Difficult Weaning from Mechanical Ventilation

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Overview

- Types of Weaning
- Causes of Difficult Weaning
- Detection
- Management
- Modes of Weaning

Introduction

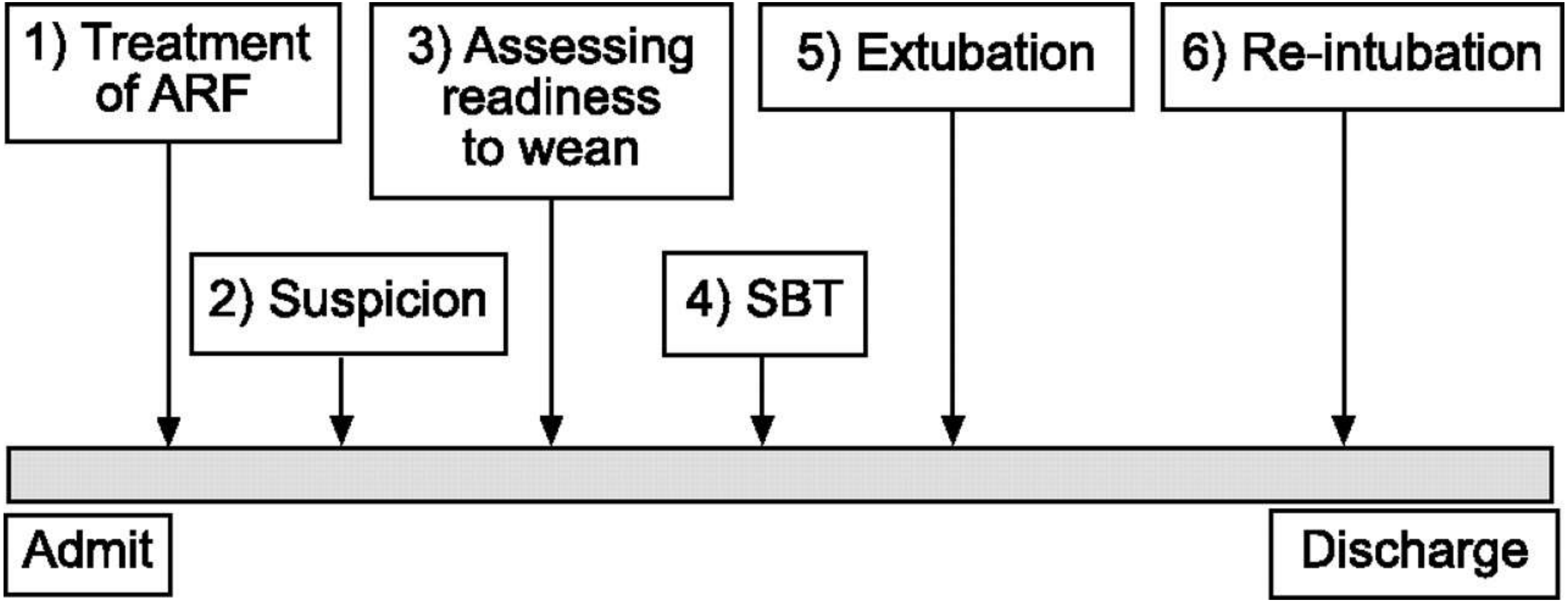
- Weaning - Entire process of liberating the patient from mechanical support
- Extubation failure occurs in up to 47% of patients on MV

Weaning Success	Weaning in Progress	Weaning Failure

Eur Respir J 2007; 29: 1033–1056

Indian J Crit Care Med. 2008;12(1):1-9

Stages of Weaning



Eur Respir J 2007; 29: 1033–1056

Simple weaning

Patients who proceed from initiation of weaning to successful extubation on the first attempt without difficulty

Difficult weaning

Patients who fail initial weaning and require up to three SBT or as long as 7 days from the first SBT to achieve successful weaning

Prolonged weaning

Patients who fail at least three weaning attempts or require >7 days of weaning after the first SBT

Eur Respir J 2010; 35:88

Eur Respir J 2007; 29: 1033–1056

Simple weaning group

- Half to two-third of weaning patients
- ICU mortality ~5%

Difficult weaning groups

- 26 to 39% of weaning patients
- ICU mortality ~25%
- Increased patient discomfort
- Increased mortality
- Increased ICU stay

Eur Respir J 2010; 35:88

Eur Respir J 2007; 29: 1033–1056

Significance

- Difficult-to-wean patient consumes a third of ICU resources
- ~50 % of patients with difficult weaning end up with prolonged weaning
- Hospital mortality was increased in patients with prolonged weaning (32%)

Eur Respir J. 2010;35(1):88

JICS Vol 13 No. 4, Oct 2012

Limitation of ICC

- Patients who were weaned
- Patients weaned without SBT
- Tracheostomized patients

Am J Respir Crit Care Med Vol 195, Iss 6, pp 772–783, Mar 15, 2017

Weaning according to New Definition (WIND) Classification:

- Group "No weaning": No separation attempt

Group 1 (Short weaning)	Group 2 (Difficult weaning)	Group 3 (Prolonged weaning)
1st attempt ↓ Termination of the weaning process within 1 day	1st attempt ↓ Termination of the weaning process after >1 day till <1 week	Weaning not terminated 7 days after the first separation attempt
		Group 3a / Group 3b

Am J Respir Crit Care Med Vol 195, Iss 6, pp 772–783, Mar 15, 2017

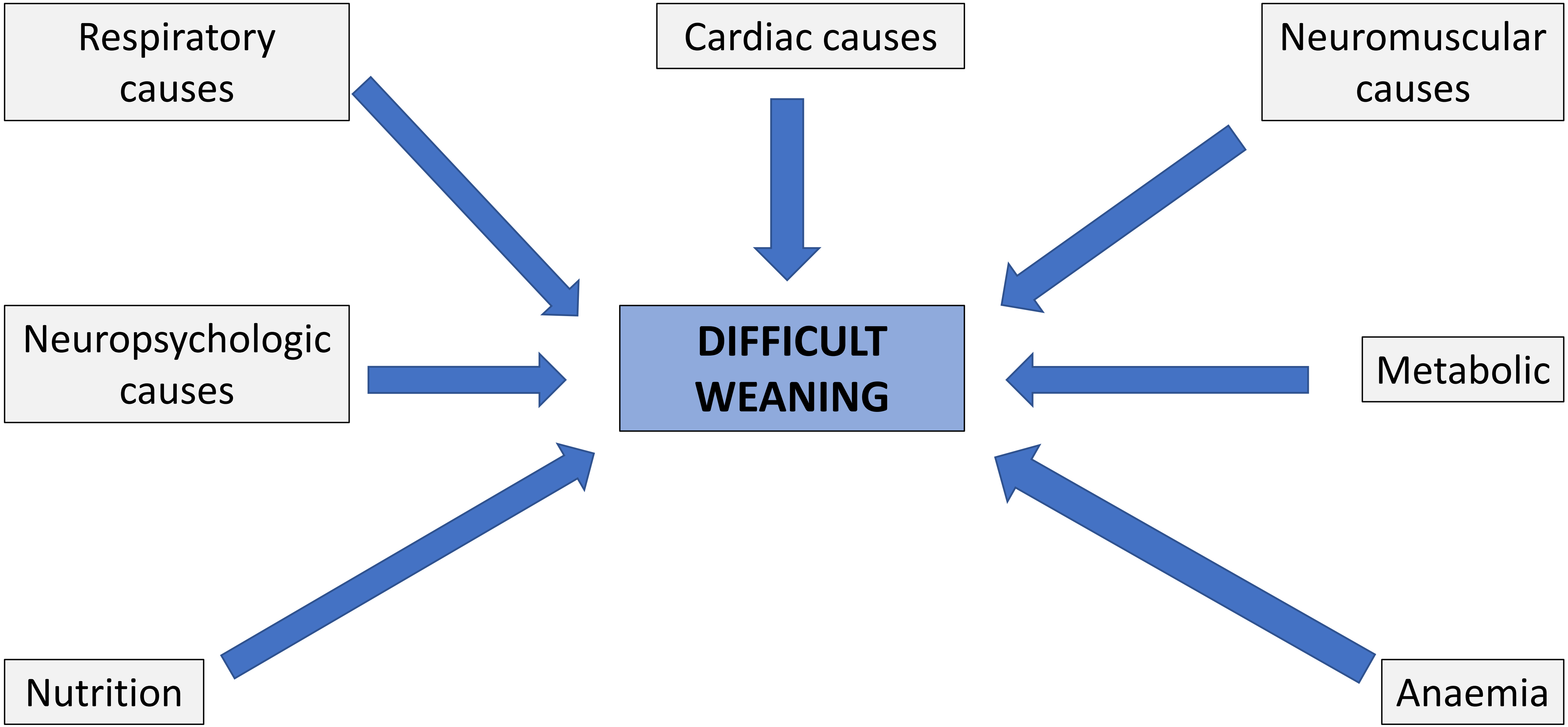
Predictor of Prolonged Mechanical Ventilation

