The Concept of Liberation and Extubation

Weaning from mechanical ventilation represents the period of transition from total ventilatory support to spontaneous breathing. About 70% of intubated mechanically ventilated patients are extubated on the first spontaneous breathing trial (SBT) attempt, whether by disconnection from the ventilator or after breathing at low levels of pressure support for short periods of time, such as 30 to 120 minutes. This pattern has recently been categorized as “simple weaning,” and the prognosis for such patients is good. The remaining patients, about 30%, need progressive withdrawal from artificial ventilatory support. These patients can be classified either as “difficult weaning” when they require up to three SBTs to achieve successful weaning, or “prolonged weaning” if they fail at least three weaning attempts or require more than 7 days of ventilatory support from the first SBT. The mortality rate for patients not simple/easy to wean is approximately 25%.

Early liberation from mechanical ventilation and removal of the endotracheal tube is clinically important. Unnecessary prolongation of mechanical ventilation increases the risks of complications including infections (particularly of bronchopulmonary origin), barotrauma, cardiovascular compromise, tracheal injuries, and muscle deconditioning. To optimize patient outcomes, clinicians should hasten the process that ultimately leads to removal of the endotracheal tube.

Liberation and extubation are different issues. Liberation refers to weaning from mechanical ventilation and means that a patient no longer requires ventilatory support. When this step is achieved, the clinician has to consider a different question: Is the patient able to breathe spontaneously without the endotracheal tube? Removal of the endotracheal tube is referred to as extubation. In terms of magnitude, the extubation failure rate—that is, the need to replace the endotracheal tube and reinstitute mechanical ventilation—is variable and ranges from 5% to 20% of extubated patients.

Mechanisms Explaining Liberation Failure

RESPIRATORY PUMP FAILURE

The most common reason for weaning failure is respiratory pump insufficiency due to an imbalance between the patient’s capabilities and respiratory demands. During spontaneous breathing, the inspiratory muscles must generate sufficient force to overcome the elastance of the lungs and chest wall (lung and chest wall elastic loads) as well as the airway and tissue resistances (resistive load). This requires signal generation in the respiratory centers of the brainstem, anatomic and functional integrity of nerves that conduct the signal, unimpaired neuromuscular transmission, and adequate muscle strength (the aggregate term is neuromuscular competence). The ability of the respiratory muscles to sustain these loads without fatiguing is called endurance and is determined by the balance between energy supply and energy demand.

Jubran and Tobin investigated the progression of respiratory mechanics during SBT in patients with chronic obstructive pulmonary disease (COPD). At the very beginning of the trials, patients who subsequently failed had a slightly higher airway resistance, respiratory system elastance, and intrinsic positive end-expiratory pressure (PEEP) compared to those who succeeded. However, during the course of the trials, respiratory mechanics progressively worsened in patients who failed to be liberated from the ventilator. Subjects who failed developed rapid, shallow breathing, and most developed an increase in PaCO₂. Together these abnormalities resulted in increased inspiratory muscle effort which, in some patients, was probably close to the threshold of muscle fatigue.

The issue of fatigue has been revisited by Laghi et al. The authors studied 19 intubated patients during weaning from mechanical ventilation. Eleven patients failed and eight succeeded. Several physiologic indices were measured before and 30 minutes after SBT. The transdiaphragmatic twitch pressure, elicited by magnetic bilateral phrenic stimulation, did not differ before the SBT between the patients that failed or succeeded at ventilator liberation, and this variable did not decrease after the trial in either group. A fall in transdiaphragmatic twitch pressure is a physiologic index of low-frequency fatigue. Patients failing the SBT were reconnected to the ventilator because of clinical signs of intolerance. These alterations, together with the reinstatement of mechanical ventilation, are mechanisms that might defend against the development of low-frequency fatigue. It was concluded that weaning failure was not accompanied by low-frequency diaphragmatic fatigue, although weaning-failure patients exhibited severe diaphragmatic weakness, since twitch pressures were always low.

