Difficult weaning
Pathophysiology and Management

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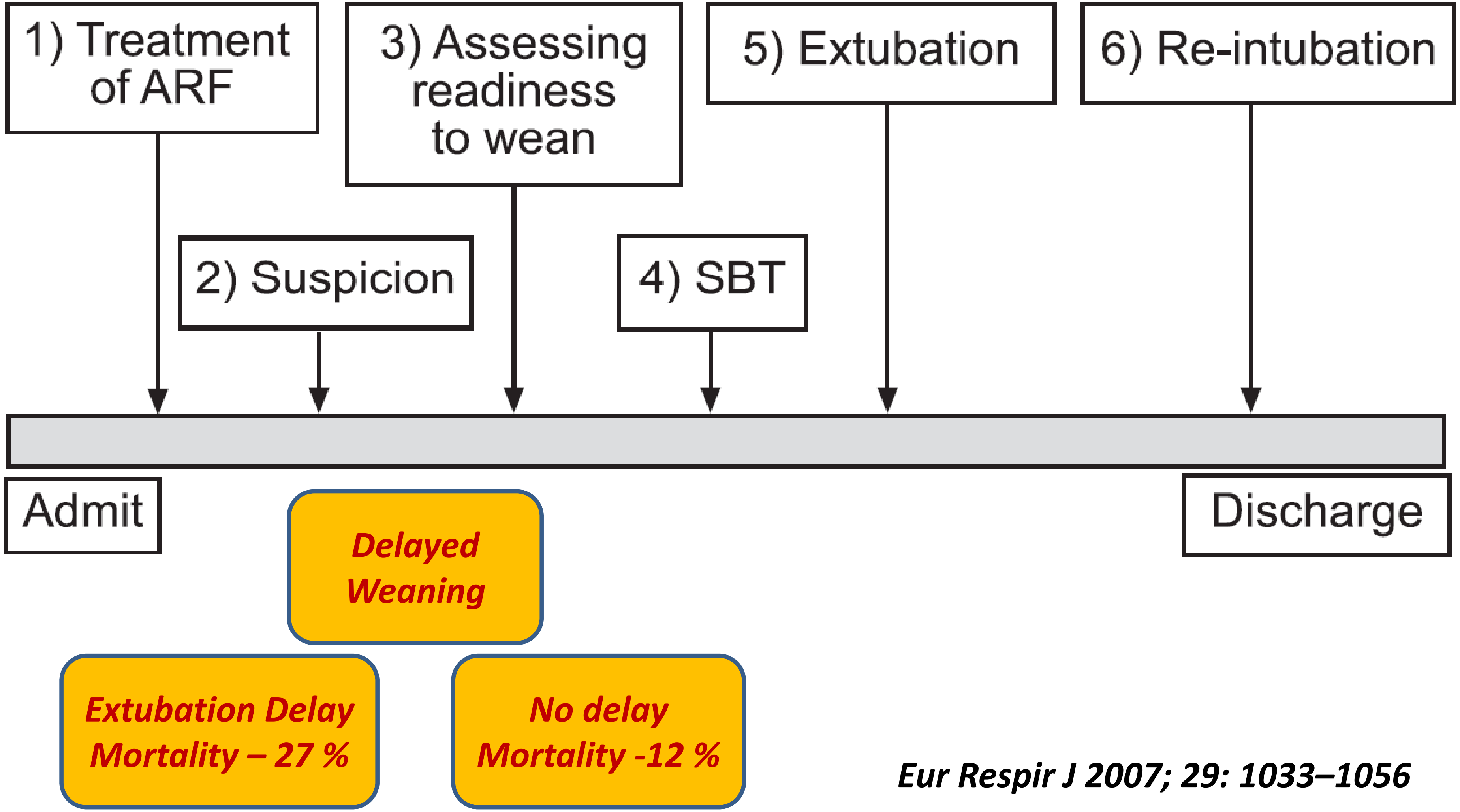
Weaning - Entire process of liberating the patient from mechanical support and from the endotracheal tube, including relevant aspects of terminal care



Eur Respir J 2007; 29: 1033–1056

Weaning – Classification (Brochard)

Group	Definition
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 3 SBT's or as long as 7 days from the first SBT to achieve successful weaning
Prolonged weaning	Patients who fail at least 3 weaning attempts or require >7 days of weaning after the first SBT

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Magnitude of the problem

- 20 % of all initial weaning attempts in mechanically ventilated ICU patients fail.
- Prolongation of mechanical ventilation is associated with weaning failure.
- Also occurs after elective surgery, albeit with a low incidence. (< 5 %).
- Weaning – Predominant clinical problem during recovery from critical illness. (>50 % of total ICU time.)
- PMV – 6 % ventilated patients & 37 % ICU resources.
- COPD – Independent risk factor.

