BREAS | NEWSLETTER

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Mechanical ventilation: What are we doing to the patient?

As clinicians, when it comes to mechanical ventilation (MV) we often concentrate more on ventilating the lungs and maintaining appropriate pH, PaO_2 and $PaCO_2$ levels, and we may sometimes forget the effects positive pressure has on other body organs such as the heart, kidneys and brain.

Positive pressure, when it is introduced into the thorax, is transmitted up the spinal cord to the brain, compresses blood vessel leading to and from the heart and affects other organ systems. In addition, the timing of ventilation (ventilator inspiratory to expiratory cycling time) may conflict with the patient's neurologic breath stimulation causing patient-ventilator asynchrony.

This edition of the Breas Clinical Services Newsletter focuses on how MV may affect other organ systems, patient-ventilator asynchrony, and different methods of monitoring, measuring and detection.

NEWS IN MARCH 2015

- Cardiorespiratory effects of mechanical ventilation
- Measuring Respiratory Mechanics
- What is the best way to measure a patient's response to mechanical ventilation?

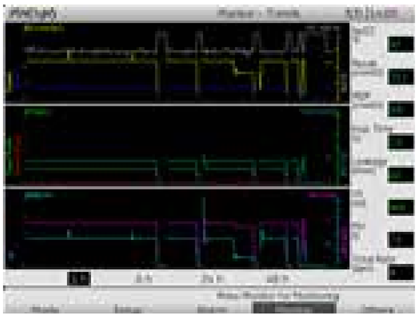
BREAS Clinical Services ... we're here to serve you

Breas Clinical Service's mission is to champion excellence in innovation, demonstrate clinical expertise, and provide clinical leadership to the company and the customers we serve. We plan to do this by partnering with key opinion leaders to help design and develop products and services that are clinically relevant and beneficial in improving patient care and quality of life.

Cardiorespiratory Effects of Mechanical Ventilation

Ira M Cheifetz MD FAARC, published a very informative article on this subject in Respiratory Care, December 2014 Vol 59 No 12, entitled: "Cardiorespiratory Interactions: The Relationship Between Mechanical Ventilation and Hemodynamics." Dr. Cheifetz states, "from the perspective of the clinician, an understanding of the complex physiologic interactions between the respiratory and cardiac systems is essential for optimal patient management." The mean airway pressure (MAP) directly influences the mean intrathoracic pressure, which in turn can influence cardiac output. However, Dr. Cheifetz states that, "it should be noted from the start that PPV can positively or negatively impact the cardiovascular status, although most often, no overall effect is seen due to the body's ability to compensate for changes in intrathoracic pressure." Physiologic differences affect the interaction of positive pressure ventilation (PPV) on the right and left sides of the heart.

The right ventricle receives blood from beyond the thorax (ie, from the superior and inferior vena cava) and pumps it within the thorax. As such, the flow of blood to the right ventricle is sensitive to alterations in mean intrathoracic pressure for several physiologic reasons. During spontaneous breathing (ie, negative intrathoracic pressure), right atrial pressure is low, impedance to blood flow to the right ventricle is also low, and systemic venous return is normal. Initiation of PPV (invasive or noninvasive) increases intrathoracic pressure, which is transmitted to the right heart (ie, increased right atrial pressure) and can result in a decrease in systemic venous blood return (ie, decreased right heart preload). This effect is most pronounced in situations of significant increases in mean intrathoracic pressure and/or decreases in intravascular volume (eg, septic, hemorrhagic, or hypovolemic shock).



"Mean airway pressure directly influences the mean intrathoracic pressure which in turn can influence cardiac output."

In summary, PPV increases mean intrathoracic pressure and reduces right ventricular performance by decreasing right ventricular preload. Although this may be of more concern in the ICU than in the home setting, clinicians still need to appreciate the role that PPV can play on the patient's hemodynamic status, especially patients with cardiac disease.

