

Weaning from mechanical ventilation in 21st century

Dr. P .K .Dash.

Additional Professor in Anaesthesiology
Sree Chitra Tirunal Institute for Medical Sciences ant Technology
Trivandrum 695011
Kerala

Mechanical ventilation is an art supported by numerous scientific inputs. Weaning or more precisely discontinuation from mechanical ventilation is most difficult process and includes post extubation care.

We shall discuss this topic under the following heads

- Introduction
- Spontaneous Breathing Trial
- Reversible contributors to ventilator dependence
- Pressure Support
- Process of Weaning
- Protocolised weaning process
- Non Invasive ventilation
- Tracheostomy
- Conclusion

Introduction:

Mechanical ventilation is a lifesaving intervention used to treat hundreds of thousands of critically ill patients each year. Among the many goals of care in these patients one is certainly most important ie. early liberation from the ventilator. Clinical trials conducted in the 1990s, compared multiple approaches to ventilator weaning and produced results that established the efficacy of a daily spontaneous breathing trial (SBT) for expediting liberation from mechanical ventilation. Use of patient-targeted sedation protocols also improve patient outcomes.

Decision to intubate and mechanically ventilate a critically ill patient obligates a physician to later decide when it is appropriate to allow spontaneous, unassisted ventilation and to proceed with extubation. Patients who pass an SBT and then undergo a trial of extubation (TOE) may fail because of airway incompetence (ie, they are aspirating but not yet breathing rapidly and shallowly or developing worsening hypoxemia) or because of primary respiratory failure (ie, hypoxemia due to developing shunt as with atelectasis or pulmonary edema, or rapid shallow breathing as occurs with increments in respiratory load).

Delays in this process are associated with significant increase in hospital costs, morbidity, and mortality. The benefits of shortening the duration of mechanical ventilation have long been suspected, and this led many physicians to develop methods for “weaning” their patients from mechanical ventilation.

Most such patients are extubated quite readily. As many as 20% of mechanically ventilated patients, however, will fail in their first attempt at weaning, and more than 40% of the total duration of MV is spent in the weaning process. In a national survey from major Canadian teaching hospitals, approximately 95% of Physicians acknowledged ever performing spontaneous breathing trials (SBT) in clinical practice. Of these, 95.6% and 32% reported conducting daily and twice-daily screening to identify SBT candidates, at least sometimes.

Spontaneous breathing trial

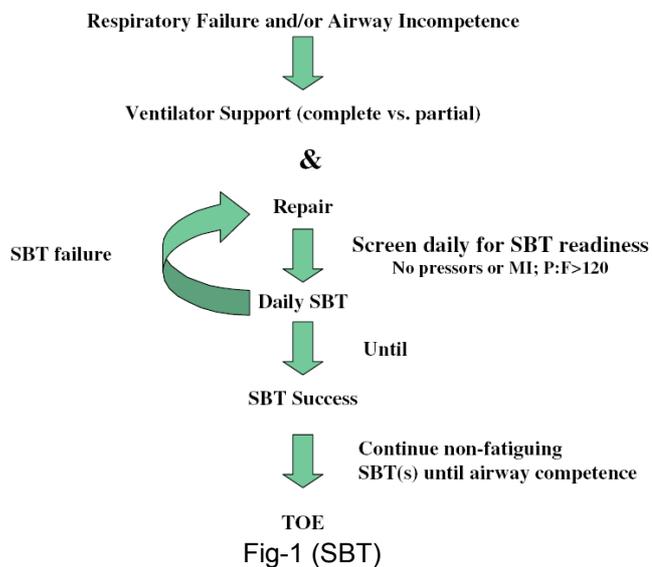
The three most common techniques to conduct SBT included;

- pressure support (PS) with positive end-expiratory pressure (70.8%),
- continuous positive airway pressure (35.7%),
- use of a T-piece (25.0%)

When you fail to wean look for the key elements to optimize weaning

- Determine cause of ventilatory dependency
- Rectify correctable problems
 - Pulmonary gas exchange
 - Fluid balance
 - Mental status
 - Acid-base status
 - Electrolyte disturbance
- Consider psychological factors
- Optimize posture
- Provide ambulation

The process of spontaneous breathing trial is like this



Identifying patients who are candidates for SBT

Hemodynamic parameters

Nearly all studies and reviews published to date have suggested patients should be “hemodynamically stable” before weaning . Accordingly, measures of hemodynamic stability including blood pressure and absence of cardiac ischemia have been those most often cited as prerequisites for studies and clinical guidelines.

