

## ICU CORNER

### Mechanical ventilation: Weaning and extubation

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#### GENERAL INFORMATION

*ICU CORNER is a section of OPUS 12 Scientist dedicated to brief topic reviews geared toward preparation for the various Critical Care Board Examinations. Each quarterly edition of OPUS 12 Scientist will contain one or two condensed overviews, accompanied by a list of selected references. Contributions via regular article submission process are welcome, subject to Editorial Board and Section Editor approval.*

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#### INTRODUCTION

Discontinuation of mechanical ventilatory support represents a milestone in the progression to patient recovery in the intensive care unit (ICU). Despite advances in mechanical ventilation and respiratory support, the science of determining if the patient is ready for extubation is still very imprecise. As a result, reported reintubation rates vary from 2% to as high as 25%, depending on the ICU population studied. The 'optimal' reintubation rate is not known, but it has been postulated that a number between 5% and 10% indicates the 'optimal' point, where relatively few extubations fail but the extubation protocols are not too 'conservative' so as to unduly prevent appropriate extubations.

It has been estimated that over 40% of time spent on mechanical ventilation can be attributed to the weaning process itself. Delays in extubation have been associated with increased complication rates, including ventilator-associated pneumonia, airway trauma, increased hospital costs, and mortality. On the other hand, premature discontinuation of ventilatory support carries its own set of risks, including difficulty in re-establishing an airway, eight-fold higher odds ratio for nosocomial pneumonias, compromised gas exchange, and a 6- to 12- fold increased mortality risk.

Liberation from mechanical ventilation is usually undertaken only after the underlying pathologic process that prompted the initiation of mechanical ventilation is improved or resolved. A focused, simple daily screening can identify patients who are potential candidates for extubation. These assessments are multifaceted, and usually include the overall patient condition and hemodynamic stability, neurological and muscular status, the adequacy of gas exchange, among other variables. Daily screening can reduce the number of patients receiving mechanical ventilation for more than 21 days and has been associated with reduced in-hospital mortality. In approximately 10% to 20% of mechanically ventilated patients, the weaning and extubation process can be very difficult and protracted – a phenomenon

associated with the duration of mechanical ventilation of greater than 21 days.

#### WEANING PARAMETERS

Some of the **objective** parameters used in determining whether a patient is able to come off the ventilator include: (a) PaO<sub>2</sub>/FiO<sub>2</sub> ratio >150-200; (b) level of positive end expiratory pressure (PEEP) between 5-8 cm H<sub>2</sub>O; (c) FiO<sub>2</sub> level <50%; (d) pH > 7.25; and (e) ability to initiate spontaneous breaths. Some of the **subjective** parameters used in determining the ability to liberate from mechanical ventilation include: (a) hemodynamic stability; (b) absence of active myocardial ischemia; (c) absence of clinically significant, vasopressor-requiring hypotension; (d) appropriate neurological examination; (e) improving or normal-appearing chest radiogram; and (f) adequate muscular strength allowing the capability to initiate/sustain the respiratory effort.

Because of the lack of sensitivity and specificity of the criteria listed above, significant research effort was devoted to determining clinically useful **weaning parameters**. There are two prominent reviews published in the late 1990's that generated a set of evidence-based clinical practice guidelines for managing the ventilator weaning process and extubation.<sup>2, 17</sup> Another meta-analysis evaluated a possible role of various clinical measurements as predictors for successful extubation.<sup>19</sup> Cumulatively, this work generated a list of several useful weaning and extubation parameters that are widely used today (**Table 1**). Despite very high sensitivity (78% to 100%), however, these parameters were plagued by low specificity (11% to 36%).<sup>14</sup> Such low specificity in weaning parameters contributes to preventing of weaning and extubation in certain percentage of patients who are otherwise able to breathe independently.