I-TRACH Criteria

Intubation in the ICU	Hospitalized in ICU for >24 hrs
Tachycardia	Heart rate>110
Renal dysfunction	Blood urea nitrogen>25 mg/dL
Acidemia	pH<7.25
Creatinine	>2.0 or>50% increase from baseline values

Criteria ≥4 more likely to require MV>7 days
Sensitivity-61.8%, Specificity 82%

J Intensive Care Med. 2018;33(10):567


Respiratory causes
Cardiac causes
Neuromuscular causes
Neuropsychologic causes
DIFFICULT WEANING
Metabolic
Nutrition
Anaemia

Central drive

- Sedation, analgesia
- Coma
- Raised intracranial pressure
- Hypercapnia

Respiratory muscle strength

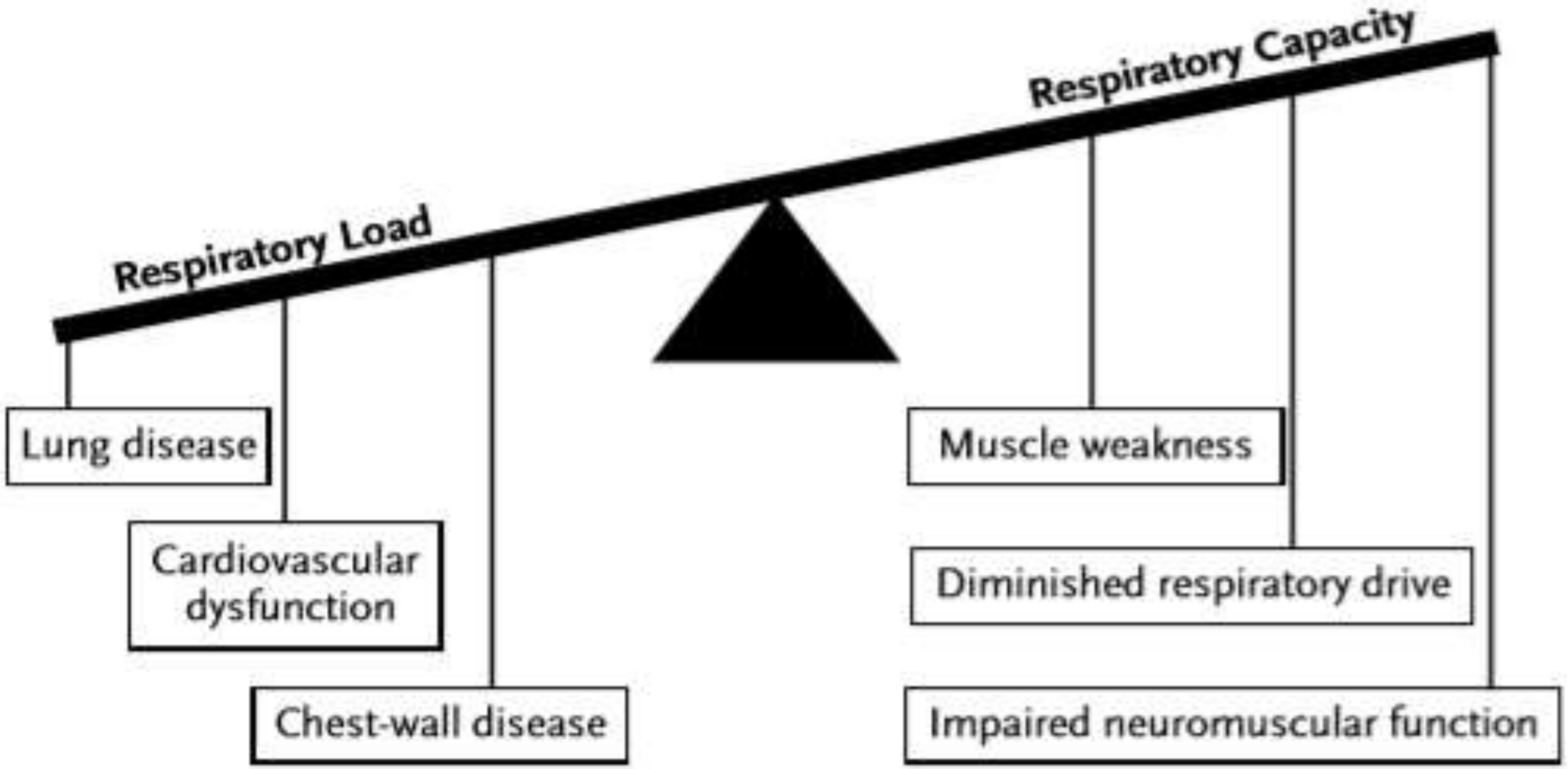
- Hypophosphataemia
- Disuse atrophy
- Sepsis
- Polyneuropathy/myopathy

Load applied to the muscles

- Hyperinflation
- Left ventricular failure
- Bronchospasm
- Lung fibrosis

Thorax 2002;57:986–991

Respiratory causes



N Engl J Med 2012;367:2233-9

Respiratory or Ventilatory causes

- Increased ventilator demand
    - Hypoxemia
    - Elevated dead space
    - Excess carbon dioxide production
    - Metabolic acidosis
    - Neuropsychiatric factors

Factors affecting Respiratory mechanics

- Increased resistive load and Reduced compliance

Increased airway resistance

- Tube
- Central airways
- Small airways

Reduced compliance

- Chest wall
- Lung

Respiratory or Ventilatory causes

- Decreased ventilatory drive
  - Excess sedation
  - Metabolic alkalosis
  - Central nervous system disease
  - Central sleep apnea
  - Obesity hypoventilation syndrome