COMMON DISORDERS THAT ALTER THE BALANCE OF CAPACITY AND LOAD IN CRITICAL ILLNESS

Reduced Neuromuscular Capacity

Reduced output of the respiratory control centers may occur following administration of sedatives, narcotics, and anesthetic agents. Phrenic nerve dysfunction can occur after traumatic injuries (e.g., high cervical spine lesions) and is also common after cardiac surgery. Diaphragmatic dysfunction may occur following upper abdominal surgery, and an elegant study has shown atrophy of diaphragm fibers after only 18 hours of mechanical ventilation and complete diaphragmatic inactivity. Critical illness polyneuropathy and myopathy, which are frequent complications of sepsis and multiple organ system failure, may also impede weaning. Finally, neuromuscular blocking agents (with or without concomitant corticosteroids) and aminoglycosides may contribute to weaning failure. In addition, malnutrition and deconditioning due to prolonged bed rest/mechanical ventilation can induce severe muscle dysfunction.

In a multicenter study by De Jonghe et al., a high incidence of intensive care unit (ICU)-acquired neuromuscular dysfunction was reported in patients without preexisting neuromuscular disorders who underwent mechanical ventilation for at least 7 days. In this group of 95 patients, 25% were diagnosed with acquired paresis. The duration of mechanical ventilation after the removal of sedation was significantly longer in patients with paresis compared to those who without paresis (18 vs. 8 days; P = 0.03). In this investigation, the independent predictors of ICU-acquired paresis were female sex, number of days with dysfunction of two or more organs, duration of mechanical ventilation before awakening, and administration of corticosteroids. The same group also found that respiratory muscle weakness was associated with delayed extubation.

Increased Muscle Loads

Increased work of breathing results from increased mechanical loads (elastic and/or resistive) and processes that require higher minute ventilation. Increased ventilatory requirements are common in critically
ill patients, particularly during periods of hyperthermia, overfeeding, and hyperventilation (related to anxiety and/or pain). An increase in the dead space/tidal volume ratio is another source of increased ventilatory need.

Increased elastic workloads occur when lung and/or chest wall compliance is reduced (e.g., pulmonary edema, extreme hyperventilation during an acute asthmatic attack, pulmonary fibrosis, abdominal distension, obesity, trauma, or thoracic deformities). The presence of intrinsic PEEP is another example of increased elastic workload and is a relatively common phenomenon, especially in patients with COPD. Dynamic pulmonary hyperinflation, apart from generating an elastic threshold load, places the diaphragm at a mechanically disadvantageous position in which its capacity to generate pressure decreases.

Resistive work of breathing during critical illness may increase because of bronchospasm, excessive secretions, endotracheal tube resistance (which augments with kinking and deposition of secretions), and ventilator valves/circuits and humidifiers, especially when conditioning of inspired gases is provided with heat and moisture exchangers. The latter also increase the instrumental dead space.

Cardiovascular Dysfunction

The presence of cardiovascular dysfunction can contribute to weaning failure by increasing loads on the respiratory system and by reducing neuromuscular capacity. A study by Epstein showed that as many as one third of weaning failures resulted solely or in part from congestive heart failure (CHF), although other studies found that fewer episodes of weaning failure (14%) were due to cardiovascular reasons. Cardiovascular dysfunction may result from physiologic changes that occur during the resumption of spontaneous unassisted breathing. When spontaneous breathing resumes, intrathoracic pressure swings during inspiration are negative, a situation that results in increased left ventricular preload and afterload. A significant decrease in left ventricular ejection fraction has been described during spontaneous breathing trials in COPD patients without coronary artery disease.

Increased myocardial loading may be sufficient, especially when coupled with left ventricular noncompliance, to precipitate CHF (which stiffens the lungs and further increases respiratory muscle load). Moreover, increased heart loads augment myocardial oxygen demand and may precipitate myocardial ischemia in patients with coronary artery disease. Myocardial ischemia causes left ventricular dysfunction that may induce acute pulmonary edema and arterial hypoxemia.

Jubran et al. examined hemodynamics and mixed venous saturations in patients during weaning trials. Successfully weaned patients demonstrated increases in cardiac index and oxygen transport compared to values during mechanical ventilation. Patients who failed weaning did not increase oxygen delivery to the tissues owing in part to elevated right- and left-ventricular afterloads. Consequently, these abnormalities can jeopardize respiratory muscle function.

In ICU patients, CHF may be diagnosed for the first time or worsen in patients with this condition as a consequence of increase in venous return, volume overload, or catecholamine release induced by physiologic stress, such as weaning. These factors have negative effects on cardiac function, and together with hypoxemia can result in the development of acute pulmonary edema. Impairment of cardiovascular function can be magnified in the setting of positive fluid balance.

It has been recently shown that performing an SBT in difficult-to-wean patients with a T-tube (instead of pressure support and PEEP) elicits a totally different cardiovascular response and, as expected, as long as support is added (in the form of pressure support and PEEP) the respiratory and cardiovascular function both improve.

