

Weaning from Mechanical Ventilation

Stay Poised between Load and Strength

OXYGEN consumption (\dot{V}_{O_2}) of respiratory muscles during mechanical ventilation is usually computed as the difference between \dot{V}_{O_2} during controlled ventilation and \dot{V}_{O_2} during spontaneous ventilation. This method, though, is impractical and sometimes even impossible. In a study published in this issue of ANESTHESIOLOGY, Bellani *et al.* used another interesting approach to evaluate the value of \dot{V}_{O_2} in weaning.¹

The objective of weaning from mechanical ventilation is to decrease the level of ventilatory support provided by the ventilator, forcing the patient to assume a greater proportion of the ventilatory workload. In other words, with weaning from mechanical ventilation, the work of breathing shifts from the ventilator to the patient. Although most patients wean from mechanical ventilation with little difficulty, some patients are unable to sustain the necessary work of breathing and develop signs of fatigue. It is important to recognize when a patient is failing a weaning trial. A failed weaning trial may induce significant cardiopulmonary distress and is discomforting for the patient. When weaning failure is recognized, ventilatory support should be reestablished without delay.

Commonly used criteria for the discontinuation of a weaning trial include tachypnea; hypoxemia, tachycardia, or bradycardia; hypertension or hypotension; and agitation, diaphoresis, or anxiety. \dot{V}_{O_2} of respiratory muscles could be another valuable parameter in a weaning trial. In healthy subjects, the \dot{V}_{O_2} of respiratory muscles is low and normally not more than 5% of total \dot{V}_{O_2} of the whole body. In critically ill patients who wean from mechanical ventilation, the \dot{V}_{O_2} of respiratory muscles can be much higher, and an increased \dot{V}_{O_2} of respiratory muscles has been suggested to predict weaning failure.²⁻⁵

Bellani *et al.* measured \dot{V}_{O_2} with reduction of the pressure support level, and as such they were able to compare minimum \dot{V}_{O_2} as well as the absolute increase of \dot{V}_{O_2} between patients who successfully passed a weaning trial and patients who were unable to sustain the decrease in ventilatory assistance.¹ In each weaning trial, starting from 20 cm H₂O, pressure support was decreased in steps of 4 cm H₂O, lasting 10 min each, until 0 cm H₂O. The average \dot{V}_{O_2} from the last

minutes of each step was measured by indirect calorimetry. If a patient developed signs of respiratory distress, according to standard criteria, it was decided that the weaning trial was unsuccessful. The investigators hypothesized that during weaning from mechanical ventilation, when the pressure support level reduced, the \dot{V}_{O_2} would increase more in patients who failed a weaning trial.

Patients who failed a weaning trial had a higher minimum \dot{V}_{O_2} compared with patients who successfully completed the weaning trial (215 ± 53 vs. 174 ± 44 ml/min). Surprisingly, however, the absolute increase from minimum \dot{V}_{O_2} to maximum \dot{V}_{O_2} observed was lower in patients who failed a weaning trial (52 ± 24 vs. 94 ± 71 ml/min).

The findings of this study are, at least in part, in line with previous observations. Indeed, several studies report that an increased \dot{V}_{O_2} of respiratory muscles is associated with weaning failure.²⁻⁵ Some studies, though, dispute this association.^{6,7} Notably, there is large variety in study designs, and patient groups studied are considerably different across the published studies, making comparison difficult.

The findings of this study contradict the initial hypothesis. Indeed, whereas Bellani *et al.* hypothesized that during weaning from mechanical ventilation, the \dot{V}_{O_2} would increase more in patients unable to sustain the decrease in ventilatory assistance, the absolute increase in oxygen consumption from minimum \dot{V}_{O_2} to maximum \dot{V}_{O_2} observed in these patients was actually lower than in patients who were successfully weaned. But isn't this what the investigators should have expected?

Patients who have been on the ventilator for days to weeks are usually not only those who are severely ill (and thus have a high total \dot{V}_{O_2}) and those who still suffer from respiratory distress (and thus have a high \dot{V}_{O_2} of respiratory muscles), they could also suffer more from significant loss of (respiratory) muscle mass (and thus may not be able to further increase \dot{V}_{O_2}). Of note, there is at least a suggestion that patients in this study who failed a weaning trial were severely ill for a longer period of time and had more respiratory distress:

◆ This Editorial View accompanies the following article: Bellani G, Foti G, Spagnoli E, Milan M, Zanella A, Greco M, Patroniti N, Pesenti A: Increase of oxygen consumption during a progressive decrease of ventilatory support is lower in patients failing the trial in comparison with those who succeed. ANESTHESIOLOGY 2010; 113:378-85.

