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EDITORIAL

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Apples and oranges

Comparing different modalities of mechanical ventilation

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When introducing new tools in the management of diseases, one of the most important steps is the comparison with well established treatments. This is also true, although difficult to do, when evaluating new modalities of mechanical ventilation.

The main goals of mechanical ventilation are: (1) to correct abnormalities in arterial blood gases, (2) to maintain alveolar ventilation ($\dot{V}a$) and lung volume and (3) to unload the respiratory muscles [1]. Abnormalities in arterial blood gases can be reversed by increasing $\dot{V}A$, ventilated lung volume, and oxygen (O_2) supplement. This could be easily obtained with the volume-preset modalities (assist/control ventilation: ACV) [2]. The unloading of respiratory muscles has been greatly improved by pressure-preset modalities like pressure support ventilation (PSV). PSV provides breath-by-breath ventilatory support synchronized with the inspiratory effort of the patient. It has been defined as an accessory respiratory muscle [3].

In recent years, significant technological advances have been made with mechanical ventilators more responsive to changes in patients' ventilatory demands, and interactions between the patient's ventilatory pump and the ventilator's work have been taken into account to assess the outcome of mechanical ventilation. In the ACV mode, tidal volume (V_T) is unaffected by patient effort, the end of the ventilator inspiratory phase is totally independent of the end of the patient's neural inspiratory phase and is a function of set V_T and flow rate. The patient does not control either of these variables and often the ventilator antagonizes the patient, a struggle often ended by the patient's being sedated [2]. In PSV mode, the airway pressure (P_{aw}) rises to a level preset by the operator after the ventilator has been triggered: P_{aw} is therefore independent of patient effort. In this case, and unlike ACV, the ventilator does not antagonize the patient, and ventilatory output is under his/her control to some extent. Complex interactions between the patient and the ventilator characteristics determine the end of the ventilator inspiration, which may or may not coincide with the end of the patient's inspiratory effort [3]. With ACV or PSV, V_T and pressure assistance, respectively, are decided by the caregiver and are independent of the patient's effort. However this apparent advantage in some circumstances may result in under- or over-assistance and/or in patient-ventilator dyssynchrony [4, 5].

The study by Wrigge et al. [6] published in this issue of Intensive Care Medicine compares the effects on breathing pattern and inspiratory work of breathing (WOB) of PSV and two different levels of proportional assist ventilation (PAV). PAV is a new mode of partial ventilatory support with the peculiar characteristic that the ventilator generates pressure in proportion to instantaneous patient's effort, allowing him/her to attain whatever ventilation and breathing pattern seems to fit the ventilatory control system, on a breath-by-breath basis [7]. Briefly, following the equation of motion of the respiratory system, the pressure applied (P_{appl}) to inflate the system is dissipated to overcome the elastic (i. e. elastance: E) and resistive (i. e. resistance: R) loads in proportion to the patient's volume (V) and flow ($\dot{V}$), respectively:

$$P_{appl} = ExV + Rx\,\dot{V} + P0 \tag{1}$$

where P0 is the initial pressure in the system. With PAV, the pressure applied to the respiratory system results from the combination of the patient's inspiratory muscle effort (P_{mus}) and the positive pressure applied to the airway opening by the ventilator (P_{aw}). The latter is given by the level of assistance set by the caregivers to unload specifically the elastic (VA: volume assist) and resistive burden (FA: flow assist) in proportion to V and $\dot{V}$ respectively. Therefore:

$$P_{aw} = \text{VxVA} + \dot{V}\text{xFA} \qquad (2)$$

And hence, combining Eq. 1 and Eq. 2

$$P_{mus} = \text{Vx(E-VA)} + \dot{V}\text{x(R-FA)} + \text{P0} \qquad (3)$$

This equation indicates that the degree of assistance will depend on the levels of VA and FA set by the caregiver and will be proportional to the volume and flow chosen by the patient. With PAV there is no target flow, volume or pressure and the responsibility of guiding the ventilatory pattern is shifted completely from the caregiver to the patient with the purpose of improving the patient-ventilator interaction. PAV requires an intact control of breathing [7].

This study [6] shows that the differences of breathing pattern were small between PAV and PSV when mean inspiratory pressure was comparable. However, during PAV a higher variability of V_T, as compared with PSV, was observed. After reduction of mechanical unloading from 80% to 50%, with PAV the patients increased inspiratory effort and WOB to maintain a comparable ventilation [6]. These authors conclude that although the breathing pattern does not differ by a large amount between the investigated modes, the higher variability of V_T during PAV indicates an increased ability of the patients to control it in response to alterations in respiratory demand.