In the ICU there are new noninvasive tools available that help physicians make the diagnosis of cardiovascular dysfunction, such as echocardiography and measurement of plasma B-type natriuretic peptide (BNP). One study found that patients exhibiting weaning failure had higher BNP values than patients who were successfully weaned.

Patients who failed weaning were treated with diuretics, and this was accompanied by successful extubation and a decrease in BNP levels. Another study compared the use of echocardiography in diagnosing pulmonary edema induced by weaning. The authors showed that an increase in the value of the pulmonary artery occlusion pressure (PAOP) was correlated with echocardiographic signs of increased in left-ventricular filling pressures.

Mechanisms Explaining Extubation Failure

Extubation failure can be defined as reinstitution of ventilatory assistance within 24 to 48 hours of extubation. Consequently, the extubation failure rate is the number of patients requiring reinstitution of mechanical ventilation divided by the total number of extubated patients. The reintubation rate may differ according to the etiology of respiratory failure. For instance, in a study that included 217 medical and surgical patients, Vallverdú et al. noted that the overall reintubation rate was 15% and ranged from 36% (15 of 42) in neurologic patients to 0% (zero of 13) in COPD patients. The reintubation rate in patients who had acute respiratory failure of other etiologies was 9% (8 of 93). Data by Esteban et al. indicate that the reintubation rate is about 13% to 19%.

Mechanisms explaining extubation failure include impending abnormalities not diagnosed at the time extubation is performed (e.g., pneumonia, ongoing cardiac failure) and the inability to keep the tracheobronchial tree free of copious secretions. Intubation can result in laryngotraheal injury, which tends to occur more frequently with increasing duration of intubation and in women, which could explain some episodes of extubation failure.

Extubation failure results in a marked increase in the duration of mechanical ventilation, ICU and hospital stay, need for tracheostomy, and hospital mortality. The etiology of extubation failure also influences outcome. Interestingly, patients requiring reintubation because of respiratory failure had a mortality rate of 30%, whereas mortality in patients needing reintubation because of upper airway obstruction was only 7%. In one study, the time to reintubation was found to be an independent predictor of outcome.

Indices to Predict Weaning Outcome

Many indices have been proposed in an attempt to predict weaning outcome and have used assessment of: (1) simple ventilatory parameters, (2) oxygenation, (3) respiratory muscle strength, (4) central respiratory drive, (5) respiratory muscle reserve, (6) work of breathing, (7) different variables of respiratory function, and (8) the pattern of spontaneous breathing in terms of tidal volume (Vt) and respiratory rate (f) or f/Vt.

Yang and Tobin studied the predictive power of several weaning indices and showed that the rapid, shallow breathing index (f/Vt) had the best predictive value. In their study, 95% of patients with a ratio f/Vt greater than 105 failed during a test of spontaneous breathing. In general, except for f/Vt, these indices exhibit relatively poor positive and negative predictive values. In addition, the performance of these indices is affected by a number of factors, such as selection bias, outcome misclassification, and confounding variables.

The rapid, shallow breathing index appears to be the most useful bedside method for screening a patient for readiness for liberation. If the value is less than 105, 30 to 120 minutes of an SBT should be used as confirmation of the patient’s capability of breathing spontaneously without assistance. Screening tests are typically performed when the pretest probability of a condition is low. High-sensitivity tests (as is the case with f/Vt) are very useful for screening: weaning success is high among patients in whom the test is positive (f/Vt <105) and low among those in whom the test is negative (f/Vt >105). However, since f/Vt has low specificity (a relatively large proportion of
Indices to Predict Extubation Failure

The frequency of reintubation and the adverse impact it has on survival indicate that accurate prediction of extubation outcome is important. Most clinicians assess patient readiness for both liberation and extubation by conducting an SBT of variable duration. The crucial importance of performing an SBT before deciding on extubation has been highlighted by Zeggwagh et al. These authors proceeded directly to extubation (without performing an SBT) after medical ICU patients had demonstrated clinical improvement. Of the 119 episodes of extubation, 44 (37%) subsequently required reintubation. This rate is much higher than that reported for patients who were extubated after passing an SBT.