Thorax 2002;57:986-991

Importance

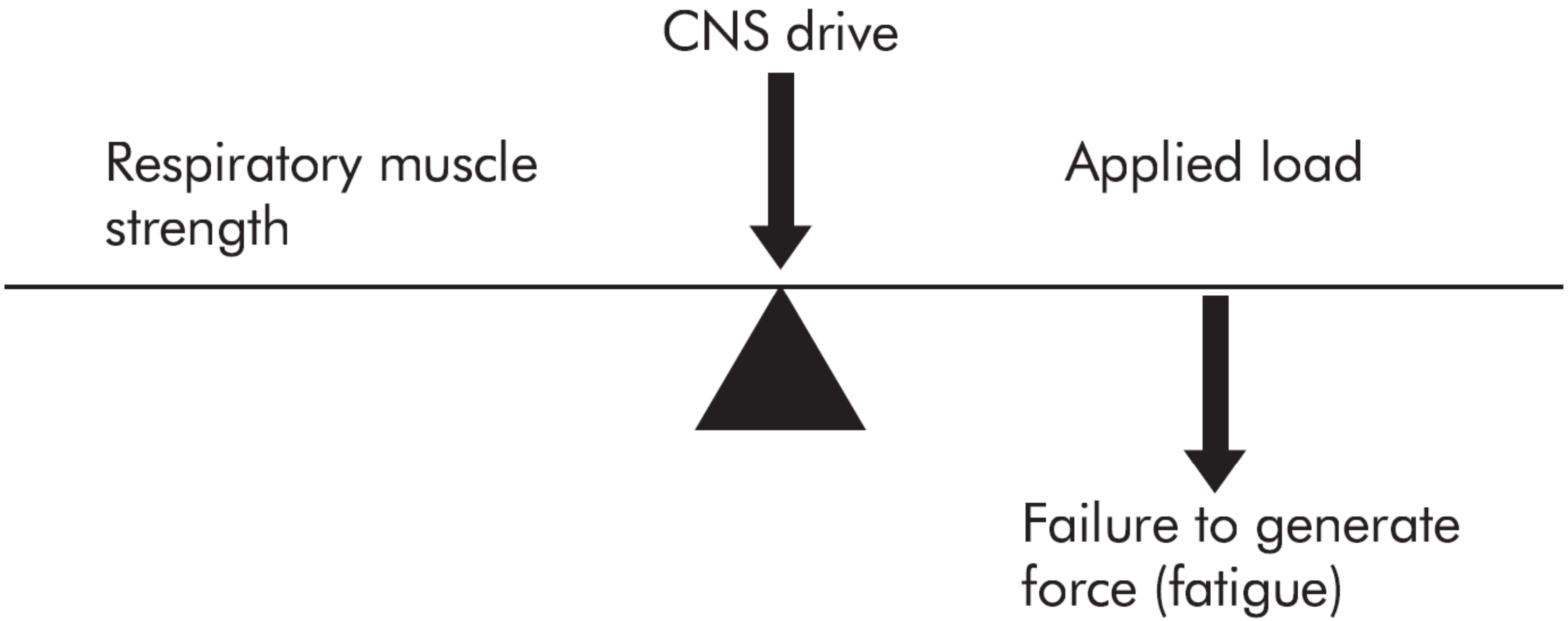
- Simple Weaning - 69% of weaning patients.
- Good prognosis
- ICU mortality ~5%
- In-hospital mortality ~12%.

- Difficult and prolonged weaning ~ 31% of weaning patients.
- Worse prognosis.
- ICU mortality ~25%.

- Approximately 50 % of patients with difficult weaning end up with prolonged weaning.

- Delay in weaning – Patient discomfort, ↑ Mortality, ICU time and economic concerns.

Pathophysiology of weaning failure (Components)



