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Predicting Extubation Failure

Is It in (on) the Cards?

Determining readiness for liberation from mechanical ventilation (weaning) and the optimal technique to facilitate the process for patients who prove more difficult to wean is of considerable clinical relevance. Yet, once mechanical ventilation is no longer required, the clinician must address the separate question of whether or not the patient can tolerate removal of the endotracheal tube (*eg*, extubation). The process and outcome of extubation has received increasing attention among clinical investigators. Recent work clearly demonstrates that liberation and extubation are discrete processes with distinct pathophysiologic causes and unique outcomes.

Unsuccessful extubation (the need for reintubation) occurs in up to 20% of patients within 24 to 72 h of planned extubation. Factors that appear to increase the risk are the type of patient (*eg*, medical ICU), age > 70 years, higher severity of illness at weaning onset, use of continuous IV sedation, and possibly a longer duration of mechanical ventilation prior to extubation.[1]

Studies[2–6] demonstrate that unsuccessful extubation is associated with increased hospital mortality especially for general surgical and medical patients. In addition, unsuccessful extubation significantly prolongs the duration of mechanical ventilation, ICU and hospital stay, and need for tracheostomy.[3] The etiology of unsuccessful extubation influences outcome, with mortality lowest for airway problems (upper-airway obstruction, aspiration, excess pulmonary secretions) and highest when reintubation results from other reasons.[4,5,7] Possible explanations to explain the high mortality seen with unsuccessful extubation include a sicker patient population, direct complications of reintubation, the adverse effect of prolonged mechanical ventilation, or clinical deterioration between extubation and reintubation. In contrast, Coplin et al[8] recently demonstrated that brain-injured patients experiencing a potentially unnecessary delay in extubation experienced higher mortality and longer ICU stay when compared to patients expeditiously extubated.

Given the risks associated with extubation delay and those of unsuccessful extubation, what should an "acceptable" unsuccessful extubation rate be? Cardinal and colleagues[9] recently addressed this issue by constructing a decision analytic model. These investigators found that there is no fixed acceptable probability of unsuccessful extubation. Of the factors studied, the rate of improvement in the patient's condition (*eg*, the change in probability of tolerating extubation) over time had the greatest influence on the decision to extubate. When the rate of improvement was high, the best approach was to continue mechanical ventilation unless the probability of unsuccessful extubation was very low (*eg*, < 5%). Conversely, when there was little or no chance for further improvement, the best decision was extubation.

The frequency of reintubation and the adverse impact on outcome indicate that accurate prediction of extubation outcome is potentially important. Currently, clinicians often simultaneously assess patient readiness for liberation and extubation by conducting a spontaneous breathing trial (SBT) after the patient has demonstrated clinical recovery and his/her condition is hemodynamically stable. The optimal pre-extubation mode of ventilation (continuous positive airway pressure, T-piece, or pressure support) and duration of the SBT (30 to 120 min) has not yet been identified.[4,5] Nevertheless, when extubation occurs without an SBT, the reintubation rate is prohibitively high.[10]

Can physiologic measurements further improve extubation prediction and beyond that, outcome? Many "classical" predictors (*eg*, negative inspiratory force, minute ventilation, frequency-tidal volume ratio) were conceived based on their capacity to identify an imbalance between respiratory capacity and load, the principal cause for weaning failure. Although capacity-load imbalance can also lead to unsuccessful extubation, evidence suggests that other causes are frequently responsible. This difference in pathophysiology provides some explanation for the observation that, in general, most "weaning predictors" are less accurate in predicting extubation outcome.[1] Although positive weaning test results are highly associated with successful extubation, they offer only marginal improvement from prediction based solely on successful completion of an SBT. In contrast, the majority of patients having a negative weaning test result can be successfully extubated as long as they have satisfactorily completed an SBT. One weaning parameter that may have utility in predicting extubation outcome is the airway occlusion pressure (P_{100} or airway occlusion pressure at 0.1 s [$P_{0.1}$]), especially when normalized for maximal inspiratory pressure (MIP) [$P_{0.1}$/MIP].[11] In addition, the $P_{0.1}$ can be measured during face mask pressure-support ventilation after extubation and may provide an early indicator of the likelihood of extubation success.[12] Although these more technologically complex approaches are encouraging, prospective validation studies are not yet available.

