New Dual Ventilator Modes: Are We Ready to Perform Large Clinical Trials?

Mechanical ventilation is usually achieved using either volume-controlled or pressure-controlled ventilation.[1,2] Moreover, it can be applied as full ventilatory support, for which the total work of breathing (total WOB) is performed by the ventilator, without any active participation of the patient, or with a partial support, for which the total WOB is shared by the patient (patient WOB) and the ventilator (ventilator WOB), depending on the ventilator settings and the respiratory muscle capacity of the patient. Briefly, 4 key variables will influence the quality of the assistance delivered by the ventilator: volume-control versus pressure-control, and full support versus partial support. The clinician should choose between these variables to find the best combination for each patient. With volume control, a set tidal volume (V_T) is delivered regardless of the respiratory-system compliance and airways resistance, but the airway pressure varies with respiratory system mechanics and patient effort. Therefore there is a risk of inducing barotrauma, such as pneumothorax, with high delivered pressures. With volume control, pressure will increase with worsening lung mechanics; this increase in pressure is not desirable. With volume control, increased respiratory drive (eg, ventilatory demand increase) can result in asynchrony, because flow is fixed. On the contrary, with pressure control without spontaneous breathing, the airway pressure is fixed, which reduces the risk of barotrauma, but the V_T is variable. With pressure control, V_T will decrease with worsening lung mechanics; this could cause hypoventilation, which may lead to alveolar hypoventilation and severe respiratory acidosis. With pressure control and spontaneous breathing, increased respiratory drive will result in an increase in V_T. This may improve patient-ventilator synchrony but put the patient at increased risk for over-distention lung injury.

Not surprisingly, the question, "Which is better: pressure or volume?" is often asked, and sometimes even expert physicians have difficulty answering. Obviously, the answer is delicate, because each mode has some advantages and some drawbacks. Probably part of the answer may be: "You should use the mode that you and your staff know well and have the most experience with. As such, it is probably the safer mode for your patient." Indeed, "You can kill a lung with pressure mode and you can kill a lung with volume mode."[1] Probably the applied settings, monitoring, and skills of the clinician are more important factors than the ventilator type and the mode used.

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In theory, so as to combine the advantages of volume-control and pressure-control ventilation, manufacturers developed "dual-modes," which combine aspects of both volume-controlled and pressure-controlled ventilation. These dual-control modes, or adaptive pressure control modes (APC), use closed-loop feedback control systems that adapt the ventilator output based on the difference between the measured ventilation and a predefined target. In fact, these APC modes are pressure-controlled modes that use a target V_T and/or minute ventilation for feedback control. Thus, the level of airway pressure delivered is continuously adjusted to deliver the preset volume. These "improvements" have become possible through technological evolutions and clinician-manufacturer cooperation. Moreover, contrary to introduction of a new drug, which requires animal and clinical studies and may take many years before clinicians can prescribe it, for many ventilation modes manufacturers need only to demonstrate engineering success in a lung model in order to obtain marketing approval through the United States Food and Drug Administration; clinical studies are not required. In Europe the procedure is similar.

When the patient can breathe spontaneously with either flow-cycled or time-cycled breaths delivered from the ventilator, APC behavior may be complicated to understand because the software developed by each manufacturer has different input and output variables.[3] For example, with a simple volume-guaranteed pressure-control mode such as Volume Support Ventilation in the Maquet Servo ventilator or Adaptive Pressure Ventilation in the Hamilton Galileo ventilator, an increase in ventilatory demand (eg, adding a heat-and-moisture exchanger, which increases mechanical dead space) results in a decrease in the pressure support provided by the ventilator, which is the opposite of the desired response.[4,5]

To date there have been no randomized controlled trials with large numbers of patients to evaluate the use of APC modes in the intensive care unit or during general anesthesia. While many new ventilator modes have failed to impact outcomes (improved safety, improved patient comfort, decrease weaning duration, cost effectiveness, etc), the pursuit of innovations and inventions by clinicians and manufacturers should continue.

In this issue of RESPIRATORY CARE, Mireles-Cabodevila and Chatburn[6] performed a bench study and found that APC algorithms differ between ventilators in their response to increasing patient effort. Notably, some ventilators allow the patient to assume all of the WOB, and some provide a minimum level of WOB regardless of patient effort. The authors evaluated the relationship between ventilator work output and patient effort (muscle pressure [P_{mus}]) in APC mimicked by an active test lung.[6] The APC modes were all time-cycled: AutoFlow (Dräger Evita XL), VC+ (Puritan Bennett 840), APV (Hamilton Galileo), and PRVC (Siemens Servo-i and Siemens Servo 300). Ventilators showed 3 patterns of behavior in response to an increase in P_{mus}: (1) ventilator WOB gradually decreased to 0 J/L as P_{mus} increased; (2) ventilator WOB decreased at the same rate as P_{mus} increased, with a plateau at $P_{mus} = 10$ cm H_2O, by delivering a minimum inspiratory pressure level of 6 cm H_2O; (3) ventilator WOB decreased as P_{mus} increased to 10 cm H_2O, as in patterns 1 and 2, but then decreased at a much slower rate.[6]

In this well-performed bench study, the authors nicely showed that (1) commercially available APC modes function differently, (2) provision of a minimum level of support pressure seems necessary for safe use,[7,8] (3) some APC modes use a similar software but have different names, which sometimes increase the confusion for users, and (4) APC cannot distinguish improving lung mechanics from an inappropriate increase in patient effort, thus leaving open the possibility of decreasing ventilator support in a patient who needs it, as previously reported in clinical conditions.[4,5]

Although these findings by Mireles-Cabodevila and Chatburn[6] are from a bench study, they have not only research implications but also clinical implications. If clinicians use a particular APC mode in clinical practice or in the area of research, they should know the behavior of this APC mode, and thereby determine for themselves whether ventilator support is not needed (eg, is the patient ready to be liberated from the ventilator?) or the support is inappropriately low (eg, could the patient's clinical status be worsened by use of this mode?). The results of the study highlight the importance and irreplaceable role of the clinician in the choice of the initial settings (ie, V_T or pressure level) and the need to periodically reevaluate these settings.[6]

Through the findings of this study, Mireles-Cabodevila and Chatburn[6] contribute additional evidence to stimulate clinicians and researcher to know well the algorithm of the APC mode employed. This is important, given that some ventilators allow the patient to assume all of the WOB and some provide a minimum level of WOB, regardless of patient effort. Moreover, these results should encourage manufacturers to continue to develop ventilator innovations in collaboration with clinicians, as opposed to engineering alone, and to modify the algorithms of some APC modes available on the market, to ensure safe use. Finally, the number of new modes of ventilation available in a new ventilator should not be the sole factor considered when choosing the ventilator to purchase or to use. Sometimes "more is less," because too much choice may be dangerous for patient safety. To choose a new ventilator, the quality and safety of available ventilatory modes should be given priority over the quantity of modes!

The number of mechanically ventilated patients is likely to increase in the future.[9] Even if collaboration between clinicians and manufacturers seems synergetic today and appears to benefit patients, with the increase in commercially available sophisticated ventilation modes there is a great need for large observational and randomized clinical studies to better define the appropriate role of APC modes.

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The author has disclosed no conflicts of interest.

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