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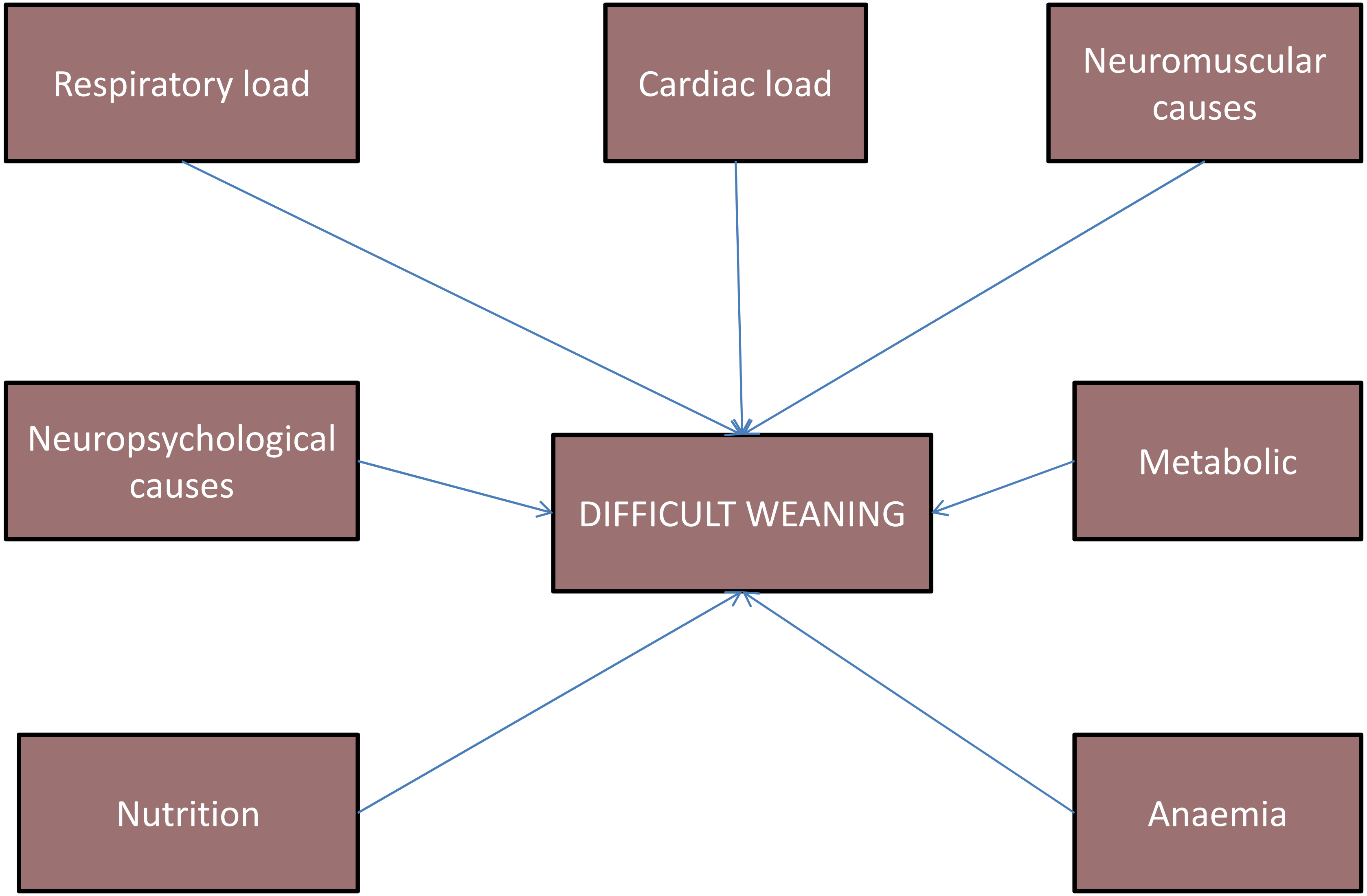
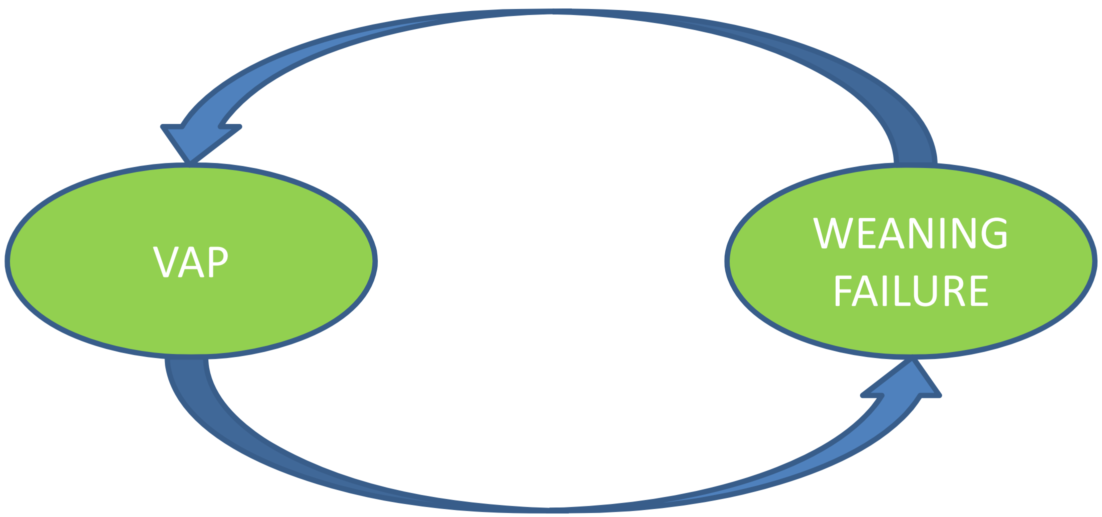

Respiratory load
Cardiac load
Neuromuscular causes
Neuropsychological causes
DIFFICULT WEANING
Metabolic
Nutrition
Anaemia

Respiratory load

- Function of the resistance and compliance of the ventilator pump.
- ***Inappropriate ventilator settings*** – Increased WOB.
- 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 flow.
- Ineffective triggering.
- Expiratory effort prior to switchover from mechanical inflation to exhalation
- High intrinsic PEEP.

- ***Reduced pulmonary compliance***
- Pneumonia (At admission or VAP).
- Cardiogenic or noncardiogenic pulmonary oedema
- Pulmonary fibrosis
- Pulmonary haemorrhage
- Other diseases causing diffuse pulmonary infiltrates.

