Removing the Critically Ill Patient from Mechanical Ventilation

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INTRODUCTION

Mechanical ventilation is a life-saving intervention in a critically ill patient. Ever since the first ventilators were developed, physicians have been working on the best way to liberate patients from them. Efficient weaning from mechanical ventilation is important to decrease morbidity, mortality, and hospital length of stay (LOS). Weaning is a team effort involving nursing, pharmacy, and respiratory therapy. The physician is the leader of the team and must be actively involved in the process. In most cases, weaning is a straightforward endeavor. Occasionally weaning is more challenging and requires skill, experience, and intuition. The following is a practical, evidence-based approach to wean mechanical ventilation, with a focus on surgical patients.

SEDATION, ANALGESIA, AND SEDATION HOLIDAYS

Most patients who are intubated endotracheally need analgesia and sedation. The purpose of analgesia is to control pain. The purpose of sedation is to control anxiety, agitation, and delirium.
**Analgesia**

Fentanyl, hydromorphone, and morphine are common choices for analgesia. Fentanyl has an onset of 1–2 minutes and duration of 0.5–1 hour, which makes it easy to titrate. Morphine and hydromorphone have slightly longer time of onset (2–3 minutes) and longer duration of action (2–4 hours), making these drugs better for longer-term use. Any of these drugs can be used with intermittent dosing or a continuous infusion.1

**Sedation**

Anxiety comes from the noxious stimulation of the endotracheal tube, nasogastric tube, or orogastric tube. Further stimuli include being connected to monitors, blood draws, x-rays being performed, unusual sounds, disruption of sleep/wake cycle, lights being on, noise in general, and being turned. Agitation can also be secondary to baseline mental illness, traumatic brain injury, advanced age, and drugs used in the intensive care unit (ICU).

**Choice of Sedation Agent**

The ideal sedation agent will keep a patient calm and cooperative, has a short half-life, does not cause hypotension, and has a wide therapeutic window. No single agent is good for all situations. For short periods of intubation (<48 hours) intermittent- or continuous-infusion midazolam is an effective and inexpensive drug. For longer periods of intubation (>48 hours), a long-term and cost-effective agent such as lorazepam is ideal, given intermittently or as continuous infusion if needed. Another agent with a short half-life is propofol. This convenience comes with the increased cost and the risk of propofol infusion syndrome.2 Defining the incidence of propofol infusion syndrome is difficult, but the risk definitely increases as the dose and number of days on propofol increases. Dexmedetomidine is an $\alpha_2$ agonist that can provide sedation and analgesia. Dexmedetomidine may have an advantage over midazolam in that there is less time on the ventilator with the trade-off of more bradycardia.3 If agitation from delirium is a component, then an antipsychotic, like haloperidol, can be used.1

**Sedation Level**

The goal is for the patient to be calm and cooperative. Multiple sedation scales have been developed; a commonly used scale is the Richmond Agitation-Sedation Scale (RASS). The RASS scale is reliable and reproducible and correlates with dose of sedation medicines.4 The goal of RASS is 0 (alert and calm) or -1 (drowsy).

**Sedation Holidays**

Excess sedation must be avoided. It is well established that for patients on a continuous infusion of a sedative, and if the clinical situation allows, their sedation should be stopped at least once per day to evaluate their mental status and determine if they can undergo a weaning trial. This sedation holiday has been found to decrease the duration of mechanical ventilation and length of stay in the ICU.5 A further study of 336 nonsurgical ICU patients found that a daily sedation interruption combined with a daily spontaneous breathing trial (SBT) resulted in decreased ventilator days, decreased ICU and hospital LOS, and improved 1-year survival.6

**WEANING TRIALS**

*Is This Patient Ready for a Weaning Trial?*

First, it should be determined why the patient was intubated and if that process is now over. Do they have a traumatic brain injury? Were they intoxicated when they came
into the trauma bay? Do they have COPD? Is it a postoperative CABG that comes back intubated as a matter of protocol? Does the patient have pneumonia? The inciting process that caused respiratory failure should be resolved or improved before starting a weaning trial and working toward extubation.