Although the authors have done their best to overcome the difficulties of comparison of different modalities of ventilation, their results [6] must be evaluated in the frame of their specific experimental design. In clinical and physiological studies of comparison of different modalities of mechanical ventilation applied either invasively or non-invasively [8, 9, 10, 11, 12], a major problem is the definition of the comparable "independent variable" to avoid the risk of comparing different technologies, settings, patients or even treatments. In other words, it is extremely important to define what we want to know. Keeping in mind the above and commonly accepted goals of mechanical ventilation [1], we might look for differences in the goals obtained ("dependent variables": e.g. arterial blood gases, minute ventilation, respiratory muscle unloading etc.) for a given (and comparable) ventilator setting of the studied modalities ("independent variable": e.g. same V_T, P_{aw}, timing etc.). The alternative approach may well be used (that is, considering the ventilator setting as the dependent variable for a given goal).

In this study [6], to avoid the "apples and oranges trap", the authors chose the level of PSV to match the same mean inspiratory pressure as measured during the highest level of PAV assistance. Another way to compare these two modalities of mechanical ventilation might be to use the same degree of respiratory muscle unloading as the independent variable. Both ways do exclude the possibility of random application of different modalities and this is not a secondary issue for an experimental design. Furthermore, the latter way involves either invasive (oesophageal, gastric pressures) and/or more sophisticated measurements (electromyography of respiratory muscles). A third, simpler, possibility might be to apply different modalities of mechanical ventilation "at patient's comfort". This criterion may be useful when patient-ventilator interactions have to be taken into account to assess the outcome of modalities of mechanical ventilation like PAV. This way could afford a random application of modalities and could avoid invasive and troublesome measurements, and this is also a clear advantage for the patients, especially in view of a non-invasive application. Nevertheless, the analysis of the theoretical basis of different modalities of mechanical ventilation shows that the respective main goals are different, therefore even choosing the same independent/dependent variables may not be sufficient to avoid the risk of comparing apples with oranges.

Different modes of mechanical ventilation are available to tailor ventilatory assistance to a patient's needs and characteristics. PAV can be considered a new addition to other more conventional and widely used modes of mechanical ventilation with the theoretical advantage of improving patient-ventilator interaction [7]. However, adequate guidelines for the proper setting of PAV to an individual patient's lung mechanics, as required by the theoretical background of PAV, are still missing, especially for non-invasive delivery. In addition, prospective clinical trials aimed to investigate whether PAV has real advantages over the existing modes of mechanical ventilation in the long run have not been completed yet. Nevertheless, PAV is not only a promising addition in the world of mechanical ventilation, but it is also a powerful tool to study the patient's control of breathing. In fact, any abnormality in the central controller will be disclosed by PAV, which is a patient's guided mode of ventilatory support. Therefore PAV can be not only an alternative mode of mechanical ventilation, but also a diagnostic tool in a poorly explored area such as control of breathing in mechanically ventilated patients.

References

1. Tobin MJ (1994) Mechanical ventilation. N Engl J Med 330: 1056–1061
2. Mador MJ (1994) Assist-control ventilation. In: Tobin MJ (ed) Principles and practice of mechanical ventilation. McGraw-Hill, New York, pp 207–219
3. Brochard L (1994). Pressure support ventilation. In: Tobin MJ (ed) Principles and practice of mechanical ventilation. McGraw-Hill, New York, pp 239–257
4. Rossi A, Appendini L (1995) Wasted efforts and dyssynchrony: is the patient-ventilator battle back? Intensive Care Med 21: 867–870
5. Nava S, Bruschi C, Rubini F, Palo A, Iotti G, Braschi A (1995) Respiratory response and inspiratory effort during pressure support ventilation in COPD patients. Intensive Care Med 21: 871–879
6. Wrigge H, Golisch W, Zinserling J, Sydow M, Almeling G, Burchardi H (1999) Proportional assist versus pressure support ventilation: effects on breathing pattern and respiratory work of patients with chronic obstructive pulmonary disease. Intensive Care Med 25: 790–798
7. Younes M (1994) Proportional assist ventilation. In: Tobin MJ (ed) Principles and practice of mechanical ventilation. McGraw-Hill, New York, pp 349–370
8. Leung P, Jubran A, Tobin MJ (1997). Comparison of assisted ventilator modes on triggering, patient effort and dyspnea. Am J Respir Crit Care Med 155: 1940–1948
9. Valentine DD, Hammond MD, Downs JB, et al. (1991) Distribution of ventilation and perfusion with different modes of mechanical ventilation. Am Rev Respir Dis 143: 1262–1266
10. Giannouli E, Webster K, Roberts D, Younes M (1999) Response of ventilator-dependent patients to different levels of pressure support and proportional assist. Am J Respir Crit Care Med 159: 1716–1725
11. Vitacca M, Rubini F, Foglio K, Scalvini S, Nava S, Ambrosino N (1993) Non-invasive modalities of positive pressure ventilation improve the outcome of acute exacerbations in COLD patients. Intensive Care Med 19: 450–455
12. Girault C, Richard JC, Chevron V, et al. (1997) Comparative physiologic effects of noninvasive assist-control and pressure support ventilation in acute hypercapnic respiratory failure. Chest 111: 1639–1648