Patients incapable of protecting their airway and clearing secretions with an effective cough are at increased risk for extubation failure. Traditional assessment has consisted in demonstrating a cough reflex when the airways are stimulated with a suction catheter and by the absence of excessive secretions, but these criteria have not been standardized. In mechanically ventilated subjects, a "sawtooth" pattern on the flow-volume curve indicates the presence of excess airway secretions but does not provide quantitative information.

Although tolerance of an SBT up to 120 minutes is a good predictor of successful extubation, Vallverdú et al. noted that a high percentage (36%) of neurologic patients who successfully passed a 2-hour SBT and were extubated needed subsequent reintubation. Coplin et al. have studied extubation in brain-injured patients. Their data provide no justification for delaying extubation in patients whose only indication for prolonged intubation is a depressed level of consciousness. This study found that timely extubation of patients who met standard weaning criteria appeared to be safe, with no increased risk of reintubation or subsequent tracheotomy, potentially beneficial (associated with a lower incidence of pneumonia), and less expensive (shorter ICU and hospital cost). In that study, the reintubation rate was 18% (24 of 136 patients). Only two components of a semiquantitative assessment of need for airway care were associated with successful extubation: spontaneous cough ($P = 0.01$) and suctioning frequency ($P = 0.001$).

Smina et al. studied a group of 95 patients admitted to a medical ICU who passed an SBT and were ready to be extubated. They found that patients with peak expiratory flows equal to or below 60 L/min were five times as likely to have an unsuccessful extubation as patients with expiratory flows greater than 60 L/min. These data emphasize the notion that patients incapable of protecting the airways and clearing secretions are at increased risk for unsuccessful extubation.

Progressive Withdrawal of Mechanical Ventilation

Weaning from mechanical ventilation represents the period of transition from total ventilatory support to spontaneous breathing. The most common techniques used to withdraw mechanical ventilation in patients who failed an initial weaning trial are pressure-support ventilation (PSV) and breathing through a T-piece. Two prospective multicenter randomized clinical trials have shown that the use of synchronized intermittent mandatory ventilation (SIMV) is less efficacious than the other techniques.

ROLE OF PROTOCOLS

Various studies have shown that weaning protocols administered by nursing and respiratory care staff can shorten the duration of mechanical ventilation. The methodological approach is nearly always the same and primarily consists of daily checking of the patient's ability to breathe spontaneously. This simple approach is associated with faster extubation and a shorter ICU stay, without any increase in the reintubation rate.

An important study revealed that abrupt daily interruption of sedation significantly reduced the duration of mechanical ventilation. More recently, a no-sedation strategy has shown better results than daily interruption of sedation. However, because this was a single-center study with several limitations, the findings must be confirmed before this strategy becomes more generalized. Because sedation and weaning from mechanical ventilation cannot be separated from one another, when these two strategies are combined (i.e., daily interruption of sedation and systematic use of SBTs to hasten liberation from the ventilator), the results are better than if the two strategies are used separately.

The impact of protocols in hastening the weaning process has been questioned. In a prospective controlled trial, Krishnan et al. compared protocol-based weaning to usual physician-directed weaning in a closed medical ICU with high physician staffing levels and structured system-based rounds. The authors could not document any improvement in clinical outcomes with protocols. These results have stimulated debate regarding the use of protocols and especially about what is understood by control groups and usual care.

PRESSURE-SUPPORT VENTILATION

Pressure-support ventilation allows patients to retain relative control over respiratory rate and timing, inspiratory flow rate, and tidal volume. During weaning, the PSV levels are decreased according to the patient's clinical tolerance, usually by steps of 2 to 4 cm H$_2$O at least twice a day. In general, clinical tolerance to a level of PSV of about 8 cm H$_2$O without PEEP is required before performing extubation, although this level may vary according to a given patient's overall clinical status.

Clinical experience and data coming from clinical trials suggest that "optimal" initial levels for PSV are those that provide respiratory rates between 25 and 30 breaths/min. In this scenario it is particularly important to rule out the existence of asynchronous breathing or ineffective respiratory effort, respiratory events that are especially prevalent in COPD patients. Ineffective effort occurs when the patient initiates inspiration that does not trigger the ventilator. A study has shown that high pressure-support levels, large tidal volumes, and increase in serum bicarbonate level with alkalosis were associated with ineffective triggering. Therefore, a ventilator setting with a high level of pressure support can be the cause of patient-ventilator asynchrony. The patients who showed ineffective triggering exhibited a longer time on mechanical ventilation, and tracheostomy was more frequent in these patients. The same group of authors performed a second study in difficult-to-wean patients who exhibited ineffective efforts while being ventilated with PSV. The study found a decrease in the number of ineffective efforts—without changes in the work of breathing and without modifications in the respiratory rate—when pressure support levels were reduced. These studies show that some patients are receiving excessive levels of mechanical ventilation during the weaning process. This situation can result in delaying the moment of performing an SBT if the patient is unnecessarily ventilated with a high level of pressure support.

