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P H Y S I C I A N S[®]

Section III: Other Issues in Weaning

Ventilator Modes Used in Weaning*

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Weaning techniques include spontaneous breathing trials (SBTs), pressure-support ventilation (PSV), and synchronized intermittent mandatory ventilation (SIMV). SBTs can be conducted using one of several approaches, including T-piece breathing, low-level continuous positive airway pressure, low-level PSV, or setting the ventilator to flow-triggering with no pressure applied to the airway. The SBT can be used as a method to identify extubation readiness or as a weaning technique in which the duration of the trial is gradually increased over time. With pressure-support weaning, the level of pressure support is gradually reduced over time. With weaning using SIMV, the mandatory rate setting on the ventilator is gradually reduced. Randomized controlled trials have reported the poorest weaning outcomes using SIMV. Although new ventilator modes have been introduced to facilitate weaning, to date there is no evidence to support the use of these modes. Noninvasive positive-pressure ventilation also has been reported to facilitate weaning, but the ability to generalize these findings remains to be determined. (CHEST 2001; 120:474S–476S)

Key words: mechanical ventilation; noninvasive positive pressure ventilation; pressure support ventilation; spontaneous breathing trial; synchronized intermittent mandatory ventilation; weaning

Abbreviations: CPAP = continuous positive airway pressure; NPPV = noninvasive positive-pressure ventilation; PSV = pressure-support ventilation; SBT = spontaneous breathing trial; SIMV = synchronized intermittent mandatory ventilation

Weaning involves a change in the interaction between the patient and the ventilator. The intent of the weaning process is to decrease the level of support provided by the ventilator, requiring the patient to assume a greater proportion of the ventilatory workload. Thus, the work of breathing is shifted from the ventilator to the patient. The three general approaches to weaning are the spontaneous breathing trial (SBT), pressure-support ventilation (PSV), and synchronized intermittent mandatory ventilation (SIMV).

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DESCRIPTION OF WEANING TECHNIQUES

SBTs

The SBT is the oldest ventilator weaning technique. In the traditional approach, the patient is removed from the ventilator and humidified supplemental oxygen is provided to the airway. This approach is often referred to by the appearance of the device used (*ie*, T-piece or T-tube). Humidified gas is typically provided as a heated or cool aerosol of water from a large-volume nebulizer. For patients with reactive airways, this aerosol may induce bronchospasm. In these cases, a non-aerosol-generating humidification system such as a heated passover humidifier should be used. Passive humidifiers (*eg*, artificial noses) should be avoided due to their dead space and resistive workload.

There are two distinctly different applications of the SBT. The first application is to identify extubation readiness. Although a 2-h SBT is commonly used to identify extubation readiness, one study¹ reported similar outcomes with 30-min and 2-h SBTs. Another study² reported that SBT failure occurred between 30 and 120 min in 36% of patients, but it is unknown whether the prolonged SBT contributed to failure. The second application of the SBT is for weaning, in which the length of each SBT is increased, with alternating periods of ventilatory support and the SBT. For the chronically ventilator-dependent patient, this process may require weeks. For the patient with a marginal respiratory reserve, nocturnal mechanical ventilation may be required in support of spontaneous breathing during the waking hours.

The SBT can be conducted without removing the patient from the ventilator. This approach was legitimately criticized with older-generation ventilators due to the unresponsiveness of the demand valves. However, the current generation of ventilators is very responsive to patient effort, particularly with the use of techniques such as flow-triggering. There are several advantages to performing the SBT without removing the patient from the ventilator. No additional equipment is required. If the patient fails the SBT, ventilatory support can be reestablished quickly. All of the monitoring systems and alarms on the ventilator are available during the SBT, which may allow the prompt recognition that the patient is failing the SBT. Most of the literature related to weaning used a traditional SBT (*ie*, the patient was removed from the ventilator), although several studies^{3,4} allowed the performance of the SBT with the patient attached to the ventilator.

There are several approaches to the SBT. It can be performed with no positive pressure applied to the airway, with a low level (*eg*, 5 cm H₂O) of continuous positive airway pressure (CPAP), or with a low level of PSV (*eg*, 5 to 8 cm H₂O). Proponents of the CPAP approach argue that this maintains functional residual capacity at a level similar to that following extubation. For the patient with

obstructive lung disease, it is argued that this low level of CPAP maintains the patency of small airways if the patient cannot control exhalation due to the presence of the artificial airway (eg, pursed lips). For most patients, there is no evidence that a low level of CPAP is beneficial during the SBT, but this practice is not harmful. In patients with marginal left ventricular function, however, a low level of positive intrathoracic pressure may support the failing heart. Such patients may tolerate a CPAP trial but may develop congestive heart failure when extubated.⁵