Are patients who require vasoactive medications candidates for SBT?

Shock is expected to increase the work of breathing (increased CO₂ production associated with lactic acidosis) while the respiratory muscles are not receiving adequate substrate. If shock cannot be reversed rapidly, and work of breathing is excessive, it is theoretically reasonable to assume the work of breathing for the patient by initiating mechanical ventilation to allow a limited oxygen delivery to other shocked organs. SBT might be conducted with great care, after considering the relative risks (worsened cardiopulmonary status) and benefits (earlier extubation).

Are patients with evolving or threatening myocardial infarction or ischemia candidates for weaning?

The optimal timing for SBT following a documented myocardial infarction (MI) has never been studied. Most patients with acute MI do not require endotracheal intubation and mechanical ventilation, but those who do are most often in shock or suffering severe left ventricular dysfunction precipitating congestive heart failure. In this particularly ill subset begin SBT when myocardial ischemia and/or infarction are treated as evidenced by normalization of the electrocardiogram and decreasing cardiac enzymes. In this manner, monitoring of electrocardiograms and cardiac enzymes, coupled with resolution of pulmonary edema to sufficient oxygenation (PaO₂/FiO₂), guides when to begin SBT safely.

Is there any maximal or minimal heart rate threshold for performing SBT?

SBTs are not performed on patients with

- (1) bradycardia requiring pacemaker placement (eg, complete heart block),
- (2) sinus tachycardia >140/min
- (3) sustained tachyarrhythmia.

Nearly all clinicians are likely to agree that these three situations are potentially life threatening and the augmentation of catecholamines during weaning and/or risks of cardiac arrest outweigh potential benefits associated with earlier extubation.

Respiratory parameters

The landmark study on weaning parameters, published by Yang and Tobin examined whether a number of respiratory parameters measured during 1 to 2 minutes of unsupported breathing, including respiratory rate, tidal volume, minute volume respiratory mechanics, oxygenation, and f/Vt, predicted weaning outcomes.

Three variables predicted failure very well:

- tidal volume <325 mL (negative predictive value [NPV] = 94%),

- negative inspired pressure >-15 cmH₂O (NPV = 100%),
- $f/V_t > 105$ /min/L (NPV = 95%).
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The f/V_t was most consistently and powerfully predictive of both SBT and extubation outcomes

Is there a body temperature above which SBTs should not be performed?

There are no data suggesting that body temperature in itself (not accompanied by other signs of sepsis) precludes successful weaning. In fact, in a study conducted of septic patients on their first day of weaning, 26% (6 of 23) of those with maximal temperatures $>38.3^{\circ}\text{C}$ in the previous 24 hours were successfully extubated. Accordingly, hyperthermia by itself should not be used to preclude SBTs testing for readiness.

Is there a hemoglobin below which SBTs should not be performed?

Although data supporting that anemia negatively impacts weaning outcomes are sparse, it was found that patients with $\text{Hgb}\% < 10$ g/dL were five times as likely to fail to wean successfully compared with those > 10 g/dL. But as of now it is not appropriate to gate SBT based on circulating hemoglobin concentration.

Monitoring during SBT

When patients develop subjective distress that is not allayed with bedside coaching, sustained hypertension, tachycardia, or tachypnea during SBTs, the trial is abandoned BEFORE the patient fatigues and/or experiences cardiorespiratory collapse associated with acidemia and/or hypoxemia in the late stages of failure.

The parameters are wide and range from heart rate to Gastric intramucosal pH

Identifying patients who have passed SBT who are candidates for a trial of extubation (TOE)

Once a patient has “passed” an SBT, again determined by the parameters monitored and described above, clinicians must determine whether patients require the endotracheal tube. “Airway competence” infers sufficient airway reflexes (eg, cough, gag) to

- prevent secretions from above the glottis from dripping continually into the trachea,
- clear secretions that have dripped down from above or been produced below the glottis to above the glottis so they can be swallowed or suctioned.

