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Critical Care Update

Weaning

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Mechanical ventilation is 1 of the most commonly used support therapies in the intensive care unit (ICU). Like any other intervention, however, it is not without risk and must be used judiciously because risk increases with each ventilator day. Unfortunately, premature extubation requiring retintubation also results in complications. Various methods have been used to assess patient readiness for ventilator liberation, ranging from physician discretion to nurse- and respiratory therapist–driven protocols. We present here a series of recent publications regarding extubation strategies and postextubation optimization. First, the most recent recommendations from *Chest* and our current weaning practices followed by recent data on postextubation management with noninvasive positive-pressure ventilation and high-flow nasal oxygen and finally new frontiers with proportional assist ventilation and a reminder of the impact of prolonged mechanical ventilation.

Schmidt GA, Girard TD, Kress JP, et al. Liberation from mechanical ventilation in critically ill adults: Executive Summary of an Official American College of Chest Physicians/American Thoracic Society Clinical Practice Guideline. *Chest.* 2017;151:160-165.

Ouellette DR, Patel S, Girard TD, et al. Liberation from mechanical ventilation in critically ill adults: an official American College of Chest Physicians/American Thoracic Society Clinical Practice guideline: inspiratory pressure augmentation during spontaneous breathing trials, protocols minimizing sedation, and noninvasive ventilation immediately after extubation. *Chest.* 2017;151:166-180.

Dries DJ, McGonigal MD, Malian MS, et al. Protocol-driven ventilator weaning reduces use of mechanical ventilation, rate of early reintubation, and ventilator-associated pneumonia. *J Trauma.* 2004;56:943-952.

Mechanical ventilation is an invaluable tool to stabilize the condition of patients in respiratory failure, shock states, or requiring complex medical and surgical multiorgan support. Ventilator treatment should be withdrawn as quickly as possible when no longer necessary to reduce the likelihood of ventilator-associated complications. The clinician should quickly define and treat the underlying cause of respiratory insufficiency, allowing discontinuation of ventilator support at the earliest possible time.

In 1987, Hall and Wood proposed that the gradual withdrawal of mechanical ventilation is probably not needed in the majority of patients. This practice inappropriately shifts physician attention to ventilator manipulation while diverting attention from treatment of the patient pathophysiology. A variety of strategies have been proposed to facilitate separation of the patient from the mechanical ventilator. Although consensus has not been achieved regarding the optimal ventilator settings to permit separation, it is clear that strategies that rapidly identify and allow patients to appropriately make the transition to spontaneous respiration will be successful in the majority of cases. As new strategies for liberation from mechanical ventilation are evolving, physician resources and time needed to provide critical care may be reduced. A growing body of evidence suggests that allied health care practitioners can implement respiratory care protocols with good clinical outcomes for critically ill patients monitored by blood gas analysis and supported by interventions such as chest physiotherapy and early ambulation.

In a statement jointly released by the American Thoracic Society and the American College of Chest Physicians, new consensus recommendations for ventilator weaning have been proposed. The first recommendation from this group is that patients receiving mechanical ventilation for > 24 hours should undergo spontaneous breathing trials with inspiratory pressure augmentation. Typically, this is done with some form of pressure support ventilation. Second, sedation reduction based on institutional protocols is recommended to minimize the risk of prolonged sedation, which increases the duration of mechanical ventilation support. The third and strongest recommendation from this group is that patients deemed to be at high risk for extubation failure who have been receiving mechanical ventilation for more than 24 hours and who have otherwise passed a trial of spontaneous breathing should be extubated to preventive noninvasive (mask or cannula) ventilation. This is the strongest recommendation from this writing group, and additional data on noninvasive ventilation support are provided later. Fourth, in patients who are acutely hospitalized and ventilated > 24 hours, early mobilization protocols are recommended even before the ventilator is removed. Fifth, the authors recommend consistent use of an institutional ventilator liberation protocol. Finally, when patients are determined to be at risk for complications of airway edema after removal of the endotracheal tube, a course of systemic steroids is recommended to reduce airway edema beginning at least 4 hours before extubation. Remarkably, these authors stop short of recommending specific protocols for sedation reduction and ventilator weaning. Only the recommendation for use of postextubation noninvasive ventilation in high-risk patients is considered strong.

The standard weaning protocol in use in my institution begins with sedation assessment using a standard sedation scale, which is recorded to trend the degree of sedation in

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each patient. Patients are then evaluated for propriety of a weaning trial. Criteria for identifying patients as appropriate candidates for a weaning trial include adequate oxygenation; limited minute ventilation; appropriate hemodynamic status; and, perhaps most important, elimination or stabilization of the presenting problem requiring mechanical ventilation. Patients can be excluded from this protocol by physician decision or by the presence of a surgical airway. Evaluation of patients for appropriate weaning takes place on an ongoing basis and is driven by the nursing staff and unit-based respiratory care practitioners.

Patients meeting the initial screening criteria are placed on a spontaneous breathing trial typically involving the use of continuous positive airway pressure with a limited amount of pressure support ventilation consistent with the recommendations of the American College of Chest Physicians and the American Thoracic Society. (We have noted that the use of pressure support ventilation also allowed minimal changes in the ventilator circuit tubing.) Patients are followed closely with recording of respiratory parameters including the rapid shallow breathing index (respiratory rate divided by tidal volume in liters). The duration of this assessment is 20 minutes to 2 hours. At the conclusion of weaning assessment, extubation assessment is performed. Hemodynamic and respiratory status is again evaluated as well as level of consciousness and the ability of the patient to control secretions. Pressure in the endotracheal tube cuff is reduced, and the patient is examined for an air leak around the tube. Patients deemed appropriate candidates for extubation are reviewed with the physician staff based in the ICU, and decisions regarding extubation are made. In routine cases, patients deemed appropriate candidates for extubation are extubated and placed on supplemental oxygen without specific assistance of resident or attending staff. In a survey conducted in our unit a number of years ago, we were able to show a reduction in ventilator-associated pneumonia episodes with use of our ventilator separation protocol.

