Assessing Respiratory System Mechanical Function

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KEYWORDS

• Lung compliance • Esophageal pressure • Impedance • Lung injury • Respiratory mechanics
• Ventilator graphics

KEY POINTS

- Assessment of the respiratory system mechanical function in critically ill patients can detect early signs of abnormalities that could affect patient outcomes.
- The patient-ventilator interaction can be evaluated through noninvasive and invasive methods.
- A wide range of measurements and calculations of respiratory mechanics are available to optimize the selection of ventilatory modalities and specific ventilator parameters.
- All ventilatory strategies should be directed to minimize the patient's work of breathing and minimize lung injury.

INTRODUCTION

The assessment of the respiratory mechanical function during mechanical ventilatory support refers to the evaluation of respiratory system physiology and ventilator performance through a variety of methods with the ultimate goal of understanding the interactions between applied pressures and flows inside the respiratory system.[1] Early detection of abnormalities in this interaction is critical because it could affect the patient's outcomes. In the critical care setting, it has become increasingly important to recognize whether the respiratory function has improved or deteriorated, whether the ventilator settings match the patient's demand, and whether the selection of ventilator parameters follows a lung-protective strategy. Respiratory measurements include several single and combined parameters but also a long list of derived values. In order to obtain these values and identify abnormalities in the respiratory mechanical function, a variety of monitoring methods are currently available to clinicians. Ventilator graphics, esophageal pressure, intra-abdominal pressure, and electric impedance tomography are some of the best-known monitoring tools to obtain measurements and adequately evaluate the respiratory system mechanical function.

Almost 16 years after the National Institutes of Health Acute respiratory Distress Syndrome (ARDS) Network (ARDSnet) reported the benefits of lower tidal volumes (VTs) on survival rates for

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mechanically ventilated patients with ARDS, much research has been focused on methods that evaluate the effects of other respiratory parameters in the overall management of patients undergoing mechanical ventilation.[2,3] Evaluations of positive end-expiratory pressure (PEEP), synchrony, flow delivery, breath cycling, triggering, alveolar stress, and alveolar distension, among others, have become routine in the critical care setting. It must be remembered that mechanical ventilation is a supportive therapy and as such it should be carefully monitored to minimize complications.

This article reviews some of the basic and advanced methods to assess the respiratory system mechanical function as well as the most current evidence that supports their use in the critical care setting.

VENTILATOR GRAPHICAL DISPLAYS

Modern ventilators continuously measure pressure, flow, and volume in the ventilator circuit and can display a variety of waveforms. Common scalar displays provide a representation of pressure, flow, and volume against time, whereas loops show 2 parameters plotted against each other. These displays constitute the fastest and most readily available tools to evaluate respiratory system mechanical function.[4,5]

Common Scalar Displays

Pressure-time displays

Airway pressure (P_{aw}) is displayed on the ventilator screen as a function of time. The shape of the P_{aw} waveform is influenced by inspiratory flow, respiratory system mechanics, and the presence of patient's inspiratory effort. Delivery of flow using a square versus decelerating pattern also provides a different configuration to the pressure-versus-time waveform (Fig. 1).

Alveolar versus airway pressure Because peak inspiratory pressure (P_{peak}) is always be greater than alveolar pressure (P_{alv}) during inspiration because of the presence of flow and airway resistance, P_{alv} is estimated with an end-inspiratory pause (EIP) maneuver. Applying an EIP for 0.5 to 2 seconds during passive breathing allows pressure equilibration throughout the system while flow decreases to zero. Under these static conditions, a plateau pressure (P_{plat}) measured at the proximal airway approximates the P_{alv} (Fig. 2).

During pressure control ventilation P_{plat} is equal to the applied inspiratory pressure if flow is zero at the end of the set inspiratory time. An EIP can also be applied during pressure control ventilation to measure P_{plat} in passive patients. Special

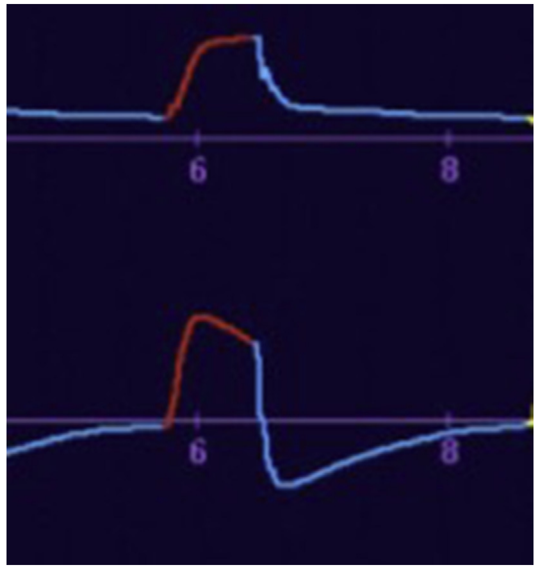

Fig. 1. Pressure and flow curves showing the typical appearance of a pressure-limited ventilation in which the inspiratory flow pattern is decelerating.

consideration needs to be given to the fact that P_{plat} can be greatly affected by low chest wall compliance (C_{CW}) so it should be used as a surrogate for P_{alv} only when C_{CW} is normal.

Limiting P_{alv} (P_{plat}) to 30 cm H_2O seems to decrease the risk of alveolar overdistension and ventilator-induced lung injury.[6] However, some clinicians have argued that there may not be a

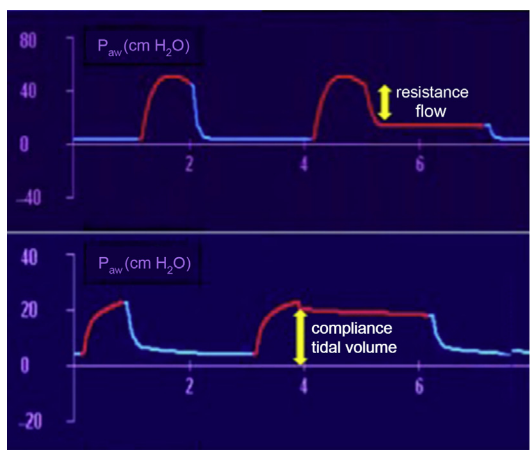

Fig. 2. Pressure-time scalars showing the effect of an EIP. With a period of no flow, the pressure equilibrates to the P_{plat}. P_{plat} represents the peak alveolar pressure. The gradient between the peak inspiratory pressure (PIP) and P_{plat} is determined by resistance and flow. The gradient between P_{plat} and PEEP is determined by VT and respiratory system compliance.