GUIDELINES

Position Statement of ISCCM Committee on Weaning from Mechanical Ventilator

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Abstract

Background and purpose: Weaning from a mechanical ventilator is a milestone in the recovery of seriously ill patients in Intensive care. Failure to wean and re-intubation adversely affects the outcome. The method of mechanical ventilation (MV) varies between different ICUs and so does the practice of weaning. Therefore, updated guidelines based on contemporary literature are designed to guide intensivists in modern ICUs. This is the first ISCCM Consensus Statement on weaning complied by a committee on weaning. The recommendations are intended to be used by all the members of the ICU (Intensivists, Registrars, Nurses, and Respiratory Therapists).

Methods: A Committee on weaning from MV, formed by the Indian Society of Critical Care Medicine (ISCCM) has formulated this statement on weaning from mechanical ventilators in intensive care units (ICUs) after a review of the literature. Literature was first circulated among expert committee members and allotted sections to each member. Sections of the statement written by sectional authors were peer-reviewed on multiple occasions through virtual meetings. After the final manuscript is accepted by all the committee members, it is submitted for peer review by central guideline committee of ISCCM. Once approved it has passed through review by the Editorial Board of IJCCM before it is published here as "ISCCM consensus statement on weaning from mechanical ventilator". As per the standard accepted for all its guidelines of ISCCM, we followed the modified grading of recommendations assessment, development and evaluation (GRADE) system to classify the quality of evidence and strength of recommendation. Cost–benefit, risk-benefit analysis, and feasibility of implementation in Indian ICUs are considered by the committee along with the strength of evidence. Type of ventilators and their modes, ICU staffing pattern, availability of critical care nurses, Respiratory therapists, and day vs night time staffing are aspects considered while recommending for or against any aspect of weaning.

Result: This document makes recommendation on various aspects of weaning, namely, definition, timing, weaning criteria, method of weaning, diagnosis of failure to wean, defining difficult to wean, Use of NIV, HFOV as adjunct to weaning, role of tracheostomy in weaning, weaning in of long term ventilated patients, role of physiotherapy, mobilization in weaning, Role of nutrition in weaning, role of diaphragmatic ultrasound in weaning prediction etc. Out of 42 questions addressed; the committee provided 39 recommendations and refrained from 3 questions. Of these 39; 32 are based on evidence and 7 are based on expert opinion of the committee members. It provides 27 strong recommendations and 12 weak recommendations (suggestions).

Conclusion: This guideline gives extensive review on weaning from mechanical ventilator and provides various recommendations on weaning from mechanical ventilator. Though all efforts are made to make is as updated as possible one needs to review any guideline periodically to keep it in line with upcoming concepts and standards.

Keywords: Difficult weaning, Liberation from mechanical ventilator, Mechanical ventilation, Position statement, Tracheostomy, Ventilator liberation, Weaning, Weaning from mechanical ventilation.

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Introduction and Purpose

Mechanical ventilation (MV) is, and will remain, one of the life-saving treatments in intensive care. Weaning from a mechanical ventilator is as important as its initiation. Periodic relook at global standards for weaning is required. This statement is intended to be a comprehensive document on weaning, that will guide Intensivists, not only in India, but also for many resource-limited countries. All the authors have tried their best to include the latest literature on the topic, but due to the ever-expanding quantum of literature periodic updates will be required.

Methods

Composition of a Committee on Weaning

The Guideline Committee of ISCCM has appointed a chairperson, for a committee on weaning from mechanical ventilators. Chairperson, then selected committee of 5 members from across the nation, based on their expertise, qualifications, and experience in Critical

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Care Medicine. After discussion amongst the experts, 42 questions were drafted, addressing different aspects of weaning in critically ill patients and literature was vigorously searched over 3 months. Further, discussions were carried on in the expert group over each drafted question and recommendations for each question were made as per the consensus. The draft was reviewed by the committee on weaning and the ISCCM guideline committee. The final document is published in IJCCM after the editorial board review.

Summary of Questions and Recommended Actions for Weaning from Mechanical Ventilator

To form these position paper guidelines, the committee has decided to enlist 42 clinical questions on weaning. The concept of the GRADE System was taken into consideration during committee meetings so that a balance between the evidence base and practicality in Indian ICUs is maintained.[1–3] Each question has answers in the form of a recommendation of the committee, followed by a summary of supporting literature. Table 1 summarizes the recommendations.

Clinical Questions

1. What is weaning? (Definition of weaning from mechanical ventilator)

Recommendation: We recommend uniform definition of weaning (success or failure) in clinical practice and research to facilitate standards in communication and clinical documentation.

The word "Weaning" means, to accustom someone without something, on which they have become dependent. Despite remarkable advances in the field, MV must be considered a potentially dangerous supportive therapy in intensive care units (ICUs). Weaning from MV is defined as a systematic way of removing of patient from the support of a mechanical ventilator. Many societies and experts prefer the word "discontinuation from or Liberation from ventilation" rather than weaning, as all patients have not developed a dependency on it. We prefer to use the conventional term "Weaning" as most Intensivists across India are accustomed to the terminology and use it in all day-to-day communication as well as documentation in clinical notes.

Weaning can account for 40–50% of the time on MV.[4,5] Definition of Weaning success or failure, takes "48 hours from initiation of weaning" as a time point. Weaning success means, ventilator support can be stopped completely after first SBT within 48 hours. Failure to do so, resulting in re-intubation or NIV support, within that time frame is labeled Weaning failure (see details of ventilator under question 15). Weaning is called simple (success in first SBT), difficult (success in up to third SBT in first 7 days), or Prolonged if more than 7 days are required for weaning.[4] The longer the duration of MV, the more the morbidity [ventilator associate pneumonia (VAP), ventilator associated tacheobronchitis (VAT), Airway trauma and mortality].[5,6] Incidence of weaning failure varies from 14 to 32% (average 21%). As per one study patients with weaning failure and consequent prolonged ventilation, though account for only 7% of total ventilated patients, consumes 37% of ICU resources. So weaning failure is detrimental not only to the patient but also to the institute and burden on health care in general.[6,7]

2. How do I manage an ICU patient on ventilator to facilitate early weaning (shorten time on ventilator)?

Recommendation: We recommend ventilation strategies aimed at minimizing complications due to Mechanical ventilation, sedation and intensive care to facilitate timely weaning.

on Weaning from Mechanical Ventilator. Indian J Crit Care Med 2024;28(S2):S233–S248.

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Conflict of interest: None

Mechanical ventilation can be harmful and even fatal if complications due to ventilation are not prevented. Many aspects of MV (controlling peak pressure, plateau pressure, tidal volume, driving pressure, power) as well as the use of prophylactic practices in intensive care (fast hug bid, fast hugs in bed please), not only reduce lung injuries but also ICU acquired infections, bedsore, disuse muscle atrophy, etc.[8,9] Due to heterogeneity in ICU population in need for MV, one cannot have a study of a particular set of ventilation strategy and its effect on weaning. However, effect of sedation, NMB use, daily awakening, and protocolized weaning is discussed in detail in the sections below. The proposed strategy for managing a patient on a ventilator to facilitate weaning is shown in Table 2.

3. What is effect of primary diagnosis on type of weaning?

Recommendation: We recommend intensive care team to anticipate type (Simple, difficult, or prolonged) of weaning as per patient's underlying disease, indication and duration of mechanical ventilation.

Medical patients have a higher incidence of weaning failure than cardiothoracic and non-neurology surgical patients.[10–12] Etiology of respiratory failure which requires mechanical ventilatory support for its treatment (primary diagnosis) has an immense influence on the pattern of weaning.

