WEANING FROM MECHANICAL VENTILATOR

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WEANING

- ***Weaning from mechanical ventilation means the transition from total ventilatory support to spontaneous breathing.***
- **Usually a rapid and smooth process in most of the patients**
- **Can become a progressive and prolonged process in 20–25% of the cases. These patients require a systematic approach for successful liberation from the ventilator.**

- **Weaning has two components:**
  - **Liberation from the ventilator**
  - **Extubation.**

Step 1: Identify readiness for weaning

- **Weaning should never be hurried as it can be successful only when the patient is ready both physically and mentally.**
- **At the same time, it should also not be delayed as it is associated with complications.**

- **Any patient on MV should be considered for weaning if he/she fulfils the readiness criteria as mentioned below.**

1. Prerequisites “readiness criteria”

- **The underlying reason for MV has been stabilized and the patient is improving.**
- **The patient is hemodynamically stable on minimal-to-no pressors.**
- **Oxygenation is adequate (e.g., PaO2 /FiO2 > 200, PEEP < 5–8 cm H2O, FiO2 < 0.5).**
- **The patient is able to initiate spontaneous inspiratory efforts.**
- **Besides these criteria, the patient should be**
  - **Afebrile (temperature <38°C),**
  - **Have stable metabolic status (pH ³ 7.25),**
  - **Adequate hemoglobin (e.g., Hb > 8–10 g/ dL), and**
  - **Adequate mentation (e.g., arousable, Glasgow coma scale >13).**

2. Understand the predictors of successful weaning

- **The predictors of successful weaning have been designed from physiologic parameters to help the decision-making process. However, none of the tests alone are particularly powerful, and clinical judgment is of paramount importance.**

- **Rapid shallow breathing index (RSBI) is assessed by putting patient on T-piece for 2 min (>3min by some authors)**
  - **– *F (frequency)/V t (tidal volume in litres) less than 100 is predictor of* successful weaning.**
  - **– The threshold of 100 is not binding and can be relaxed by 10–20 in patients with endotracheal tube size less than 7 and in women.**
- **Minute ventilation less than 10 L/min.**
- **Respiratory rate (RR) less than 35 breaths/min.**
- **Maximum inspiratory pressure more negative than −30 cm H 2 O.**
- **Vital capacity >10 ml/kg.**

Step 2: Prepare for weaning

- **Stop continuous infusion of sedation daily to awaken the patient to do Spontaneous awakening trial(SAT) (Daily Sedation Vacation)**
- **Communicate with patient, explain the procedure, and calm them.**
- **Record baseline parameters and keep flow sheet at the patient's bedside.**
- **Keep a calm peaceful environment and have the nurse or physician remain at the bedside to offer encouragement and support.**
- **If patient fails SAT , restart sedation on half of the previous dose.**
- **If patient passes the SAT after stopping sedation, assess the patient for spontaneous breathing trial (SBT) based on the prerequisites criteria mentioned in step 1.**

- **Clinical Criteria of SAT failure**
  - **Anxiety, agitation, or pain**
  - **Respiratory rate >35/min**
  - **SpO2 <88%**
  - **Respiratory distress**
  - **Acute cardiac arrhythmia**

Step 3: Do spontaneous breathing trial (SBT)

- **Whenever possible, position the patient upright in bed.**
- **Thoroughly suction the endotracheal tube and ensure patency.**

- **Any of the following modes can be chosen for SBT:**
  - **A. T-piece:**
  - **B. Pressure support:**

- **Duration: The duration should be 30–120 min—shorter time for the patients on the ventilator for less than 1 week and longer for the patients on prolonged MV.**

Step 3: Do spontaneous breathing trial (SBT) Cont.

- T-piece:
- **Patients are disconnected from the ventilator and made to breathe humidified oxygen—air mixture through a T-piece connected to the endotracheal/ tracheostomy tube for 30–120 min.**
- **Increased respiratory load is offered by the endotracheal tube. Dyspnea and fatigue should be carefully avoided.**

Step 3: Do spontaneous breathing trial (SBT) Cont.