**What are Ventilator Criteria for Starting a Weaning Trial?**

To start a weaning trial, the sedation should have worn off, and the patient should be awake, alert, and following commands. The patient should have adequate oxygenation (Partial pressure of oxygen >60 mm HG or oxygen saturation >92%) on minimal vent settings such as fraction of inspired oxygen ≤40% and Positive end-expiratory pressure (PEEP) ≤5. There should be no hemodynamic instability, signs of myocardial ischemia, or elevated intracranial pressure.

**How Is a Weaning Trial Performed?**

The most common way to perform a weaning trial is to perform an SBT. The patient is placed on a pressure support trial that provides no scheduled mechanical breaths. The ventilator will provide a continuous-positive airway pressure (CPAP) that is sufficient to overcome the resistance of the ventilator tubing and the endotracheal (ET) tube. Commonly accepted pressure support settings for a weaning trial are 5–8 cm H₂O. Some ventilators have built-in automatic tube compensation feature. The patient should be told about the weaning trial and given reassurance. Neither the fraction of inspired oxygen nor the PEEP is changed during a pressure support trial because they should have already been weaned down.

Another method of doing a weaning trial is a T-piece trial. A T-piece trial is one in which an oxygen tank is connected to a plastic T-piece at the end of the ET tube. It provides blow-by oxygen with minimal positive pressure to help overcome the resistance of the ET tube. Because of the pressure support setting on modern ventilators, T-piece weaning is used much less frequently in ICUs today.

**What Parameters During an SBT Predict Successful Extubation?**

The traditional parameters of a successful trial are:

- Vital capacity (VC) 12–15 mL/kg (840 mL–1050 mL in a 70-kg patient)
- Tidal volume (TV) ≥5–7 mL/kg (350 mL–490 mL in a 70-kg patient)
- Respiratory rate (RR) <25
- Maximum inspiratory pressure (also called negative inspiratory force) ≥20 cm H₂O.

All of these pulmonary numbers are based on predicted body weight, which is calculated from height. For example, a man who is 5 ft, 10 in tall has a predicted body weight of 68.5 kg. This ideal person has the same TV and vital capacity parameters as a man who is 5 ft, 10 in tall weighing 100 kg or 200 kg.

**Rapid Shallow Breathing Index**

An intubated patient who is tachypneic and takes shallow breaths during a weaning trial will continue to take shallow breaths once the ET tube is out, putting him or her at high risk for reintubation. The quantification of rapid and shallow breathing was first described in 1991 as the ratio of the respiratory frequency (f), divided by the tidal volume (Vₜ) in liters. This ratio was subsequently called the rapid shallow breathing index (RSBI). For example, a patient taking 500 mL tidal volumes 20 times per minutes has an RSBI of 40 (20/0.5). An RSBI less than 100 had a sensitivity of 0.97 and specificity of 0.64 and was felt to be the best single predictor of successful weaning. In this
original article, the RSBI protocol was performed with the patient disconnected from the ventilator, the patient breathing room air for 1 minute, and with measurements taken using a spirometer. The RSBI is rarely calculated this way today. Modern ventilators can calculate the RSBI over the time of a weaning trial with the patient still connected to the ventilator.

Subsequent research on the RSBI has been done in different patient populations, and its usefulness as a weaning parameter has been variable. In a study of 40 postoperative surgical patients on a pressure support of 5 cm H₂O, an RSBI of 65 had sensitivity of 0.9 and specificity of 0.8 for successful extubation.⁸

Summary of Parameters

Clinicians cannot always rely on any one number to indicate that a patient will be extubated successfully.⁹ For example, consider a patient with a traumatic brain injury, an RSBI of 63 (f = 21, TV = 0.3) during a weaning trial, and a neurologic examination that shows they are not yet consistently following commands. Extubating at this time may result in the patient accumulating secretions, aspirating, and having subsequent reintubation. A patient like this may be better off with a tracheostomy and weaning them safely off the ventilator from there. Understanding everything that is going on with the patient is imperative to make the best decision about extubation.

