Arch Crit Care Med. 2016 November; 1(4):e8363. doi: 10.17795/accm-8363.

Published online 2015 November 28. **Review Article**

Weaning the Patient from the Mechanical Ventilator: A Review Article

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Received 2015 October 01; **Revised** 2015 October 15; **Accepted** 2015 November 15.

Abstract

Weaning the patient from mechanical ventilation is a major challenge for the intensivist. "Wean" means to separate gradually. The term "Liberation" is a better term since the patients can be more quickly removed from the ventilator based on their clinical conditions. In this review article, the initial required criteria to start and weaning methods from mechanical ventilation were evaluated based on various studies; and at the end, the protocol for separation of mechanical ventilation is recommended. Studies showed that prolonged mechanical ventilation is associated with ventilator-associated complications such as pneumonia, ventilator-induced lung injury and increased mortality. Making premature or delayed decision in weaning the patient from the ventilator increases the mortality rate. Studies also showed that using clinical parameters for weaning the patient from the ventilator is better than clinical judgments alone. Duration of weaning from the ventilator must be more than 40% of the duration of full support ventilation. The method of SIMV is not suitable for weaning from the ventilator, while spontaneous breathing test is more suitable. After improving oxygenation, first Fio2, PEEP, and then respiratory rate are reduced. Weaning from the ventilator starts early in the morning. The infusion of sedating medications should be discontinued and, if necessary, administered by bolus infusion. In case of intolerance, weaning from the ventilator will be postponed to 24 hours later.

Keywords: Weaning, Mechanical Ventilation, Intensive Care Unit

1. Introduction

From the first moment that the patient is connected to the ventilator for mechanical ventilation, the goal is to wean the patient from the ventilator and let the patient to tolerate breathing spontaneously. Weaning from the ventilator at intensive care units is a major challenge for intensivist. "Wean" means to separate gradually. The term "Liberation" is better since the patients can be more quickly removed from the ventilator based on their clinical conditions (1-3).

If the patient does not tolerate spontaneous breathing trial or needs a re-intubation within 48 hours, weaning failure occurs (4).

Weaning can be divided to three categories: simple, difficult, and prolonged. If the patient can be weaned from the ventilator at the first attempt, it is called simple weaning. If the patient cannot be weaned from the ventilator at the first attempt, during less than seven days or less than three attempts, the weaning is called difficult. If after three times the patient cannot be separated from the ventilator or the weaning process lasts more than seven days, it is called prolonged weaning (4, 5).

The most common causes of mechanical ventilation include acute respiratory failure, pneumonia, heart failure, sepsis, trauma, and acute respiratory distress syndrome (ARDS). Studies showed that prolonged mechanical ventilation is associated with complications such as ventilator-associated pneumonia; ventilator induced lung injury and increased mortality (1, 2, 6-11).

Making premature or delayed decision in weaning the patient from the ventilator increases the mortality rate. Studies also showed that using clinical parameters for weaning the patient from the ventilator is better than clinical judgments alone (1, 4, 12).

In this review article, the initial required criteria to start and the weaning methods from mechanical ventilation were evaluated based on various studies; and at the end, the protocol for separation of mechanical ventilation was recommended.

2. Parameters of Weaning from Ventilator (Recognition of Readiness to Wean)

Factors and variables that should be checked before weaning from the ventilator and corrected to near normal

condition are all summarized below.

Underlying cause of acute respiratory failure has started to improve. There should be no evidence of sepsis (5, 13).

Cardiovascular status should be stable, no arrhythmia. Blood pressure should be stable without the need for vasopressors such as dopamine at high doses (2, 4, 13).

The patient should be conscious, and cough and gag reflex should be intact. In case of patient's loss of consciousness, weaning should be done after tracheotomy (4, 13, 14).

Patients should have PEEP less than or equal to 5 cm H_2O, or Fio_2 less than or equal to 40%, Pao2 equal or more than 60 mmHg (2, 4).

Inspiratory tidal volume in spontaneous breathing should be more than 5 mL / kg. The minute ventilation to maintain normal levels of Paco2 should be less than 10 liters or more than 5 liters/minute. Vital capacity of the patient should be more than 15 mL / kg. In spontaneous breathing, respiratory rate of patients must be less than 25 minutes; respiratory rate should be calculated for one minute (4, 5, 15).