VAP & WEANING FAILURE INTERPLAY

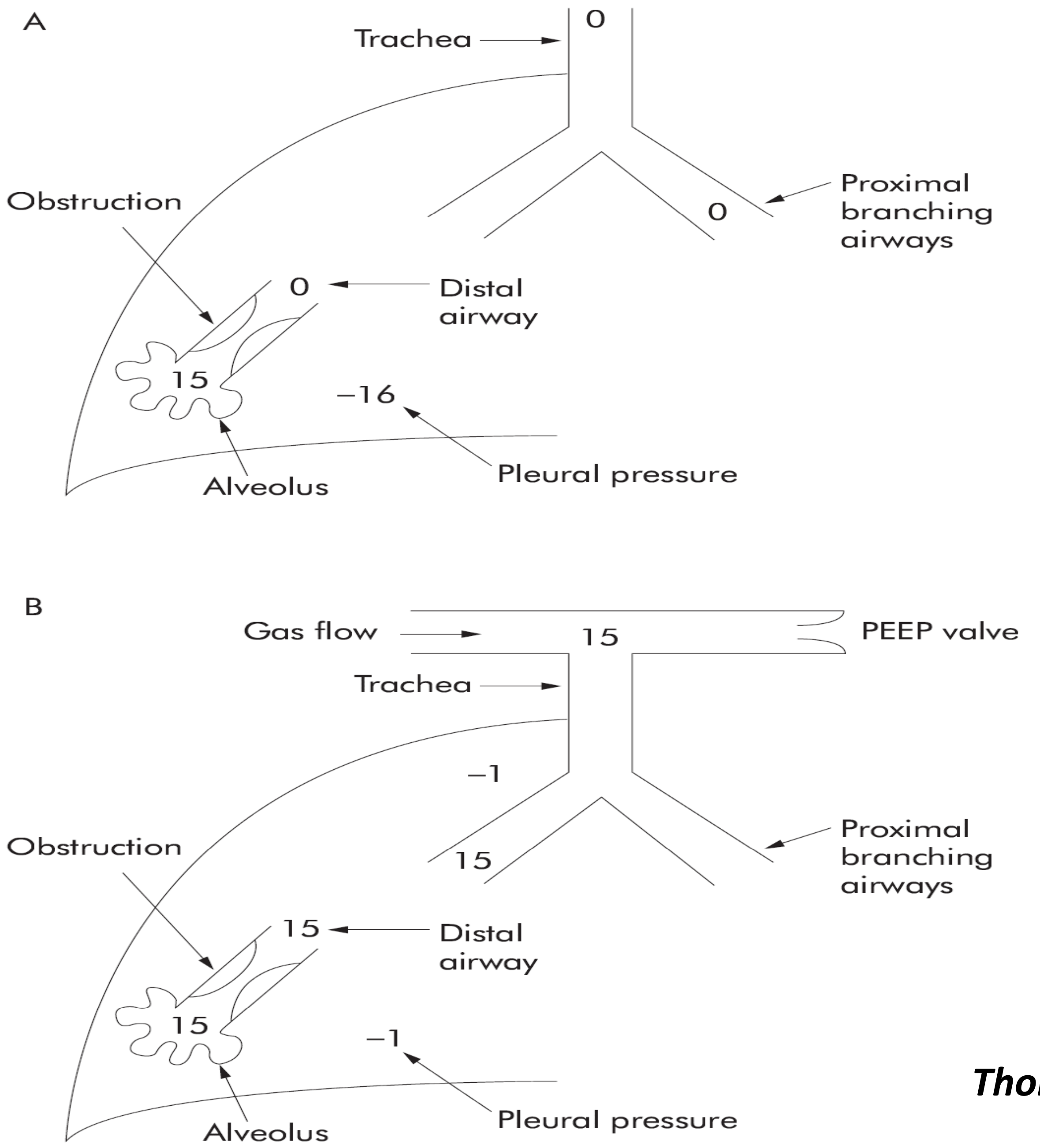


- ***Airway bronchoconstriction***.

- ***Increased resistive load***
- During SBT- Endotracheal tube.
- Post-extubation - Glottic oedema, increased airway secretions, sputum retention.

- ***Dynamic hyperinflation – Auto PEEP***.
- COPD
- Also associated with increased cardiac load.

Threshold effect of Auto - PEEP



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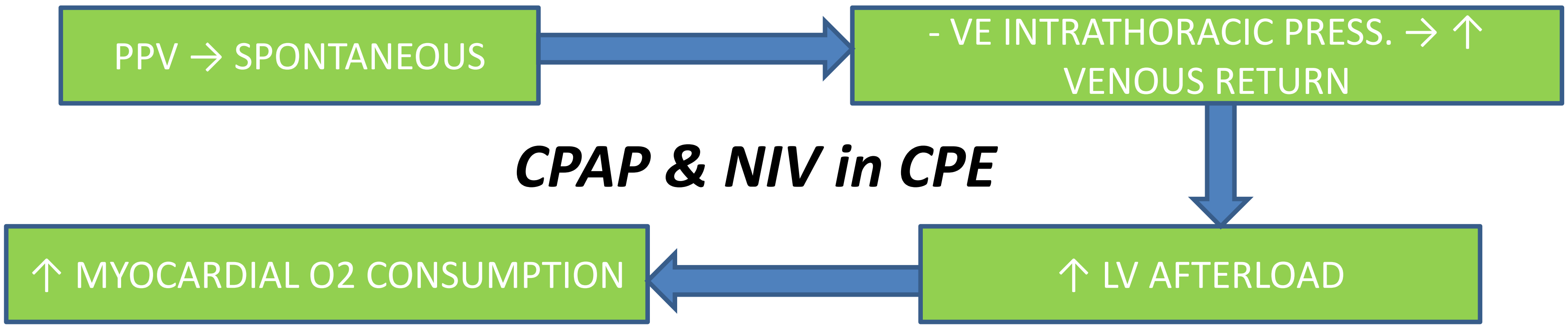
Cardiac load

- Ischaemic heart disease, valvular heart disease, systolic or diastolic dysfunction prior to, or identified during critical illness.
- Especially important - Myocardial dysfunction which is only apparent when exposed to the workload of weaning.
- HOW DOES LATENT MYOCARDIAL DYSFUNCTION BECOME MANIFEST DURING WEANING ??