- Most patients ventilated for general anesthesia for surgery can be weaned and extubated in less than 24 hours. These simple wean patients rarely require any special strategy.
- Seneff et al., on over 5,915 patients, studied aspects that affect the duration of MV and determined the relative contribution of patient and disease factors to it. It suggests that ICU admission due to conditions or diseases like pneumonia, ARDS, neuromuscular disease, head trauma, or postoperative intracerebral hemorrhage are associated with prolonged ventilation and delayed weaning.[12]
- Elevated acute physiology score (APS) of APACHE III, on day one in the ICU has a more linear correlation (25%) with duration of ventilation as compared to the admission from another ICU, another hospital, or the medical ward (6.1%). Postoperative ICU admissions have a shorter duration of MV. Factors associated with-longer duration of ventilation and affect weaning were: Higher $PaCO_2$, serum blood urea, serum creatinine, arterial pH, white blood cell counts, temperature (4.8%), and low S. albumin (2.9%) on the day of ICU admission. Obstructive or restrictive lung disease (2.4%) and extended hospital length of stay prior to ICU admission (4.3%) affect the duration as well.
- Duration of MV increased as the PaO_2/FiO_2 ratio dropped near 150 mm Hg and then decreased due to early mortality at lower than 150 mm Hg. The same is true for the age of the patient. The average duration of MV increased with age up to 85 years and then started reducing as mortality rises at age above 85 years.
- I-TRACH score is designed to anticipate the need for MV or more than 7–14 days. The score is calculated on the following parameters; Intubation in the ICU, heart rate >110 beats per min, renal dysfunction (BUN >25 mmol/L), Acidosis with pH <7.25, creatinine (>2.0 or >50% rise from baseline) and decreased

Table 1: Summary of recommendations by ISCCM committee on weaning

Questions		*Recommendations of committee on weaning*
1	What is weaning?	We recommend uniform definition of weaning (success or failure) in clinical practice and research to facilitate standards in communication and clinical documentation
2	How do I ventilate to facilitate early weaning (shorten time on ventilator)?	We recommend ventilation strategies aimed at minimizing complication due to MV, sedation and intensive care to facilitate timely weaning
3	What is effect of primary diagnosis and duration of ventilation on weaning?	We recommend intensive care team to anticipate type (simple, difficult, prolonged) of weaning as per patients' underlying disease, indication and duration of MV
4	When to initiate weaning process?	We recommend to start planning for weaning process from the beginning of MV, however criteria for weaning preparedness need to be fulfilled before SBT can be planned
5	Role of sedation strategy on weaning.	We recommend institution based sedation protocol for better titration of sedative agents and avoid benzodiazepines based sedation regimen for long term sedation
6	Role of daily sedation window in weaning.	We recommend daily sedation window and review the sedation regime in patients who are on MV for more than 24 hours
7	Role of ABCDEF weaning bundle on weaning.	We recommend ABCDEF weaning bundle to be used in ICU for all patients who are on MV for more than 24 hours
8	Role of neuroparalysis strategy on weaning.	We recommend intermittent boluses over infusion of neuro-muscular blocker agents (NMBAs). If NMBAs infusion is required, it should not be continued for more than 48 hours
9	Role of muscular weakness, neuromyopathy in weaning.	We suggest to rule out ICU acquired weakness as a cause of difficult weaning. Use of NMBAs and co-administration of NMBAs with corticosteroid should be avoided
10, 11	Role of hydration and electrolyte imbalance in weaning.	We recommend to avoid positive fluid balance at least 24 hours before weaning trial We suggest to correct electrolyte imbalance (sodium, chloride, potassium, phosphate, magnesium) before initiation of weaning
12	Role of diaphragmatic ultrasound in predicting weaning	Although diaphragmatic ultrasound is a promising diagnostic tool, we suggest to develop more standardized protocols, for further research and clinical application
13	How to prepare for weaning?	We recommend protocoled preparation for weaning
14, 15	Which modes should be used for weaning?	We recommend SBT by T-piece or PSV method We suggest to use adaptive support ventilation (ASV) or neurally adjusted ventilatory assist (NAVA) or any other newer modes if equipment and expertise are available
16–18	Which weaning indices to use, their role in predicting weaning?	We recommend RSBI as the weaning index as it is easy, reproducible and simple Routine use of other weaning indices is not recommended as they are complex, difficult to measure or interpret and may require special equipment Other weaning indices can be utilized for specific situations for example, those with inconclusive or variable RSBI, or some clinical dilemma
19	When to consider weaning is successful or failed?	We recommend considering subjective and objective criteria to conclude weaning success or failure
20	When to repeat an attempt once failed?	We suggest repeating SBT after 24 hours or after resolution of the reason for failed SBT, whichever is earlier
21	How to ventilate in the interim period?	We recommend to use either PSV or Controlled ventilation (non-fatiguing strategy) before giving another SBT
22	What to do, when fail to wean (difficult weaning)?	We recommend a structured approach to diagnose and treat the cause of weaning failure before offering repetitive SBTs
23	Which extubation criteria to be used (extubation screening)?	We recommend monitoring a combination of various criteria as per the clinical scenario
24–28	What helps in preventing accidental extubation?	We recommend incorporating identification of delirium as a cause of agitation in sedation protocol We recommend use of physical restraints only in clinically appropriate situations and not as routine part of therapy We recommend standardizing endotracheal tube securement and developing protocols to identify patients ready for weaning and extubation We suggest adequate nurse: patient ratio to help prevent unplanned extubation We recommend quality surveillance to identify and reduce the incidence of unplanned extubation in a unit
29	When to re-intubate after accidental extubation?	We recommend re-intubation after unplanned extubation in patients with upper airway obstruction, increased secretion burden, respiratory failure due to exhaustion, impaired or reduced level of consciousness, and cardiopulmonary arrest

(Contd...)

Table 1: *(Contd...)*

Questions		*Recommendations of committee on weaning*
30, 31	Role of cuff leak test in extubation.	We suggest performing a cuff leak test in mechanically ventilated adults who meet extubation criteria and are considered at high risk for post-extubation stridor We recommend having a protocoled surveillance, assessment, and treatment policy in the units to obviate the routine need to perform CLT prior to extubation
32, 33	Post-extubation stridor and role of medications on its prevention and treatment	We recommend administering systemic corticosteroids at least 4 hours pre-extubation in patients to prevent stridor and re-intubation in high-risk population We make no recommendations on the role of steroids when patients are not selected Non-invasive ventilation should not be used in the treatment of patients with post-extubation stridor
34	Role of heliox in post-extubation stridor	No recommendation can be given on routine use of Heliox for post-extubation stridor
35	Does tracheostomy help in early weaning?	We recommend tracheostomy as a mean to facilitate weaning in difficult to wean patients
36–38	Do weaning to NIV or high flow nasal oxygen (HFNO) helps?	We recommend that NIV should be used as weaning strategy for difficult weaning We suggest HFNO as a post-extubation weaning strategy for hypoxemic patients at risk of developing acute respiratory failure We do not give preference of either modalities, HFNO or NIV, for weaning
39	Do specialized weaning centers help?	We suggest that patients with weaning failure can be considered for transfer from acute care settings to a specialist center, where available
40	Do nurse or respiratory therapist driven protocol lead to early weaning?	We suggest implementation of nurse or respiratory therapist driven weaning protocol after adequate training and competency assessment
41	Effect of ICU staffing on weaning success?	No recommendation can be given on the effect of ICU staffing on weaning success
42	What are future perspectives in weaning?	No specific recommendation can be given on use of artificial intelligence or bio-signal based weaning protocols as of now