PROTOCOL-DRIVEN WEANING FROM MECHANICAL VENTILATION

Traditionally, a physician writes an order for every single ventilator change. A synchronized intermittent mandatory ventilation wean involves gradually turning down the set rate of breaths until the patient is generating all of his or her own breaths. Then potentially a different physician is in charge of the analgesia and sedation regimen. This protocol may cause the patient to stay on mechanical ventilation longer because (1) the sedation level may be too deep for them to participate in a weaning trial and (2) when the patient is awake enough, the ventilator needs to be adjusted in a timely fashion to the appropriate setting so that weaning can take place.

Working together, physicians, nurses, respiratory therapists, and pharmacists developed protocols that allow weaning to happen without a specific directive from the physician. If a patient is deemed ready for a weaning trial, the protocol has the nurse lighten the sedation, and the respiratory therapist makes the vent changes to put the patient on an SBT. This coordination allows weaning trials to take place irrespective of physician workload in the ICU that day or even physician presence at the bedside.

The SBT is done typically once a day, usually in the morning. The typical length of time of the SBT is 30–120 minutes.⁶ An SBT is considered a failure if the patient becomes tachypneic or hypoxic or develops respiratory distress or an arrhythmia. In the event of failure, the patient is immediately returned to a resting mode of mechanical ventilation, such as assist/control or SIMV with a rate of 12–16. If the patient stays on the SBT and meets traditional weaning parameters and RSBI, a physician order is needed to extubate the patient. Most protocols call for the SBT to be done once a day, and if the procedure fails, it is not tried again until the next day. However, if for some reason other factors were not optimal at the time of the SBT (analgesia, sedation, delirium, fluid overload), it may be reasonable to try again later in the day after a period of rest and the other factors have been corrected.

Results of studies of protocol-driven weaning have been encouraging. One study involving medical ICU patients and trauma ICU patients showed the time on the ventilator was decreased by nearly half along with a decrease in VAP.¹⁰ Another study in
a multidisciplinary surgical ICU showed reduced use of mechanical ventilation, lower reintubation rates, and decreased ventilator-associated pneumonia.\textsuperscript{11} Meta-analysis of 11 studies of protocolized weaning showed a 25\% reduction in the total duration of mechanical ventilation for protocolized versus nonprotocolized weaning.\textsuperscript{12} Overall, having a weaning protocol ensures that every patient who is eligible gets an SBT with extubation as early as possible.

**ROLE OF TRACHEOSTOMY**

The common indications for tracheostomy in a mechanically ventilated general surgery and trauma patient are prolonged mechanical ventilation/failure to wean (the most common reason), inability to protect airway (because of head injury or stroke), and inability to cough/handle secretions. The benefits of tracheostomy are less damage to the larynx, easier oral care, decreased work of breathing (less dead space), potentially less time spent in the ICU, and potentially decreased time spent on mechanical ventilation. Timing of tracheostomy has been controversial regarding early (around 7 days) versus late (\(\geq 10\) days). One review and practice guideline showed no mortality difference between early and late tracheostomy. For trauma patients with head injuries, early tracheostomy decreased the days of mechanical ventilation and ICU LOS. For patients without head injuries there is less benefit regarding days of mechanical ventilations and ICU LOS.\textsuperscript{13} Although are conflicting data, early tracheostomy does not seem to prevent ventilator-associated pneumonia.\textsuperscript{14}

**THE DIFFICULT-TO-WEAN PATIENT**

It may be difficult to wean patients off the ventilator for a variety of reasons, including delirium and preexisting lung disease, such as COPD. One aspect of delirium in the ICU is agitation.\textsuperscript{1} An agitated patient is commonly tachypneic; it is difficult to wean a tachypneic patient because their RSBI is high. The source of agitation, for example, inadequate analgesia, inadequate sedation, or delirium, must be controlled. The most common treatment for delirium is haloperidol (Haldol).\textsuperscript{1} Caution is advised to watch for QT prolongation and extrapyramidal side effects from Haldol.