The level of external PEEP used in patients with clinically suspected dynamic hyperinflation and dynamic airway collapse should be adjusted with great caution, since measurement of dynamic intrinsic PEEP in spontaneously breathing patients is not easily performed. To that end, it has been suggested that external PEEP can be titrated according to the changes in airway occlusion pressure.

SPONTANEOUS BREATHING WITH T-TUBE

Tolerance to breathing through a T-tube represents a good test to evaluate patients' capacity to maintain autonomous spontaneous
breathing. The optimal duration of a T-tube trial is at least 30 minutes and no more than 120 minutes.

The main disadvantage of the T-piece trial is related to the absence of a connection to a mechanical ventilator. Since the patients are not monitored by the alarms on the ventilator, they need to be closely supervised, and this is highly demanding for the nursing staff. Additionally, the transition between periods of muscular rest and periods of spontaneous unassisted breathing with a T-tube can be excessively abrupt for some patients, especially for those who have panic reactions after disconnecting from the ventilator and those with latent left-ventricular failure and myocardial ischemia.

NONINVASIVE VENTILATION

We must distinguish three scenarios:
1. When noninvasive ventilation (NIV) is used as a substitute for invasive ventilation in patients with chronic respiratory failure who do not meet extubation criteria. This situation is found in patients with chronic respiratory failure who present with difficult weaning and high risk for a tracheotomy. In studies examining the use of NIV in this setting, the control group, patients were extubated only after having passed the weaning test, while patients in the intervention group were extubated despite having failed the test but were immediately given intensive NIV. Of the three published studies, two showed a higher percentage of successful weaning with lower mortality rates in the NIV group, while one found no differences.
2. Preventive NIV in patients at high risk of reintubation. In this situation, the weaning test is passed, and all criteria for extubation are present. The endotracheal tube is then removed, but the patient is considered an a priori high-risk candidate for reintubation. Examples of such patients include those who present hypercapnia at the end of the weaning test, patients older than 65 years with a history of heart problems, and patients whose weaning was difficult. Of the three studies that have been carried out, one showed a reduction in the reintubation rate when NIV was used post extubation, while the other showed, in addition to the reduced reintubation, a decrease in the mortality rate.
3. NIV for "de novo" respiratory failure after extubation. A Canadian study examined the use of NIV for respiratory failure after extubation but found no difference, either in terms of reintubation or mortality. In 2004, a study was published questioning the use of NIV for de novo postextubation respiratory failure. The patients were randomized to receive treatment with oxygen and usual care versus NIV treatment and intubation if needed. Although the rate of reintubation was similar to the Canadian study, the group treated initially with NIV had a higher mortality rate. The authors concluded that NIV could delay reintubation in certain patients, leading to a worse outcome. However, the data from this study are difficult to interpret, since a subgroup of patients who failed usual treatment were given an NIV trial before intubation. These individuals fared much better than those who received NIV from study entry. These results have put an end to the indiscriminate use of NIV, so that NIV is only recommended in specific populations, including those with chronic respiratory problems and postoperative patients.

NEW MODALITIES

Several novel weaning modalities have been examined, including those using closed-loop PSV providing continuous adaptation of ventilator assistance to patients’ needs 24 hours a day. A recent study examined this modality in two groups of patients during the weaning period. In the “usual weaning group,” weaning was performed as usual based on written weaning guidelines. In the “study group,” weaning was carried out using a computer-driven weaning protocol. Weaning time was reduced in the study group in comparison to the usual weaning group (3 days versus 5 days, respectively). Reduction in weaning time was associated with a decrease in both total duration of mechanical ventilation and ICU length of stay. A study performed in Australia by Rose et al. showed different results. In that study, the authors compared an automated weaning system group with a usual care control group, and no differences were found in weaning time between groups.

ROLE OF TRACHEOTOMY

With the introduction of percutaneous techniques performed at the bedside, tracheotomy has become an increasingly common intervention in ICUs. Tracheotomy can facilitate weaning by reducing dead space and decreasing airway resistance, improving clearance of secretions, reducing the need for sedation, and decreasing the risk of aspiration. Nevertheless, the results from different studies are controversial.