The risk for extubation failure increases for patients with upper-airway obstruction and those incapable of protecting the airway and expelling secretions with an effective cough. Although assessment of upper-airway patency is challenging in the intubated patient, an association between the absence of an audible air leak, after deflation of the endotracheal tube balloon, and the subsequent development of postextubation stridor has been demonstrated (qualitative cuff leak test).[13] Miller and Cole,[14] using a quantitative cuff leak test (average difference between inspiratory and expiratory volume after balloon deflation) observed that a cuff leak volume of $\leq$ 110 mL predicted postextubation upper-airway obstruction, findings that could not be reproduced in a larger study[15] of postoperative cardiothoracic surgical patients.

Traditional airway assessment has also consisted of ensuring an adequate gag reflex, demonstrating a cough reflex using a suction catheter and by the absence of "excess" secretions. Quantitative approaches, such as measurements of peak cough flow rate[16] or maximal expiratory pressure,[6] may prove useful in predicting extubation outcome, but insufficient study has been carried out. Although airway secretions can be detected by observing a "saw-tooth" pattern on the flow-volume curve, this does not provide a quantitative assessment.[17] Recently, Coplin et al[8] used a six-part semiquantitative airway care score to assess extubation outcome in brain-injured patients. Although measurements made on the day of extubation were not predictive of outcome, two individual components (spontaneous cough and suctioning frequency) measured at the time that ventilatory support was no longer required were predictive of eventual successful extubation.

The study by Khamiees et al presented in this issue of *CHEST* (see page 1262) is the first to definitively demonstrate that a semiobjective assessment of cough strength and secretion volume can accurately predict extubation outcome among patients successfully completing an SBT. The authors found that patients with moderate or abundant secretions were more than eight times as likely to have unsuccessful extubation as those with no or small amounts of secretions. Specifically, patients requiring endotracheal suctioning every 2 h or less were 16 times as likely to experience unsuccessful extubation as patients suctioned less frequently. Patients with weak cough were four times as likely to have unsuccessful extubation compared to patients with stronger cough. When both weak cough and moderate or abundant secretions were present, the risk of unsuccessful extubation was further increased. The authors also applied a simple, but novel, concept in demonstrating that the inability to propel secretions onto a white index card, held a short distance from the endotracheal tube, predicted unsuccessful extubation. One limitation of this well-performed study is that a single observer performed the semiobjective scoring. In addition, the interaction between secretions, cough, and mental status was not examined. Interestingly, in the study by Coplin et al,[8] brain-injured patients with lower Glasgow Coma Scale scores were not at increased risk for unsuccessful extubation.[8] Lastly, although the mechanism remains unclear, the authors also found that patients with anemia (hemoglobin level $<$ 10 g/dL) were five times as likely to have unsuccessful extubation as patients without anemia.

What should the clinician do when extubation is unsuccessful? The available studies[2,7] indicate that rapid reinstitution of invasive ventilatory support may improve outcome. If that is the case, is there a role for noninvasive ventilation (NIV)? A study[18] comparing COPD patients treated with noninvasive pressure support for postextubation hypercapnic respiratory failure to historical matched control subjects found that fewer NIV patients required reintubation and the length of ICU stay decreased. In contrast, a recent preliminary report[19] found similar reintubation rates and mortality in patients with postextubation respiratory failure randomized to NIV compared to those managed with standard care. The high reintubation rate (approximately 70%) in this study suggests that "late" application of NIV may be ineffective and perhaps earlier intervention is warranted. Yet, in a randomized controlled study of all extubated patients, no difference in the need for reintubation was observed when comparing patients receiving immediate postextubation bilevel positive-pressure ventilation delivered via face mask vs those managed with oxygen alone.[20] Further studies are needed to define the role of NIV when applied at the first sign of trouble after extubation.

In conclusion, prediction of extubation outcome is of potential importance because both extubation delay and unsuccessful extubation are associated with a poor outcome. Although accurate prediction remains challenging, the study of Khamiees et al indicates that a systematic, semiquantitative approach to secretion and cough assessment has the potential to identify patients at elevated risk for unsuccessful extubation. Given the findings of this study and those of the report by Cardinal and colleagues,[9] the next step may be to investigate if therapies aimed at enhancing cough and reducing secretions can increase the likelihood of successful extubation. The association of anemia and unsuccessful extubation also deserves further investigation, including studies addressing the question of whether strategies to increase hemoglobin can improve extubation outcome.

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