Upper and lower airway reflexes are a complex symphony of neurologic inputs to coordinate muscles that gag, cough, and swallow. In addition, intact sensory pathways are required. Global neurologic condition may also be germane, so that patients who do not sense their secretions can be instructed to cough, or to sigh and combat atelectasis on command. The amount of airway secretions is the final important variable, since excessive or tenacious secretions may overwhelm competent airways.

Post-test probability of extubation failure was nearly 50% in patients who had passed an SBT but who had two of three negative prognostic signs:

- excessive secretions (>2.5 mL/H),
- weak cough (<60 L/min),
- gross neurologic dysfunction

Reversible contributors to ventilator dependence

Improve Neuromuscular Capacity

- Treat sepsis
- Reduce sedatives and narcotics to least needed to awaken rapidly without agitation (consider using ultra-short-acting agents in anticipation of SBT)
- Avoid exhausting breathing trials (stop trials or add more support if frequency >35/min)
- Eliminate excess work of breathing during fully supported breathing (preferably by using ventilator mode and settings – flow characteristics, tidal volume – that promote synchrony/comfort)
- Nutritional support without overfeeding (aim to achieve a normal prealbumin)
- Identify and treat cardiac ischemia in vulnerable patients (eg, SBT failure with new wheezing)
- Replace Potassium, Magnesium and Phosphate to normal
- Limit use of neuromuscular blocking drugs to only if absolutely necessary (eg, ARDS with high PEEP or life-threatening status asthmaticus)
- Consider stopping aminoglycosides and reducing corticosteroids
- Consider rare causes including: Neurologic disease/occult seizures, Hypothyroidism
- Critical illness myopathy/polyneuropathy

Reduce Respiratory Load

Resistance

- Bronchodilators
- Remove excess airway secretions
- Corticosteroids only if aerosolized bronchodilators fail to reduce Raw <20 cmH₂O
- Treatment of upper airway obstruction due to edema (eg, corticosteroids)

Elastance

- Treat pulmonary edema (proactively retrieve excess salt/water with diuretics)
- Treat pneumonia
- Reduce intrinsic PEEP with bronchodilators and corticosteroids if necessary

- Drain large pleural effusions
- Decompress abdominal distention and drain large ascites
- Evacuate pneumothoraces

Minute volume

- Treat sepsis
- Antipyretics
- Correct metabolic acidosis
- Resuscitate shock and hypovolemia
- Reduce intrinsic PEEP (contributing to dead space) with bronchodilators
- Maintain least PEEP possible
- Identify and treat pulmonary embolism
- Avoid overfeeding

Improve Oxygenation

- Attention to fluid balance and retrieval of fluid in recovery phase of illness
- Identify and treat pneumonias early
- Identify and treat atelectasis (with sighs, tidal volumes sufficient to recruit without overdistending; eg, tidal volume yielding $P_{plat} = 20\text{--}25$ cmH₂O; or intermittent positive pressure breathing when atelectasis complicates extubation)
- Identify and treat cardiac ischemia if contributing to SBT failure

Pressure Support Ventilation

In 1989, Kacmarek and colleagues described pressure support ventilation (PSV) for the management of adult patients who required mechanical ventilation. PSV was designed to provide an inspiratory pressure assist during spontaneous breathing to overcome the imposed work of breathing. Refinements in ventilator technology and signal detection enabled the use of PSV in the neonatal population in the early 1990s.

PSV is delivered to the mechanically ventilated patient during spontaneous breathing. It is a triggered mode, with changes in airway pressure or flow used as the trigger signal. Following detection of spontaneous patient effort, the ventilator delivers a breath that is flow cycled but time limited.

Successful weaning of the SIMV rate in preterm infants must be accompanied by an increase in spontaneous inspiratory effort to compensate for the reduction in mechanical support. Increased mechanical loads and poor spontaneous respiratory effort are common in preterm infants, however, and may delay the weaning process. The addition of PSV during weaning provides elastic unloading, averts diaphragmatic overexertion and fatigue, and facilitates the weaning process by alleviating some of the resistive work of breathing.