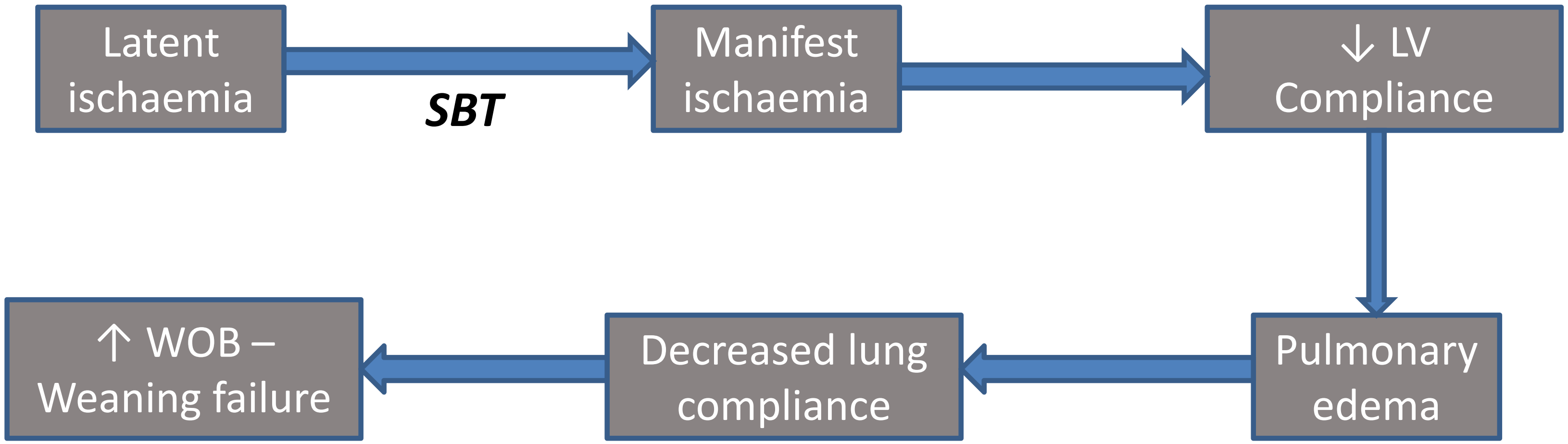


- ***Dynamic hyperinflation***
- ↑ PVR → ↓ RV Filling → ↓ Cardiac output.

- ***Increased metabolic demand of weaning***.

- ***Unresolved systemic disease (Sepsis).***

- ↑ Serum lactate , ↓ SvO2, Gastric mucosal pH – Prediction of weaning failure



Neuromuscular competence

- Any component of the neuromuscular transmission and performance apparatus.

- ***Depressed central drive***
- Complete absence / Reduction in drive.
- Encephalitis, brainstem haemorrhage/ischaemia and neurosurgical complications.

- ***P 0.1*** – Index of drive

- Raised with hypercapnic challenge and is also high in patients suffering ventilatory failure.

- Patients able to breathe during SBT's- Low P0.1, Increase drive and MV during a hypercapnic challenge. (Ventilatory reserve, nearly fixed in fail. to wean)

- Titration of drive on PSV (using P 0.1), adjustments of PEEP for Auto- PEEP.

- Metabolic alkalosis, mechanical ventilation itself & the use of sedative/hypnotic medications.

- ***Peripheral neuromuscular dysfunction***
- Important after ruling out cardio-respiratory causes.
- Common – Upto 62 %.
- Most is acquired, pre-existing may become apparent – MND, MG, GBS.

- ***CINMA (Critical illness neuromuscular abnormalities)***
- Most common peripheral neuromuscular disorders encountered in the ICU.
- Usually involve both muscle and nerve.

- Severity of illness, multiple organ dysfunction, exposure to corticosteroids, presence of hyperglycaemia and prolonged ICU stay.

- Muscle weakness - Bilateral, symmetrical & most marked proximally.
- EMG - Sensorimotor axonopathy with preserved velocities and decreased amplitude of compound action potentials.

- Confirmation by electrophysiological testing and muscle biopsy when appropriate.

- Type II fibre drop-out with a loss of myosin filaments - consistent finding.

- Contribution to PMV - in ICU patients.
- Association with an increased duration of weaning or weaning failure.
- Multivariable analysis - CINMA - An independent risk factor for duration of mechanical ventilation and weaning failure, including the need for tracheostomy.

- Usually improves over weeks
- May persist & interfere with ADL.