ABG (Hco3-PH-Pco2-Po2) should be in the normal range. Shunt ratio should be less than 20% and Pao2 / Fio2 $\geq$ 150. Static compliance should be more than 25 mL/cm H_2O (13, 15, 16).

P 0.1 indicates normal respiratory drive and its normal range is less than 3 - 6 cm H_2O. Its measurement in patients with chronic obstructive pulmonary disease (COPD) is very important to start weaning from mechanical ventilation (17).

Weaning index or Rapid Shallow Breathing Index (RSBI) should be $\leq$ 105. The RSBI refers to the number of breaths per minute divided by the tidal volume in spontaneous breathing by liters. It is also called Tobin index and is the most important criterion for weaning. If the index is less than 105, it is likely to have a successful weaning of more than 80%. If it is more than 105, it is likely to be about 95% to have a failure in the weaning process. In asthma patients, this number is recommended to be less than 80 (4, 18-22).

The difference of A-ao_2 should be less than 350 mm Hg with Fio_2 equal to 100% (9). maximum inspiratory pressure (MIP) should be more than 25 cm of water (11). Capacity of arterial oxygen (hemoglobin) should be normal (2, 5, 13, 15).

Intravascular volume should be normal and the urine flow should be 0.5 mL / kg per hour. The patient should have a normal condition in terms of electrolytes such as calcium, potassium, phosphorus and magnesium. Nutritional status of patients should be normal (13, 23, 24).

3. Key Points Regarding the Strategy of Weaning from the Ventilator

Once a day, the infusion of sedative drugs should be discontinued and the patient's level of consciousness and weaning parameters should be evaluated. The infusion of sedating medications should be discontinued and, if necessary, administered by bolus infusion; this can shorten the duration of weaning (2, 25, 26).

Duration of weaning from the ventilator must be more than 40% of the duration of full support ventilation (27).

Immobility causes muscle weakness and delays weaning. Therefore, moving the patient, bringing down the patient from bed, and even walking with a ventilator, if the patient is tolerating, can make the weaning of the patient from the ventilator faster (4).

Positive balance of fluid increases the risk of intolerance for weaning. Because hypervolemia increases lung water and requires higher PEEP, the administration of diuretics may be helpful in these cases (2).

Weaning from the ventilator should be done in the morning and it should be tried to not last to midnight. If the patient tolerated weaning from the ventilator during the day, it can be continued during the night (2, 5, 13).

If the patient did not tolerate weaning from the ventilator, the level of support begins to make the patient feel comfortable. Retrying to wean from the ventilator will be postponed to 24 hours later (2, 13, 28).

Weaning methods include (1, 4, 29):

1- Gradual decreased mandatory respiratory rate (SIMV weaning)

2- Spontaneous breathing test (T. Piece weaning)

3- Gradual reduction in pressure (Pressure support weaning)

4- The continuous positive airway pressure (CPAP) method

5- The synchronized intermittent mandatory ventilation (SIMV) + pressure support ventilation (PSV) weaning

6- Non-invasive positive pressure ventilation (NIPPV) weaning

7- New methods for the weaning of mechanical ventilation

Symptoms of intolerance in weaning the ventilator include respiratory rate higher than 35 per minute or 10% more than basic number. Increased respiratory rate is the first sign of intolerance. Other symptoms include Spo_2 less than 90%; heart rate higher than 140 or 20% more than the basic number; systolic pressure higher than 180 mmHg or less than 90 mmHg; anxiety, sweating, cardiac arrhythmias; increased Paco2 8 mmHg or PH less than 7.30; loss of consciousness (4, 5).

The synchronized intermittent mandatory ventilation (SIMV) method: mandatory breathing can be gradually reduced from 12 to 4 every four hours. Speed of mandatory breathing reduction depends on the patient's tolerance. By reducing mandatory breathing, symptoms of intolerance would be evaluated. This method alone is used less frequently. Today, ventilators also need CPAP and PSV in addition to SIMV (5, 30, 31).

Pressure support ventilation (PSV) method: in this method the pressure support starts 10 - 20 cm H_2O. Acceptable respiratory rate is 12-25 per minute. Gradually, 2-5 cm H_2O is decreased daily to reach a low level of pressure support of 5-10 cm H_2O (to overcome the resistance caused by the endotracheal tube and circuit). If the patient had weaning index of $\leq$ 105 after half an hour to two hours, the patient was be separated from the ventilator (2, 5).