Table 2: Proposed strategy for managing a patient in ICU on ventilator to facilitate weaning

Complications of mechanical ventilation	*Steps to prevent them*
Sedation and immobilization:	
Deep vein thrombosis and pulmonary embolism	Early mobilization
Pressure sore: Pain and infections	DVT prophylaxis
Delirium	Pressure sore prevention
	Minimize use of Benzodiazepines
Need for prolonged IV access and its complications	Implement CLABSI bundle
	Remove invasive lines at earliest possible
Disuse atrophy of diaphragm and respiratory muscles	Shift to spontaneous mode of ventilation as soon as possible
Critical Illness polyneuropathy Critical Illness myopathy	Minimize exposure to Neuromuscular blockade, corticosteroid, aminoglycosides, polymyxins and neuro-myotoxic molecules
Ventilator associated Pneumonia	Implement VAP prevention bundles
Barotrauma	Do not allow Ppeak >40 cm H_2O
(Pneumothorax- Hypotension)	Limit Pplat below 30 cm H_2O
	Limit driving pressure <15 cm H_2O
	Set and review Ppeak and Vt alarms on Ventilator
Atelectotrauma	Minimize time spent with FiO_2 = 1.0 (100% oxygen)
Hypoxia, hyperoxia	Use minimum FIO_2 to keep SpO2-90–94%
Reduced lung compliance	
Volu-trauma	Ventilate with tidal volume 6–8 mL/kg (avoid above 10 mL/kg)
Trans alveolar translocation of bugs, pneumothorax, mediastinal emphysema	Down titrate pressure support to limit higher tidal volumes causing pVILI
Bio-trauma	Open lung strategy, Lung protective ventilation
Cytokine surge leading to AKI, hypotension, Multi-organ dysfunction syndrome	Limit driving pressure (ΔP) <15 cm H_2O
Airway injury and peri-intubation or peri-extubation deteriorations	Use of structured airway assessment to diagnose difficult airway pre-emptively
Laryngeal edema, tracheal edema, ulcers, clots airway obstruction, stridor, dysphonia	Use rapid or delayed sequence intubation protocol Use extubation and post-extubation management protocol

bicarbonate level (HCO3 <20 meq/L). Any score of four or more helps one to anticipate the subsequent need for MV beyond 7–14 days at the time of intubation.[13]

4. When to initiate weaning process?

Recommendation: We recommend to start planning for weaning from the beginning of mechanical ventilation, however criteria for Weaning Preparedness need to be fulfilled before SBT can be planned.

As weaning involves meticulous planning before the execution of actual steps, planning must begin as soon as MV (NIV or Invasive) is initiated. Weaning success and the time it takes, depend on many factors [sedation, interdepartmental trips, alertness, mechanical ventilator-associated complications, hospital acquired infections (HAIs), etc.]. One needs to attend and optimize all these factors as best as possible right from the moment a clinician thinks of putting a patient on MV and this needs time. Treatment of the underlying disease and preventing insult (addition of one more factor) which can adversely affect the weaning process must be an integral part of the ventilation and patient care regime to facilitate early weaning. However certain objective criteria (Tables 3 and 4) need to be full filled before one thinks to consider SBT.[14]

ABCDEFGHI–is a neumonic used as an aid to remember major factors to check readiness of weaning.

Table 3: Criteria for readiness for SBT (weaning)[14]

Criteria for readiness for SBT (weaning)
Required criteria
1. The cause of the respiratory failure has improved
2. PaO_2/FiO_2 ≥1 50* or SpO_2 ≥ 90% on FiO_2 ≤ 40% and positive end-expiratory pressure (PEEP) ≤5 cm H_2O%
3. pH >7.25
4. Hemodynamic stability (no or low dose vasopressor medications)
5. Able to initiate an inspiratory effort
Additional criteria (optional criteria)
1. Hemoglobin ≥7 mg/dL
2. Core temperature ≤38–38.5° Centigrade
3. Mental status awake and alert or easily arousable

Modified from Ref 14

Table 4: ABCDEFGHI–a pneumonic for screening for readiness to wean

A	Aim of the ventilation met with (indication of MV resolved) Alert and Afebrile
B	Breathing indices within acceptable limits and no distress
C	Circulation–Hemodynamically stable
D	Drugs–no sedative or NMBA drug effect
E	Electrolytes: no sodium, potassium, calcium, magnesium or phosphate disturbances
F	Fluid status: not dehydrated, not oedematous
G	Glucose-Euglycaemia, no hypo or hyper-glycaemia
H	No hallucinations/no delirium. Co-operative patient
I	No impending procedures or transfers

5. Role of sedation strategy on weaning

Recommendation: We recommend institution-based sedation protocol for better titration of sedative agents and avoid benzodiazepines based sedation regimen for long term sedation.

Sedation strategy is the art of maintain a balance between patient comfort on the ventilator and the dose of sedative agents. There is no single protocol or strategy which can be applicable to all patients. One can have local institute-specific protocols for better titration of sedation agents. They vary from patient to patient, one disease to another, one day to another, and thus need to be customized each time.

Sedation protocol has an advantage over random sedation prescriptions. It helps to set a system that helps better adjustment of sedation doses to achieve an optimal predefined sedation level. This has been proven to lower the duration of MV, ICU length of stay, and hospital stay. We found six un-blinded randomized control trials that compared groups of patients managed with or without protocols aimed at sedation optimization.[15–21] Intensive care unit length of stay was reduced in " with protocol group". They found no difference in the duration of MV or short-term mortality. There was heterogeneity in the management of patients in the control group among studies. Those studies, which showed no benefit of protocol had lighter levels of sedation in the control groups compared with those that did reveal a benefit. A study by Brook et al., evaluated the effect of protocol-directed sedation among critically ill patients with acute respiratory failure. It showed use of the protocol, can reduce the duration of MV, ICU and hospital lengths of stay, and the requirement for tracheostomy.[18] A meta-analysis by Qi et al., showed that the use of nurse-led sedation protocols caused a significant drop in ventilation days within ICUs. We recommend the use of sedation protocol over no protocol for ICU patients on mechanical ventilators as it helps to minimize sedation and shorten ventilation days (early weaning).[19]

Sedcom and Mends studies have shown that Benzodiazepine use not only prolong ventilation days and ICU, LOS but also, is associated with the increased occurrence of delirium in the ventilated patients. Hangover of midazolam effect due to its active metabolite contribute to undesirable sustained effect after midazolam infusion stopped. Trend of sedation protocols is moving from the deep sedation to lighter sedation to analgo-sedation (analgesia first followed by sedatives if required) to no sedation for MV in the ICUs.[20] We recommend use of Benzodiazepine sparing sedative strategy by using alternative medications like Propofol, Dexmedetomedine, Ketamine and non-pharmacological means for managing pain, agitation and delirium sleep promotion (earplugs, eyeshades, light music, etc.).

6. Role of daily sedation window in weaning

Recommendation: We recommend daily sedation window and review the sedation regime in patients who are on mechanical ventilation for more than one day.