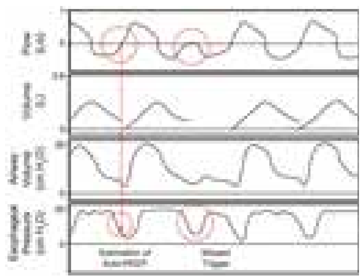
Identifying Asynchrony, Triggering Events & Increased WOB Using Respiratory Mechanics

Dean Hess, PhD, RRT, FAARC published a thorough article in Respiratory Care, November 2014 Vol 59 No 11, in which he explains respiratory mechanics.

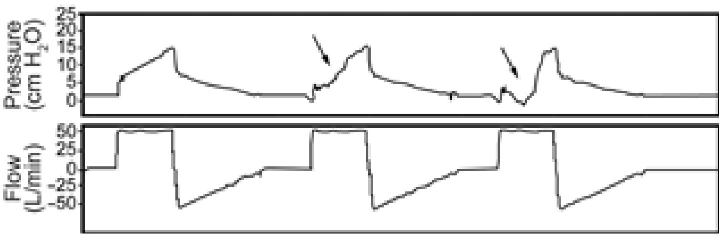
According to Hess, "respiratory mechanics refers to the expression of lung function through measures of pressure and flow. From these measurements, a variety of derived indices can be determined, such as volume, compliance, resistance, and work of breathing (WOB). Waveforms are derived when one of the parameters of respiratory mechanics is plotted as a function of time or as a function of one of the other parameters. This produces scalar tracings of pressure-time, flow-time, and volume-time graphics, as well as flow-volume and pressure-volume (P-V) loops."

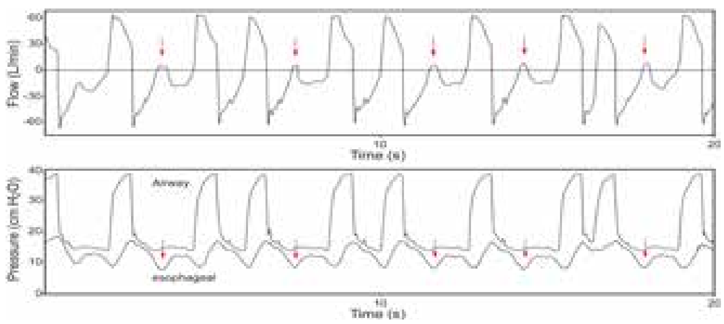
Measurement and graphic display (wave form) of certain respiratory mechanics functions such as pressure, flow and volume are useful in detecting clinical anomalies such as intrinsic PEEP (auto-PEEP), increased work of breathing (WOB) and patient-ventilator asynchrony to name a few.

Patient-ventilator asynchrony can usually be detected by changes in the pressure waveform, which varies from breath to breath. Asynchrony is particularly identifiable during volume control ventilation (VCV).



Hess explains that a special form of patient-ventilator asynchrony can occur during pressure support ventilation, in which the patient actively exhales to terminate the inspiratory phase. This is seen as a pressure spike at the end of inspiration, causing the ventilator to pressure-cycle to the expiratory phase. Hess cautions that, "it is important to judge the presence of asynchrony when assessing respiratory mechanics, as this has the potential to bias assessments of respiratory mechanics such as Pplat and stress index." He notes that the stress index is used to assess the shape of the pressure-time curve during constant flow-volume control ventilation.





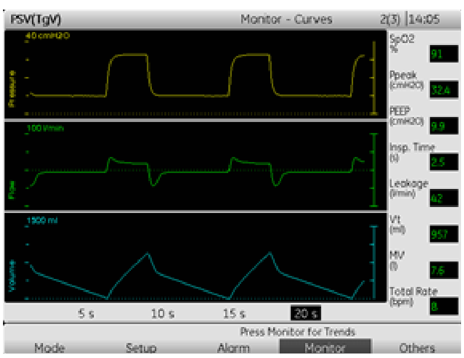
Monitoring the expiratory flow is also important for detecting missed triggering events and so, patient-ventilator asynchrony.