Accepted for publication May 14, 2010. The author is not supported by, nor maintains any financial interest in, any commercial activity that may be associated with the topic of this article.

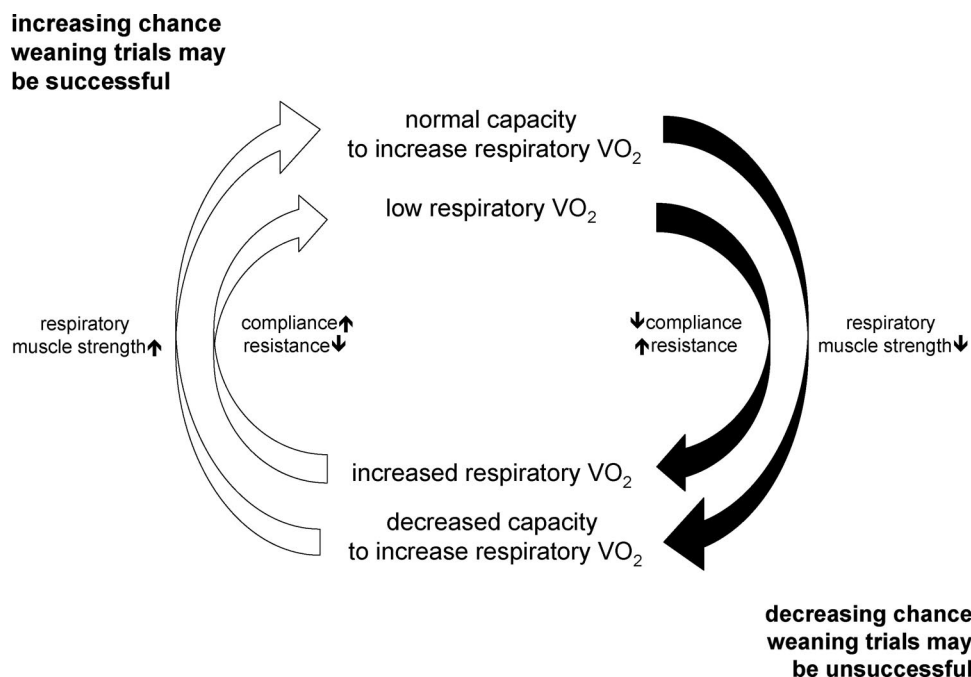


Fig. 1. Schematic view of load (a function of compliance and resistance of the respiratory system) and strength (a function of respiratory muscle strength) in patients weaning from mechanical ventilation. The *filled arrows* indicate the decrease in lung compliance and increase in airway resistance (*inner circle*) and the decrease in respiratory muscle strength (*outer circle*) that can be seen in mechanically ventilated patients during the initial days to weeks in the intensive care unit. The *open arrows* indicate the increase in lung compliance and decrease in airway resistance and the increase in muscle strength that can be found in mechanically ventilated patients who recover from their critical illness. Bellani *et al.* show that a combination of increased oxygen consumption ($\dot{V}O_2$) of respiratory muscles and inability to further increase $\dot{V}O_2$ is associated with a higher chance of weaning failure.¹

they were on ventilatory support longer (20 [10–42] *vs.* 11 [6–26] days), they needed higher levels of positive end-expiratory pressure (6.9 ± 2.1 *vs.* 6.4 ± 1.6 cm H₂O), and they had lower respiratory system compliance (37 ± 13 *vs.* 48 ± 15 ml/cm H₂O) and higher respiratory system resistance (17.8 ± 4.6 *vs.* 15.9 ± 3.6 cm H₂O per l per s). Differences were not statistically significant, but the study might have been underpowered to show these differences. Unfortunately, the investigators did not report on differences in muscle mass and/or strength between patients who successfully passed a weaning trial and those who failed a weaning trial.