- Pressure support:
- **The pressure support level is to be gradually reduced, titrated to RR and patient comfort.**
- **A level of 6–8 cm H_2O pressure support is considered to overcome the tube resistance.**
- **Put the patient on PS of 6–8 cm H 2 O and PEEP of 4-6 cm H_2O.**

- **Duration: The duration should be 30–120 min—shorter time for the patients on the ventilator for less than 1 week and longer for the patients on prolonged MV.**

Step 4: Monitor closely

- **Patient comfort, dyspnea, and all vital and respiratory parameters should be closely monitored. SBT should be terminated if it fails**
- **SBT should be tried at least once in 24 h. More frequent SBTs do not help.**
- **At the end of the trial, if it succeeds, the patient is considered for extubation.**

Failure of SBT

- **Objective measurements**
  - **PaO 2 < 50–60 mmHg on FiO 2 ³ 0.5 or SaO 2 < 90%**
  - **PaCO 2 > 50 mmHg or an increase in PaCO 2 > 8 mmHg**
  - **pH < 7.32 or a decrease in pH > 0.07 pH unit**
  - **Rapid shallow breathing index >105**
  - **RR > 35 or an increase of >50%**
  - **Heart rate >140 or an increase of >20%**
  - **Systolic blood pressure >180 or an increase of >20%**
  - **Systolic blood pressure <90**
  - **Cardiac arrhythmias**

Failure of SBT (Cont.)

- **Subjective clinical assessments**
  - **Agitation and anxiety**
  - **Depressed mental status**
  - **Diaphoresis**
  - **Cyanosis**
  - **Evidence of increasing effort**
  - **Increased accessory muscle activity**
  - **Facial signs**

Step 5: Extubate the patient

- After undergoing a successful SBT, a few more criteria should be fulfilled before deciding about extubation:
- Adequate cough reflex—spontaneously or while suctioning.
- Patient should be able to protect airways, and they should follow simple commands.
- Secretions should not be copious.
- A cuff leak of less than 110 mL measured during assist-control ventilation helps to identify patients who are at high risk of developing postextubation stridor/ obstruction of airway.
- No radiological or surgical procedure is being planned in the near future.
- Extubation should not be done at the end of the day.

TABLE 16-6 Weaning Protocol for Mechanical Ventilation

Step	Criteria	Results
1	Does the patient show: • Evidence of some reversal of underlying cause for ventilatory failure? • Presence of inspiratory effort? • Hemodynamic stability? (absence of myocardial ischemia, hypotension, use of vasopressor) • Adequate oxygenation and acid-base status? (PaO_2/F_1O_2 >150 mm Hg, PEEP <8 cm H_2O and pH ≥7.25) • Light sedation or better? (brief eye contact to voice command)	If YES to *all five* questions, proceed to STEP 2. If NO to *any one* question, postpone weaning until next day.
2	Perform and measure rapid shallow breathing index (RSBI or f/V_T) with mandatory frequency turned off and pressure support ≤8 cm H_2O, PEEP ≤5cm H_2O, measurements taken following ≥3 min of spontaneous breathing. Is RSBI (f/V_T) < 100 breaths/min/L?	If YES, proceed to STEP 3. If NO, postpone weaning until next day.
3	Can patient tolerate: Spontaneous breathing trial for up to 30 minutes without termination? (See termination criteria* below.)	If YES, proceed to ventilator discontinuance or evaluate for extubation. If NO, repeat weaning until next day.

Termination criteria: Spontaneous frequency >35/min for 5 min; SpO2 <90%;Heart rate >140/min or 120% of baseline; Systolic pressure >180 mmHg or <90 mm Hg; Signs of anxiety or use of accessory muscles.

Step 6: Monitor for extubation failure

- After extubation, the patient should be observed closely for signs of extubation failure as mentioned below:
- RR more than 30/min for 2 h
- Heart rate more than 140 beats/min or sustained increase or decrease of more than 20%
- Clinical signs of respiratory muscle fatigue or increased work of breathing
- SaO 2 less than 90%; PaO 2 less than 80 mmHg, on FiO 2 more than 0.50
- Hypercapnia (PaCO 2 > 45 mmHg or >20% from preextubation), pH < 7.33

Step 7: Try noninvasive ventilation (NIV)

- If the signs of extubation failure are present, the physician should try NIV particularly in conditions where its role is proved; for example, in COPD, postoperative failure after lung resection surgery, or decompensated obstructive sleep apnea.
- NIV has the advantage of reduced complications and better patient interactions.
- However, it is important to keep in mind that it should not delay reintubation (if required), and every hour that a patient spends on NIV when intubation is clearly required increases mortality and delays recovery.