Ventilatory causes

Ventilator Circuit

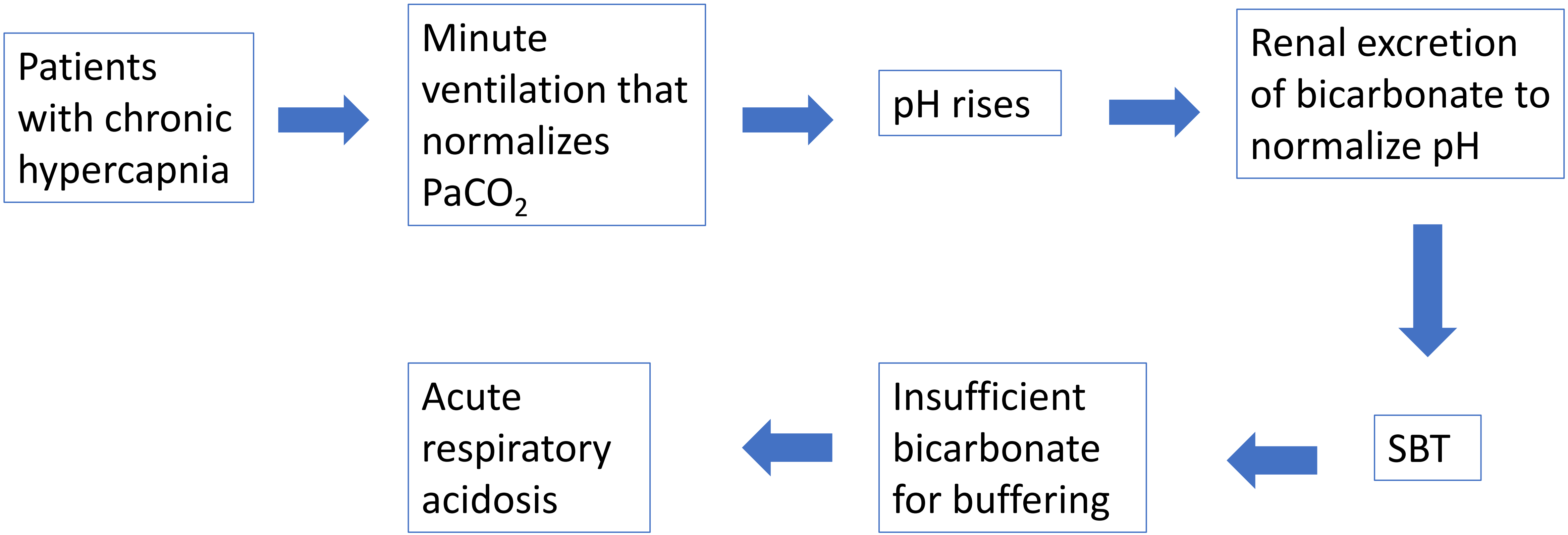
- Equipment dead space
- Circuit compliance
- Exhalation valve dysfunction
- Increased resistance

Inappropriate Setting

- Ventilator dysynchrony - e.g., inadequate inspiratory flow rate or flow trigger setting
- Lead time between onset of inspiratory effort and the onset of flow delivery
- Respiratory effort after onset of exhalation
- Ineffective triggering
- Expiratory effort prior to switchover from mechanical inflation to exhalation
- High intrinsic PEEP

Respiratory or Ventilatory causes

Overventilation:



When to suspect respiratory cause

- COPD, asthma and ARDS patients
- Reduced compliance
- Development of PEEPi:
  - Expiratory flow limitation
  - High breathing frequency
  - Loss of elastic recoil of the lung
  - Patient-ventilator asynchrony (ineffective triggering)

Critical Care 2010, 14:245

When to suspect respiratory cause

- PEEPi was found to be higher in COPD patients with weaning failure compared with those successfully weaned

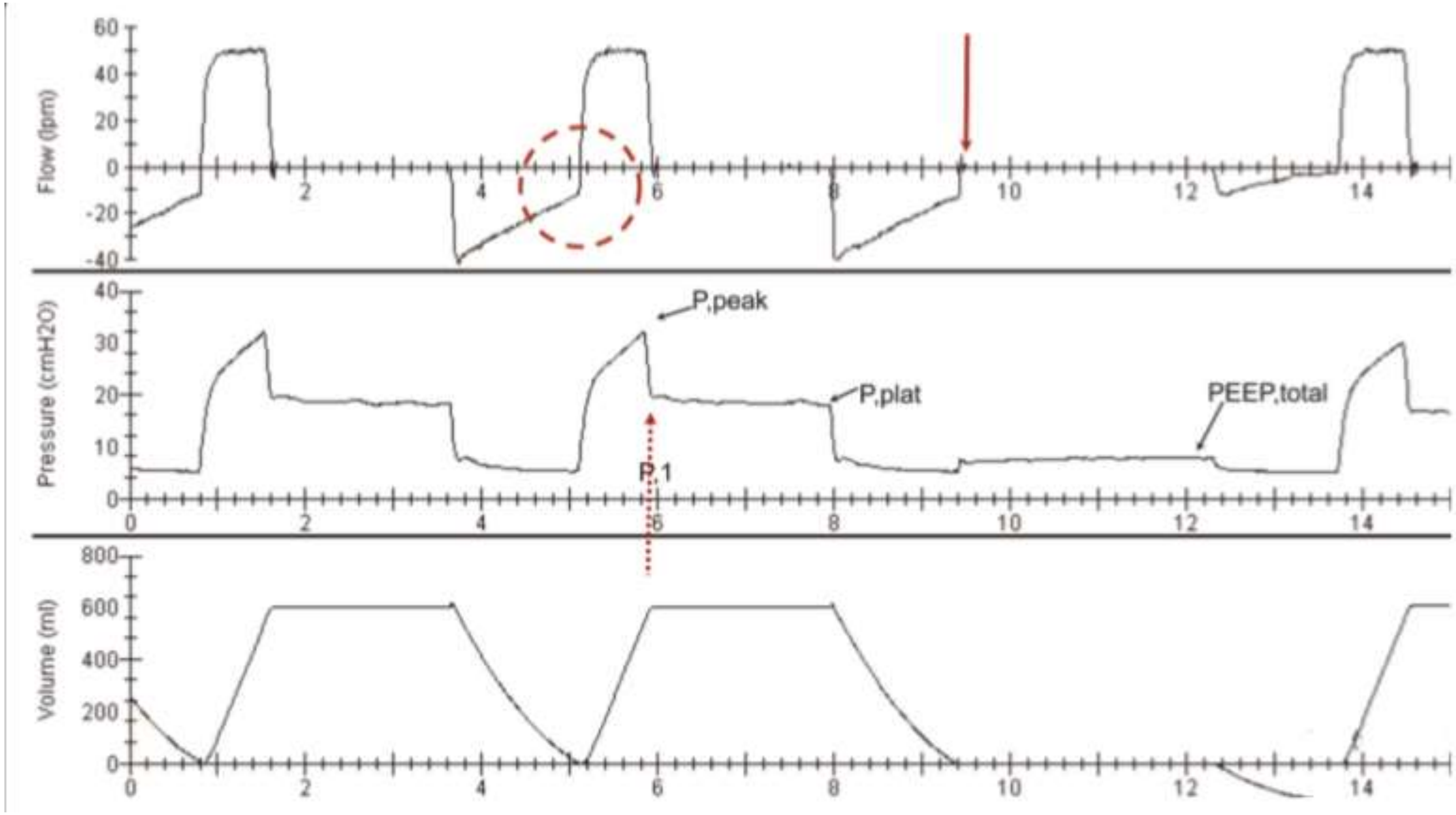
- Duration of mechanical ventilation was significantly longer in patients with ineffective triggering (>10% of all breaths) compared with those having lower incidence of ineffective triggering

Crit Care Med 2009, 37:2740-2745.

Respir Crit Care Med 1997, 155:906-915.