The continuous positive airway pressure (CPAP) method: the patient is connected to the ventilator and the patient respiratory rate, tidal volume and other respiratory parameter are monitored. This method can be useful in patients who are at risk of atelectasis and hypoxemia after weaning from the ventilator. CPAP is usually used by 5 - 10 CmH_2O (4).

Spontaneous breathing trial (SBT) method: In this method, after the initial evaluation (especially surgical patients and duration of ventilation less than a week), the assisted mandatory ventilation turns to one of the spontaneous breathing methods and then if the patient tolerates, endotracheal tube can be removed. There are three methods for spontaneous breathing (4, 5).

1- CPAP: In this method CPAP 5- 10cm H_2O with the minimum PSV are used to overcome the circuit resistance for patients, who are at risk of hypoxia (2, 4).

2- Pressure support ventilation (PSV): In this method, patients are supported with minimum pressure support to overcome the circuit resistance. However, if the pressure is higher than 8 cm H_2O, it is called support breathing (2, 4).

3- Spontaneous breathing: In this method, the patient will not receive any assisted ventilation, and patients are connected to the mechanical ventilation or T-piece with specified FIO_2, and the tidal volume and respiratory rate depends on the patient's efforts. The ventilator monitors all the inspiratory and expiratory tidal volume, respiratory rate, airway pressure, FIO_2 and respiratory system compliance and alarms any changes in the patient's condition, especially apnea (2, 4).

Non-invasive positive pressure ventilation (NIPPV) weaning: In this method, in case of consciousness and improvement of the underlying disease and acceptable oxygenation, extubation can be done and noninvasive ventilation with biphasic positive airway pressure (BiPAP) can be connected; then, gradually the assistance levels decrease to wean the patient from the ventilator. This method shortens the weaning duration and is recommended for COPD patients (4, 32, 33).

The non-invasive ventilation (NIV) method is appropriate for the prevention of re-intubation, but in a patient, who developed respiratory distress after extubation, this method is not appropriate, the patient must be intubated and receive mechanical ventilation (4, 33).

Extubation: The endotracheal tube can be removed if the patient could tolerate spontaneous breathing with T-Piece for 30 - 120 minutes and there should be no impairment of ABG, state of consciousness or cardiac function. Early removal of the endotracheal tube (early extubation) increases the possibility of re-intubation and postponed extubation increases complications related to the endotracheal tube. First, the process is completely explained to the patient to decrease their anxiety. Re-intubation equipment must be prepared. The patient should be in a sitting position. The suction is used in patient's mouth and airway. After deflation of the endotracheal tube, the tube comes out at the end of expiration and then supplemental oxygen is provided by mask or nasal catheter. By controlling ABG and clinical status, the supplemental oxygen is gradually reduced until full termination. Fifteen percent of patients need re-intubation (2, 4, 34).

4. Protocol of Weaning from the Ventilator

Daily review of the patients for weaning from the ventilator should be based on a specific protocol to reduce ICU hospitalization and improve the outcome (1, 4, 34).

In short, to reduce the risks of weaning, a combination of the above methods can be used. When the patient has acceptable oxygenation with 50%, the ACMV mode must be turned to SIMV to reduce the respiratory rate. Then, it is gradually reduced to reach eight. Then PSV mode is selected with support level of 10 - 15 cm H_2O and the support level is gradually reduced based on respiratory rate to 8 cm H_2O. If the patient tolerated this (Table 1) for an hour, Wean index is calculated. If it is less than 105, the patient can be separated from the ventilator and connected to the T-Piece with oxygen.

Figure 1 shows the weaning process based on BTS / ICS, SCCM and ATS guidelines with little or no modification in accordance with ventilator facilities and levels of nursing education in Iran. According to guidelines, the appropriate level of PEEP to start weaning is less than 8 cm H_2O. We believe the appropriate level of PEEP for weaning is 5 cmH_2O.

In COPD patients, BTS / ICS Guidelines recommended that the patient should breathe with minimal (< 8) or no PS during the SBT (35)

Table 1. Patients Lack of Tolerance Criteria

Number	Patients Lack of Tolerance Criteria
1	RR > 35/min
2	Decreased arterial PH < 7.32
3	Spo2 < 90%
4	Increased Etco2 > 10 mmHg
5	HR > 140/min or 20% increase in HR
6	Increased respiratory effort (nasal flaring)
7	SBP > 180, DBP > 90 mm Hg or Hypotension
8	Anxiety
9	Diaphoresis

Abbreviations: RR, respiratory rate; Spo2, saturation of peripheral of O_2; HR, heart rate; SBP, Systolic blood pressure; DBP, Diastolic blood pressure.