Proponents of the low-level PSV approach to the SBT argue that this overcomes the resistance to breathing through the artificial airway. However, this argument fails to recognize that the upper airway of the intubated patient is typically swollen and inflamed. One study⁶ reported a similar resistance to breathing through the upper airway after extubation as that with the endotracheal tube in place. Resistance through the artificial airway is affected by many factors, including the inspiratory flow of the patient, the inner diameter of the tube, whether the tube is an endotracheal or tracheostomy tube, and the presence of secretions in the tube. This makes it difficult to choose an appropriate level of pressure support to overcome tube resistance. However, one study⁷ reported similar weaning outcomes when the SBT was performed with a T-piece or with 7 cm H₂O PSV. If a passive humidifier is used, a low level of PSV is needed because of the imposed resistance and dead space of the device.⁸⁻¹⁰

PSV Weaning

With PSV, all breaths are patient-triggered and pressure-limited. When the level of pressure support is high relative to patient effort, nearly full ventilatory support is provided. As the level of pressure support is decreased, more patient effort is required to maintain the minute ventilation. With pressure support weaning, the level of pressure support is decreased as tolerated by the patient. When a low level of PSV is successful (eg, 5 to 10 cm H₂O), the patient is considered to be ready for extubation.

During PSV, the breath is normally flow-cycled to the expiratory phase. That is, the ventilator cycles to the expiratory phase when flow decelerates to a ventilator-determined level (eg, 5 L/min or 25% of the peak inspiratory flow). This can be problematic with the following two clinical conditions: (1) a ventilator system leak; and (2) a high airways resistance and compliance (ie, a long time constant such as occurs with COPD patients). With these conditions, inspiration may be prolonged. If the patient actively exhales, this may cycle the ventilator to the expiratory phase. Alternatively, the ventilator will time-cycle the breath after 3 to 5 s.

Two studies^{11,12} have reported expiratory muscle activation during PSV in some patients with COPD. Because of the slow inspiratory flow deceleration in these patients, the inspiratory phase of the ventilator may exceed the neural inspiratory time of the patient. In this case, the patient actively exhales to terminate the inspiratory phase. This results in expiratory muscle loading and patient discomfort. The following actions may improve this effect: (1) the use of a lower level of pressure support; (2) the use

of pressure control instead of pressure support (in which the inspiratory time is set to a short enough time to avoid active exhalation); and (3) the use of a ventilator with an adjustable flow termination during pressure support. Newer-generation ventilators allow an adjustment of the rise time at the beginning of the pressure-support breath as well as the adjustment of the termination flow at the end of the pressure-support breath. Although these ventilator embellishments are appealing, they have been subjected to virtually no scientific study, and their effect on weaning outcomes is yet to be determined.¹³

SIMV

With SIMV, breaths can be either mandatory ventilator-controlled or spontaneous. The mandatory breaths are synchronized with patient effort (ie, they are patient-triggered). The mandatory breaths can be either volume-controlled or pressure-controlled. The remaining inspiratory efforts of the patient produce spontaneous breaths that may be pressure-supported. The original intent of SIMV was to rest the respiratory muscles during the mandatory breaths and to work the muscles during the spontaneous breaths. Weaning is achieved by decreasing the mandatory breath rate, requiring more spontaneous breathing effort to maintain the minute ventilation.

There is evidence that respiratory muscle rest does not occur during the mandatory breath delivery of SIMV.^{14,15} In fact, respiratory center output and respiratory muscle activity is as great during the mandatory breaths of SIMV as the spontaneous breaths. In other words, the respiratory center does not adapt its output in anticipation of the next breath type delivered from the ventilator. Thus, SIMV may result in a fatiguing load on the respiratory muscles rather than alternating periods of rest and exercise.

New Weaning Modes

The newer generation of ventilators features modes alleged to facilitate weaning. These include modes such as "volume support," "automatic tube compensation," and "adaptive support ventilation." The only literature concerning these modes relates to technical performance and anecdotal reports. There is currently no evidence that these modes improve weaning outcomes over existing modes¹³ (to my knowledge).

COMPARISON OF WEANING TECHNIQUES

There are now well-conducted studies, including level I evidence,^{16,17} to guide the choice of weaning technique. Two prospective, randomized, controlled trials were similar in their design. These studies reported that about two thirds of patients are successfully extubated after the first T-piece trial. In those who failed the first-day T-piece trial, the pooled results of these studies show no difference in outcome (duration of ventilation) for T-piece and PSV. Both T-piece and PSV were superior to SIMV in both studies.¹⁸

There has been increasing interest in the use of noninvasive positive-pressure ventilation (NPPV) in recent years. Although NPPV has been used primarily as a

method to avoid intubation, it has also been used as a technique to facilitate weaning. The pooled results from two prospective, randomized, controlled trials^{19,20} suggest reductions in the duration of mechanical ventilation, the length of ICU stay, mortality, and the incidence of nosocomial pneumonia with extubation to NPPV used as a weaning technique.¹⁸ Appropriate patient selection and the feasibility of the widespread application of these findings remain to be determined.