Diagnosis of respiratory causes

- PEEPi can be measured adequately is by using an esophageal balloon



Management of respiratory causes

- Changing the cycling-off criterion from 5% to 40% significantly reduce PEEPi and Work of breathing

- Patients with asthma and COPD should be treated optimally to reduce bronchoconstriction

- Optimizing compliance
    - Reducing edema of the lung and chest wall
    - Resolving atelectasis and thoracocentesis
    - Removing ascites

Cardiac causes

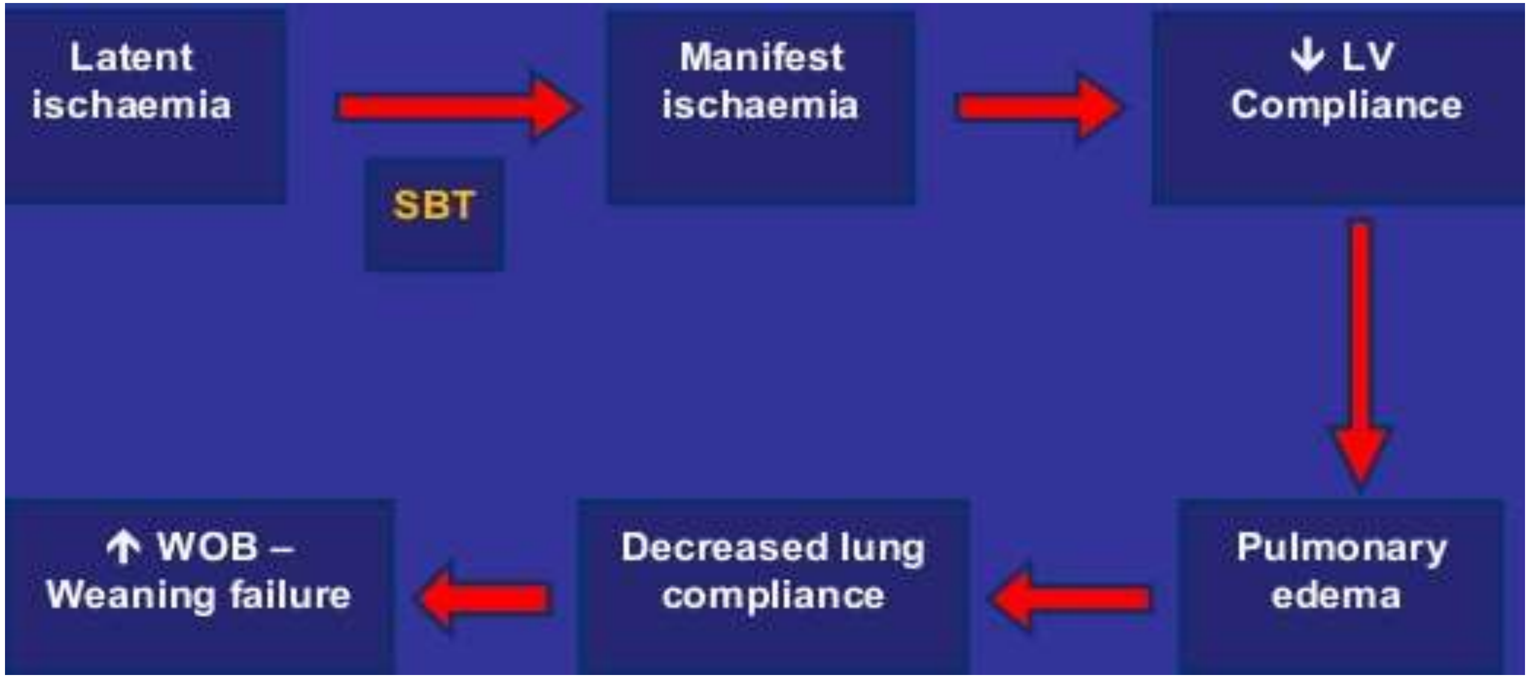
- Prevalence of weaning-induced cardiovascular dysfunction occur in upto 59% of patients

- Patients at high risk -
  1. Pre-existing cardiac disease
  2. COPD

Crit Care. 2016;20:369

Cardiac causes

- Weaning may induce myocardial ischemia in susceptible patients
- Pulmonary edema
- Fluid overload



Cardiac causes

- Dres et al. demonstrated that SBT-induced increases in BNP level by >12% suggest diagnosis of weaning-induced pulmonary edema contributing to weaning failure, with a sensitivity of 76% and a specificity of 78%

- PLR did not increase the cardiac index by >10 % before the SBT, the occurrence of SBT failure related to cardiac dysfunction was predicted with a sensitivity of 97 % and specificity of 81 %

Crit Care Med. 2014;42:1882–9

Intensive Care Med. 2015;41:487–94

Cardiac causes

Patients with COPD but without cardiac disease

↓

Weaning attempt

↓

Increased left ventricular afterload

↓

Significant reduction in left ventricle ejection fraction

Intensive Care Med
1994, 20:181-186

Diagnostic methods to detect cardiovascular dysfunction

History-predisposing risk factors
Clinical assessment
Exclude other causes

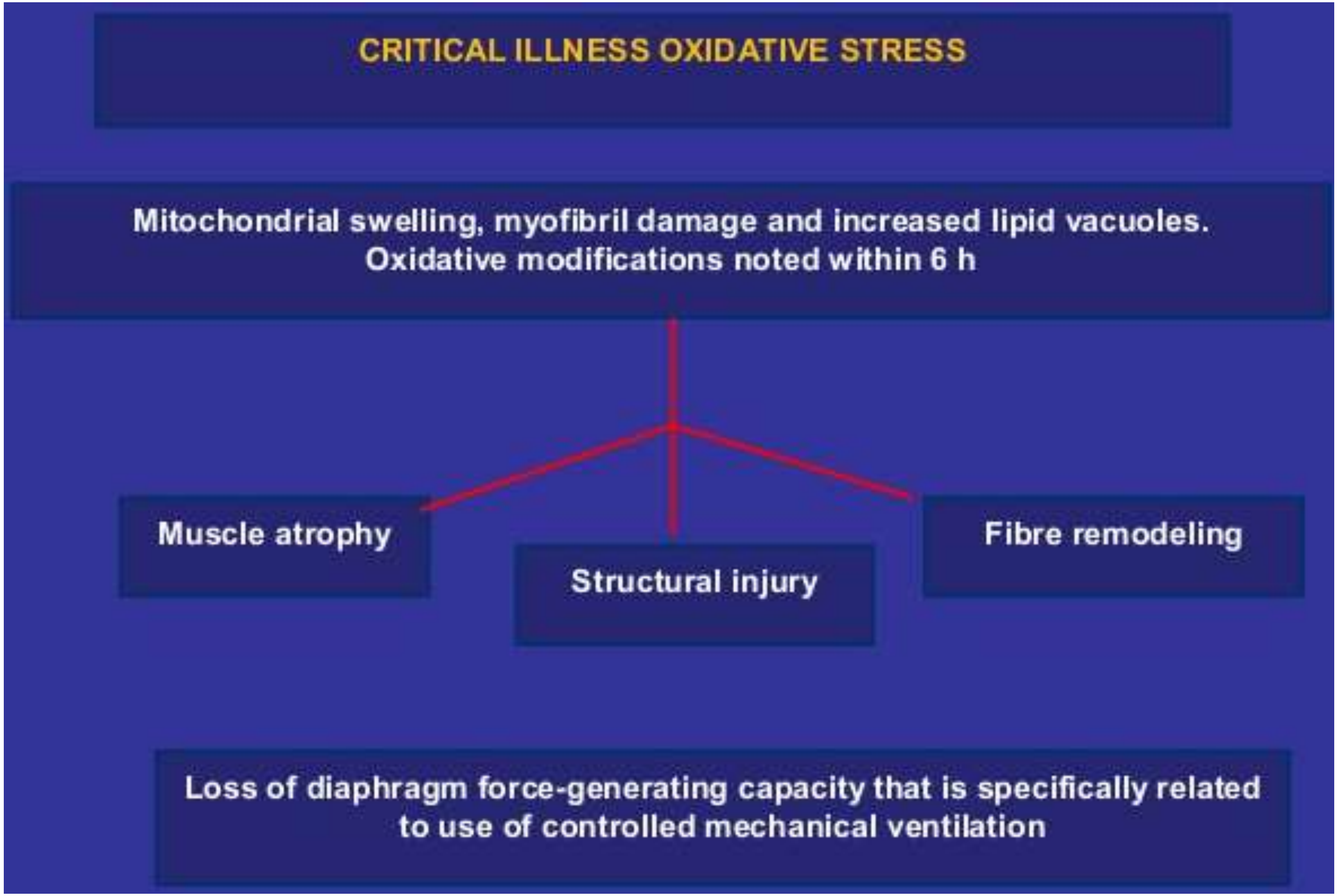
Electrocardiogram
Trans-thoracic Echocardiography
Lung Ultrasound
BNP