Psychological dysfunction

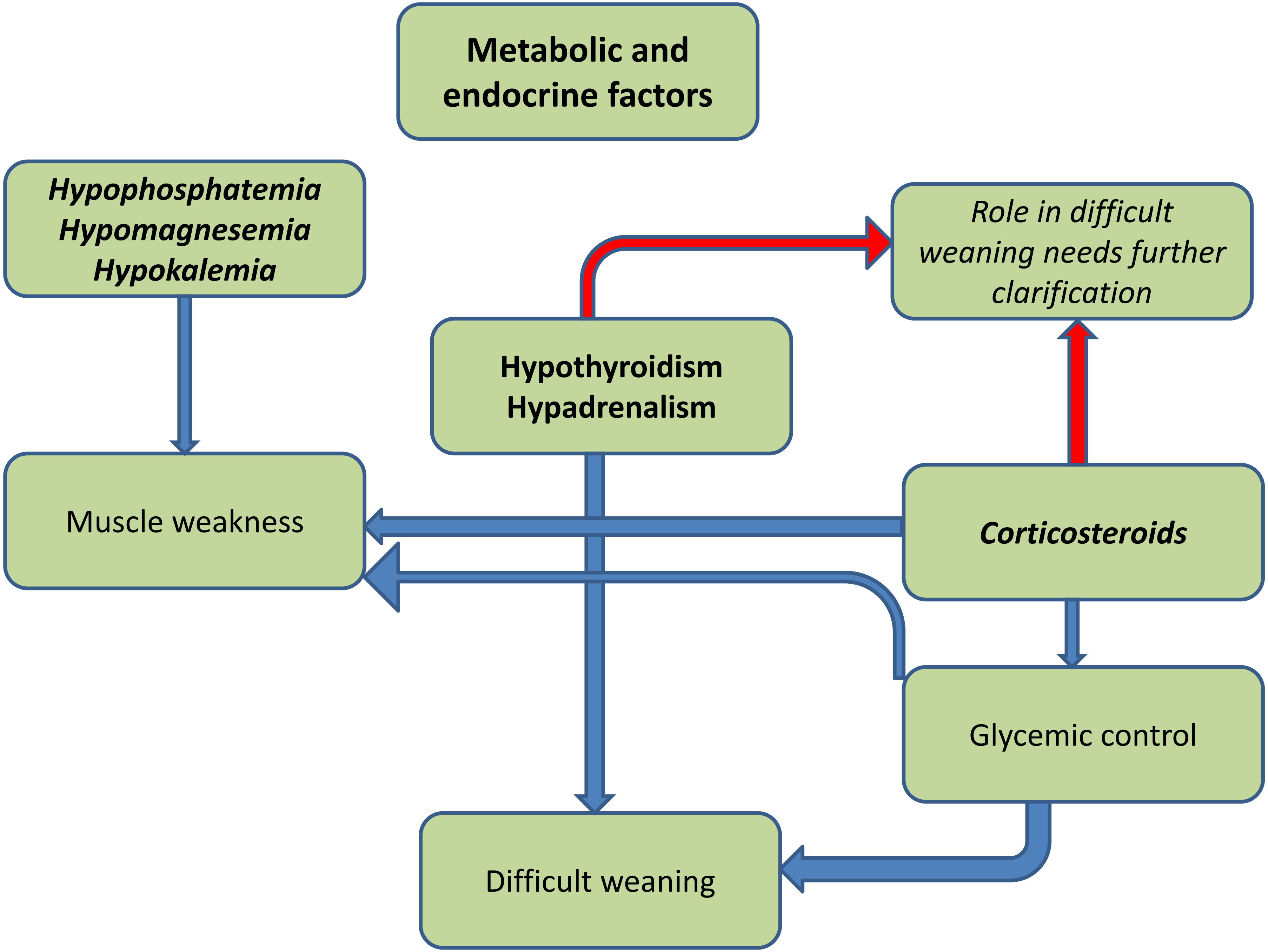
- ***Delirium***
- Associated with many modifiable risk factors. (Prev. – 22 to 80 %).
- Associated with prolonged ICU stay.
- Predictor of higher mortality up to 6 months after discharge from the ICU.
- Not yet proven to be directly linked to weaning difficulties.

- ***Anxiety & Depression***
- Significant anxiety during ICU stay and the process of weaning.
- Memories of distress may remain for years.
- Prevalence - 30–75%.
- Dyspnoea, inability to communicate & sleep disruption.

- ***Sleep disturbances***
- Most ICU patients unable to rest & sleep.
- Nightmares – 25 %.
- PSG's- Frequent arousals and sleep fragmentation.
- Relation to ventilatory mode .
- Ambient noise

- ***Depression***

- ***NUTRITION***
- ***Overweight*** - ↓ respiratory compliance, ↑ closing volume/FRC ratio and ↑ WOB. ?? Prolongation of ICU stay & not MV duration.
- ***Malnutrition*** – 40 % of critically ill pts.
- Data linking to difficult weaning limited.
- ↓ ventilatory drive & limited muscle mass.



Metabolic and endocrine factors
Hypophosphatemia
Hypomagnesemia
Hypokalemia
Role in difficult weaning needs further clarification
Hypothyroidism
Hypadrenalism
Muscle weakness
Corticosteroids
Glycemic control
Difficult weaning

VIDD & CRITICAL ILLNESS OXIDATIVE STRESS

Loss of diaphragm force-generating capacity that is specifically related to use of controlled mechanical ventilation

Mitochondrial swelling, myofibril damage and increased lipid vacuoles. Oxidative modifications noted within 6 h

- Muscle atrophy
- Structural injury
- Fibre remodelling

Anaemia

• Desired haemoglobin regarding weaning ??

•Previous weaning guidelines - 8–10.

•Liberal red blood cell transfusion strategy maintaining haemoglobin concentration at 10–12 did not decrease the duration of MV in critically ill.

•COPD - ↓ MV & WOB

- ***Testing for respiratory muscle strength***
- Pimax - < 20 cm H2O – Associated with inability to wean.
- Measurement difficult – Movement of ET, inability to sustain 1 sec plateau & inability to reach RV before max. insp. effort.

- Gasping against a closed airway.

