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Pressure Control Ventilation

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As mechanical ventilators become increasingly sophisticated, clinicians are faced with a variety of ventilatory modes that use volume, pressure, and time in combination to achieve the overall goal of assisted ventilation. Although much has been written about the advantages and disadvantages of these increasingly complex modalities, currently there is no convincing evidence of the superiority of one mode of ventilation over another. It is also important to bear in mind that individual patient characteristics must be considered when adopting a particular mode of ventilatory support. As emphasized in the 1993 American College of Chest Physicians Consensus Conference on Mechanical Ventilation, "although the quantitative response of a given physiologic variable may be predictable, the qualitative response is highly variable and *patient specific*" [1].

Partly because of the inherent difficulties in working with pressure ventilation, the Acute Respiratory Distress Syndrome (ARDS) Network chose to use a volume mode of support for their landmark low tidal volumetrial [2]. The preference for volume ventilation at ARDS Network centers was later demonstrated in a retrospective study of clinicians' early approach to mechanical ventilation in acute lung injury/ARDS. Pressure control was used in only 10% of the patient population before study entry. There was a modest tendency to use pressure control ventilation (PCV) in patients with more severe oxygenation defects (PaO_2/FiO_2, or P/F <200) and a greater tolerance for higher airway pressures when using this mode. Volume control ventilation (VCV) in an assist-control or synchronized intermittent mandatory mode, however, was clearly a preferred method of support [3].

PCV may offer particular advantages in certain circumstances in which variable flow rates are preferred or when pressure and volume limitation is required. These desirable characteristics of PCV, however, can produce

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unanticipated consequences when ventilatory strategies used in volume modes are similarly applied in pressure-regulated ventilation. The goal of the following sections is to provide clinicians with a fundamental understanding of the dependent and independent variables active in PCV and describe features of the mode that may contribute to improved gas exchange and patient-ventilator synchronization.

It is important to stress that any method of mechanical ventilation may contribute to secondary forms of injury in heterogeneous lung disease and that the injury incurred is currently beyond our capability of recognizing at the bedside. Developments in our understanding of pressure-volume curves and the recent demonstration of microscopic shear and stress injury in animal models of ventilator-induced lung injury call into question the whole concept of "safe" ranges of pressure and volume in mechanical ventilation [4–8]. As we explore the characteristics of flow and pressure generation in PCV, we draw attention to those aspects of pressure ventilation shown to be associated with adverse outcomes in experimental settings. In this way we hope to provide clinicians with a balanced framework in which to choose the most appropriate method of ventilatory support.

Physiology of pressure control ventilation

PCV, unlike volume targeted modes, is pressure and time cycled and generates tidal volumes that vary with the impedance of the respiratory system. A working understanding of the factors that determine volume delivery is necessary for proper implementation of this mode of ventilation. During the inspiratory phase of PCV, gas flows briskly into the ventilator circuit to pressurize the system to a specified target. Once the target pressure has been reached, flow is adjusted to maintain a flat or "square wave" pressure profile over the remainder of the set inspiratory time [9,10]. This goal is achieved by sampling airway pressure approximately every 2 msec to provide critical feedback to flow controller mechanisms within the ventilator. By tracking the rate of change in pressure during inspiration, appropriate deceleration can occur as the pressure ceiling is approached. If the gradient between the circuit pressure and pressure target is large, flow is brisk. As the gradient between the recorded pressure and preset target narrows, flow decelerates to prevent overshoot. When impedance to flow is modest, the resulting flow curve demonstrates uni-exponential decay [11]. In situations of airflow obstruction, pressure targets are typically reached at lower flow rates, which contributes to a decelerating ramp profile (Figs. 1 and 2).

Flow into the ventilator circuit continues until conditions relating to pressure and time are met. Once the pressure within the alveolus rises to the level of the ventilator circuit, the gradient driving flow no longer exists and flow ceases. This process has important implications for tidal volume delivery in situations of altered compliance and resistance, as discussed later. In the PC mode of ventilation, the inspiratory time (I time) over which the pressure