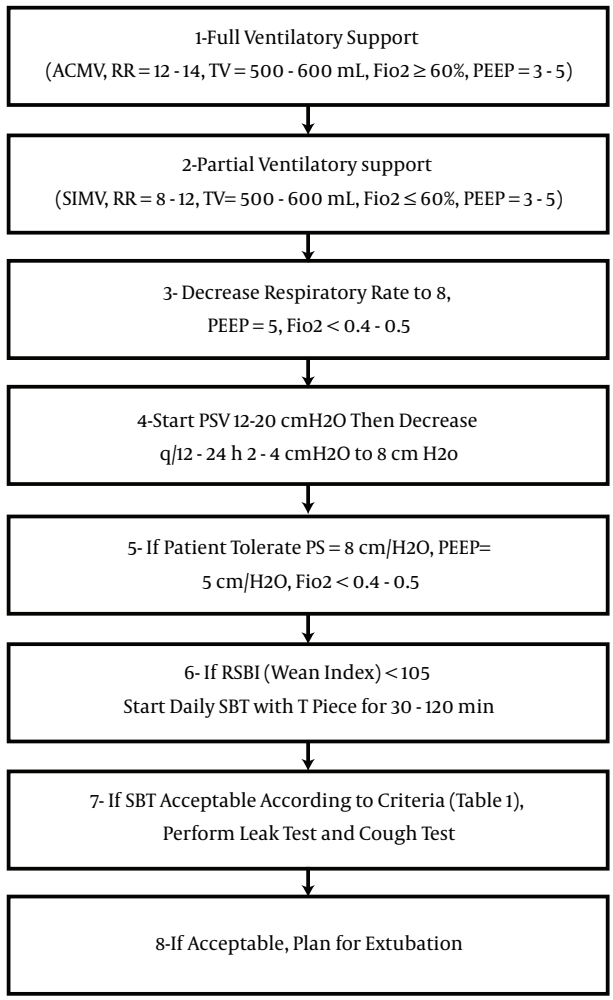

Figure 1. Recommended Steps for Weaning

According to certain guidelines computer-automated weaning is recommended, but currently except in some special centers of Iran, there is not enough advanced ventilator and adequate trained nurses for this method.

5. Conclusion

The time required for weaning from ventilator must be more than 40% of the duration of mechanical ventilation. The SIMV method is not suitable for weaning from mechanical ventilation, but spontaneous breathing methods are suitable for weaning. After improving oxygenation, the Fio_2 and PEEP should be first reduced, followed by reduction of respiratory rate (by changing the mode). Weaning from the ventilator starts in the morning. At the time of weaning, the infusion of sedating medication should be stopped and administered via the bolus method if necessary. Weaning from the ventilator should be done once a day in the morning.

In case of intolerance, weaning from the ventilator can be postponed for 24 hours. One parameter should be removed each time and at the same time it should be tried not to reduce the amount of oxygen and PEEP, respiratory rate, and the PS level. A maximum of 10% - 15% of support level should be reduced each time. The support level should not be reduced earlier than 30-120 minutes.

6. Future Research on Weaning of Mechanical Ventilation

Familiarity with new methods for weaning from ventilator such as PAV (proportional assist ventilation), ASV (adaptive support ventilation), Auto mode, ATC (automated tube compensation), NAVA (neural adjusted ventilation assisted), and knowledge base system (KBS) will be higher in the future and the weaknesses of the methods will be resolved (4, 5, 13, 36-38).

New methods of mechanical ventilation have the benefits of pressure ventilation with a minimum delivery guarantee of tidal volume. Patients need less breathing tasks and are more comfortable that way. In this methods, the volume or pressure are controlled based on physiology feedback of patient's breathing. In KBS, the ventilator is set on PCO2 (Capnography), and tidal volume and respiratory rate are applied with regards to variables that the user sets. These methods have the ability to gradually decrease the support level. Today, new ventilation techniques are also used for weaning of mechanical ventilation from the ven-

tilator, but the widespread use of these methods requires further studies (4, 39, 40).

Acknowledgments

Hereby, the significant cooperation of Ms. Damavandi and Ms. Heidarnia in treatment and nursing processes is highly appreciated and we thank the clinical research development unit of Rouhani Hospital of Babol.

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