Daily interruption of sedative medications (Infusions) in critically Ill patients undergoing MV was first studied by John. P. Kress. He found that sedation vacation is associated with reduced duration of MV and LOS in the ICU.[21] These findings were further reinforced by a randomized control trial (RCT) in 2008 by Timothy D Girard, where researchers found better outcomes in mechanically ventilated patients who were given SAT followed by SBT.[22] A randomized controlled trial published in 2010 found that the duration on MV, and ICU and Hospital LOS were lesser in the group not using sedation.[23] Continuous sedation was identified as an independent risk factor for pneumonia in patients on mechanical ventilators.[24] For weaning from MV, the first step is to discontinue or taper down sedation. This can be achieved by either daily interruption of sedation or active decrement in the level of sedation that allows the patient to be optimally calm but responsive. Sedation vacation has been associated with reduced ICU LOS and mortality in studies. It also helps to avoid drug accumulation and side effects due to over-sedation. Finally, it also helps to assess the patient's neurological and respiratory status, as well as readiness to wean from sedation and MV.[25]

7. Role of ABCDEF weaning bundle on weaning

Recommendation: We recommend ABCDEF weaning bundle to be used in ICU for all patients who are on mechanical ventilation for more than one day.

Society of Critical Care Medicine created the ABCDEF bundle. It serves as a guide for the ICU team in improving care for critically ill patients. The key components of the ABCDEF bundle are: (A) Assess, prevent, and manage pain; (B) Both spontaneous awakening trials (SAT) and spontaneous breathing trials (SBT); (C) Choice of analgesia and sedation; (D) Delirium assessment, prevention, and management; (E) Early mobility and exercise; and (F) Family engagement and empowerment.[26] Routine use of each of this component of this bundle has been shown to increase survival, reduce delirium, have fewer days on MV, and have fewer ICU readmissions.[27] A few decades ago, the care of a patient on a ventilator required deep sedation, Immobility, and minimal family engagement. However, modern principles of critical care encourage one to use lighter sedation to facilitate early mobility. Early diagnosis and treatment of delirium with increasing family involvement is highly desirable. This paradigm shift is due to the recognition of the long-term consequences of critical illness and the impact of prophylactic practices routinely performed in the ICU. The ABCDEF bundle has been developed to address these needs. It helps in early weaning from MV as it avoid over sedations, and promotes early mobility which prevents muscle atrophy, and reduces the risk of delirium.

8. Role of Neuro-paralysis strategy on weaning

Recommendation: We recommend intermittent boluses over infusion of NMBAs. If NMBAs infusion is required, it should not be continued for more than 48 hours.

The primary role of NMBAs in ARDS patients is to reduce patient-ventilator dyssynchrony. We should avoid NMBAs if the patient is tolerating MV with sedation only. If neuromuscular blockade use is inevitable to facilitate lung protective ventilation, intermittent NMBA boluses along with deep sedation are preferred over an NMBA infusion. If NMBA infusion must be used due to high requirements, it should not be continued for more than 48 hours. When NMBAs are given with corticosteroids or infused for more than 48 hours, it increases the risk for ICU-acquired weakness. Cis-atracurium was the only agent studied in large RCTs in ARDS patients, and so is the preferred agent for NMB infusions. The impact of using other NMBA infusions for patients with ARDS is not known as not been studied formally. The two largest trials used Cis-atracurium at a fixed dose of 15 mg bolus followed by an infusion of 37.5 mg/h for 48 hours. As the relation between the dose of Cis-atracurium and adverse effects is unclear, one may titrate the dose to clinical effect.[28] Apart from ARDS, NMBAs are also used for rapid sequence intubation, for patient-ventilator dyssynchrony in patients on MV, to reduce intra-abdominal pressure and risk of barotrauma. It also helps to control shivering, and muscle oxygen consumption and limit the rise in intracranial pressure. Neuromuscular blockade use leads to prolonged immobility with resultant development of ICU-acquired weakness, myopathy, pressure ulcers, nerve injuries, and increased risk of deep venous thrombosis.[29] Vecuronium is metabolized via hepatic mechanisms to a large extent. however, its elimination half-life is still increased in patients with reduced Renal function. Duration of action of Atracurium is unaffected by renal failure.

9. Role of muscular weakness, neuromyopathy in weaning

Recommendation: We suggest to rule out ICU acquired weakness as a cause of difficult weaning. Use of NMBAs and co-administration of NMBAs with corticosteroid should be avoided.

It is estimated that about 62% of patients with weaning failure have some form of neuromuscular weakness.[30] Critical illness neuropathy, Critical illness myopathy, and critical illness polyneuromyopathy are common causes of neuromuscular weakness contributing to weaning failure. It increases LOS in ICU as well as ventilator dependence. Several independent risk factors for the development of ICU-acquired weakness have been found. They are divided into modifiable and non-modifiable risk factors. The severity of critical illness is the most important factor. Higher the severity of critical illness and multi-organ failure, prolonged ventilator and ICU stay increases the likelihood of ICU-acquired weakness. High lactate levels, old age, and female gender are particularly at higher risk.[31] Among the modifiable risk factors degree of hyperglycemia, the use of certain drugs like corticosteroids, beta agonists and vasoactive agents increases the risk of ICU-acquired weakness.[32]

10. Role of hydration in weaning

Recommendation: We recommend to avoid positive fluid balance at least 24 hours before weaning trial.

Weaning and extubation are milestones for critically ill patients who are managed with mechanical ventilators. It was found that negative fluid balance reduces the incidence of weaning failure. Positive fluid balance is found as a risk factor for extubation failure. One prospective observational study showed that, as compared to the standard clinical weaning procedure, a weaning protocol where positive fluid balance was avoided for at least 24 hours before weaning led to better a success rate.[33] Negative fluid balance is associated with weaning success, but it is not associated higher probability of extubation success. The potential mechanisms remain unproven. In one randomized trial on B-type natriuretic peptide (BNP) guided fluid use strategy was compared with usual care. The BNP-guided group had more negative cumulative and average daily fluid balance during weaning. It was associated with higher number of ventilator-free days. Both groups had similar fluid intake during weaning, which implies, that fluid intake may have little impact on weaning or extubation outcome.[34] The use of diuretics to achieve negative fluid balance is controversial. Upadya et al. reported that administration of diuretics was associated with negative fluid balance but it was not independently associated with weaning outcomes.[35]

11. Role of electrolyte imbalance in weaning

Recommendation: We suggest to correct electrolyte imbalance (sodium, chloride, potassium, phosphate, magnesium before initiation of weaning).

Electrolyte abnormalities, including very low levels of phosphate and magnesium, affect skeletal muscle function. In difficult-weaning patient these small corrections can prove pivotal. No studies have investigated the role of electrolyte abnormalities in weaning failure specifically. Metabolic disturbances that increase the work of breathing affect weaning, including metabolic acidosis and fever. Malnutrition and reduced muscle mass contribute to difficult weaning. Feeding should be optimized to prevent under- and overfeeding.[36]

12. Role of diaphragmatic ultrasound in predicting weaning

Recommendation: Although diaphragmatic ultrasound is a promising diagnostic tool, we suggest to develop more standardized protocols, for further research and clinical application.

One of the reasons for weaning failure in mechanically ventilated patients is Diaphragmatic dysfunction. Its prevalence ranges from 33 to 90%.[37] Even a short duration of MV can lead to diaphragmatic weakness. The use of NMBAs causes disuse atrophy of both types of fibers namely fast-twitch and slow-twitch. This ultimately leads to diaphragmatic dysfunction. Diaphragm atrophy can result in prolonged MV, increased ICU length of stay, and a higher rate of complications.[38] Bedside or Point-of-care ultrasound can be used to visualize diaphragm in patients on MV. Diaphragmatic ultrasound is a readily amiable bedside tool. It helps to detect diaphragmatic dysfunction, to anticipate extubation failure, to monitor respiratory workload and to assess atrophy in mechanically ventilated patients.[38] Diaphragmatic ultrasound has been extensively studied as a predictor of successful weaning from MV. However, it remains difficult to draw general conclusions from individual studies due to the marked variation in study design and population. Though defined cut-offs for measurements of diaphragmatic ultrasound have been agreed but more robust data is required to support the same (Tables 5 and 6).

