CHEST Postgraduate Education Corner

CONTEMPORARY REVIEWS IN CRITICAL CARE MEDICINE

Discontinuing Mechanical Ventilatory Support*

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The ventilator discontinuation process is a critical component of ICU care. Ongoing ventilator dependency is caused by both disease factors (*eg*, respiratory, cardiac, metabolic, and neuromuscular) and clinician management factors (*eg*, failing to recognize discontinuation potential and inappropriate ventilator settings/management). A multispecialty evidence-based task force has recommended a series of guidelines that begins with a daily ventilator weaning screen focusing on disease stability/recovery, gas exchange, hemodynamics, and respiratory drive that should be done on every patient receiving mechanical ventilatory support. In those passing this screen, a spontaneous breathing trial (SBT) should be performed. The decision to remove the artificial airway in those patients successfully passing an SBT requires further assessment of the patient's ability to protect the airway. Managing the patient who fails the SBT is one of the biggest challenges facing ICU clinicians. In general, stable, comfortable modes of assisted/supported ventilatory support should be provided between the daily weaning screen/SBT. New evidence suggests that early tracheostomy placement may facilitate the ventilator withdrawal process in those patients requiring prolonged ventilatory support. ***(CHEST 2007; 132:1049–1056)***

Key words: mechanical ventilation; respiratory failure; weaning

Abbreviations: ASV = adaptive support ventilation; f = frequency; F_{IO_2} = fraction of inspired oxygen; NIV = noninvasive ventilation; PAV = proportional assist ventilation; PEEP = positive end-expiratory pressure; PES = esophageal pressure; P_{Imax} = maximal inspiratory pressure; PRVC = pressure-regulated volume control; PTP = pressure-time product; SBT = spontaneous breathing trial; SIMV = synchronized intermittent mandatory ventilation; T_I = inspiratory time; $\dot{V}_E$ = minute ventilation; VS = volume support; V_T = tidal volume

As respiratory failure and the need for mechanical ventilatory support stabilizes and begins to reverse, clinical attention shifts to the process of ventilator withdrawal or discontinuation. In these patients, ongoing ventilator dependency is caused by the following two fundamental problems: (1) disease-imposed factors, such as mechanical and/or gas exchange issues that continue to require positive pressure ventilation; and/or (2) clinician-imposed factors, such as either clinician delay in recognizing the ability of a patient to have mechanical ventilation discontinued or inappropriate ventilator settings that overload (or underload) respiratory muscles, preventing recovery. With respect to this latter point, several large clinical trials[1–3] have clearly demonstrated that many assessment/management strategies can cause considerable undue delay in ventilator withdrawal. Moreover, some trials[4–7] of protocol-driven ventilator discontinuation procedures have clearly demonstrated that traditional "standard care" is often associated with significant delays in ventilator withdrawal.

Clearly, ventilator management should be aimed at getting the patient off ventilator support as rapidly as possible. Delayed discontinuation of mechanical ventilatory support exposes patients to unnecessary risks of infection, stretch injury, sedation needs, airway trauma, and costs. The discontinuation process must be performed with proper caution and monitoring, however, because premature withdrawal has its own problems. These include the loss of

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airway protection, cardiovascular stress, suboptimal gas exchange, and muscle overload and fatigue.[8,9]

When Should Ventilator Discontinuation Be Considered?

In general, when a patient's underlying respiratory disease begins to stabilize and reverse, consideration for the discontinuation of mechanical ventilation should begin. A multi-society-sponsored, evidence-based task force (hereafter referred to as the *task force*)[1] has recommended that a patient should be considered a candidate for withdrawal of ventilation if (1) the lung injury is stable/resolving; (2) the gas exchange is adequate with low positive end-expiratory pressure (PEEP)/fraction of inspired oxygen (F_{IO_2}) requirements (*eg*, PEEP, < 5 to 8 cm H_2O; F_{IO_2}, < 0.4 to 0.5); (3) hemodynamic variables are stable (*eg*, without significant needs for therapy with pressors); and (4) there is the capability to initiate spontaneous breaths. This information is usually readily available, and the task force recommends that these issues be assessed daily as a "wean screen."[1] An extrapolation of this concept could be taken to the postsurgical arena where respiratory recovery is often rapid and the wean screen could be performed on a more frequent basis (*eg*, every hour).

