South Afr J Anaesth Analg. 2022;28(5 Suppl 1):S178-181
https://doi.org/10.36303/SAJAA.2022.28.5.2897

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

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Weaning from mechanical ventilation

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Keywords: mechanical ventilation, invasive procedure, respiratory system support

Introduction

Mechanical ventilation (MV) is an integral part of intensive care for critically ill patients.[1] The first mechanical ventilators and ventilatory support were made popular in the early 1950s during the polio epidemic. The first ventilators were bulky and mainly negative pressure ventilators. Over the years the development of positive pressure ventilators has progressed significantly. There has been a significant improvement in technology, ventilatory software and ventilatory modes from different positive pressure ventilator developers.

Invasive mechanical positive pressure ventilation is an invasive procedure requiring airway intubation or tracheostomy.[2] The current common mechanical ventilators target or control pressure and volume variables. Ventilator breaths can be continuous mandatory ventilation (CMV), assisted (patient triggered), synchronised intermittent mandatory ventilation (SIMV), or spontaneous breaths.[2,3]

Critically ill patients require MV as a form of respiratory system support to improve oxygenation, ventilatory support and reduce work of breathing. Invasive mechanical ventilation (IMV) is required in patients needing airway protection or with hypoxic and hypercarbia respiratory failure irrespective of the cause when non-invasive modes have failed.[4]

Some commonly encountered causes of respiratory failure in critically ill patients include respiratory infections (pneumonia), acute respiratory distress syndrome (ARDS) both primary and secondary, acute exacerbation of asthma, chronic obstructive pulmonary diseases (COPD), heart failure, sepsis, neuromuscular disorders, coma and complications of trauma and surgery.

During MV, both subjective and objective ongoing patient monitoring is required to improve patient comfort, patient ventilator synchrony and to avoid ventilator-associated events (VAEs). The physical examination for airway patency, respiratory function, arterial blood gases, chest radiographs (CXR) and ultrasound (US) examination are required, depending on patient clinical response during IMV.

MV is an artificial form of ventilation, it is invasive and is not without complications. Protocol-based assessment of critically ill patients on IMV for clinical improvement and readiness to be liberated or weaned from mechanical ventilation improves outcomes by reducing mechanical ventilation-associated complications, weaning duration and ICU length of stay.[5] Spontaneous breathing trial (SBT) is a standard procedure for weaning in IMV.

Weaning from mechanical ventilation

MV is associated with an increased risk of complications, such as a 1% chance of developing a VAE for each day the patient is intubated, with an attributable mortality rate as high as 20–50%.

The aim of early patient weaning from mechanical ventilators is to shorten the ventilation time, decrease ICU length of stay, and decrease morbidity and mortality associated with ventilatory support.[6]

Weaning from MV has evolved since the introduction of positive pressure ventilation in Copenhagen by Dr Ibsen during the polio epidemic. The early use of oesophageal-balloon catheters measuring work of breathing was soon followed by SIMV as a weaning mode.

Weaning definition and classification

Weaning from MV is defined as a systematic approach in gradual decrease in ventilatory support in ventilated patients until successfully extubating patients whose underlying initial insult is resolving.[4,7]

Classification according to ICC

Simple weaning: accounts for 30–60% of success with lower mortality of 5–10%.

Difficult weaning: a patient may require up to three SBTs or up to seven days to wean. For each failure to wean in these patients, the potential cause must be identified and managed.

Prolonged weaning: this occurs when patients fail weaning more than three SBTs or require more than seven days to be liberated from mechanical ventilation.[4,8]

A recent weaning definition according to the WIND study includes four groups:

- Never had SBT as a result of mortality/transfer or successful extubating without SBT mortality in the study accounted for 86%.
- Group 1: mean ventilation of three days, first SBT to success 0 days, and mortality in the study 5–8%.
- Group 2: mean ventilation of nine days, first separation attempt to success three days, with mortality of 16.5%.
- Group 3: mean mechanical ventilation of 19 days. Mean from first separation attempt to success 11 days, and mortality of 29.8%.[9]

Critically ill intubated patients' expected course

Patients admitted and ventilated in ICU do not all follow an ideal progression of admission requiring respiratory support, treatment of underlying cause, reversal/resolution of initial insult requiring intubation, weaning from ventilation and discharge.

Physicians looking after critically ill patients should daily assess or screen patients for readiness to wean from mechanical ventilation as the reason for them to be MV resolves.[4]

The patient readiness for weaning screen needs to be multi-systemic in nature. The systems assessed in the screening process, irrespective of the initial insult requiring MV, are as follows:

Neurological assessment

Patients who are sedated need a sedation holiday. Patients need to be awake, alert and following commands before attempting the weaning process.