13. How to prepare for weaning?

Recommendation: We recommend protocolized preparation for weaning.

Protocol for preparation and procedure for weaning should contain the following elements:

14 and 15. Which modes should be used for weaning?

Recommendation: We recommend SBT by T-piece or PSV method.

Many different modes or methodologies are used to assess the adequacy of breathing during weaning. As per the literature, no mode or technique is superior to others in early extubation, rate of re-intubation or increasing ventilator-free days. The duration of SBT is usually 30–120 minutes in all studies. Two types of modes are routinely used: SBT with T-piece (disconnecting the patient from the ventilator circuit and attaching T-piece tube with oxygen) and SBT with PSV mode with pressure support of 8 cm H_2O and PEEP of 5 cm H_2O.

Success in first with the use of PSV is associated with a shorter weaning period but it may underestimate the work of breathing that may be required post-extubation. It was believed that it may be associated with a higher risk of extubation failure. Sklar et al. suggested that PSV may compensate for the additional work

Table 5: Protocol for preparation and procedure for weaning[39,40]

Preparation:
Inform the patient (if conscious), about
The steps of Weaning process and what is expected of him or her.
Regarding the procedure in detail (first to remove ventilator and then to remove Endotracheal Tube
Probable difficulty in breathing through the tube
Reassurance
Use ventilator cards which helps intubated patients to communicate (like sign boards)
Suctioning equipment, Oxygen therapy devices, oral and nasal airways and Intubation tray should be standby. (including equipment for difficult intubation)
Procedure:
Once preparation is done, keep patient in comfortable propped up position.
Pre-oxygenation (increase FiO_2 by 10–20% except in COPD patients)
Do thorough endotracheal, nasogastric and oral suctioning.
Plan the mode of weaning- low pressure support or T-piece
Take patient off the ventilator if weaning is planned through T-piece OR switch over to low pressure support mode (Pressure Support 6–8 cm H_2O above PEEP and PEEP 5 cm H_2O)

Modified from references 39 and 40

Table 6: Parameters to be observed during weaning[41,42]

Following parameters should be observed while weaning	
Patient's clinical status	*Monitoring parameters*
Breathlessness or respiratory distress	HR-watch for tachycardia, arrhythmia
Profuse diaphoresis	BP-watch for accelerated hypertension
Use of accessory muscles of respiration	SpO_2-watch for desaturation
Paradoxical breathing	CO_2-watch for increasing $ETCO_2$
Bronchospasm	ABG- after 30–120 minutes.
Altered mental status	Weaning index-Preferably RSBI

Modified from references 41 and 42

imposed by the endotracheal tube and thereby reduce the external respiratory work and oxygen consumption by respiratory muscles during SBT.[42] Pellegrini et al.[43] concluded that in simple wean patients, PSV may be better but in prolonged weaning patients, T-piece might be associated with a shorter weaning. Thille et al.[44] have concluded recently that PSV did not result in significantly more ventilator-free days at day 28 as compared to T-piece in patients who had a high risk of extubation failure. Daily SBTs led to early extubation in a study by Esteban et al., when compared to gradual PSV or SIMV weaning.[45] Brochard et al.[46] compared three methods of gradual withdrawal from ventilatory support and concluded that gradual PSV weaning had a shorter weaning duration and higher weaning success including extubation as compared to daily T-piece SBT or SIMV weaning. SIMV and CPAP are no longer routinely used.

Recommendation: We suggest to use Adaptive Support Ventilation (ASV) or Neurally Adjusted Ventilatory Assist (NAVA) or any other newer modes if equipment and expertise are available.

Adaptive support ventilation is considered a closed-loop controlled ventilator mode which is used for optimization of patient's work of breathing. A maximum plateau pressure and desired minute ventilation are set and it automatically selects the ventilatory pattern as per the settings and respiratory mechanics. Neurally adjusted ventilatory assist is a mode of partial ventilatory assist in which the proportion of the ventilatory assistance (timings and intensity) is determined by respiratory drive. The respiratory drive is measured by the electrical activity of the diaphragm.

Dongelmans DA et al.[47] demonstrated ASV as a safer and more useful mode while extubation time was similar to other modes. Linton et al. tried ASV in chronic respiratory patients and found that it is a cost-saving option in terms of the need for ICU-trained manpower and respiratory therapists. Kirakli C et al.[48] showed that ASV may be used as a weaning mode in severe COPD patients with the benefit of shorter weaning time. A recent meta-analysis by Yuan et al.[49] concluded that, as compared to PSV, NAVA was associated with an increased chance of weaning success, a higher number of ventilator-free days, a lower duration of MV, and lower hospital mortality.

16–18. Which weaning indices to use and what is their role in predicting weaning?

Recommendations: We recommend RSBI as the weaning index as it is easy, reproducible and simple. Routine use of other weaning indices is not routinely recommended as they are complex, difficult to measure or interpret and may require special equipment. Other weaning indices can be utilized for specific situations for example, those with inconclusive or variable RSBI, or some clinical dilemma.

Weaning Indices (Indices that Predict Successful Ventilator Discontinuation)

Discontinuation of MV, SBT, and extubation are planned according to 'fitness' for weaning, objective parameters like ABG, and subjective observation of clinical condition. Many weaning indices help in predicting weaning success, i.e., no need for re-intubation or re-ventilation. Multiple indices were developed and tested over time. No single index is best or ideal to predict in all patients as there is lots of heterogeneity in the type of patients, number of ventilation days, premorbid conditions, course of illness, severity of illness, etc., (Table 7).

There are many weaning indices and predictors described in literature as follows:

Rapid Shallow Breathing Index (RSBI)

Yang and Tobin described RSBI:f/VT in 1991 and it one of the most popular weaning indexes.[50] It is easy to measure even by nurses, does not require any cooperation from patients, and showed reasonable predictability at cut off of 105 (<105: positive and >105: negative). Positive RSBI, indicate a higher likelihood of weaning success with a specificity of 64%, sensitivity of 97%, NPV of 95% and PPV of 78%.[51] Recent meta-analysis involving 10,946 patients concluded moderate sensitivity (0.83, moderate certainty) but poor specificity (0.58, moderate certainty) for RSBI. Rapid shallow breathing index cut-off of <80 or 80–105 showed similar sensitivity, and specificity.[52]

Other Weaning Indices (WI)

Weaning index was first used by Huaringa et al.[52] For predicting weaning success, WI has a sensitivity was 98%, specificity was 89%, PPV was 95%, NPV was 94%, and area under the ROC curve was 95.9. Multiple integrated weaning indices were proposed by Vahedian-Azimi A et al.[53] They concluded that the Statistical values of ten formulae for proposed variables were more than 87% (0.87–0.99).

There are many other indices proposed by various investigators like occlusion pressure (P0.1), P0.1/maximum inspiratory pressure ratio, gastric mucosal acidosis, diaphragmatic ultrasound-based indices, esophageal pressure, compliance, rate, oxygenation, pressure (CROP index), the compliance, oxygenation, respiration, effort (CORE index), etc. But either they are not validated in further studies or difficult to measure at the bedside or complex or require further studies to know the accuracy, sensitivity, or specificity.[54–57]

19. When to consider weaning is successful or failed?

Recommendation: We recommend considering subjective and objective criteria to conclude weaning success or failure.