How Should Discontinuation Potential Be Assessed in Those Passing the Wean Screen?

A number of parameters have been found to be associated with the success or failure of ventilator discontinuation.[10–13] A summary of the better studied ones is given in Table 1. Some of these are readily obtained (*eg*, vital capacity, minute ventilation [$\dot{V}_E$], frequency /tidal volume [V_T] ratio, muscle force generated during 20 s of effort against a closed airway [maximal inspiratory pressure (P_{Imax})], and patient observations). Other parameters, however, require more sophisticated measurements. For instance, an esophageal balloon to measure esophageal pressure (PES [an estimate of pleural pressure]) is necessary to assess patient muscle loads quantified as work or pressure-time products (PTPs) per breath (work = $\int$ PES $\times$ V_T; PTP = $\int$ PES $\times$ T_I [where T_I is inspiratory time]).[14–17] These indexes of muscle load can be expressed with respect to time (*eg*, work/min), to ventilation (*eg*, work/L) or to maximum muscle strength (*ie*, PTP/P_{Imax} ratio). Multiplying the PTP/P_{Imax} ratio by the T_I fraction (*ie*, T_I/total breathing cycle time ratio) results in the pressure-time index, which can be a useful predictor of fatigue when > 0.15.[15]

Integrated factors also have been employed.[10] The CROP index multiplies dynamic compliance by Pa_{O_2}/alveolar P_{O_2} ratio by P_{Imax} and divides this product by the respiratory rate.[18] Other integrated scores incorporate PES load calculations and may use neural networks.[19] Important clinical assessments in evaluating ventilator discontinuation potential include subjective dyspnea, accessory muscle use, diaphoresis, tachycardia, abdominal paradox, and subjective comfort.

Analyses of receiver operating characteristics curves have shown that none of these indexes alone are sufficiently sensitive and specific to be useful in predicting the success of ventilation discontinuation in an individual patient.[1,10] Moreover, the likelihood ratios for all of these parameters (*ie*, the percentage increase in predicting success using the parameter), while always statistically significant in population

Table 1—*Measurements Performed Either While Patient Is Receiving Ventilatory Support or During a Brief Period of Spontaneous Breathing That Have Been Shown To Have Statistically Significant Likelihood Ratios To Predict Outcome of a Ventilator Discontinuation Effort in More Than One Study

Parameters	Studies, No.	Threshold Values	Range of Positive LRs
Measured on ventilator			
$\dot{V}_E$	20	10 to 15 L/min	0.81 to 2.37
P_{Imax} (NIF)†	36	−15 to −30 cm H_2O	0.23 to 3.01‡
$P_{0.1}$/P_{Imax} ratio	4	0.30	2.14 to 25.3
CROP	2	13	1.05 to 19.74
Measured during a brief period of spontaneous breathing			
RR	24	30 to 38	1.00 to 3.89
V_T	18	325 to 408 mL (4 to 6 mL/kg)	0.71 to 3.83
RR/V_T ratio (f/V_T ratio)	20	60 to 105 /L	0.84 to 4.67

*CROP = dynamic compliance $\times$ Pa_{O_2}/alveolar P_{O_2} $\times$ P_{Imax})/RR; RR = respiratory rate; LR = likelihood ratio; $P_{0.1}$ = inspiratory pressure against a closed shutter 100 ms after effort initiation; NIF = negative inspiratory force. Table was adapted from MacIntyre et al.[10]

†Measured against a closed shutter after 20 s

‡One study reported an LR of 35.79.