Narrative Review

Weaning from mechanical ventilation: a narrative review

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Abstract: The process of "weaning" from mechanical ventilation involves several assessments and steps to support a patient in reaching a "liberation" from the ventilator and allow for spontaneous breathing. The weaning process consists of evaluating if the patient is able to breathe with minimal or no ventilation support. This assessment is performed by a diagnostic test named spontaneous breathing trial (SBT), repeated every 24 hours to ensure extubation success. Even though many patients do not meet the eligibility criteria for starting the weaning process, they can still be weaned. For this reason, these criteria should be evaluated in order to assess a possible weaning, rather than adopting absolute standards which have to be met simultaneously. The SBT helps the healthcare professionals to understand the patient's capacity to sustain physiological breathing once they are extubated (or on spontaneous breathing if a tracheostomy tube is maintained in place). Several patients fail to meet the weaning criteria after less than 20 minutes of the SBT. Therefore, a 30-minute trial is enough to estimate the patient's capacity to withhold spontaneous breathing.

Even if the SBT is currently the gold standard method to conduct the weaning trial, it does not prevent the occurrence of complications after extubation such as upper airways obstruction, increased resistance, loss of airway protective reflexes, cough efficiency, and drainage of tracheobronchial secretions. The preventive use of NIV or High Flow Nasal Cannula is strongly recommended for patients experiencing extubation failure and mechanically ventilated for more than 24 hours after an SBT.

A well-performed SBT usually leads to definitive extubation; on the other hand, SBT failure requires a comprehensive investigation on potentially reversible conditions. Prolonged weaning is highly wasteful in terms of time and resources due to the need for a systematic and multidisciplinary approach to successfully face the weaning process.

Keywords: Mechanical Ventilation, Weaning, ICU, Spontaneous Breathing Trial.

Introduction

The process of "weaning" from mechanical ventilation (MV) involves several assessments and steps to aid a patient in reaching a complete separation from the ventilator and obtaining spontaneous breathing. This does not necessarily involve detachment from an artificial airway such as the tracheostomy tube. In fact, even if spontaneous breathing is present, in some cases the patients cannot protect their airways. Therefore, the operator needs to achieve the *"liberation"* of the patient from the ventilator and concurrently from the artificial airway (this usually occurs when the artificial airway is an endotracheal tube). There are multiple advantages in weaning patients from artificial airways; these include reduction of the excessive respiratory work caused by the endotracheal tube, decrease in the risk of ventilator-associated pneumoniae (VAP), promotion of the patient's verbal communication and comfort; reduction of sedation needs, promotion of effective cough, clearance of secretions and sinus improvements.

The weaning process consists of *two phases*[1]:

1. Evaluating if the patient is eligible for weaning;
2. Performing the spontaneous breathing trial (SBT), a diagnostic test to ensure extubation success.

Weaning Eligibility Criteria

Patients that meet the criteria will be considered ready to be weaned from mechanical ventilation. In fact, not extubating patients that fit the criteria for weaning is more damaging than a failed SBT.

Even though many patients do not meet the eligibility criteria, they can still be weaned. For this reason, these criteria should be evaluated in order to assess a possible weaning, rather than adopting absolute standards which have to be met simultaneously. Table 1 summarizes the principles emanated from the International Consensus Conference (ICC)[2], which should be considered prior to starting the SBT procedure.

Table 1: Eligibility criteria for weaning
Resolution of the illness underlying the need for mechanical ventilation (MV) if such illness is the cause for intubation;
Cardiovascular stability (heart rate ≤ 140, systolic blood pressure range of 90-160 mmHg, absence of acute myocardial ischemia, absence or minimal use of vasopressor drugs);
Adequate consciousness levels (evaluate the sedation levels daily and, if possible, reduce them)
Appropriate use of oxygen, defined by $PaO_2/FiO_2 \geq 150$ mmHg, O_2 saturation ≥ 90% with $FiO_2 \leq 0.4$;
Positive End Expiratory Pressure (PEEP) ≤ 8 cmH2O;
Patient collaboration;
Effective cough;
Excessive respiratory secretions;
Respiratory Rate ≤ 35 Respiratory Rate/min;
No significant respiratory acidosis;
Tidal Volume (Vt) > 5 ml/kg with low support;
Rapid Shallow Breathing Index (RSBI) < 105 breaths/min/L
Metabolic stability

Considering the eligibility criteria, this trial allows the healthcare professionals to understand the patients' ability to sustain physiological breathing (or spontaneous breathing if a tracheostomy tube is maintained in place) after extubation. The literature mentions different methods[3]:

- the T-tube, which provides an oxygen supply without the use of positive pressure;
- pressure support ventilation (PSV) up to 5-7 cmH_2O with or without positive end-expiratory pressure (PEEP) and Automatic Tube Compensation (ATC);
- continuous positive airway pressure (CPAP).