Failure of SBT: Defined by subjective indices like respiratory distress, altered mental status, profuse diaphoresis, use of accessory muscles of respiration, etc., and by objective indices like obvious tachypnoea, tachycardia, accelerated hypertension, shock, respiratory acidosis, precipitation of cardiac arrhythmias, etc.[55]

Weaning success: As per the International Consensus Conference and the majority of other studies, it is defined as no requirement of reinstitution of ventilatory support in the 48 hours after extubation.

Weaning failure: It is defined as the patient did not tolerate or fail SBT or required re-intubation/reinstitution of ventilator support within 48 hours after extubation or if a patient dies within 48 hours after extubation.

As per weaning according to a new definition (WIND), separation attempt means SBT with or without extubation in intubated patients and no requirement of ventilator support 24 hours in tracheotomized patients.[55] Weaning success was defined as no reintubation required within 7 days after extubation and no ventilator support required for 7 days after separation attempt in tracheotomized patients.

20. When to repeat Weaning attempt once failed?

Recommendations: We recommend repeating SBT after 24 hours or after resolution of the reason of failed SBT whichever is earlier.

21. How to ventilate, if patient fails SBT, in the interim period?

Recommendation: We recommend to use either PSV or Controlled ventilation (non-fatiguing strategy) before giving another SBT.

Table 7: Comparison of weaning indices

Index	*Cut off value*	*Equation/Measurement*	*Remarks*
Respiratory rate (RR)	<30/min		– Simple – Part of a routine monitoring
Tidal volume (Vt)	>5 mL/kg	– By Spirometer if patient is on T-piece – By Ventilator expiratory parameters if patient is on PSV by keeping PSV and PEEP at 0	– Require spirometer – Part of a routine monitoring on ventilator screen
Forced vital capacity (FVC)	>15 mL/kg	Same as Tidal Volume	Difficult to measure in all patients
Minute ventilation	<15 L/min	Vt x RR	Easy to measure
Rapid shallow breathing index (RSBI)	<105 breaths/min/L	f/Vt: frequency/Vt	– Most studied – Easy to measure – Very popular – Simple to measure – High sensitivity but less specificity
Maximum inspiratory pressure (PImax)	< –30 cm H_2O (Normal: –90–120 cm H_2O)	Breathing with ventilator valves closed (Pimax Maneuver)	Requires patient's co-operation
P0.1/PImax	> 0.3 P0.1 is pressure at the airway opening 0.1 s after start of inspiratory flow	P0.1/PImax	– Complex – No added advantage
P0.1 x f/VT	<300		Less studied
Dynamic compliance, rate, oxygenation, max inspiratory pressure (CROP index)	>13	(Cdyn × PImax × (PaO_2/PAO_2))/f	Complex
Dynamic compliance, oxygenation, rate, effort (CORE index)	>8	Cdyn × (PImax/P0.1) × (PaO_2/PAO_2)/f	– Complex
Weaning index (WI)	<50	RSBI × EI × VDI (EI: peak pressure /negative inspiratory force; VDI: MV/10)	– Complex
integrative weaning index (IWI)	>25	(CRS × SaO_2)/(f/VT) (CRS = Static compliance of the respiratory system)	– Very complex – Labor intensive
Heart rate, acidosis, consciousness, oxygenation, respiratory rate (HACOR)	≥5	Predicts weaning failure	– Complex – More validated for predicting NIV failure
Diaphragmatic RSBI	1.767	RR/diaphragmatic displacement (in millimeters) and expressed as breath/minute/millimeter.	– Predicts weaning failure – Requires expertise – Require larger study
Minute ventilation recovery time		Calculated before and 30 min after SBT	– Simple but in accurate – Multiple confounding factors

22. What to do when one fail to wean (Difficult weaning)?

Recommendations (Difficult/Prolonged Weaning): We recommend a structured approach to diagnose and treat the cause of weaning failure before offering repetitive SBTs.

The cause of difficult weaning can be established by a systematic approach including respiratory mechanics-related issues (like increased respiratory workload or decreased respiratory capability), neuromuscular issues (like critical illness neuromyopathy) or cardiovascular issues (like fluid overload, left heart failure), metabolic issues (like non-resolution of primary disease or sepsis or accumulation of sedative drugs, etc.), endocrine issues or psychological issues (like delirium, depression, poor sleep quality, etc.). Aggressive physical therapy targeted toward improving respiratory muscle strength and nutrition should be provided for this category of patients. The common reasons for prolonged weaning are Accumulation of fluid or sedative drugs, myopathy, neuromyopathy, persistent sepsis, excessive secretions, significant cardiovascular dysfunction, psychological issues, poor sleep quality, diaphragmatic dysfunction, endocrine or metabolic reasons, nutritional failure, etc.

23. Which extubation criteria to be used (extubation screening)?

Recommendation: We recommend monitoring a combination of criteria as per the clinical scenario.

Various criteria for extubation are:

- Has the acute indication for intubation been resolved?
- Airway/Breathing—no significant airway, facial, or neck swelling; was it difficult intubation; did the patient fail extubation in the last 72 hours; no acute indication that the patient will fail to protect own airway; adequacy of oxygenation ($FiO_2 \leq 0.4$, PaO_2 >60 mm Hg, PEEP: +5 – +8); adequacy of gas exchange; chest X-ray should be stable or improving; results of SBT.
- Airway protection and patency factors—the patient should be breathing effectively without any exertion, ability to protect the airway (cough reflex), the volume of tracheobronchial secretions and suctioning frequency (≤4 hourly), cough strength, level of consciousness, cuff leak test.
- Spontaneous breathing trial—there are uncertainties on the duration of the test, optimal level of PEEP to be used, and definition of SBT pass or fail. Successful accomplishment of SBT does not necessarily imply that the patient is ready for extubation.
- Circulation—no tachycardia, nil or low dose vasoactive agents, systolic BP >90 mm Hg or mean BP >60 mm Hg, stable cardiac rhythm, no ongoing myocardial ischemia.
- Neurological—level of consciousness, no ongoing sedation or neuromuscular blockade, neck holding, able to hold up arms in the air for 15 seconds, good pain control.
- Fluid/electrolyte status—no significant acid-base disturbances, no significant electrolyte disturbances, optimized fluid status
- Others—easy vs difficult intubation, need for any procedures, time of the day, staff skill in unit overnight.
- Measured parameters—RSBI <105 breaths/minute/L, intrapulmonary shunt fraction via pulmonary artery catheter <15%, physiological dead space <40%, vital capacity of 15 mL/kg or more, maximum negative inspiratory force of 30 cm H_2O or more.
- Rapid shallow breathing index is used to predict extubation if the primary indication for invasive ventilation is a respiratory issue.[58,59] Rapid shallow breathing index predicted 58% extubation success in a prospective observational study. Though simple to perform, it is a poor indicator as nearly two-thirds of the patients are intubated for non-respiratory indications.[60] Ventilator support settings and variation due to SBT initiation can influence RSBI.

Multiple prediction scores have been developed to predict extubation outcomes in patients on invasive ventilation. The ability of indicators to predict extubation outcomes has varied among studies.[61] Each variable is a predictor of extubation failure with varying results depending upon the population studied, trained expertise, and medical resources available in the clinical setup with a synergistic effect of these factors.[58,59,61] Predicting a patient's predisposition to be extubated is dependent on many physiological variables. There are no gold standard indices to predict extubation.

24–28. What helps in preventing unplanned extubation?