Recognition of Weaning Failure

It is important to recognize when a patient is failing a weaning trial. A failed weaning trial is discomforting for the patient and may induce significant cardiopulmonary distress. The following are the commonly listed criteria for the discontinuation of a weaning trial^{1,3,4,7,16,17}:

- Tachypnea (respiratory rate, > 35 breaths/min for ≥ 5 min);
- Hypoxemia (oxygen saturation by pulse oximeter, < 90%);
- Tachycardia (heart rate, > 140 beats/min; or sustained rate increase, > 20%);
- Bradycardia (sustained heart rate decrease, > 20%);
- Hypertension (systolic BP, > 180 mm Hg);
- Hypotension (systolic BP, < 90 mm Hg); and
- Agitation, diaphoresis, or anxiety; in some patients, these are not due to weaning failure and are appropriately treated with verbal reassurance or appropriate pharmacologic support.

When weaning failure is recognized, ventilatory support should be promptly reestablished.

REFERENCES

- 1 Esteban E, Alia I, Tobin MJ, et al. Effect of spontaneous breathing trial duration on outcome of attempts to discontinue mechanical ventilation. *Am J Respir Crit Care Med* 1999; 159:512–518
- 2 Vallverdu I, Calaf N, Subirana M, et al. Clinical characteristics, respiratory functional parameters, and outcome of a two-hour T-piece trial in patients weaning from mechanical ventilation. *Am J Respir Crit Care Med* 1998; 158:1855–1862
- 3 Ely EW, Baker AM, Dunagan DP, et al. Effect of the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *N Engl J Med* 1996; 335:1864–1869
- 4 Ely EW, Bennett PA, Bowton DL, et al. Large scale implementation of a respiratory therapist-driven protocol for ventilator weaning. *Am J Respir Crit Care Med* 1999; 159:439–446
- 5 Lemaire F, Teboul J, Cinotti L, et al. Acute left ventricular

- dysfunction during unsuccessful weaning from mechanical ventilation. *Anesthesiology* 1988; 69:171–179
- 6 Straus C, Louis B, Isabey D, et al. Contribution of the endotracheal tube and the upper airway to breathing workload. *Am J Respir Crit Care Med* 1998; 157:23–30
- 7 Esteban A, Alia I, Gordo F, et al. Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. *Am J Respir Crit Care Med* 1997; 156:459–465
- 8 Iotti GA, Olivei MC, Palo A, et al. Unfavorable mechanical effects of heat and moisture exchangers in ventilated patients. *Intensive Care Med* 1997; 23:399–405
- 9 LeBourdelle G, Mier L, Fiquet B, et al. Comparison of the effects of heat and moisture exchangers and heated humidifiers on ventilation and gas exchange during weaning trials from mechanical ventilation. *Chest* 1996; 110:1294–1298
- 10 Pelosi P, Solca M, Ravagnan I, et al. Effects of heat and moisture exchangers on minute ventilation, ventilatory drive, and work of breathing during pressure-support ventilation in acute respiratory failure. *Crit Care Med* 1996; 24:1184–1188
- 11 Parthasarathy S, Jubran A, Tobin MJ. Cycling of inspiratory and expiratory muscle groups with the ventilator in airflow limitation. *Am J Respir Crit Care Med* 1998; 158:1471–1478
- 12 Jubran A, van de Graaff WB, Tobin MJ. Variability of patient-ventilator interaction with pressure support ventilation in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1995; 152:129–136
- 13 Hess D, Branson RD. Ventilators and weaning modes. *Respir Care Clin N Am* 2000; 6:407–435
- 14 Imsand C, Feihl F, Perret C, et al. Regulation of inspiratory neuromuscular output during synchronized intermittent mechanical ventilation. *Anesthesiology* 1994; 80:13–22
- 15 Marini JJ, Smith TC, Lamb VJ. External work output and force generation during synchronized intermittent mandatory ventilation: effect of machine assistance on breathing effort. *Am Rev Respir Dis* 1988; 138:1169–1179
- 16 Esteban A, Frutos F, Tobin MJ, et al. A comparison of four methods of weaning patients from mechanical ventilation. *N Engl J Med* 1995; 6:345–350
- 17 Brochard L, Rauss A, Benito S, et al. Comparison of three methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation. *Am J Respir Crit Care Med* 1994; 150:896–903
- 18 Cook D, Meade M, Guyatt G, et al. Evidence report on criteria for weaning from mechanical ventilation. Rockville, MD: Agency for Health Care Policy and Research, US Department of Health and Human Services, 2000
- 19 Girault C, Daudenthun I, Chevron V, et al. Noninvasive ventilation as a systematic extubation and weaning technique in acute-on-chronic respiratory failure: a prospective, randomized controlled study. *Am J Respir Crit Care Med* 1999; 160:86–92
- 20 Nava S, Ambrosino N, Clini E, et al. Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease: a randomized, controlled trial. *Ann Intern Med* 1998; 128:721–728

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