Confirmed weaning of cardiovascular origin
Determine etiology and start treatment

Neuromuscular

- Impaired respiratory drive
  - Uncommon cause of weaning failure
  - In most weaning-failure patients, respiratory drive is increased

Am J Respir Crit Care Med
1996, 154:1099-1105


CRITICAL ILLNESS OXIDATIVE STRESS
Mitochondrial swelling, myofibril damage and increased lipid vacuoles. Oxidative modifications noted within 6 h
Muscle atrophy
Structural injury
Fibre remodeling
Loss of diaphragm force-generating capacity that is specifically related to use of controlled mechanical ventilation

USG assessment for VIDD

- Anterior subcostal view- preferred method
- Diaphragmatic ultrasound using either excursion or thickening fraction has been demonstrated to perform at least equally or even better to other established weaning indices like rapid shallow breathing index-RSBI and maximum inspiratory pressure.

Sigala et al. Ann Transl Med 2017;5(4):79

Muscle Nerve. 2013 March ; 47(3): 319–329

USG assessment for VIDD

- Cut off values for diaphragmatic ultrasound predicting successful weaning were MDT >2 mm, DTF >30% and DE >1.5 cm

- Early switch from controlled MV to assist ventilation (addition of PS and or PEEP) was associated with reversal of VIDD

Ali et al. Egyptian Journal of Chest Diseases and Tuberculosis 66 (2017) 339–351

Management of Neuromuscular causes

- Airway occlusion pressure at 100 ms ($P_{0.1}$)
  - The inspiratory limb of the ventilator is occluded and the drop in airway pressure is continuously monitored
  - $P_{0.1}$ depends not only on respiratory drive but also on inspiratory muscle capacity (non-specific sign)
- Maximal inspiratory pressure
- Development of hypercapnia during a weaning trial

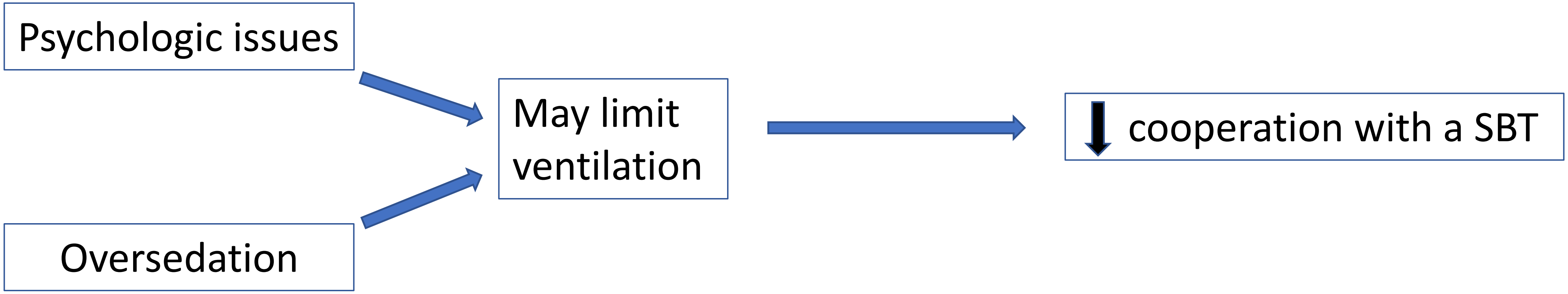
Management of Neuromuscular causes

- Antioxidants
  - Antioxidants alpha-tocopherol and ascorbic acid was associated with a reduction in ventilator-dependent days from 4.6 to 3.7 ($P < 0.05$)
- Tight glycemic control
  - Intensive glycemic control did not affect the duration of mechanical ventilation

J Resp Crit Care Med 1997, 156:1567-1571.

N Engl J Med 2009, 360:1283-1297.

Psychological



Psychological

- Depressive disorders: present in ~40% of patients undergoing weaning

Intensive Care Med 2010; 36:828

- Patients with delirium: twice as likely to be difficult-to-wean

Respirology 2016; 21:313

- Midazolam: risk factor for development of delirium
    - Sedation with dexmedetomidine reduces the incidence of delirium and reduces the duration of mechanical ventilation compared with sedation with midazolam