Cardiovascular assessment

Ideally, the patient should be haemodynamically stable on low dose or no pressors. Euvolaemic and/or negative fluid-balanced patients wean more successfully than fluid-overloaded patients.

Respiratory assessment

Oxygenation

The patient's oxygen requirements should improve or fractional inspiratory oxygen (FiO_2) should be < 40% and positive end-expiratory pressure (PEEP) 5–8.

In the screening tests, the PaO_2/FiO_2 (P/F) ratio should be more than > 150.

The rapid shallow breathing index (RSBI), also known as the Toubin index, is represented by respiratory rate/tidal volume in litres (RR/TV [in litres]) and ideally should be < 105 for a successful SBT. The RSBI < 80 is associated with a more than 90% probability of successful weaning from MV.

Other predictors of weaning and extubation success include respiratory rate (RR), cough strength, APACHE II, days on mechanical ventilation, tidal volume, haemoglobin, $PaCO_2$ diaphragmatic thickness, natriuretic peptides (BNPs), occlusion pressure (PO.1), CORE, PaO_2, arterial pH, blood urea nitrogen (BUN), integrative weaning index (IWI), heart failure, and oxygen cost of breathing (OCOB).[10,11]

Weaning process/spontaneous breathing trial

The weaning of patients from MV after screening for readiness of patient ventilator liberation requires a confirmation test in the form of an SBT. The SBT can take the form of intermittent unassisted ventilation via disconnecting a patient from the ventilator while supplementing oxygen via T-piece, or a gradual decrease in pressure support without immediately disconnecting the patient from the ventilator.[5]

The American College of Chest Physicians recommends protocol-based sedation weaning and inspiratory pressure augmented (PS = 5–8 cmH_2O) SBT rather than T-piece or CPAP without inspiratory pressure augmentation in patients ventilated for more than 24 hours.[5,6] Evidence has shown less work of breathing when SBT is done using pressure support ventilation (PSV) vs T-piece; however, work of breathing post-extubating is the same post-T-piece weaning, and PSV-based weaning may under-estimate work of breathing post-extubation, increasing the risk of reintubation.[12]

The duration of monitored SBT ranges between 30 min to 2 hours, and tolerance should prompt permanent patient ventilator liberation.[4]

Other tests that are done before extubation include leak test, negative inspiratory force (NIF), target higher pressures -15 to -30 cmH_2O. The CROP index: integrates compliance, respiratory rate, oxygenation and maximum inspiratory pressure. CROP index = $[C_D \times (PaO_2/PAO_2) \times PI\ max]/ F$. The CROP index > 13 is a good predictor of successful weaning.

Novel strategies of weaning

The new proportional assist ventilation (PAV) mode has been found to be superior in weaning success rate, shortens MV duration and ICU length of stay when compared to the standard PSV mode.[13,14]

The use of neural adjusted ventilatory assist (NAVA) mode in weaning from MV seems to improve in-hospital and ICU survival.[13]

US as a bedside non-invasive tool is used more frequently in ICU to identify patients at risk of failing the weaning process, and also diagnosing the cause of weaning failure.[11] The echocardiography can identify some cardiac causes of failure; airway US, lung US and diaphragm US are now becoming an integral part of weaning tools and diagnosing causes of failed weaning.[15] US parameters that predict IMV weaning failure are:

Cardiac (echocardiography)

LV ejection fraction < 40% before SBT.

Table I: Clinical criteria of failed IMV indices of SBT[15]

Clinical evaluation	Clinical measures
Agitation and anxiety	SaO_2 < 90% or PaO_2 < 60 mmHg if FiO_2 > 0.5
Altered mental status	$PaCO_2$ > 50 mmHg
Dyspnoea	pH < 7.32
Accessory muscle activity	RR > 35 breaths/min
Cyanosis	RR/Vt > 105 breaths/min/L
Diaphoresis	HR > 140 beats/min
	SBP > 180 mmHg or < 90 mmHg cardiac arrhythmias
	ST elevation or depression on ECG

E/A > 2 before and after SBT.

E/e' > 13 before and after SBT.

Lung

LUS score > 17 at the end of SBT B-lines > 6 on anterior fields during SBT.

Diaphragm

Diaphragmatic displacement < 10 mm during SBT.

Thickness fraction < 20–36% during SBT.