Recommendation:

We recommend incorporating the diagnosis of delirium as a cause of agitation in sedation protocol.

We recommend the use of physical restraints only in clinically appropriate situations and not as a routine part of therapy.

We recommend standardizing endotracheal tube securement and developing protocols to identify patients ready for weaning and extubation. We suggest an adequate nurse-to-patient ratio to help prevent unplanned extubation.

We recommend quality surveillance to identify and reduce the incidence of unplanned extubation in a unit.

Preventive measures:

- Quality improvement surveillance programs are associated with a reduction in unplanned extubation (UE).
- Physical restraints—Inconsistent results have been reported with the use of physical restraints on the incidence of unplanned extubation. Paradoxical findings have been reported on the use of physical restraints in patients with unplanned extubation.[62,63] On the other hand, a higher incidence of delirium (39.8%) is reported with the use of physical restraints.[64]
- Education with updated information on best practices.
- Respiratory care services and collaborative efforts with critical care teams is necessary.
- Securing the endotracheal tube—It is still a contentious issue over which fixation method is more valuable to prevent unplanned extubation ways of securing endotracheal tube or tracheostomy tube should be standardized, e.g., tape and tie together vs securement devices guided by cost and associated skin integrity issues.
- Implementing standardized practices—Documenting position of endotracheal tube referenced to teeth; documenting position of endotracheal tube referenced to chest X-ray; documenting endotracheal tube cuff pressures; ventilator circuit should be steadied with arm-support; ensuring secure endotracheal tube during inter- and intra-hospital transport.
- Pain and discomfort along with a desire to communicate increase the incidence of unplanned extubation. Assessing the degree of pain with commonly used pain scales, and controlling agitation and optimizing analgesia helps. Assessing a patient's emotional and mental status helps in safeguarding safety.
- Implementing a sedation protocol will prevent injury in patients with self-extubation.
- A number of intubation days also influences a number of unplanned extubations. A study noted patients with unplanned extubation had longer duration of MV, longer stay in the ICU, and longer hospital stay.[65]
- Protocols to identify a patient's readiness for weaning from invasive ventilation, if patients meet weaning readiness criteria, a SBT should be attempted and if they pass, they should be fast-tracked to extubation. Weaning protocols have been noted to be a significant predictor of UE with a lower re-intubation rate and significantly shorter ventilator duration in a prospective cohort study.[9]
- Having standardized sedation, weaning, and pain protocols is the strongest predictor of UE.[66] Unit protocols need to be validated annually by intensivists, respiratory care therapists, and clinical nurse specialists on the basis of current evidence-based respiratory recommendations.
- A nurse-to-patient ratio of 1:3 was associated with a higher risk of UE according to a multidisciplinary survey-nursing care is an important factor in preventing UE. Nurse experience of less than 5 years is associated with a higher risk of UE.[67,68]
- Patient load, shift arrangement with a higher prevalence of UE in units managed by junior residents and during night shifts, and interdisciplinary interaction affect UE.[69]

29. When to re-intubate after accidental extubation?

Recommendation: We recommend re-intubation after unplanned extubation in patients with upper airway obstruction, increased *secretion burden, respiratory failure due to exhaustion, impaired or reduced level of consciousness, and cardiopulmonary arrest.*

Most patients required re-intubation within 1 hour of UE.[70] Likelihood of re-intubation was associated with age > 65 years, full ventilatory support, assisted/control ventilator mode, arterial pH ≥ 7.45 before UE, PaO_2/FiO2 < 200–250 mm Hg before UE, Glasgow coma scale score <11, non-surgical patients, and presence of ≥3 comorbidities.[14,71–74]

Common indications requiring re-intubation after UE are; (1) Upper airway obstruction, (2) increased secretion burden, (3) respiratory failure due to exhaustion, (4) impaired or decreased level of consciousness, (5) cardiopulmonary arrest, (6) need for sedation for diagnostic or therapeutic procedures. Post-UE vigilance for with high-intensity monitoring is necessary to assess the for need re-intubation.

30 and 31. What is the role of cuff leak test in extubation?

Recommendation: We suggest performing a cuff leak test [CLT] in mechanically ventilated adults who meet extubation criteria and are considered at high risk for post-extubation stridor.

We recommend having a protocolized surveillance, assessment, and treatment policy in the units to obviate the routine need to perform CLT prior to extubation.

Definitions of CLT have varied among studies. Methodological differences have influenced the incidence and predictive value of CLT. A high sensitivity and specificity of CLT for post-extubation airway obstruction has been reported.[75,76] A multi-center prospective study of unselected critically ill patients noted peri-extubation stridor (PES) in less than 10% of patients.[77] A comprehensive PES risk screening tool guides intensivists to target CLT evaluations. A meta-analysis of 14 observational studies showed that performing a CLT reduced the occurrence of post-extubation stridor and decreased the rate of reintubation. However, it showed a delay in extubation of the patients.[78] Additionally, most patients whose extubation decisions are not based on CLT results are successfully extubated. A CLT decreases re-intubation rate, and PES rate, delays extubation, and does not affect the duration of MV. Cuff leak test should be reserved for patients at high risk for PES such as those who experienced traumatic intubation, required intubation for more than 6 days, have a large endotracheal tube, female gender, or required re-intubation after an unplanned extubation.[79,80] Each patient should be individually evaluated for risk factors for failed extubation as a best practice. There is no need for repeating a CLT after administration of systemic steroids.

32 and 33. Post-extubation stridor and role of medications on its prevention and treatment.

Recommendations:

We recommend administering systemic corticosteroids at least 4 hours before extubation in patients to prevent stridor and re-intubation in high-risk population.

We make no recommendations on the role of steroids in routine planned extubation.

We recommend that, Non-invasive ventilation should not be used in the treatment of patients with post-extubation stridor and consider timely re-intubation.

Prevention of Post-extubation Stridor:

A randomized, double-blind trial of methylprednisolone versus placebo before extubation in all patients (a cuff leak test was not performed) noted that steroids reduced post-extubation stridor, re-intubations, and re-intubations due to post-extubation stridor.[81] A meta-analysis documented a reduced incidence of post-extubation events compared with placebo or no treatment following prophylactic corticosteroids pre-elective extubation.[82] The effect of steroids on reintubation and stridor was more pronounced for selected high-risk patients (traumatic intubation, low cuff-leak value. or previous extubation failure), as determined by a reduced cuff leak volume. In contrast, steroid benefit was unclear when trials did not select patients for their risk of reintubation. Steroids were administered at least 4–24 hours before extubation in all but one trial. The dose and timing of steroids administered varied amongst the analyzed trials. However, the benefits of corticosteroids for the prevention of PES are seen following repeated doses of corticosteroids, or administration 12–24 hours pre-extubation.[83] The frequency and severity of adverse effects of systemic corticosteroids outweigh the benefits given their short duration of action. A repeat cuff leak test is not required after the administration of systemic steroids.[84] A prospective, randomized double-blind, placebo-controlled study noted a 50% drop in the incidence of respiratory distress and the need for reintubation in patients who were nebulized with budesonide vs saline post-extubation.[85]

Treatment of Post-extubation Stridor:

A methylprednisolone dose of 40 mg intravenously or dexamethasone 5 mg intravenously is suggested based on the dose used for prevention of post-extubation laryngeal edema or 1 mg of nebulized budesonide.