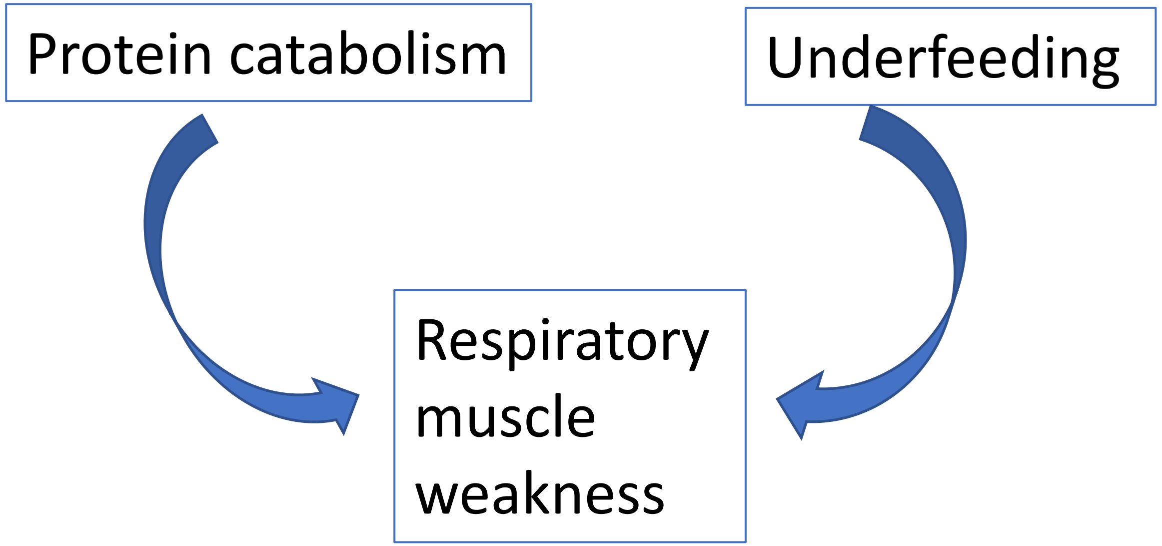
JAMA 2009, 301:489-499

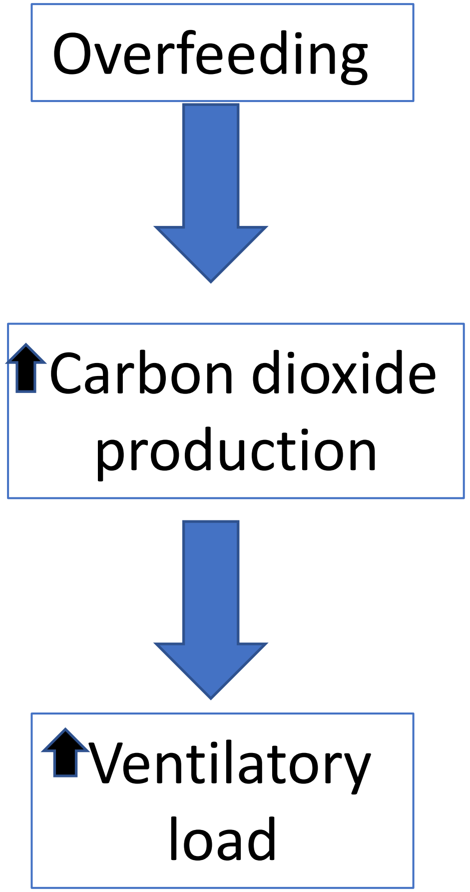
Psychological causes: Diagnosis

CAM-ICU	
Items	**Grading**
1. Acute Onset or Fluctuation of Mental Status Is the patient different than his/her baseline mental status? OR Has the patient had any fluctuation in mental status in the past 24 hours as evidenced by fluctuation on a sedation/level of consciousness scale (i.e., RASS/SAS), GCS, or previous delirium assessment?	0 absent 1 present
2. Inattention Say to the patient, "*I am going to read you a series of 10 letters. Whenever you hear the letter 'A,' indicate by squeezing my hand.*" Read letters from the following letter list in a normal tone 3 seconds apart. <u>SAVEAHAART</u> (Errors are counted when patient fails to squeeze on the letter "A" and when the patient squeezes on any letter other than "A")	0 absent (correct $\geq$ 8) 1 for inattention (correct 4-7) 2 for severe inattention (correct 0-3)
3. Altered Level of Consciousness Present if the Actual RASS score is anything other than alert and calm (zero)	0 absent (RASS 0) 1 for altered level (RASS 1, −1) 2 for severe altered level (RASS >1, < −1)
4. Disorganized Thinking <u>Yes/No Questions</u> 1. Will a stone float on water? 2. Are there fish in the sea? 3. Does one pound weigh more than two pounds? 4. Can you use a hammer to pound a nail? Errors are counted when the patient incorrectly answers a question. <u>Command</u>: Say to patient "Hold up this many fingers" (Hold two fingers in front of patient). "Now do the same with the other hand" (Do not repeat number of fingers) An error is counted if patient is unable to complete the entire command.	0 absent (correct $\geq$ 4) 1 for disorganized thinking (correct 2, 3) 2 for severe disorganized thinking (correct 0, 1)

Crit Care Med. 2017 May; 45(5): 851–857

Nutritional





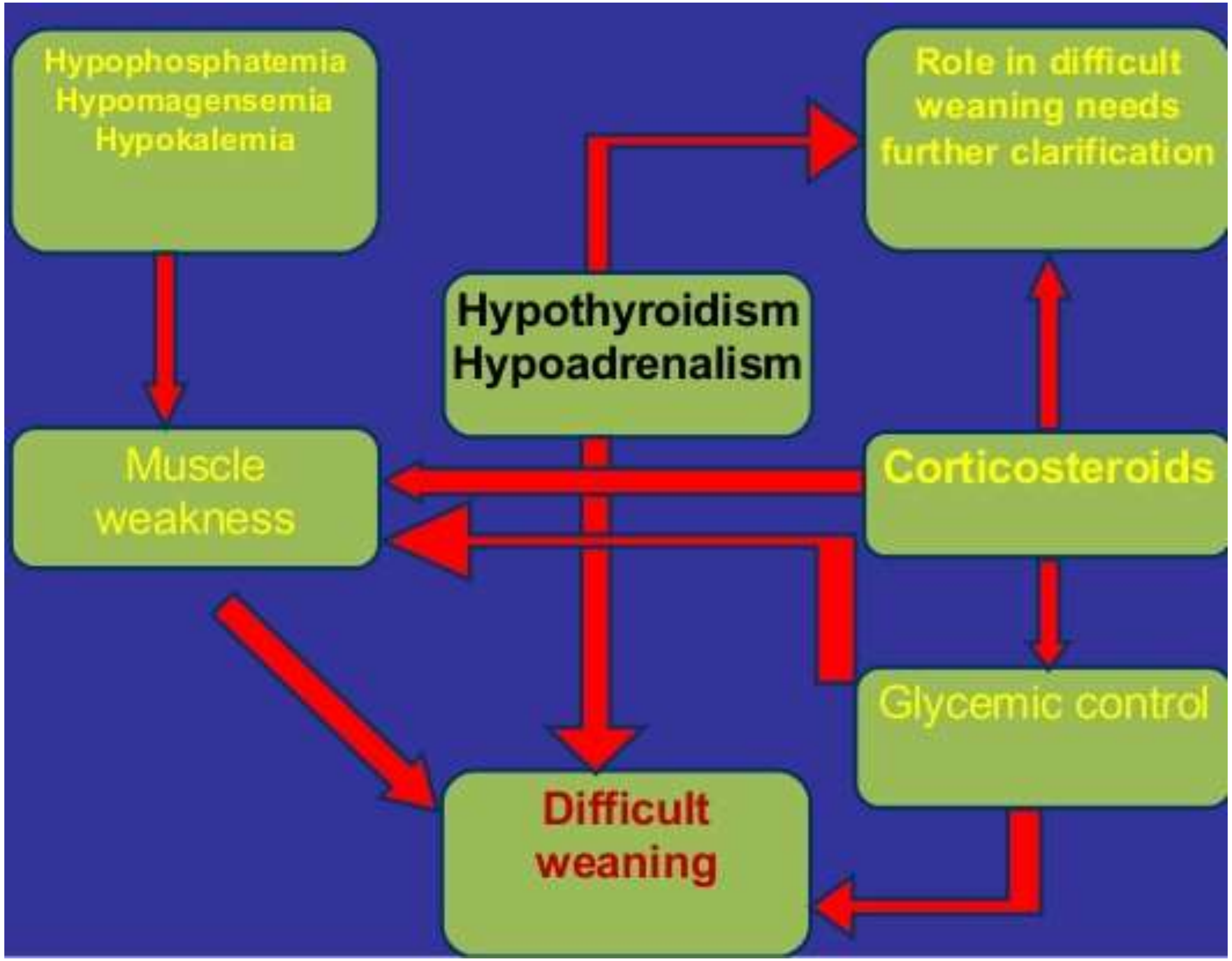
- Nutritional status evaluated by:
  BMI, plasma albumin concentration and nitrogen balance

Curr Opin Clin Nutr Metab Care 2005, 8:33-39.