Hess explains that notching in the expiratory flow wave form may suggest the presence of missed triggering events. In an article entitled, "Asynchronies during mechanical ventilation are associated with mortality" published in Intensive Care Med DOI 10.1007/s00134-015-3692-6, Blanch and fellow researchers assessed the prevalence and time course of asynchronies during mechanical ventilation (MV). They conducted a prospective, non-interventional observational study of 50 patients admitted to the ICU. Using software that distinguished ventilatory modes and detected ineffective inspiratory efforts during expiration (IEE), double- triggering, aborted inspirations, and short and prolonged cycling to compute the asynchrony index (AI) for each hour they discovered that asynchronies were detected in all patients and in all ventilator modes and noted that, the most common asynchrony overall and in each mode was IEE [2.38 % (IQR 1.36–3.61)]. The study's conclusion was that, Asynchronies are common throughout MV, occurring in all MV modes, and more frequently during the daytime, and suggested that further studies should determine whether asynchronies are a marker for or a cause of mortality. The researchers emphasized that, "Diagnosing and correcting asynchronies should be a priority throughout MV."

Respiratory mechanics (wave forms) can be a valuable tool to use when transitioning the patient from the ICU ventilator to the home ventilator, for detecting intrinsic PEEP, for detecting missed triggering events, and for evaluating patient-ventilator asynchrony. The Vivo 50 and Vivo 60 have a robust graphic waveform package for the clinician to use. In addition physiologic monitors like the $EtCO_2$ and SpO_2 monitors provide an additional valuable layer of monitoring to help detect current or impending problems with the patient or the ventilator. And with a comprehensive alarm package, the Vivo 50 and 60 help ensure the patient will be safe and well ventilated in the home or alternate care setting.

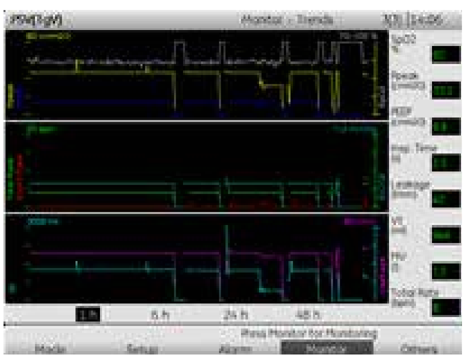
Vivo 50 & 60 Graphic Monitoring (Wave Forms) Package

Monitoring Wave Forms



Pressure, Flow and Volume Wave Forms

Trend Wave Forms



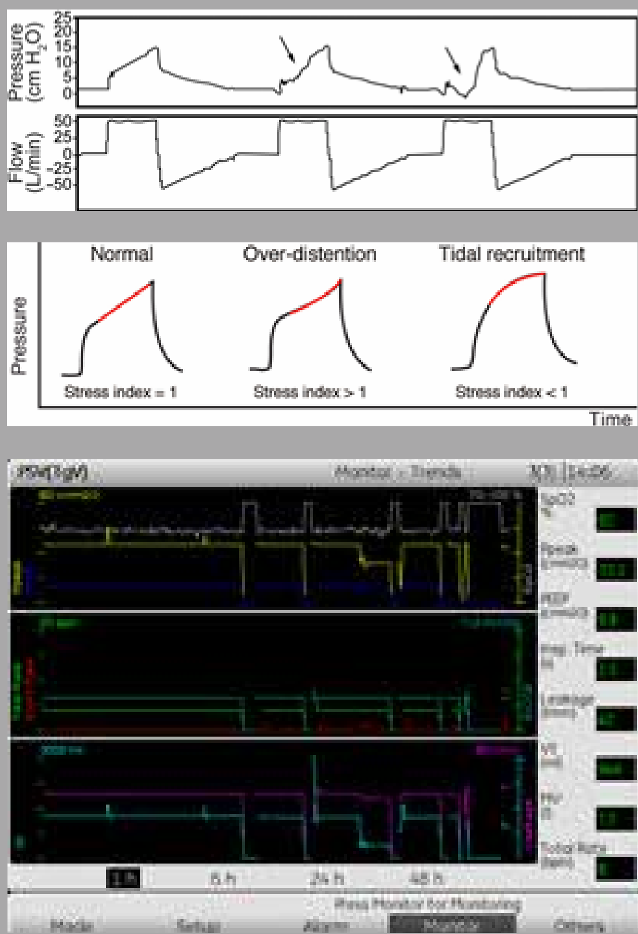
Pressure, Flow, Volume, PEEP, SpO_2, Total Rate, Spontaneous Rate, $EtCO_2$, Leakage