Parameter	Desired value
Respiratory rate	Less than 30-38 breaths/minute
Tidal volume	4-6 mL/kg
Minute ventilation	10-15 L/minute
Negative inspiratory force	-20 to -30 cm H <sub>2</sub> O
Maximal inspiratory pressure	-15 to -30 cm H <sub>2</sub> O
Mouth occlusion pressure 100 msec after the onset of inspiratory effort (P <sub>0.1</sub> ) divided by MIP	0.3
Rapid shallow breathing index (RSBI) (respiratory rate divided by tidal volume)	60-105
Rapid shallow breathing index rate [(RSBI <sub>2</sub> - RSBI <sub>1</sub> )/RSBI <sub>1</sub> ] x 100	Less than 20%
CROP score (an index including compliance, rate, oxygenation and pressure)	13

**Table 1.** Commonly used clinical parameters that predict successful weaning from mechanical ventilation.

## SPONTANEOUS BREATHING TRIALS

Taking the theory a step further, the concept of spontaneous breathing trials was conceived. It may be that the best way to assess whether the patient is likely to tolerate extubation is to perform a trial of spontaneous ventilation. Studies have shown that between 60% and 80% of mechanically ventilated patients can be successfully extubated after passing a **spontaneous breathing trial (SBT)**. However, there is still a lot of controversy as to what is the best way to perform such spontaneous breathing trials, and many studies failed to demonstrate any significant differences between: (a) continuous positive airway pressure of 5 cm H<sub>2</sub>O versus T-piece for one hour; (b) T-piece versus pressure support of 7 cm H<sub>2</sub>O; and (c) duration of spontaneous breathing trial of 30 minutes versus 120 minutes. Given these mixed findings, it may be that the optimal way of interpreting SBT is to combine objective and subjective indicators of intolerance or failure of SBT (**Table 2**).

### Indicator of failure

#### Inadequate gas exchange

Arterial oxygenation saturation (SaO<sub>2</sub>) <85% - 90%  
 PaO<sub>2</sub> <50 - 60 mmHg  
 pH < 7.32  
 Increase in PaCO<sub>2</sub> >10 mmHg

#### Unstable ventilatory/respiratory pattern

Respiratory rate >30 - 35 breaths/minute  
 Respiratory rate change over 50%

#### Hemodynamic instability

Heart rate >120 - 140 beats/minute  
 Heart rate change greater than 20%  
 Systolic blood pressure >180 mmHg or <90 mmHg  
 Blood pressure change greater than 20%  
 Vasopressors required

#### Change in mental status

Coma  
 Agitation  
 Anxiety  
 Somnolence

#### Signs of increased work of breathing

Nasal flaring  
 Paradoxical breathing movements  
 Use of accessory respiratory muscles

#### Onset of worsening discomfort ± diaphoresis

**Table 2.** Indicators of failure during spontaneous breathing trials.

## RSBI RATE

There is also evidence that the rapid shallow breathing index (RSBI) rate, or a measure of change of RSBI over time, may offer more predictive value than its RSBI predecessor. **RSBI = respiratory rate/tidal volume**. The **RSBI Rate** is calculated by obtaining the difference between the initial RSBI and the final RSBI, and then dividing the result by the initial RSBI. The resulting number is then multiplied by 100. The mathematical formula is as follows: **RSBI Rate** = [(RSBI<sub>2</sub> - RSBI<sub>1</sub>)/RSBI<sub>1</sub>] x 100. It was shown that **RSBI Rate** of less than 20% was over 90% sensitive and 100% specific for predicting weaning success. It had a positive predictive value of 100% and a negative predictive value of over 81%.<sup>21, 23</sup>

## EXTUBATION

Once a determination has been made that a patient is likely to tolerate spontaneous, unassisted breathing, a decision has to be made with regards to actually discontinuing the artificial airway. One must keep in mind that failure to extubate can occur for reasons that are not directly related to weaning failure. Several important factors have to be carefully considered prior to extubation, including: (a) the presence of a patent airway; (b) patient ability to consistently protect the airway; (c) patient ability to clear secretions; (d) mental status compatible with maintenance of airway and secretion clearance; and (e) absence of any other reasons for potential post-extubation failure (i.e., severe pain preventing adequate respiratory function, presence of apnea, poorly controlled seizures, risk of massive upper gastrointestinal bleeding, etc).