Intravenous corticosteroids and nebulized epinephrine (dose-1 mg in 5 mL) for 24–48 hours, and elevation of the head end of the bed to reduce venous congestion help lessen edema.[26]

A multicenter randomized trial comparing non-invasive ventilation (NIV) to standard medical therapy for patients with respiratory failure post-extubation did not find any difference in the need for re-intubation between the two groups. Additionally, the median time from respiratory failure to reintubation was longer in the NIV group.[86]

Re-intubation is the definitive treatment and should not be delayed in indicated patients.

34. Role of HELIOX in post-extubation stridor.

Recommendations: No recommendation can be given on routine use of Heliox for post-extubation stridor

Anecdotally using heliox is associated with reduced need for intubation. Clinical efficacy in adults is yet to be proven. Further robust research in the form of prospective randomized clinical trials is needed to validate the therapeutic efficacy of Heliox and study reduction in re-intubation rate in those with post-extubation stridor.[87] However, till more evidence is available it is not possible to recommend the routine use of heliox in non-intubated patients with expiratory airflow limitation.

35. Does Tracheostomy help in early weaning?

Recommendation: We recommend tracheostomy as a mean to facilitate weaning in difficult to wean patients.

Due to the physiological advantages of reduced dead space, less airway resistance, decreased work of breathing, better pulmonary toileting, less likelihood of tube obstruction, improved patient comfort, less need for sedation, and more chances of moving patient out of the ICUs, tracheostomy is likely to facilitate weaning.

Beyond these, in a prospective study, Mohr et al. concluded that tracheostomy facilitates weaning by a mechanism other than improvement in ventilatory mechanics and gas exchange.[88] The literature has shown a beneficial effect of early tracheostomy on difficult weaning.[89,90] A position statement by the ISCCM expert panel states that "early tracheostomy may reduce the duration of MV and may result in more ventilator-free days in critically ill patients".[91] However, cohort studies have also reported a longer durations of MV and ICU and hospital stay in tracheostomised patients but effects on mortality are inconsistent.[92]

36–38. Do weaning to NIV or HFNO helps?

Recommendations:

We recommend that NIV should be used as weaning strategy for difficult weaning.

We suggest HFNO as a post-extubation weaning strategy for hypoxemic patients at risk of developing acute respiratory failure.

We do not give preference of either modalities, HFNO or NIV, for weaning.

Randomized control trial and meta-analysis have clearly shown the beneficial effects of judicious NIV for weaning. Cochrane review showed that weaning with NIV significantly reduced mortality, weaning failures, ventilator-associated pneumonia, and LOS in ICU and in hospital, reduced rates of tracheostomy, reintubation, and total duration of MV but no significant effect on the duration of ventilation related to weaning.[93] Mortality benefits were significantly greater in trials on patients with COPD than in mixed patient populations.[93] Lately, the clinical benefit of HFNO on weaning has been suggested due to a moderate PEEP effect with increased end-expiratory lung volume, CO_2 washout from nasopharyngeal dead space, and preservation of mucosal function. This leads to improved oxygenation, optimal secretion removal, decreased airway resistance, intrinsic PEEP, and work of breathing, without adding to patient discomfort.[94] Compared to conventional O_2, HFNO has been shown not only to improve oxygenation and respiratory comfort but also to decrease the need for reintubation and post-extubation NIV in the ICU population.[95] In patients at low risk for extubation failure, HFNO has also been demonstrated to decrease post-extubation ARF and reintubation rate within 72 hours.[96] High flow nasal oxygen has advantages over NIV as it is a simpler technique, better tolerated, and more comfortable. Moreover, it can be used in a complementary way with preventive post-extubation NIV in high-risk patients for reintubation, especially in acute ARF. We need further randomized controlled studies to see whether HFNO can substitute for NIV to prevent reintubation, or even to treat post-extubation ARF.[96–98]

39. Do specialized Weaning Centers help?

Recommendation: We suggest that patients with weaning failure can be considered for transfer from acute care settings to a specialist center, where available.

For difficult-to-wean patients or patients who need to be on home ventilatory support, for continuity of care, specialized units or units in centers with the appropriate multidisciplinary expertise of different professional groups involving the respiratory therapist, specialized nurse, and the necessary infrastructure are proposed. These centers need to have interdisciplinary and inter-hospital collaborations between specialists due to the heterogeneous clinical profiles of the patients and the different structural organizations of the hospitals. In a multi-center non-randomized controlled observational German study on 61 patients considered unfit for weaning admitted to a weaning center, 82% were successfully weaned off from invasive ventilation in the weaning centers, 34% of them with the aid of NIV, and the survival rate at 1 year was higher than in the group without invasive ventilation (90 vs 55%).[99] In another prospective observational cohort study of 262 patients admitted to a specialist weaning center in the UK, favorable short-term and long-term clinical outcomes were seen in patients with weaning delay and failure.[100] It is premature for the panel to recommend specialist centers for weaning in resource-limited Indian settings but the panel does suggest the creation of such centers for resource optimization.

40. Do Nurse or Respiratory therapist driven protocol lead to early weaning?

Recommendation: We suggest Implementation of nurse or respiratory therapist driven weaning protocol after adequate training and competency assessment.

Literature has shown a positive impact on outcomes with nurse or respiratory therapist-driven weaning as compared to physician-led weaning.[101] A meta-analysis of three studies including 532 patients, showed a significant difference in reducing the duration of MV (mean differences = –1.69 days), ICU LOS (mean differences = –2.04 days, I2 = 18%, and p = 0.00001); and hospital LOS (mean differences = –2.9 days, I2 = 0%, and p = 0.00001) with a nurse-led weaning protocol.[102] A 2011 Cochrane systematic review and meta-analysis concluded that protocolized weaning in comparison with usual care, the average total time spent on the ventilator was reduced by 25%, the duration of weaning was reduced by 78%, and the length of ICU stay reduced by 10% without adverse outcomes.[103] A multi-center prospective cohort study by Teixeira et al. concluded that use of a protocol in patients failing their first SBT led to significantly higher extubation rates with reduced mortality. Extubation failure reduced to 13.3% in the protocol group from 30.4% in the non-protocol group.[104] Another randomized controlled trial in a coronary care unit showed significantly faster times to extubation and lower reintubation rates (16.7%), once weaning protocol was initiated.[105]

41. Effect of ICU staffing on weaning success?

Recommendation: No recommendation can be given on the effect of ICU staffing on weaning success.

Although it is expected that a better nurse-patient ratio would result in successful weaning outcomes, no convincing literature is available studying the impact of nursing staff ratio on weaning.

42. What are future perspectives in weaning?

Recommendation: No specific recommendation can be given on use of artificial intelligence or bio-signal based weaning protocols.

An AI prediction model with machine learning algorithms with the use of artificial intelligence with physiological parameters as predictors of weaning success has been brought into clinical practice. These AI models develop an application to evaluate risk based on patients previous medical data, the clinical and laboratory parameters, and ventilatory settings to assist clinicians predict patient outcomes.[106] A bio-signal-based weaning prediction practice, which would continuously reflect the patient's clinical and physiological progression over time seems to be a promising tool to assist clinicians in determining the optimal extubation time. Bio-signal data-based markers obtained during SBTs including electrocardiogram (ECG), respiratory impedance, photoplethysmography (PPG), arterial blood pressure, and ventilator parameters, would provide a better physiological information about the patient's status.[107] A prospective study of retrospectively analyzed breathing pattern variability in a surgical ICU in 78 mechanically ventilated postoperative patients showed that small breathing pattern variability is associated with a high incidence of weaning failure. This Breathing pattern variability can potentially serve as a weaning predictor.[108] All these parameters need well-planned RCTs but have promising future prospects.

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