What is the best way to measure a patient's response to mechanical ventilation?

There are several ways to measure a patient's response to mechanical ventilation (MV) – whether the goal is to determine patient-ventilator asynchrony, lung compliance, work of breathing or muscle function. In an article published in Respiratory Care (September 2014, Vol 59 No 9) entitled, "Assessing Respiratory Function Depends on Mechanical Characteristics of Balloon Catheters", Stephan Walterspacher MD, et. al., state, "to date, esophageal (and gastric) pressure measurement is considered the accepted standard in the discrimination of respiratory effort-related arousals during sleep. It is indispensable in measuring lung and chest wall compliance, work of breathing, respiratory muscle function (ie, transdiaphragmatic pressures) and is valuable for the assessment of trigger function as well as patient-ventilator synchrony in mechanically ventilated patients."

Although esophageal and gastric pressure measurement may be the standard for determining a patient's response to MV, it is limited primarily to the ICU setting and is not currently practical for home use. So, what is practical for use in assessing the patient's response to MV in the home setting? Manel Lujan, et. al., published an interesting article entitled "Home Mechanical Ventilation Monitoring Software: Measure More or Measure Better?" (Arch Bronconeumol. 2012;48(5):170–178). In that article he and his colleagues noted the increased use of noninvasive ventilation (NIV) in Europe and subsequently an increased interest in understanding the consequences of patient–ventilator interaction on lung mechanics. More specifically they wondered about the effects on lung mechanics of different ventilator modes and parameters, which can be modified by clinicians. Several home ventilators and RAD devices now incorporate the ability to measure, record and download data regarding a patient's response to MV and to certain adjustable parameters, e.g., Rise Time, inspiratory trigger, expiratory trigger etc.

MEASURING RESPIRATORY MECHANICS



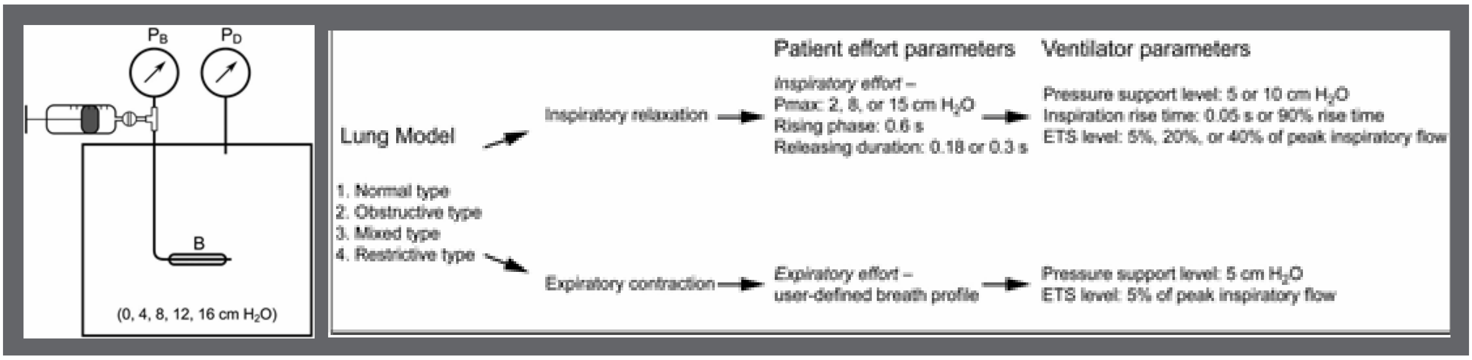
In the Lujan study the objective was to develop a "critical and argumentative analysis" of the software programs incorporated in the ventilators tested, and to critique the forms of presentation of their measurements on the screen, with emphasis placed on the pros and cons of each one. What they concluded was that, some of the data displayed was too difficult to read because there were so many graphs presented and that, a screen that displayed graphs for flow, pressure and volume–time, leak calculation and maybe one for a biological variable like SpO_2 or $EtCO_2$ should be sufficient. They suggest that incorporating an algorithm to automatically interpret episodes associated with oxygen desaturation (e.g., leaks, upper airway obstruction, ineffective triggering, etc.) might aid clinicians in decision-making as to how to adapt the ventilator to the patient and, could potentially increase the possibilities for researching the effects of patient-ventilator asynchronies.