Step 7: Try noninvasive ventilation (NIV) (Contd.)

- **NIV is used in three clinical settings:**
- – As an alternative weaning technique for the patients who failed SBT: Extubate and put on NIV—well-documented role in COPD patients without signi fi cant comorbidities and in centers with expertise in NIV use.
- – As a prophylactic measure for the patients with a high risk of reintubation: Studied in postoperative patients. Start NIV electively after successful SBT and extubation.
- – As the treatment of respiratory insuffi ciency after extubation (postextubation failure): Useful in COPD.

Step 8: Identify difficult weaning

- Weaning success is defined as extubation and the absence of ventilator support 48h following extubation.
- ***Weaning failure*** *is defined as one of the following:*
- – Failed SBT
- – Reintubation and/or resumption of ventilator support following successful extubation
- – Death within 48 h following extubation
- The term ***weaning in progress*** *is used for the patients who are extubated, but* remain supported by NIV.
- ***Difficult weaning*** *—Patients who fail initial weaning and require up to three SBT* or as long as 7 days from the first SBT to achieve successful weaning.
- ***Prolonged weaning*** *—Patients who fail at least three weaning attempts or require* more than 7 days of weaning after the first SBT.

Step 9: Ascertain the cause of weaning dif faculty

- Carry out a detailed examination of the patient, and look for the cause of difficult weaning.

- Make a checklist based on pathophysiologic mechanisms:
- **I. Inadequate respiratory drive**
- Excess of sedatives
- Central nervous system abnormality
- Sleep deprivation

- **II. Inability of the lungs to carry out gas exchange effectively**
- Unresolving pneumonia
- Unresolved pulmonary edema/ fluid overload
- Undiagnosed pulmonary embolism
- The splinting effect of obesity, abdominal distension, or ascites

Step 9: Ascertain the cause of weaning dif faculty (Contd.)

- **III. Respiratory muscle fatigue/weakness**
- Nutritional and metabolic deficiencies
- Critical illness polyneuropathy/myopathy
- Hypokalemia
- Hypomagnesemia
- Hypocalcemia
- Hypophosphatemia
- Hypoadrenalism
- Hypothyroidism
- Corticosteroids: myopathy, hyperglycemia
- Chronic renal failure
- Systemic disease sepsis: impaired diaphragmatic force generation

Step 9: Ascertain the cause of weaning dif faculty (Contd.)

- Refractory hypoxemia and hypercapnia
- Persistently increased work of breathing
- Ineffective triggering, auto-PEEP
- Increased resistance due to ventilator tubings or humidification devices
- Poor cardiac performance
- Neuromuscular dysfunction/disease
- Drugs
- **IV. Anxiety**
- It is difficult to distinguish anxiety from ventilatory failure. If in doubt,
- always presume it to be ventilatory failure.
- **V. Psychological dependency in difficult weaning**

Step 10: Treat all the reversible causes identified

- Provide good nutrition, but avoid overfeeding.
- Have good glycemic control (110–140 mg/dL).
- Correct metabolic factors (especially metabolic alkalosis).
- Maintain hemoglobin above 7–8 g/dL.
- Maintain adequate cardiac output and tissue perfusion.
- Treat arrhythmia.
- Treat hypothyroidism and steroid deficiency or excess.
- Control the patient's underlying illness.
- Abolish ventilator dysynchrony with appropriate inspiratory flow and trigger settings.
- Change of the mode of ventilation may help improve patient–ventilator
- interactions.

Step 10: Treat all the reversible causes identified (Cont.)

- Reverse bronchospasm as much as possible and reduce dynamic hyperin fl ation.
- Drain out signi fi cant pleural effusions and ascites.
- Treat intraabdominal hypertension.
- Treat pulmonary edema aggressively.
- Discontinue the use of steroids, aminoglycosides, colistin, and statins, if possible.
- Avoid flu id overload in renal failure and cardiac failure—do dialysis if indicated.
- Make the patient comfortable.
- Aggressive physiotherapy and mobilization.
- Reverse oversedation.
- Treat anxiety: Improve patient communication, use relaxation techniques, and
- give low-dose benzodiazepines.
- Diagnose and treat narcotic/benzodiazepine withdrawal.
- Treat delirium and depression.
- Ensuring nighttime sleep may be helpful.