- *Evidence suggests that the most successful weaning strategy involves the development of a weaning protocol implemented by the nurses and respiratory therapists that begins testing for the opportunity to reduce ventilatory support soon after intubation and reduces the support at every reasonable opportunity*
- *Differences in clinicians' intuitive threshold for reduction and/or discontinuation of ventilatory support may have a greater impact on failure of SBT and/or reintubation than do modes of ventilator weaning*
- *Low levels of pressure support may be beneficial during trials of unassisted breathing*
- *There may be significant benefits to early extubation and institution of NPPV for patients who are alert, cooperative, and ready to breathe without an artificial airway*
- *Many weaning and extubation parameters have relatively poor predictive power, likely due to the presence of selection bias in clinical trials investigating these parameters*
- *The role of computerized weaning protocols has not been established*
- *Identification of factors associated with ventilator dependence (i.e., iatrogenic, mechanical, psychological, process of care factors, systemic disease factors, and long-term hospitalization complications) should concentrate on those factors that are potentially reversible*
- *Intensivist teams should search for ALL causes that are potentially contributory to ventilator dependence for patients requiring mechanical ventilation of greater than 24 hours duration*
- *The removal of the artificial airway from a patient who has been successfully discontinued from ventilatory support should be based on assessments of airway patency and the ability of the patient to consistently protect the airway*
- *Airway assessments generally include testing for the quality of the cough with airway suctioning, the absence of excessive secretions, and/or the frequency of airway suctioning (i.e., every two hours or less frequently)*

**Table 3.** Important points to remember when instituting ventilator weaning and attempting extubation.

There are other important factors that have to be considered prior to extubation. While there is some evidence that successful extubation in comatose patients is possible, most intensivists agree that the patient should show at least some capability to

interact with the environment and the healthcare team prior to removal of the artificial airway. Patients with poor cough and moderate to severe secretions have been shown to have a high rate of failed extubation despite successfully completing SBT. Many of the patients who develop post-extubation stridor can be treated with steroids, epinephrine, non-invasive ventilation, and potentially the use of helium-oxygen gas mixture (Heliox). In general, less than 50% of patients with post-extubation stridor require reintubation.

Another important consideration is the assessment of airway patency prior to extubation. Here, the absence of an audible air leak after endotracheal tube balloon deflation has been associated with an increased risk of post-extubation stridor and subsequent need for reintubation. Another method of assessing the amount of 'cuff leak' consists of dividing the expiratory volume by the inspiratory volume and multiplying the result by 100. The 'cuff leak' value of less than 12% to 16% has been shown to be predictive of extubation failure. Among patients on assist-control ventilation, a 'cuff leak' of less than 110 mL between inspiratory and expiratory volumes has been shown to predict the development of post-extubation stridor.



**Historical note:** Paracelsus (1493-1541) was an alchemist, physician, astrologer, and general occultist. Born Phillip von Hohenheim, he later took up the name Philippus Theophrastus Aureolus Bombastus von Hohenheim, and still later took the title Paracelsus, meaning "equal to or greater than Celsus", a Roman encyclopedist from the first century known for his tract on medicine. At the age of 16 he started studying medicine at the University of Basel, later moving to Vienna. He obtained his doctorate degree from the University of Ferrara. Paracelsus, sometimes called the father of toxicology, wrote: "*All things are poison and nothing is without poison, only the dose permits something not to be poisonous.*"

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## PERSISTENT FAILURE TO WEAN AND/OR EXTUBATE

If failure to wean and/or extubate persists despite maximal and repeated efforts to achieve these endpoints, other steps may be required prior to successfully liberating the patient from mechanical ventilatory support. Some patients require prolonged and more gradual ventilatory weaning, which may be best facilitated by tracheostomy placement. In addition, data from observational studies shows that up to 60% of ventilator-dependent patients who are discharged from the ICU can be successfully weaned when they are transferred to specialized units dedicated to ventilator weaning.

## SUMMARY

The process of weaning from mechanical ventilation and subsequent extubation constitutes a significant portion of the patient's ICU stay. Although many variables for successful outcomes have been identified, specific and reliably reproducible criteria have not been clearly established. Currently, combining objective and subjective endpoints represents the most reliable strategy for weaning from mechanical ventilation and subsequent extubation. Until more reliable weaning and extubation strategies emerge, it may be that weaning parameters are best individualized for each distinct clinical and patient scenario.

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