In a different article entitled, "Simulation of Late Inspiratory Rise in Airway Pressure During Pressure Support Ventilation," published in Respiratory Care, February 2015 Vol 60 No 2, researchers (Chun-Hsiang Yu MD, et. al.) noted that, "the use of PSV is sometimes associated with patient-ventilator asynchrony (e.g., trigger asynchrony or double triggering). Hsiang and his colleagues go on to state, "to facilitate patient-ventilator synchrony and markedly reduce the asynchrony index, however, a number of variables can be adjusted in pressure support mode, including inspiratory rise time, pressure support level, and flow cycle criteria (ie, expiratory cycle criteria)." In addition to inspiratory related asynchronies, expiratory related asynchronies also exist. An expiratory asynchrony can occur when a ventilator breath either precedes or follows the end of neural inspiration.

Both inspiratory and expiratory related asynchronies can be detected on a graphic wave form monitor. Expiratory asynchronies (early breath termination) can be detected on the flow and pressure wave form as a distortion in the early phase of exhalation. Delayed cycling can usually be seen as an abrupt increase in the inspiratory airway pressure.

different presentations in late inspiratory rise in airway pressure (LIRAP) exists between different ventilators and that, respiratory compliance also contributes to LIRAP because of additional cycle criteria in PSV.

The schematic diagram for their study is listed below:



Hsiang and his colleagues found that "as delayed cycle beyond the end of inspiratory effort is common in PSV, an investigation of possible contributing factors to late inspiratory airway pressure rise with PSV may increase our understanding of expiratory asynchrony. Either relaxation of inspiratory muscles or contraction of expiratory muscles may lead to expiratory asynchrony, but different pathophysiology may lead to different modes of ventilator accommodation." The objective of their study was to determine the factors related to airway pressure rise near the end of inspiration during PSV. This was a bench test study using a simulation lung model. The researchers hypothesized that since ventilators rely on the proportional-integral-derivative controllers as flow changes (which vary according to the difference between current pressure and target pressure and are likely to be different among different ventilator manufacturers) therefore,

What they found was that late inspiratory airway pressure rise can occur in all types of lung models if inspiratory effort is medium to high and rate of relaxation is rapid. Also, a high flow cycle level is unlikely to abolish late inspiratory rise when inspiratory effort is high. Further, despite similar patterns of inspiratory relaxation among different ventilators, there are also sizeable differences in LIRAP among ventilators. Finally, expiratory muscle contraction may cause late inspiratory rise but only when it occurs sometime after inspiration. Their conclusion was that, a high LIRAP during PSV is an indication to a clinician that the existence of high inspiratory effort from the patient first should be considered, and management should be directed toward the underlying cause. Also, expiratory muscle contraction may lead to LIRAP when it occurs at specific times during inspiration.

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