The SBT performed through a T-tube junction (Figure 1) shows several advantages:

1. better patient's psychological conditions as if he/she was extubated[3].
2. hidden cardiomyopathies, such as coronary artery disease or left ventricle dysfunction, can be revealed during the SBT by an increase in venous return, due to the negative transthoracic pressure and cardiac work induced by spontaneous breathing in T-Tube[4].
3. the T-tube SBT can reduce MV duration, especially in patients with difficult weaning[5].

Figure 1. T-tube example

A 30-minute trial is enough to estimate the patient's capacity to withhold spontaneous breathing.[6] Several patients show failure of weaning criteria after less than 20 minutes of the SBT. In the presence of a tracheostomy tube, the removal of this device should be evaluated according to the following criteria:

- adequate swallowing ability (ensuring that there is no risk of aspiration);
- Glasgow Coma Scale > 8;
- spontaneous cough reflex;
- ability to manage secretions;
- attentive and collaborative level of consciousness.[7,8]

If SBT is successful, the next step will be extubation, or in the case of a tracheostomy tube, the patient will be maintained under spontaneous breathing through the device. Table 2 reports the weaning recommendations, which should occur on a daily basis.[1]

Table 2: Weaning recommendations on a daily basis

Healing Process (MV)	Reduce or minimize sedation levels
	Use ventilation modes that allow the patient to have a spontaneous breathing
	Daily awakening trial
	Mobilize patients as soon as possible and frequently
Weaning readiness	Standardize screening and weaning procedure
	Early check for eligible criteria even if the primary cause of MV is still present
	Avoid excessive ventilator assistance
	Observe that every ventilator breathing is triggered by the patient (prevent and avoid systematic auto-cycling)
	Disconnect the ventilator if RSBI < 105 breaths/min/L
Weaning trail	At least once a day
	SBT ~ 30 min
Extubation if SBT is successful	Promote cough
	Evaluate risk of upper airways obstruction (glottis oedema)
	Consider preventive NIV for COPD patients
	Evaluate prophylactic NIV use in patients with high risk of post extubation respiratory failure
	Do not delay re-intubation if weaning is failed
Difficult weaning	Diagnostic workup: respiratory pump insufficiency, lung parenchymal dysfunction, myocardial dysfunction
	Correct all the reversible causes for weaning failure and illnesses, and repeat the SBT
	Consider BNP measurements to find hidden cardiomyopathies
Weaning long term	Consider the plan for a tracheostomy to improve the patient's comfort and the chances to be weaned from MV
	Global (multidimensional) approach including nutrition, psychological factors and sleep cycle
	Consider specialized units if available to achieve the goal of weaning
	Discuss realistic goals to achieve with the patient

Legend: *BNP (Brain Natriuretic Peptide), COPD (Chronic Obstructive Pulmonary Disease), MV (Mechanical Ventilation), NIV (Noninvasive Ventilation), RSBI (Rapid Shallow Breathing Index), SBT (Spontaneous Breathing Trial).*

Failed Spontaneous Breathing Trial criteria

The criteria to detect the failure of a SBT are listed in Table 3.

Table 3: Subjective and objective criteria to detect SBT failure

Subjective	Objective
Agitation, anxiety, dyspnea	$PaO_2 \leq$ 50-60 mmHg with $FiO_2 >$ 50%
Altered sensorium, drowsiness	$PaCO_2 >$ 50 mmHg or increase > 8 mmHg
Peripheral or mucosal cyanosis	pH < 7.32 or pH decrease more than > 0.07 from the baseline
Diaphoresis	RR > 35/min or 50% increase from the baseline
Increased work of breathing (WOB) with the use of accessor respiratory muscles	Heart rate> 140/min or 20% increase from the baseline
	Systolic blood pressure> 180 mmHg or 20% increase from the baseline
	Systolic blood pressure < 90 mmHg
	Cardiac arrhythmia

Locate and resolve the cause (when possible) if an SBT fails. The most likely physiological causes of SBT failure are reported in Table 4. Eligibility criteria screening for SBT should be repeated every 24 hours to determine whether the extubation will be successful.[2,9]

Even if the SBT is currently the gold standard method to conduct a weaning trial, it does not prevent the occurrence of complications after extubation, such as upper airways obstruction, increased resistance, loss of airway protective reflexes, cough efficiency, and drainage of tracheobronchial secretions.[10] The preventive use of NIV or High Flow nasal cannula (HFNC) is strongly recommended in patients experiencing extubation failure and mechanically ventilated for more than 24 hours after an SBT.[11,12]

With adult patients in the acute phase of an illness that are mechanically ventilated for more than 24 hours, early mobilization and rehabilitation are recommended by the guidelines[11], to increase the chances of weaning and extubation. Patients who fail an SBT should be provided proper ventilation support to avoid fatigue.[13] Healthcare providers must set adequate levels of ventilator inspiratory support allowing the respiratory muscles to relax.