Weaning is all about load and strength (fig. 1). Reduced respiratory system compliance and/or increased respiratory system resistance put load on the respiratory muscles. In the case of severe respiratory distress, we do not even think of a weaning trial: muscle strength will never be enough to compensate for the pulmonary condition, and if it does it will only be sustained for a short period of time. Indeed, we wait for respiratory distress to resolve before the patient is subjected to a weaning trial. But when the pulmonary condition has improved, decreased ability to generate pressure and/or lack of endurance may form another reason not to perform or continue a weaning trial. Respiratory muscles could be too weak to compensate even the slightest load caused by the respiratory system. In severely weakened patients, we await muscle strength to improve before we challenge patients with a weaning trial.

The study by Bellani also adds to our knowledge on weaning from mechanical ventilation in another way. Their results suggest that significant information could come from changes in parameters during a weaning trial, in this case the change in $\dot{V}O_2$. This is in line with a recent publication on a frequently used parameter in spontaneous breathing trials, the rapid shallow breathing index (RSBI).⁸ The RSBI, calculated by dividing the tidal volume into the respiratory rate, has shown poor specificity. The problem could be that the RSBI is not dynamic, making it inadequate to predict the failure of weaning. In the above-mentioned prospective observational study, it was found that the initial RSBI was similar in patients who successfully passed a trial and patients who failed a trial.⁸ Although the RSBI tended to remain unchanged or decreased in patients who successfully passed a trial, the RSBI tended to increase in patients who failed a trial. This was caused either by an increased respiratory rate and/or decreased tidal volume, indicating worsening of the respiratory pattern. The percent change of the RSBI during a spontaneous breathing trial was a better predictor of success than a single initial determination of the RSBI. Notably, a similar change in respiratory rate was noticed in the study by Bellani *et al.*¹ Indeed, in patients who failed a weaning trial, the respiratory rate increased more than in patients who were successfully weaned from mechanical ventilation.

In conclusion, in weaning from ventilation we are frequently poised between load and strength. Although single

or initial or single measurements of parameters (*i.e.*, $\dot{V}O_2$ and RSBI) are of some use, serial measurements of the same parameters seem much more helpful.

Marcus J. Schultz, M.D., Ph.D., F.C.C.P., Department of Intensive Care Medicine, Laboratory of Experimental Intensive Care and Anesthesiology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands, and HERMES Critical Care Group, Amsterdam, The Netherlands. m.j.schultz@amc.uva.nl

References

1. Bellani G, Foti G, Spagnolli E, Milan M, Zanella A, Greco M, Patroniti N, Pesenti A: Increase of oxygen consumption during a progressive decrease of ventilatory support is lower in patients failing the trial in comparison with those who succeed. *ANESTHESIOLOGY* 2010; 113:378–85
2. Shikora SA, Bistran BR, Borlase BC, Blackburn GL, Stone MD, Benotti PN: Work of breathing: Reliable predictor of weaning and extubation. *Crit Care Med* 1990; 18:157–62
3. Shikora SA, Benotti PN, Johannigman JA: The oxygen cost of breathing may predict weaning from mechanical ventilation better than the respiratory rate to tidal volume ratio. *Arch Surg* 1994; 129:269–74
4. Mitsuoka M, Kinninger KH, Johnson FW, Burns DM: Utility of measurements of oxygen cost of breathing in predicting success or failure in trials of reduced mechanical ventilatory support. *Respir Care* 2001; 46:902–10
5. Miwa K, Mitsuoka M, Takamori S, Hayashi A, Shirouzu K: Continuous monitoring of oxygen consumption in patients undergoing weaning from mechanical ventilation. *Respiration* 2003; 70:623–30
6. Hubmayr RD, Loosbrock LM, Gillespie DJ, Rodarte JR: Oxygen uptake during weaning from mechanical ventilation. *Chest* 1988; 94:1148–55
7. Annat GJ, Viale JP, Dereyemez CP, Bouffard YM, Delafosse BX, Motin JP: Oxygen cost of breathing and diaphragmatic pressure-time index. Measurement in patients with COPD during weaning with pressure support ventilation. *Chest* 1990; 98:411–4
8. Segal LN, Oei E, Oppenheimer BW, Goldring RM, Bustami RT, Ruggiero S, Berger KI, Fiel SB: Evolution of pattern of breathing during a spontaneous breathing trial predicts successful extubation. *Intensive Care Med* 2010; 36:487–95