A patient may have decreased lung function because of COPD, which puts him or her at higher risk pneumonia. Treating pneumonia with appropriate antibiotics should result in improved lung function after a few days. A patient with COPD can be a challenge to mechanically ventilate. A general strategy is to avoid hyperinflation by keeping the minute volume \(\leq 8\) L/min, expiratory time \(\geq 4\) seconds, and a breathing rate of 8–12 breaths per minute.\textsuperscript{15} These patients also have airway obstruction that will benefit from bronchodilators, typically albuterol and ipratropium combined, given via nebulizer or metered-dose inhaler. One study found significant improvement in airway obstruction without any change in heart rate or blood pressure.\textsuperscript{16} Finally, COPD patients commonly have hypercapnia and subsequent chronic respiratory acidosis. They compensate for this condition with a chronic metabolic alkalosis, manifested by elevated bicarbonate. Increasing the ventilator respiratory rate to “blow them down” to a normal P\textsubscript{CO}_2 will result in excretion of that excess bicarbonate by the kidneys. Then, as the patient participates in subsequent SBTS, the hypercapnia will return, leading to an acute respiratory acidosis and difficulty weaning.

Once the problem is addressed in a difficult-to-wean patient, a careful wean can proceed. If progress is not being made, proceeding with tracheostomy is reasonable. With a tracheostomy, progressively longer periods are spent on pressure support
followed by progressively longer periods on tracheostomy mask (humidified room air) trials until the patient is completely liberated from mechanical ventilation.

CONSIDERATIONS WHEN WEANING AND EXUTBATING

Is the Patient Going Back to the Operating Room Soon?

Consider the following scenario: The time is noon, the patient meets all criteria for extubation, but they are returning to the operating room the next morning. Should the patient be extubated? The answer is yes. If a patient meets all of the criteria for extubation and the only reason to keep them intubated is a return trip to the operating room they should still be extubated. A patient is always better off being able to cough out their own secretions rather than having them suctioned out.

Airway Swelling and Edema

Airway swelling and edema can contribute to postextubation stridor and subsequent reintubation. One way that has been proposed to predict the development of postextubation stridor is the cuff leak test. The cuff leak test is performed by thoroughly suctioning out the mouth and pharynx above the ET tube cuff. The air is let out of the cuff. There should be an audible sound as air flows around the ET tube. The tidal volumes will be lower on the ventilator, and this amount can be quantified. A further maneuver is to remove the circuit tubing from the ET tube, briefly occlude the end of the tube with a gloved hand, and again listen to see if the patient is moving air around the tube. If no air is moving around the tube, this may be a sign of airway edema. Unfortunately, the cuff leak test is not an accurate predictor of postextubation stridor. But in high-risk patients, it may be most useful as an indicator to be more vigilant in monitoring the postextubation airway.

The 2 common pharmacologic methods of decreasing airway swelling are epinephrine and corticosteroids. Aerosolized epinephrine has been studied primarily in pediatric critical care and it does help to treat laryngeal edema. There is no difference in the efficacy or safety profile between racemic epinephrine and the l-isomer of epinephrine.

The role of corticosteroids to decrease airway swelling is less clear. A Cochrane review of 6 studies in adults found that corticosteroids were most useful when administered as multiple doses begun 12–24 hours before extubation as opposed to just a single dose closer to the time of extubation. Several corticosteroid types and dosages were used in these studies. A reasonable approach is to use corticosteroids only in patients that are at high risk for airway swelling and postextubation stridor. An appropriate corticosteroid dose is methylprednisolone 20–40 mg intravenously every 4–6 hours for 12–24 hours before extubation.

The Patient with the Difficult Airway

For every intubated patient in the ICU the physician in charge of the extubation should know the difficulty of the airway of the patient. This information must be known before extubation, not afterward when the airway is failing and the patient must be reintubated emergently. This information should be obtained by checking the emergency department or anesthesia record noting the Mallampati class, method of intubation (direct laryngoscopy, glidescope, fiberoptic, bougie use), and number of attempts, rather than relying on the nurses or the anesthesia providers to tell you about the difficult airway. If a difficult airway is discovered, a plan should be in place in case the patient needs to be reintubated emergently. Consider having intubation supplies in the room along with a bougie and cricothyroidotomy kit and an expert airway provider if appropriate.
The Patient in a Halo Vest

The most difficult airway is one in a patient in a halo vest because the cervical spine cannot be extended. In addition, if there is a spinal cord injury, the function of the diaphragm and accessory respiratory muscles may be impaired.