Metabolic

- Metabolic disturbances
- Role of corticosteroids
- Hyperglycaemia
- Hypothyroidism

Critical Care
2010, 14:245



	Airway / lung			Brain		Cardiac	Diaphragm		Endocrine	
	Resistance	Compliance	Gas exchange	Delirium	Other cognitive dysfunction				Endocrine	Metabolic
Assessment	Flow-time loops, inspiratory occlusion	inspiratory /expiratory occlusion	$(A\text{-}a)D,_{O_2}$	CAM-ICU	Screening: depression, anxiety, sleep pattern	12 lead ECG before at end SBT S_{v,O_2} before / at end SBT Echocardiography before & after SBT	Pi, max	Serial physical examination (other neuromusc disorders)		Electrolytes Blood gas Indirect calorimetry
Intervention	albuterol, steroids Repeat loops, inspiratory occlusion PEEPi:Modify EIC in PSV bronchodilators	Radiology: Pleural fluid Atelectasis Ascites Diuretics Physiotherapy		Reorientation Mobilization Haloperidol	Anxiolytics Behavioral therapy Reduce noise / light during sleep	Afterload reduction Inotropes If ischemia: betablocker optimize hemoglobin	Early mobilization	Early mobilization		Provide adequate energy intake
Advanced assessment	Diagnostic bronchoscopy during SBT				Neuropsychologist: depression, anxiety,	Pulmonary artery catheter	Diaphragm fluoroscopy / echography $P_{0.1}$	Examination by neurologist EMG, nerve conduction velocity	Plasma cortisol before / after 250 umol ACTH Plasma thyroid hormone	
Advanced intervention		Thoracosentesis				Afterload reduction Inotropes	Reduce analgetics/ hypnotics		Cortisol iv Thyroid hormone	
Rescue assessment		Contrast echocardiography: intracardial shunt				BNP	Phrenic nerve conduction velocity Transdiaphragmatic pressure using gastric and esophageal balloon Diaphragm EMG	Muscle biopsy		
Rescue intervention				Dexmedetomidine		Levosimendan Bosentan	Antioxidants (vitamin C and E) Inspiratory muscle training			

Readiness for SBT trials

1. Cause of respiratory failure has improved
2. PaO_2 /FiO_2 ≥150 or SpO_2 ≥90% on FiO_2 ≤40% and PEEP ≤5cmH_2O
3. pH >7.25
4. Hemodynamic stability (no or low dose vasopressor medications)
5. Able to initiate an inspiratory effort

Chest 2001; 120:375S

Readiness for SBT trials

Additional criteria

1. Hemoglobin ≥7 mg/dL
2. Core temperature ≤38 to 38.5°C
3. Mental status awake and alert or easily arousable

Chest 2001; 120:375S

Readiness for SBT trials

- Clinical assessment
- Objective measurements:

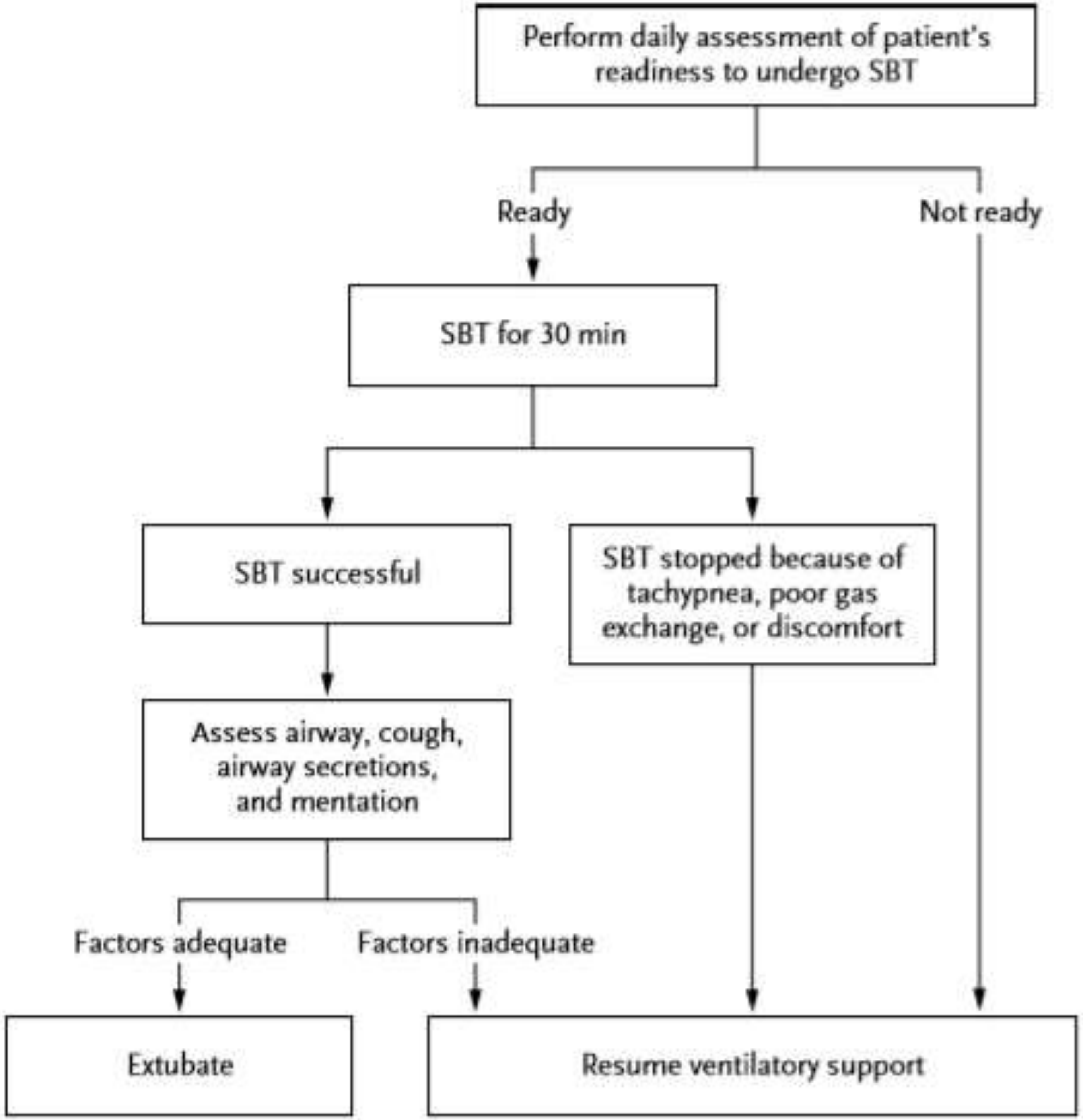
Clinical stability	Adequate oxygenation	Adequate pulmonary function	Adequate mentation
	• SaO_2 >90% on ≤FiO_2 0.4 (or PaO_2/FiO_2 ≥150 mmHg) • PEEP ≤8 cmH_2O	• RR ≤ 35 breaths/min • MIP ≤ 20 -25 cmH2O • VT > 5 mL /kg • VC > 10 mL/kg • RR/VT <105 breaths/min/L • No significant respiratory acidosis	

Eur Respir J 2007; 29: 1033–1056

Failure criteria of SBT

- Clinical assessment and subjective indices
  - Agitation and anxiety
  - Depressed mental status
  - Diaphoresis
  - Cyanosis
  - Evidence of increasing effort
- Objective measurements
  - PaO_2 ≤50–60 mmHg on FiO_2 ≥0.5 or SaO_2 <90%
  - $PaCO_2$ >50 mmHg or an increase in $PaCO_2$ >8 mmHg
  - pH <7.32 or a decrease in pH ≥0.07 pH units
  - RR/VT >105 breaths/min/L
  - RR >35 breaths/min or increased by ≥50%
  - HR >140 beats/min or increased by ≥20%
  - Systolic BP >180 mmHg or increased by ≥20%
  - Systolic BP <90 mmHg
  - Cardiac arrhythmias

Eur Respir J 2007; 29: 1033–1056



N Engl J Med 2012;367:2233-9

Assessment

- Simple Bedside Tests
- Rapid shallow breathing
  - Frequency divided by tidal volume, f/v_t
  - Sensitivity of 0.97 with a specificity of 0.64