Jaber S, Lescot T, Futier E, et al. Effect of noninvasive ventilation on tracheal reintubation among patients with hypoxemic respiratory failure following abdominal surgery: a randomized clinical trial. *JAMA*. 2016;315:1345-1353.

Hernández G, Vaquero C, González P, et al. Effect of postextubation high-flow nasal cannula vs conventional oxygen therapy on reintubation in low-risk patients: a randomized clinical trial. *JAMA*. 2016;315:1354-1361.

Spoletini G, Garpestad E, Hill NS. High-flow nasal oxygen or noninvasive ventilation for postextubation hypoxemia: flow vs pressure? *JAMA*. 2016;315:1340-1342.

Respiratory failure after extubation after abdominal surgery or prolonged mechanical ventilation often requires reintubation. Although prolonged mechanical ventilation in the ICU is associated with increased mortality, reintubation is also associated with an increased risk of mortality and respiratory complications including aspiration and pneumonia. Thus, there is significant interest in the identification of strategies to help support patients at risk for postextubation respiratory failure to reduce the need for reintubation and improve ultimate outcomes. Two contemporary options include noninvasive positive-pressure ventilation via a sealed mask and, more recently, high-flow nasal oxygen therapy with delivery of up to 60 L/min flow of gas via loose-fitting nasal prongs. Both strategies avoid invasion of the upper airway and its attendant complications.

Through a combination of variable flow, mask seal, and expiratory valves, noninvasive ventilation may deliver continuous positive airway pressure or bilevel positive airway pressure. In the bilevel mode, higher pressure during inspiration is combined with a lower pressure during expiration similar to what is typically provided by the ventilator with positive end-expiratory pressure (PEEP). Both inspiratory and expiratory pressures are independently adjusted. By applying extrinsic PEEP, noninvasive ventilation may counterbalance the auto-PEEP phenomenon in patients with chronic obstructive pulmonary disease (COPD) and reopen flooded alveoli in acute pulmonary edema secondary to heart failure, resulting in improved gas exchange and lung compliance. In addition, adding inspiratory pressure during noninvasive ventilation assists inspiration and reduces the work of breathing, forestalling the onset of respiratory muscle fatigue and failure. For these reasons, noninvasive ventilation is recommended for patients presenting with respiratory failure in the emergency department, particularly if attributable to COPD or acute cardiogenic pulmonary edema. Unfortunately, patients frequently tolerate noninvasive ventilation poorly because of mask discomfort or claustrophobia associated with these masks, limiting the number of hours per day that mask ventilation can be used.

High-flow nasal oxygen is humidified and delivered at body temperature allowing avoidance of cooling and desiccation of the nasal mucosa and is perceived by most patients to be more comfortable than standard high-flow oxygen masks or noninvasive ventilation. High-flow rates match with the high spontaneous inspiratory flow rates generated by patients with shortness of breath, reducing entrainment of room air and permitting delivery of more consistent fractions of inspired oxygen, which can be adjusted up to 100%. High-flow nasal oxygen flushes out anatomic dead space in the upper airway, improving respiratory efficiency and reducing the respiratory rate. Furthermore, high-flow therapy delivers a low level of positive airway pressure (0.5-1 cm H_2O per each 10-L/min increment) that recruits alveoli and increases end-expiratory lung volume. Humidification of this high-flow gas also promotes mobilization of secretions, whereas less obtrusive nasal prongs permit unimpeded speech and eating. Thus, unlike other forms of noninvasive ventilation, high-flow nasal oxygen is well tolerated and can usually be used continuously for days. In other feasibility studies, ICU and 90-day mortality rates were lower among patients presenting with various forms of respiratory failure in whom high-flow nasal oxygen was used.

Studies can be found to support a role for noninvasive ventilation after extubation including avoidance of reintubation, decreased length of stay, and reduced infectious complications. We are beginning to obtain data related to the optimal role for high-flow nasal oxygen in patients with various forms of respiratory failure; however, very few studies compare high-flow nasal oxygen with noninvasive ventilation. One trial in cardiac surgery patients suggests that high-flow nasal oxygen is noninferior to noninvasive ventilation in reducing the rate of treatment failure, defined as reintubation or differences in comfort, tolerance of therapy, or critical care unit mortality.

A recent issue of *JAMA* includes 2 articles comparing noninvasive ventilation via mask with standard face mask oxygen therapy in 1 trial and high-flow nasal cannula oxygen with standard face mask oxygen therapy on the other. The study of Jaber et al compared noninvasive ventilation via face mask with standard oxygen therapy among nearly 300 patients undergoing abdominal surgery. Noninvasive ventilation reduced the 7-day reintubation rate and increased ventilator-free days at 30 days compared with standard oxygen therapy. Noninvasive ventilation also reduced health care–associated infections but not mortality or hospital length of stay. Infection reduction is consistent with the theoretic advantage of avoiding prolonged endotracheal intubation provided by the use of noninvasive ventilation.

The same issue of *JAMA* included a second article cited from Hernández et al.