Step 11: Plan the weaning process in difficult weaning

1. Select the mode of ventilation

- **The mode of ventilation used should provide adequate respiratory support and prevent diaphragmatic atrophy.**
- **Pressure support ventilation: It is most commonly used, and has been shown to be better than SIMV for weaning.**
- **Continuous positive airway pressure (CPAP): Besides the usual benefits of**
- **improved oxygenation and improved left ventricular function, it has bene fi cialrole in selected patients with hypoxemic respiratory failure.**
- **Automatic tube compensation: It may be helpful in narrow endotracheal tubes to overcome tube resistance.**
- **Proportional assist ventilation: It has been studied with CPAP and shown to improve respiratory mechanics.**
- **Adaptive support ventilation: It has been shown to be better than SIMV in postcardiac surgery patients.**
- **Control Mechanical Ventilation (CMV): It has logical use in patients showing**
- **respiratory fatigue on spontaneous mode. So it is recommended to use this mode in cases of dif fi cult weaning at night to give rest to the muscles.**

Step 11: Plan the weaning process in difficult weaning (Contd.)

2. Plan tracheostomy.

- Percutaneous tracheostomy has been shown to have fewer complications than
- surgical tracheostomy and to be more cost-effective (see Chap. 96).
- Potential bene fi ts of using tracheostomy in diffi cult-to-wean patients are as follows:
  - Decreased work of breathing
  - Reduced requirement of sedation and improved patient comfort and
- cooperation
  - Earlier reinstitution of oral feeding
  - Less chances of accidental extubation
- In spite of the above-mentioned bene fi ts, tracheostomy has not been consistently
- shown to decrease mortality. It has resulted in a number of dependent
- survivors. It facilitates easier bedside management of such patients.

Step 11: Plan the weaning process in difficult weaning (Contd.)

3. Do aggressive physiotherapy and mobilization

- **Physiotherapy and mobilization are prerequisites for successful weaning.**
- **Early institution of physiotherapy in a protocol-driven approach and daily assessment to achieve maximum mobility is now an integral part of ICU management.**

4. Select proper place for weaning

- **Cost-effective care has been shown to be provided in respiratory intermediate care units and specialized regional weaning centers. It requires team effort and expertise**

Step 12: Choose a weaning protocol

- **Protocol-driven weaning has more chances of success, reduced costs, and probably reduced mortality. Two basic weaning protocols are used for a prolonged weaning patient:**
  - **Progressive reduction of ventilator support**
  - **Progressively longer periods of SBTs**
- **No significant difference in weaning success and mortality rate, duration of ventilatory assistance, or total hospital length of stay is reported between these two weaning techniques in the difficult-to-wean patients. A combination of both the protocols can also be used.**

Weaning using PSV

PSV	(1) PSV may be used in conjunction with spontaneous breathing or SIMV mode; (2) Start PSV at a level of 5 to 15 cm H_2O (up to 40 cm H_2O) to augment spontaneous V_T until a desired V_T (10 to 15 mL/kg) or spontaneous frequency (≤25/min) is reached; (3) Decrease pressure support (PS) level by 3 to 6 cm H_2O intervals until a level of close to 5 cm H_2O is reached; (4) If patient tolerates step (3), consider extubation when blood gases and vital signs are satisfactory.

Weaning using SIMV

SIMV (not recommended as a stand-alone mode for weaning)	(1) Reduce SIMV (ventilator) frequency by 1 to 3 breaths per min; (2) Monitor SpO_2, obtain ABG as needed; (3) Reduce SIMV frequency further until a frequency of 2 to 4/min is reached. This may take only hours for patients with normal cardiopulmonary functions but days for those with abnormal functions; (4) If patient tolerates step (3), consider extubation when blood gases and vital signs are satisfactory.

Based on the results of the sixth International Consensus Conference on Intensive Care Medicine, **synchronized intermittent mandatory ventilation (SIMV)** should be avoided as a stand-alone weaning modality (Boles et al., 2007). However, SIMV remains an effective tool in providing partial ventilatory support during continuous mechanical ventilation.