratory drive or a high minute volume, as seen in a septic patient.

Several things can be done to correct flow starvation. In volume ventilation, the inspiratory flow can be increased. One concern with increasing the flow too much is that it shortens the  $T_I$ ; the mechanical (ventilator's)  $T_I$  is shorter than the neural (patient's)  $T_I$ . The effects of this problem will be discussed later in the article. Studies show that rapid inspiratory flows can increase the neural breathing frequency. It can also cause breathing discomfort due to excessively forceful gas delivery. The irony of this is that RCPs commonly increase the inspiratory flow in volume ventilation when auto-PEEP is present to increase the  $T_E$ , allowing more time for the lungs to empty, but in fact they may be increasing the patient's tachypnea which in turn decreases the  $T_E$  further.

Another option for correcting flow starvation is to switch the patient from volume ventilation to pressure ventilation. The mode can stay the same (i.e. A/C or SIMV); only the machine breath type is switched. Pressure controlled ventilation has several advantages, two of which are independent control of  $T_I$  and variable patient controlled inspiratory flow. Patients can receive the flow they demand independent of the set  $T_I$ . Pressure support can be used as well. Patients with high respiratory drives and efforts need to have enough pressure to provide enough flow to meet their demand. Again, routine and thorough patient-ventilator assessments will assist the RCP in decreasing the WOB caused by flow starvation.

A  $V_T$  set too low during volume ventilation or a set inspiratory pressure resulting in a low  $V_T$  during pressure ventilation could cause a sense of breathlessness. Patients who require a low  $V_T$  for diseases such as ARDS may need increased sedation especially in patients with high respiratory drives.

Another aspect of the inspiratory phase during pressure-controlled and pressure-supported breaths is the fast rise-to-pressure time that is required to reach the set pressure at the start of the breath. Some patients with high respiratory drives may be comfortable with the fast flow and pressure spike. Others may become asynchronous with the ventilator due to this “ringing” or “spiking”, which is noticed on the pressure-time scalar. Most new microprocessor ventilators have a control that allows the RCP to tailor or shape the breath for patient comfort. This is done by the “rise time” or “slope” parameters, depending on the manufacturer of the ventilator. Patients who do not have high respiratory drives should have the rise-to-pressure time set as follows:

1. View the pressure and flow-time scalars.
2. Turn the rise-to-pressure time parameter to the “zero” position. (The fastest rise-to-pressure time)
3. Increase the time it takes to rise to the set pressure in small increments until the spike in the pressure-time scalar disappears.

In most cases, the rise-to-pressure time will change the  $T_I$  in pressure support ventilation, due to the fact that most ventilators flow cycle off when the inspiratory flow diminishes to a predetermined or clinician adjusted percentage of the initial peak flow. The rise-to-pressure time affects the initial peak flow. This could affect timing, causing patient-ventilator asynchrony. It does not affect the  $T_I$  in pressure control ventilation.

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### **Breath Cycling Asynchrony: Recognition, Causes and Interventions**

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Breath cycling is defined as the “cycling off” of the mechanical inhalation or switching from the inspiratory phase to the expiratory phase within the breath cycle.

As discussed in the previous section, there are two types of inspiratory times: neural  $T_I$  and mechanical  $T_I$  ( $T_{I,neural}$  and  $T_{I,mech}$ ); they need to be in-sync with one another. Neural and ventilator mismatching could cause asynchrony in triggering, breath delivery and/or breath cycling. When the  $T_{I,neural}$  is longer than the  $T_{I,mech}$ , breaths could double-trigger within the same respiratory cycle because the patient’s ventilatory demand is not adequately met. Lengthening the ventilator’s  $T_I$  could correct this type of cycling asynchrony. Conversely, if the  $T_{I,neural}$  is shorter than the  $T_{I,mech}$ , ineffective efforts could develop. This is due to the ventilator still delivering gas flow when the patient is ready to

exhale. If neural/ventilator timing mismatch occurs, utilize patient and graphic assessments as a guide and experiment by adjusting the  $T_I$  for optimal synchronization and comfort.

$T_I$  adjustment is different for each type of ventilation. In volume ventilation, the constant  $T_I$  is set indirectly by the RCP setting the inspiratory flow and  $V_T$ . During a pressure-controlled ventilation breath, the  $T_I$  is directly set by the RCP. In pressure support, the patient determines the  $T_I$ .

Pressure support can make the spontaneously breathing patient more synchronous with the ventilator than any of the modes and breath types. This is because the patient determines his  $T_I$ . The patient has more control over his  $T_I$  and the overall synchrony. Pressure-supported breaths are primarily flow-cycled as opposed to time-cycled in pressure-controlled and volume-controlled breaths. The flow cycling criteria is different on each specific ventilator.

With flow-cycling, the breath is terminated when the inspiratory flow decreases to a predetermined amount, usually a percentage of the initial peak inspiratory flow. With patients who have diseases with long time constants, such as COPD or patients with leaks, asynchrony may develop. The  $T_{I,mech}$  could be longer than the  $T_{I,neural}$ , causing asynchrony as described above. This could also cause further air trapping. A ventilator with the highest flow cycling (percentage) criteria should be used in these patients. Most ventilators have backup time and/or pressure cycling parameters for these patients as a safety net.

On some newer ventilators, the flow-cycling criteria percentage for pressure-supported breaths can be adjusted by the RCP. A typical range is 1-40%. This gives the RCP the ability to adjust the percentage to each patient by observing the graphics and the patient to obtain optimal synchrony. Keep in mind that using the rise-to-pressure parameter, as mentioned in the previous section, will affect the  $T_I$  as well, due a change in the peak inspiratory flow.

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### **Summary:**

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When modern day invasive mechanical ventilators were first introduced, the original aim was to simply sustain life until a patient recovered from or succumbed to his disease. In the 1970's to 1980's, adequate blood gases and atelectasis prevention were the goals. Since the mid-1990's lung protection has been the main focus of mechanical ventilation. Along with furthering lung protection, the current concentration is optimal patient-ventilator synchrony.

Patients who are more comfortable on mechanical ventilation require fewer ventilator days, resulting in less lung damage and complications, and greater overall survivability.

The importance of coordinating the patient and the mechanical ventilator certainly cannot be understated. RCPs have the essential responsibility to keep patients as safe and as comfortable as possible.