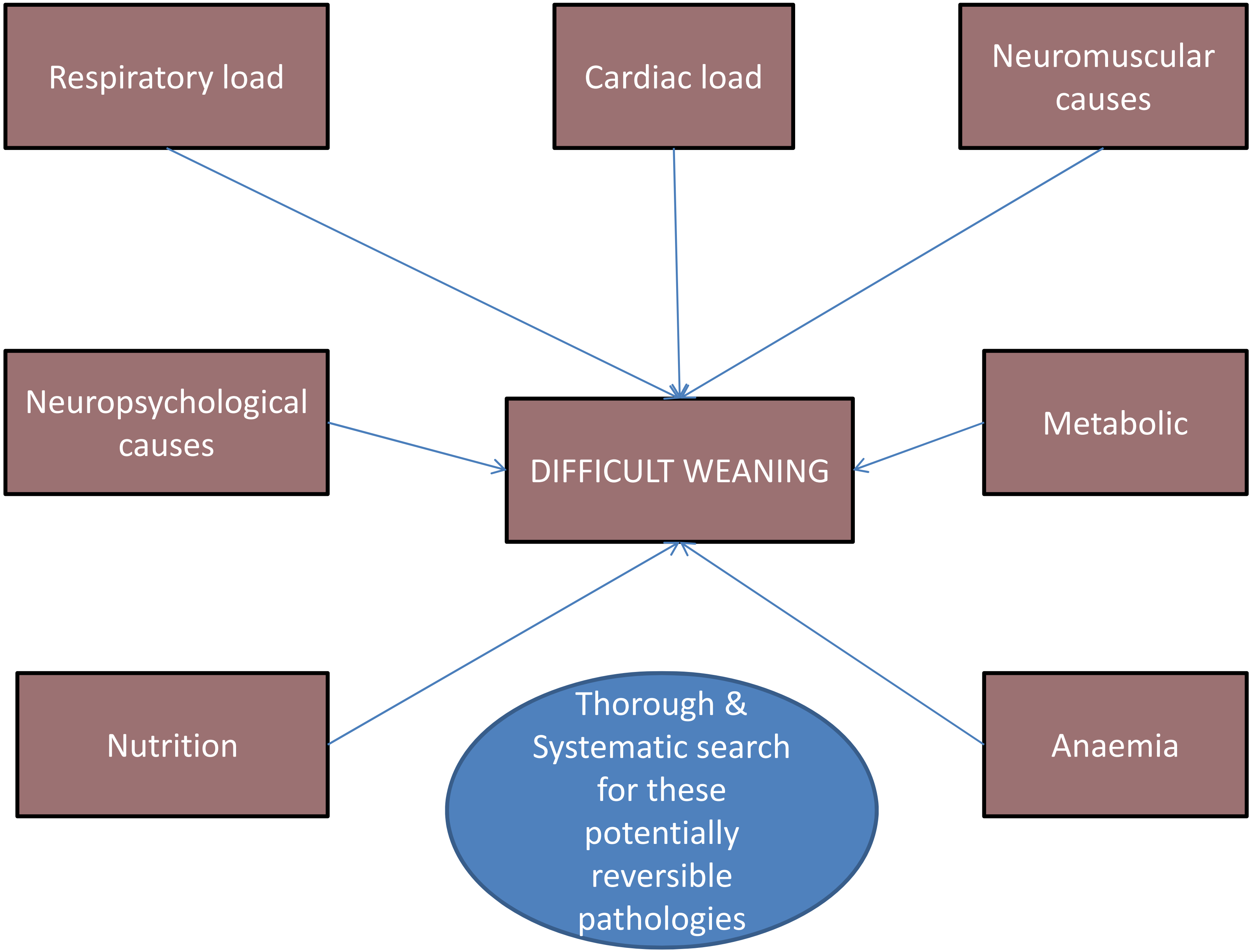
- Twitch transdiaphragmmatic pressure.

- ***Bedside tests***

- RSBI (Sensitivity 0.97 , Specificity 0.64).

- RSBI + P 0.1.

- CROP index – Not much utility.


Respiratory load
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Metabolic
Nutrition
Thorough & Systematic search for these potentially reversible pathologies
Anaemia

Management of difficult to wean patients

- Perform a thorough and systematic search for potentially reversible pathologies as previously shown.
- Pathophysiology of weaning failure in these patients may be complex and multifactorial.

- ***Respiratory load***
- Appropriate settings to prevent dys-synchrony.

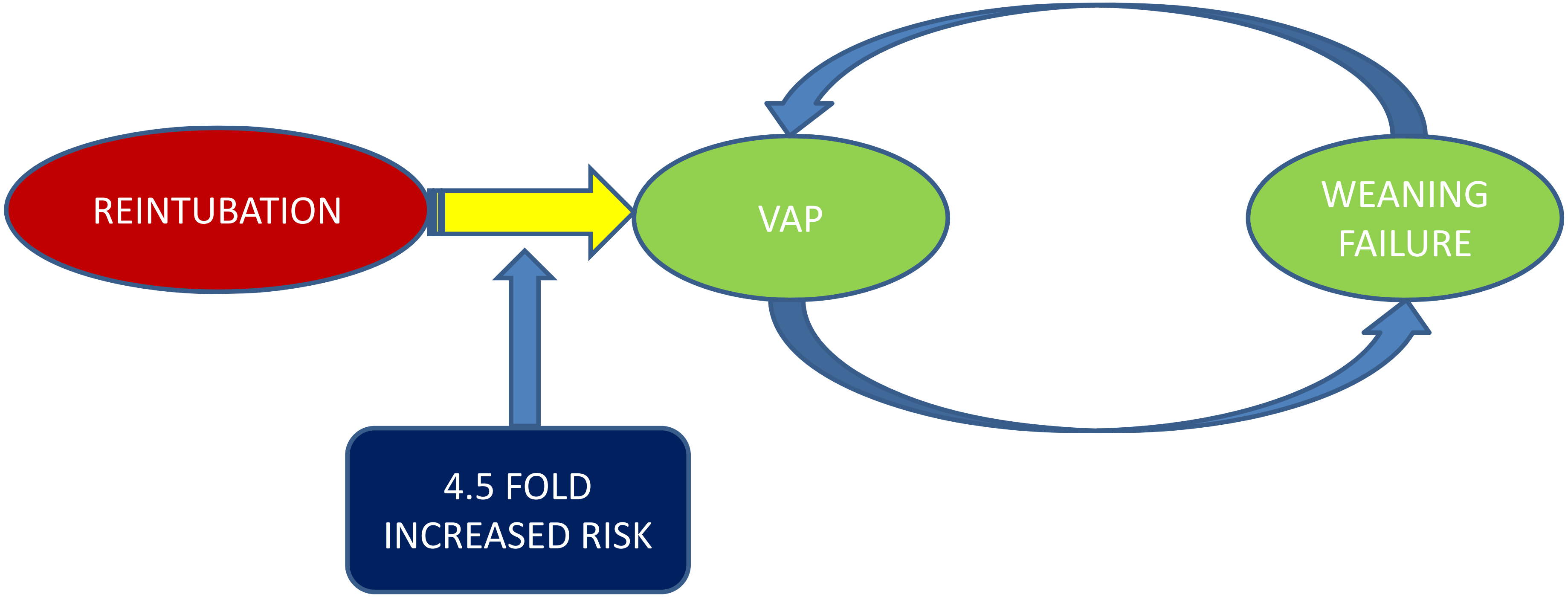
- Appropriate prevention and treatment of VAP.