PSV, one of the newest ventilatory modes, provides an inspiratory pressure boost during spontaneous breathing to overcome the imposed work of breathing. Currently, RCTs comparing PSV with the newer synchronized ventilatory modes remain limited, but all

available data indicate that PSV is safe and well tolerated even when used in premature extremely low birth weight newborn infants. Preliminary application of PSV to the neonatal population shows great promise.

Process of Weaning

Weaning from mechanical ventilation is the process of reducing ventilatory support, ultimately resulting in a patient breathing spontaneously and being extubated. This process can be achieved rapidly in >80% of patients when the original cause of respiratory failure has improved. The remaining cases will require a more gradual method of withdrawing ventilation.

A general algorithm

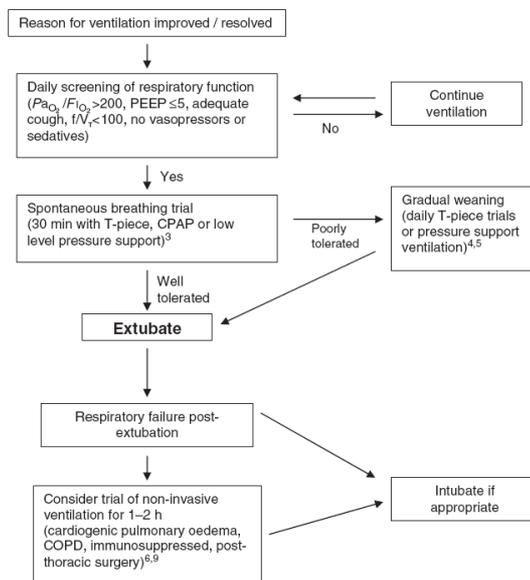


Fig-2 (Weaning)

Protocolised weaning process

The whole aim of such an approach is discontinuation of mechanical ventilation within limited resources utilising non physician health care professionals

Several studies have evaluated weaning parameters to identify patients who are ready for extubation and how to apply those parameters in a guideline or protocol for the weaning to be successful in the shortest possible time is an example of such a guideline. The initial step in any protocol-driven ventilator weaning is daily screening for readiness to wean using several weaning parameters. To do so, every appropriate patient in the ICU also should undergo a daily interruption of sedation to be in optimal neurological condition for the screening.

An example is given here

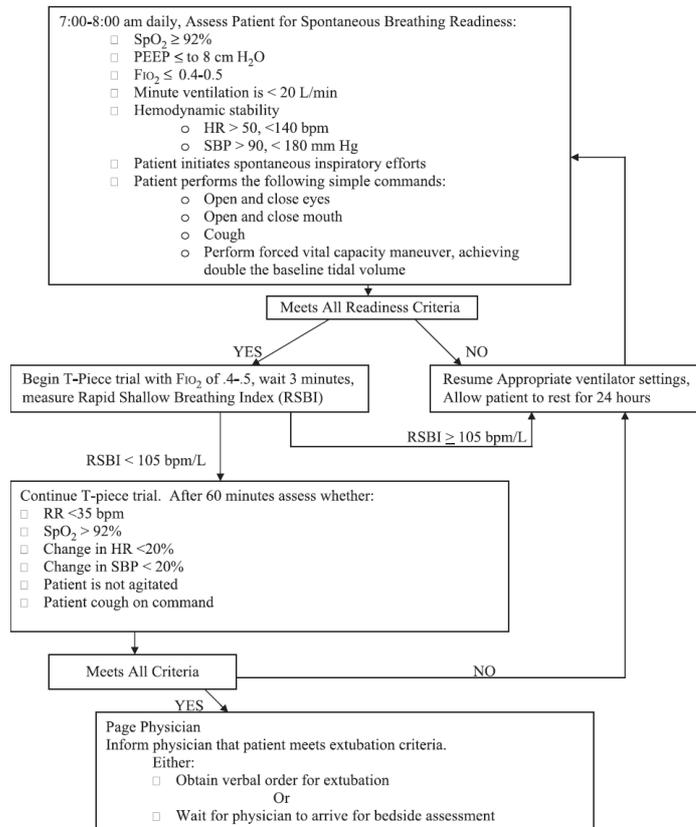


Fig-3 (Protocolised approach)

Non invasive ventilation

Patients who are re-intubated have higher complication and mortality rates. Non-invasive ventilation could not only avoid intubation in some patients, but may also have a role in preventing re-intubation in patients who have failed extubation. Patients with chronic obstructive pulmonary disease (COPD), and those who are immunosuppressed with bilateral infiltrates, have been shown to have reduced intubation and mortality rates with the application of non-invasive ventilation. Benefit has also been demonstrated for patients with cardiogenic pulmonary oedema. Whether non-invasive ventilation has advantages over CPAP has yet to be proven for this group of patients (one study actually showed a higher rate of myocardial infarction with use of noninvasive ventilation).