- Combined tests
  - Rapid shallow breathing combined with the occlusion pressure in the first 100 ms ($P_{0.1}$),an index of central drive
  - CROP index ((Cdyn × PImax × [PaO2/PAO2])/rate) which consisted of dynamic compliance (Cdyn), maximum mouth pressure (PImax), oxygenation (PaO_2/PAO_2), and respiratory rate

Am Rev Respir Dis 1993;148:860–6

N Engl J Med 1991;324:1445–50

Difficult Weaning – Mode of Ventilation

- Maintenance of a favorable balance between respiratory system capacity and load
- Attempt to avoid diaphragm muscle atrophy
- Aid in the weaning process

Available modes of weaning

<u>Conventional Modes</u>

- Spontaneous breathing trials
- Pressure support ventilation
- SIMV
- SIMV + PSV

<u>Newer Modes</u>

- Adaptive support ventilation
- Automatic tube compensation
- Proportional assist ventilation
- NAVA
- Non invasive positive pressure ventilation

Pressure Support

- Weaning by gradual pressure support (PS) reduction without an initial spontaneous breathing trial (SBT) versus PS-supported SBT: A pilot study

- Gradual reduction of PS without an initial SBT was found to be associated with better outcomes compared to once daily PS-supported SBT

Rev Port Pneumol. 2011;17(6):244---252

T-piece vs SIMV

- After failed SBT, use of progressively increased time on a T-piece or use of PSV as weaning mode are effective means of liberating patients from the ventilator.

- Literature does not support the use of SIMV alone as a weaning mode

Eur Respir J 2007;
29: 1033–1056

Research | Open Access | Published: 14 May 2020

Neurally adjusted ventilatory assist versus pressure support ventilation: a randomized controlled feasibility trial performed in patients at risk of prolonged mechanical ventilation

Population	Intervention	Outcome
72 participants open-label, parallel-group, randomized	NAVA PSV NAVA catheters were inserted within 4 h of randomization	No significant differences were observed in duration of MV, ICU or hospital stay, or ICU, D28, and D90 mortality

Hadfield et al. Critical Care (2020) 24:220

NIV

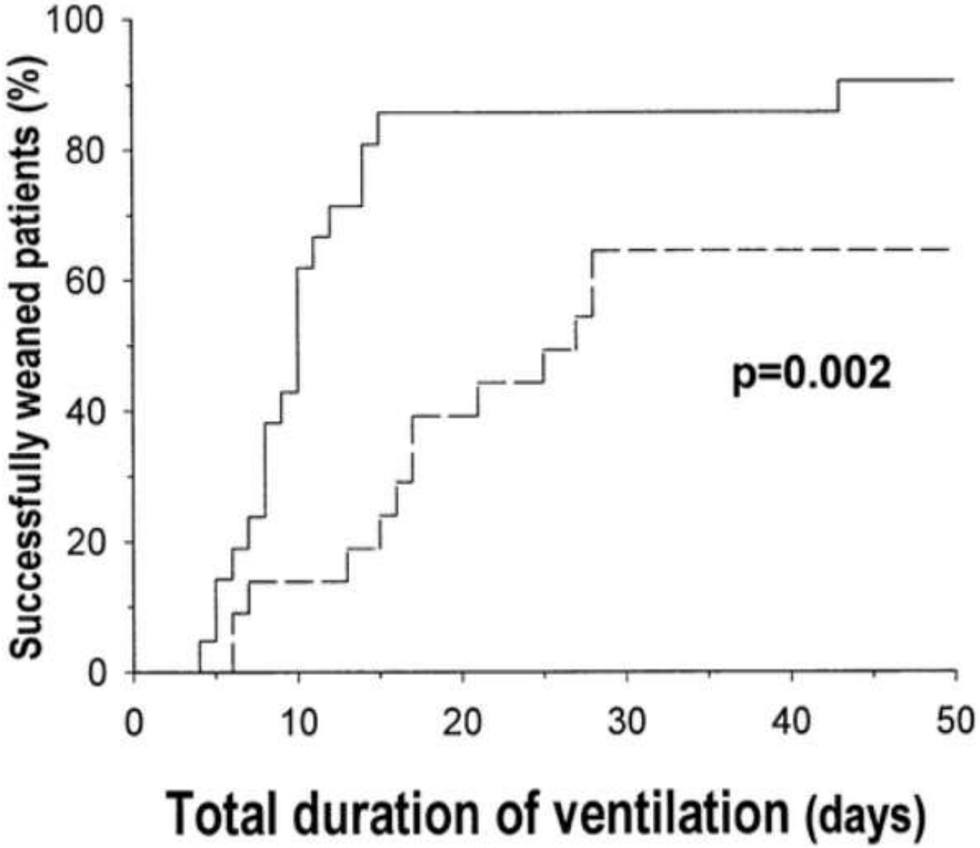
- Alternative weaning
- Prophylactic high risk for reintubation
- Post- extubation failure

RCT: NIV immediately after extubation improves weaning outcome after acute respiratory failure

- NIV prevented 48 hours reintubation if applied immediately after elective extubation in patients with more than 3 days of ARF when compared with the oxygen mask

Crit Care 2013; 17(2): R39

Noninvasive Ventilation during Persistent Weaning Failure
A Randomized Controlled Trial



Kaplan–Meier curves for patients successfully weaned from mechanical ventilation, as defined. The first of the three days without ventilatory support, either invasive (*dashed lines*) or noninvasive (*solid lines*), was considered the end of the weaning process. The probability of weaning success was significantly higher for patients from the NIV group (*solid lines*) than in the conventional-weaning group (*dashed lines*) (log-rank test). Time denotes the period from intubation to final withdrawal of ventilatory support.

Am J Respir Crit Care Med 2003; 168: 70–76

Automated versus non-automated weaning for reducing the duration of mechanical ventilation for critically ill adults and children

- Pooled data from 16 eligible trials reporting weaning duration indicated that automated closed loop systems reduced the geometric mean duration of weaning by 30%.
- There was no strong evidence of an effect on mortality rates, hospital LOS, reintubation rates, self-extubation and use of non-invasive ventilation following extubation
- Prolonged mechanical ventilation > 21 days and tracheostomy were reduced in favor of automated systems

Cochrane Database Syst Rev 2014;6:

Role of tracheostomy

Advantages

- Easier airway management
- Improved patient comfort and communication
- Reduction in sedative use
- Earlier weaning from respiratory support
- Improved respiratory mechanics
- Earlier transition to oral feeding
- Reduced oropharyngeal trauma
- Prevention of VAP

Adverse effects

- Misplacement
- Hemorrhage
- Obstruction
- Displacement
- Impairment of swallowing reflexes and late tracheal stenosis.

Crit Care Med
1997; 25: 983–988

Crit Care Med
2004; 32: 2219–2226

Role of tracheostomy

- Timing
  - Early tracheostomy vs Late tracheostomy

- Outcome
  - Longer duration of MV and length of stay in tracheostomized patients
  - A retrospective 3-yr review of 549 patients with tracheostomy reported poor survival and functional outcomes

Chest 1997; 112: 745–751

Chest 2004; 125: 220–227

Summary

Patient Intubated

Daily screen to assess readiness to wean

Thorough and systematic search for potentially reversible pathologies

SBT

Simple weaning

Difficult & Prolonged weaning

Summary

Difficult-to-wean patient

↓

Respiratory / Cardiac / Neuromuscular / Neuropsychologic / Metabolic / Nutrition

↓

Specific risk factors Diagnostics

↓

Determine the cause and start treatment

↓

SBT