A randomized controlled trial examined the hypothesis that tracheotomy performed after 6 to 8 days of endotracheal intubation compared with tracheotomy performed after 13 to 15 days would reduce the incidence of ventilator-associated pneumonia. The duration of mechanical ventilation, length of stay, and mortality were analyzed as secondary outcomes. No differences were found between the two groups in terms of incidence of ventilator-associated pneumonia. Although the numbers of ventilator-free days and ICU-free days were greater in the early tracheotomy group, there were no 28-day survival differences between the groups. Given these results, at the present time tracheotomy should not be performed earlier than after 15 days of endotracheal intubation except in selected populations.

Unplanned Extubation During Weaning

Removal of the endotracheal tube under unexpected conditions is defined as unplanned extubation. It may be deliberate (induced by the patient) as a result of patient agitation or lack of cooperation, or accidental, due to rupture of the endotracheal cuff, nursing procedures, coughing, or other events. Endotracheal unplanned/unexpected extubation (EUE) is estimated to occur in approximately 10% of intubated mechanically ventilated patients.

In a prospective study carried out during a 32-month period, 59 episodes of EUE were observed in 55 (frequency 7%) out of 750 patients who required mechanical intubation for more than 48 hours. EUE was deliberate in 78% and accidental in 22% of cases. Twenty-seven episodes (46%) occurred in patients on full mechanical ventilatory support and 32 (54%) during the weaning period from mechanical ventilation. Patients with EUE during weaning required significantly fewer reintubations than those who were not undergoing weaning (odds ratio 6.6). Only 16% of EUE patients who were undergoing weaning from mechanical ventilation (5/32) needed reintubation, whereas reintubation was required in 82% of EUE patients (22/27) receiving full mechanical ventilatory support (P < 0.01).

Epstein et al. performed a case-control study involving 75 patients with EUE and 150 controls matched for APACHE II score, presence of comorbid conditions, age, indication for mechanical ventilation, and gender. They found that EUE was not associated with increased mortality when compared to matched controls, although they noted an increased total duration of mechanical ventilation, ICU and hospital stay, and need for chronic care in the EUE group. Mortality was increased in the group that needed reintubation as compared to the group that did not. Reintubation rates were lower among patients who had an EUE during weaning trials as compared to those who had an EUE during full ventilatory support (44% in the former and 76% in the latter).

Summary

The vast majority of intubated mechanically ventilated patients can be successfully liberated from the ventilator after passing a short SBT. The best strategy to shorten the total time of mechanical ventilation...
is based on a simple daily clinical approach that evaluates the ability of patients to tolerate spontaneous unassisted breathing. This approach requires that a screening test be performed as early as possible and, if positive, the patient is continued on a confirmatory SBT of 30 to 120 minutes of duration. When patients fail SBTs, techniques for progressive withdrawal of mechanical ventilation (PSV and volume-assisted mechanical ventilation with daily SBTs) seem to be equivalent. Automated systems seem to perform as well as usual care. NIV may be useful to hasten weaning in some selected populations. Extubation failure is poorly understood and portends a high mortality rate.

**KEY POINTS**

1. Making the distinction between liberation and extubation during withdrawal from mechanical ventilation has opened a new understanding in the concept of weaning. These are different processes with different pathophysiologic mechanisms that may lead to failure in weaning or extubation.

**ANNOTATED REFERENCES**


This is the first randomized trial comparing three different methods of weaning. The authors conclude that outcome of weaning is influenced by the modality chosen during this period. The weaning duration was shorter with pressure support than with SIMV or T-piece when pooled together.


This is the first randomized trial comparing four different methods of weaning. Results showed that weaning after a once-daily spontaneous breathing trial occurred twice as fast as with pressure support and three times more quickly than SIMV. Multiple trials of spontaneous breathing did not reduce the time of weaning compared with a once-daily trial.


This physiologic study to determine the mechanisms of acute respiratory distress showed that COPD patients who failed a spontaneous breathing trial developed rapid, shallow breathing with worsening of pulmonary mechanics, which caused an increased Paco2.


Recommendation of an international multisociety consensus conference on weaning.


Randomized controlled trial demonstrating that a strategy combining cessation of sedation followed by spontaneous breathing shortens the duration of mechanical ventilation and improves outcome.

**REFERENCES**

Access the complete reference list online at http://www.expertconsult.com.