Studies looking at heterogeneous populations with acute hypoxaemic respiratory failure have found no benefit in using non-invasive ventilation to facilitate the discontinuation of conventional ventilation or avoid re-intubation. Only trials looking at patients with COPD or

cardiogenic pulmonary oedema, or with a predominance of such patients, have demonstrated improved survival, decreased pneumonia rates and decreased length of intensive care stays under these circumstances.

Tracheostomy

The incidence of disease requiring mechanical ventilation is increasing. Anywhere from 5% to 13% of mechanically ventilated patients will go on to require prolonged support. With such a large and increasing population of mechanically ventilated patients, critical care physicians will frequently face the dilemma of whether to perform tracheostomy. The decision is a complex one, requiring a detailed understanding of the risks and benefits of both tracheostomy and prolonged translaryngeal intubation. It must also be individualized, taking into consideration the patient's preferences and expected clinical course.

A suggested algorithm using Heffner's "Anticipatory Approach" and integrating the current data. (TLI is Translaryngeal Intubation) (Fig-4)

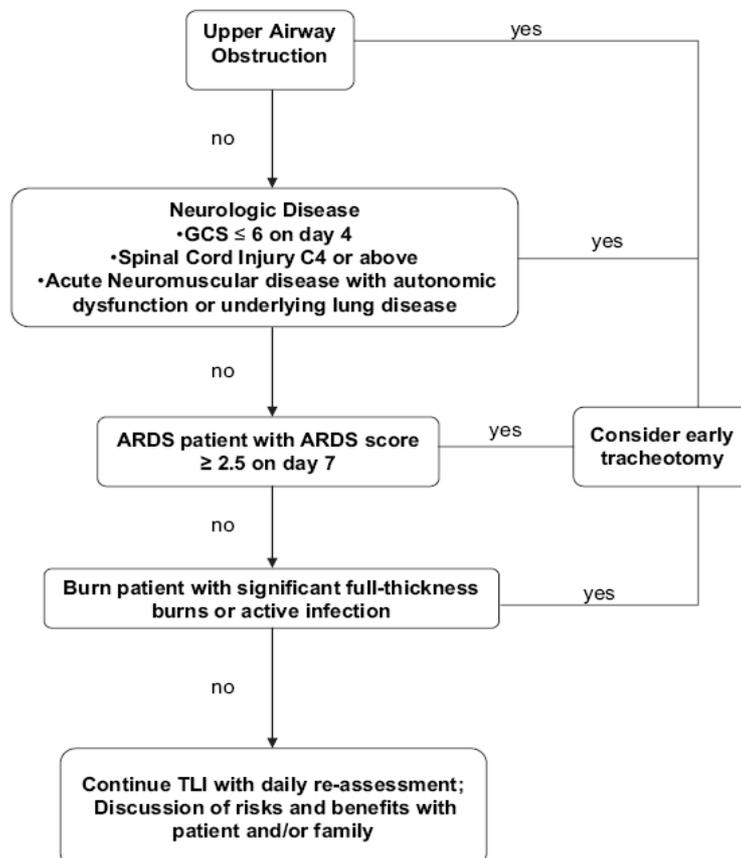


Fig-4 (Tracheostomy)

Conclusion

All patients receiving ventilatory support should be assessed on a daily basis for their suitability for weaning. This may involve meeting several preconditions, and then an SBT. If unsuccessful, weaning should be attempted using either PSV, or daily spontaneous breathing periods of increasing duration. A tracheostomy may be helpful in patients who are difficult to wean. Over 95% of patients should be weanable in this way. A few patients per year may need referral to a long-term weaning unit.

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