From an airway standpoint, first understand why the patient is in a halo vest. Look at the cervical spine images of the patient and understand the anatomy. If there is a spinal cord injury, know if muscles of respiration are affected. If they have had an operative fusion of the cervical spine, know if it was an anterior or posterior approach. Take into account other injuries, age, and comorbidities.

There must be a low threshold for performing a tracheostomy on a patient in a halo vest, because if extubation fails, it may be impossible to reintubate, resulting in death of the patient. Performing a tracheostomy and then weaning from the ventilator is the safe approach. If the patient had an anterior-approach cervical spine fusion with hardware, then waiting approximately 7 days to perform tracheostomy will result in a low risk of wound infection. A percutaneous approach in this setting may be advantageous. It is better to have a living patient with a halo and a tracheostomy than to have a deceased patient and wishing that you would have done a tracheostomy.

WHAT IS THE ROLE OF NONINVASIVE MECHANICAL VENTILATION?

Noninvasive positive pressure ventilation (NPPV) is mechanical ventilation through a tight-fitting facemask. This mask makes it difficult or impossible for a patient to cough out secretions. The mode of mechanical ventilation can be CPAP ventilation or bilevel positive airway pressure (BPAP).

CPAP delivers one level of continuous positive pressure. BPAP has 2 settings: inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). For either setting, the patient must be generating their own breaths. The IPAP is analogous to Pressure Support (PS) on a conventional ventilator, whereas EPAP is analogous to PEEP. A common initial setting for BPAP is “12 over 5,” which means an IPAP of 12 cm H$_2$O with an EPAP of 5 cm H$_2$O. In BPAP, when a patient takes a breath, the machine will increase the pressure to the mask at the level of the IPAP. When the breath is finished, the pressure in the system will be at the EPAP level. For CPAP, the pressure is always at one level regardless of whether the patient is taking a breath.

Important contraindications to BPAP include cardiac arrest, respiratory arrest, inability to cooperate, inability to protect the airway, inability to clear secretions, recent facial surgery or facial trauma, or when prolonged duration of mechanical ventilation is anticipated. NPPV is most useful in patients with a COPD exacerbation or cardiogenic pulmonary edema. It may be useful in patients who are having a hard time after extubation. In this case, a short trial of NPPV can be attempted with careful monitoring of the arterial blood gas. If the patient does not show real improvement after 1–2 hours, they need to be intubated. A Cochrane review of NIPPV as a weaning strategy in adults with respiratory failure showed a positive effect on mortality and VAP rates. Caution is advised when interpreting these results because most patients had COPD and are not generalizable to all ICU patients. A strategy of extubate to BPAP is fraught with danger and only has a chance at working in COPD patients.

BPAP IN GASTRIC BYPASS

Many patients undergoing gastric bypass surgery have diagnosed or undiagnosed sleep apnea and are at risk for postoperative respiratory failure. Can CPAP or BPAP be used after Roux-en-Y gastric bypass? Will the air pressure cause an anastamotic
leak at the gastrojejunostomy? CPAP seems to be safe after Roux-en-Y gastric bypass, particularly for patients that were on it at home and use that same setting in the hospital.\textsuperscript{24} There are case reports of BPAP causing anastamotic leaks,\textsuperscript{25} probably because the BPAP has a higher pressure setting than CPAP. The lack of a pylorus means air can flow freely into the small bowel. CPAP and BPAP must be used judiciously in the postoperative gastric bypass patient, and it is always necessary to clear any intervention with the patient’s surgeon.

**SUMMARY**

Patients must be weaned from mechanical ventilation as efficiently as possible. The most important component of weaning is the protocol-driven daily sedation holiday combined with an SBT. Oversedation must be avoided. Tracheostomy and noninvasive mechanical ventilation are important options to exercise at the right time. Understanding everything going on with the patient gives the best chance of an efficient wean from the ventilator.

**REFERENCES**


