

Applied Respiratory Physiology: Use of Ventilator Waveforms and Mechanics in the Management of Critically Ill Patients

Many innovations have occurred in mechanical ventilators over the past 25 years. These include improved gas delivery, advanced ventilator modes, and monitoring capabilities that include displays of pressure, flow, and volume waveforms. The monitoring capabilities of modern ventilators present the opportunity to apply respiratory physiology at the bedside and to use that to improve patient care. Although ventilator waveforms and respiratory mechanics measurements are provided by all modern ventilators, this information is not commonly incorporated into the everyday practice of many respiratory therapists and physicians. Most clinicians have little formal study of the interpretation of ventilator waveforms. Thus, much information scrolls by on the ventilator screen without receiving much notice. Many clinicians pay little attention beyond the digital display of respiratory rate and tidal volume. Ventilator graphics are seldom afforded the detailed pattern recognition that is commonly devoted to the electrocardiogram. In some regards, ventilator waveform technology has surpassed clinicians' ability to use this information.

Against that background, this Journal Conference was organized: Applied Respiratory Physiology: Use of Ventilator Waveforms and Mechanics in the Management of Critically Ill Patients. The conference was held April 16–18, 2004, at the CasaMagna Marriott Resort in Cancún, Mexico, and it is commemorated in this and the following issue of *RESPIRATORY CARE*. It was my pleasure to co-chair the conference with my friend and colleague, Luca Bigatello. The conference brought together a group of physicians, respiratory therapists, and engineers to present on a variety of aspects around this topic. Each presenter was asked to provide abundant illustrations, as examples to aid *RESPIRATORY CARE* readers in learning various ventilator waveforms.

The first group of papers address the physics and physiology necessary to understand respiratory mechanics measurements and ventilator waveforms. Warren Sanborn kicked off the conference with the paper, "Monitoring Respiratory Mechanics During Mechanical Ventilation: Where Do the Signals Come From?" which covers issues related to pressure and flow transducers used with mechanical ventilators, signal acquisition and processing, and how the information is displayed, stored, and retrieved.

Lluís Blanch then addressed the topic, "Respiratory Mechanics Derived From Signals in the Ventilator Circuit," in which he discusses the types of measurements that can be taken from the ventilator graphics, such as plateau pressure, resistance, and compliance. Although not commonly used, esophageal and gastric pressure measurements can provide useful information about respiratory physiology in mechanically ventilated patients. The meaning of those measurements was addressed by Joshua Benditt in his paper, "Esophageal and Gastric Pressure Measurements." Pressure-volume curves, their measurement, and their interpretation was covered by Scott Harris in his paper, "Pressure-Volume Curves of the Respiratory System." Then, "Capnographic Waveforms in the Mechanically Ventilated Patient" was covered by John Thompson. In his second presentation at this conference, Lluís Blanch discussed "Measurement of Air Trapping, Intrinsic Positive End-Expiratory Pressure, and Dynamic Hyperinflation in Mechanically Ventilated Patients," including methods to detect and quantify intrinsic positive end-expiratory pressure during spontaneous and controlled ventilation.

The second part of the conference dealt with ventilator graphics and ventilation modes. In a presentation that does not correspond to an article in these special issues, Robert Campbell addressed the topic, "Pressure, Flow, and Volume Graphics During Volume-Control and Pressure-Control Ventilation," which contrasted pressure, flow, and volume graphics during volume-control versus pressure-control ventilation. I then addressed newer embellishments that can be used with pressure-support ventilation, including adjustments of rise time and termination flow, in a paper entitled, "Ventilator Waveforms and the Physiology of Pressure Support Ventilation." The role of ventilator graphics when setting some of the newer ventilation modes was discussed by Richard Branson, in "The Role of Ventilator Graphics When Setting Dual-Control Modes."

The third part of the conference dealt with using graphics to set the ventilator. Jon Nilsestuen described how ventilator graphics can be used to detect patient-ventilator dyssynchrony in his paper, "Use of Ventilator Graphics to Identify Patient-Ventilator Dyssynchrony." Much attention has been directed to strategies to improve the outcomes of mechanically ventilated patients with acute lung injury and acute respiratory distress syndrome; monitoring

of lung mechanics of those patients was addressed by Luca Bigatello in his paper, "Respiratory Mechanics and Ventilator Waveforms in the Patient With Acute Lung Injury." Use of ventilator waveforms in patients with obstructive lung disease was discussed by Rajiv Dhand in his paper, "Ventilator Graphics and Respiratory Mechanics in the Patient With Obstructive Lung Disease." "Using Ventilator Graphics in the Patient Who Is Hemodynamically Unstable" was addressed by Charles Durbin. Respiratory mechanics are often used to identify readiness for discontinuation of mechanical ventilation and to identify reasons why a patient might fail a spontaneous breathing trial. That topic was addressed by Neil MacIntyre in his paper, "Respiratory Mechanics in the Patient Who Is Weaning From the Ventilator."

Most current-generation ventilators display graphics of pressure, flow, and volume. Additionally, all ventilators allow the measurement of plateau pressure and intrinsic positive end-expiratory pressure (auto-PEEP), and some calculate various respiratory mechanics. That information

can be used to help the clinician appropriately set the ventilator. For example, many clinicians lower the tidal volume setting on the ventilator if the plateau pressure is greater than 30 cm H₂O. But monitoring of waveforms and mechanics also allows the ventilator to serve as a probe of the pathophysiology that is keeping the patient ventilator-dependent. For example, detection of auto-PEEP suggests that the patient has an increased airways resistance. Ventilator waveforms and mechanics should be used in the management of critically ill patients. The use of that information, coupled with a careful physical examination, should improve our bedside assessment of mechanically ventilated patients.

Dean R Hess PhD RRT FAARC
Department of Respiratory Care
Massachusetts General Hospital
Harvard Medical School
Boston, Massachusetts



A nurse monitors a young patient, 1950s
Photo by Jerry Hecht
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