Table 4: common pathophysiological conditions, that can negatively impact weaning from mechanical ventilation.[2]

Respiratory load	Increasing respiratory work: inadequate ventilator settings
	Low compliance: VAP; pulmonary oedema cardiogenic or not; pulmonary fibrosis; pulmonary hemorrhage; diffuse pulmonary alveolar infiltrates.
	Bronchoconstriction and airflow obstruction
	Increased resistive load: • during SBT: endotracheal tube; • after extubation: glottis oedema; increased airway mucus secretions; sputum retention.
Cardiac load	Hidden cardiovascular disease
	Increased cardiac workload up to a dysfunctional myocardium
Neuromuscular	Respiratory drive: metabolic alkalosis; sedative-hypnotic drugs
	Ventilatory central command: neuromuscular respiratory failure
	Ventilator-induced diaphragmatic dysfunction
	Peripheral neuropathy: primary cause of weakness, numbness and pain.
Neuropsychological	Delirium, depression, and anxiety
Metabolic	Metabolic disorders linked to corticosteroids and hyperglycemia
Nutrition	Overweight, malnutrition
Anaemia	-

Classification

The weaning process is determined by the number of attempts and the time employed to liberate the patient from MV. The ICC classification is composed of three categories:

- Simple weaning: liberation from the ventilator/successful extubation after the first spontaneous breathing trial;
- Difficult weaning: liberation from ventilator/successful extubation after two or three SBTs and below seven days from the first attempt;
- Prolonged weaning: liberation from the ventilator/successful extubation after three or more SBT or more than seven days from the first attempt.

Successful weaning from a ventilator is identified when the patient does not need to be reintubated, nor any ventilatory support needs to be restored 48 hours after removing the endotracheal tube.

ICC classification presents some limitations. In 2007 two categories were not included: patients deceased before an SBT trial, and those discharged from ICU but still ventilated. ICC does not specify how to categorize tracheostomized patients and offers an unclear definition for patients undergoing NIV support within 48 hours after extubation. ICC is based on the SBT but does not consider the fact that several patients are not weaned with planned extubation. Several authors of this categorization have yet to be able to identify specific ICC definitions to classify other patients with different results in their studies.

In 2017 REVA network (Reseau Européen de Recherche en Ventilation Artificielle) submitted the WIND[14] categorization, which defines weaning as the beginning of any type of liberation trial.

For Intubated patients

1. Attempt to liberate from mechanical ventilation: SBT with or without extubation or direct extubation (whether planned or unplanned without an SBT).
2. Attempt to liberate from mechanical ventilation: non-occurred death or reintubation seven days after the extubation, regardless of whether NIV has been used or discharged from ICU. The actual weaning date is calculated retrospectively with respect to the extubation after the patient has completed seven days without reintubation.

For tracheostomized patients

- Attempt to liberate from mechanical ventilation: 24 hours or more in spontaneous ventilation mode through the tracheostomy tube without the use of mechanical ventilation.
- Attempt to liberate from mechanical ventilation: 7 consecutive days in spontaneous ventilation mode through the tracheostomy tube without using VM or the patient's discharge in spontaneous ventilation mode.

This classification includes four groups based on the weaning process duration (successful weaning or premature death). The "No weaning" group includes patients who have not had an SBT; "Short weaning": interruption within the first 24 hours of the first weaning attempt (successful weaning or premature death); "Difficult weaning": weaning has been completed after more than 24 hours but less than a week from the first attempt (successful weaning, or premature death); "Prolonged weaning": weaning process has not been successful within first seven days (successful weaning, or premature death).

Conclusions

The process of weaning critically ill patients from mechanical ventilation has significantly changed during the last forty years. The two-phased approach (daily evaluation of eligibility criteria and the SBT) is an effective procedure for early liberation from mechanical ventilation.

A well-performed SBT generally leads to definitive extubation. On the other hand, SBT failure requires a comprehensive investigation of the potentially reversible conditions. To prevent reintubation, precautionary NIV and HFNC after the extubation is also recommended. Prolonged weaning is highly wasteful in terms of time and resources due to the need for a systematic and multidisciplinary approach that successfully deals with the weaning process.[1]

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