Weaning failure requiring re-intubation

Weaning failure from MV is defined as the inability to pass SBT, or the need for reintubation within 48 hours following extubation.[4]

This may result from multiple systemic factors leading to an imbalance between the force-generating capacity of respiratory muscle and the increased load after discontinuation of MV.[7] This may result from metabolic causes and the following:

Respiratory system and airway

Decreased muscle power – NIF < -30 cmH_2O, FVC.

Decreased compliance – resulting from pulmonary oedema, consolidation, pneumothorax, pleural fluid, elevated abdominal pressure.

High airway resistance: airway oedema, tracheal stenosis.

Other respiratory causes include: Abnormal ventilatory drive, excessive secretions or poor sputum clearance and diaphragm dysfunction.

Cardiovascular system

Weaning-induced cardiac dysfunction.

Central nervous system

Delirium and the use of anxiolytics, and a low Glasgow Coma Scale (GCS) may delay weaning from ventilation.

Others: met acidosis, drugs, abnormal electrolytes, hypothyroidism, sleep deprivation and fatigue. Table I shows clinical criteria to diagnose failed weaning from MV.

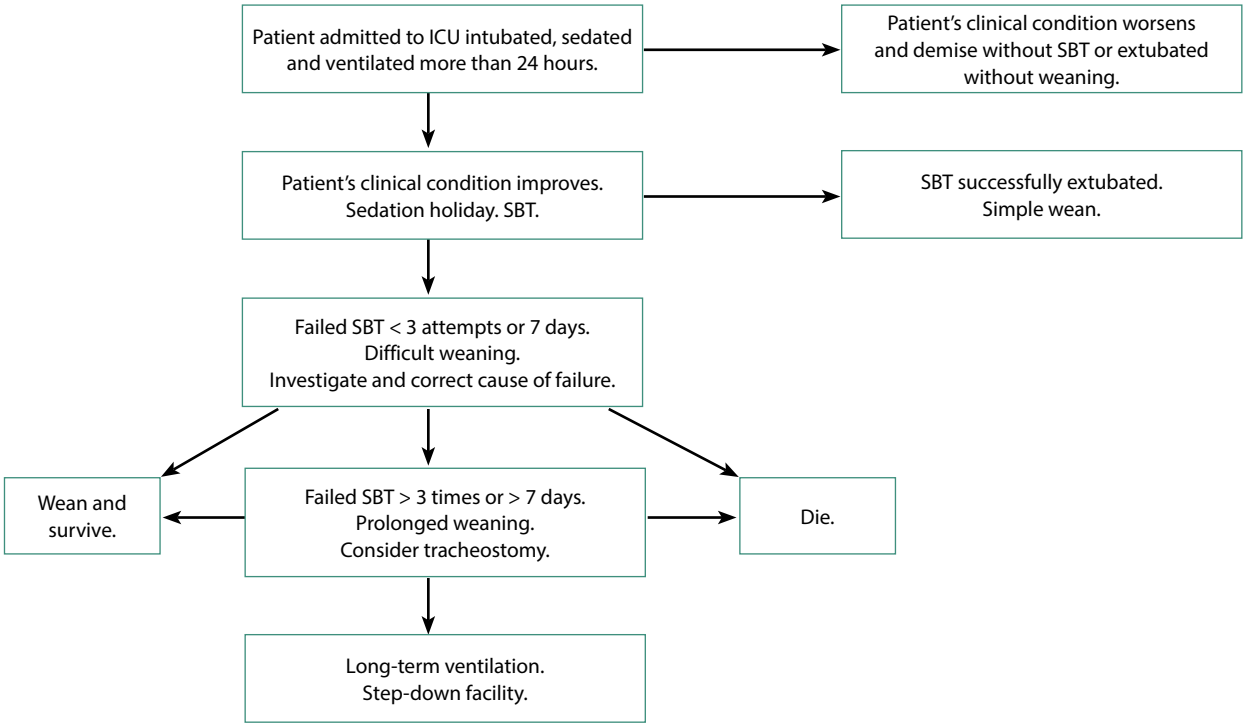

Figure 1: Patients admitted and ventilated in ICU – possible outcomes regarding weaning from ventilation[8,9]
SBT – spontaneous breathing trial, ICU – intensive care unit

Summary

Patients admitted to ICU for more than 24 hours may progress as outlined in Figure 1.

Conclusion

Patients admitted to ICU and ventilated for more than 24 hours need protocol-based weaning from MV. ICU clinicians need to perform daily screening of mechanically ventilated patients for readiness of SBT. The PSV-based SBT is the most performed weaning modality. Failure to wean from MV must be investigated and treated to hasten subsequent SBT. There are groups of patients who may require tracheostomy, non-invasive mechanical ventilation, post-extubation, or specialised step-down weaning units as a result of their difficult weaning.

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