- Treat bronchospasm adequately.

- Appropriate external PEEP to counteract Auto-PEEP.

- Endotracheal tube resistance – ATC (Drager).

- Cuff leak test – Post extubation glottic edema.
- Chest physiotherapy and suction – Secretions.



- Cardiac function optimization as clinically indicated.
- Techniques to minimize anxiety during mechanical ventilation - Improvement of speech by increasing inspiratory time and PEEP, or ventilating with bi-level PSV.
- Improvement of sleep by minimising noise, light and nursing interventions at night.
- Use of relaxation techniques, such as biofeedback.
- Correct electrolyte disturbances.
- Screen for hormone deficiency states (Hypothyroidism).

- Role of trace element and vitamin supplementations.
- *α-tocopherol and ascorbic acid, Selenium.*

- **Protocolized weaning**
- Protocol-directed daily screening of respiratory function and trials of SBT decrease the time required for extubation, the incidence of self-extubation, the incidence of tracheostomy and ICU costs, and results in no increase or even a decrease in the incidence of reintubation.

- Less likely to be effective when the majority of patients are rapidly extubated, when physicians do not extubate patients following a successful SBT, or when the quality of critical care is already high.

DIFFICULT WEANING – MODE OF VENTILATION

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

- ***Pressure support ventilation (PSV)***
- Used as the sole mode of MV during initial weaning attempts - Tested in large randomised controlled trials.

- For those patients who have repeated difficulty tolerating weaning – PSV observed to reduce the duration of mechanical ventilation.

- In several trials, intermittent T-tube was comparable to PSV as a weaning mode.
- After failed SBT, the use of progressively increased time on a T-piece is also an effective means of liberating patients from the ventilator.

- ***Weaning ERS task force consensus – PSV preferable mode for difficult and prolonged weaning.***
- ***SIMV alone – NO***
- ***SIMV + PSV – Little data.***

NIV in Weaning

Alternative weaning technique for patients who failed conventional weaning	Prophylactic measure for patients with a high risk for reintubation	Treatment of respiratory insufficiency after extubation (post-extubation failure)

- ***Ferrer M, Esqinas A, Arancibia F, et al. Noninvasive ventilation during persistent weaning failure. Am J Respir Crit Care Med 2003; 168: 70–76.***

- ***Nava S, Ambrosino N, Clini E, et al. Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease. A randomized, controlled trial. Ann Intern Med 1998; 128: 721–728.***

- ***Girault C, Daudenthun I, Chevron V, Tamion F, Leroy J, Bonmarchand G. Noninvasive ventilation as a systematic extubation and weaning technique in acute-on-chronic respiratory failure. A prospective, randomized controlled study. Am J Respir Crit Care Med 1999; 160: 86–92.***

- ***Chen J, Qiu D, Tao D. Time for extubation and sequential noninvasive mechanical ventilation in COPD patients with exacerbated respiratory failure who receive invasive ventilation. Zhonghua Jie He He Hu Xi Za Zhi 2001; 24: 99–100.***

- Failed SBTs - Intervention groups were extubated - NIV - PSV min. 15 cmH2O.
- Control groups were conventionally weaned with PSV (via standard mechanical ventilation) and extubated.
- Details of this procedure are not specified.
- All trials were not blinded and the performing departments had expertise with NIV

- ***Specific subgroup – Stable COPD patients who cannot tolerate spontaneous breathing.***
- Shortened total duration of invasive mechanical ventilation and ICU stay.
- Substantially reduced the rate of nosocomial infection.
- Significantly higher survival rate. (2/4)

- Patients who fail SBTs may be sick with substantial comorbidities and at risk for extubation failure.
- Use cannot be recommended for all patients failing a SBT.

- Should not be considered a weaning success until patients are completely liberated from NIV.

- ***CPAP***
- Role in difficult to wean patients has not been clearly evaluated.
- May be used as an aternative weaning modality in simple weaning.

- ***Automatic tube compensation (ATC)***
- Ventilatory method aimed at compensating for the nonlinear pressure drop across the endotracheal tube during spontaneous breathing.
- If an SBT fails because of a particularly narrow endotracheal tube - May be beneficial.
- Lack of controlled trials in difficult weaning patients.

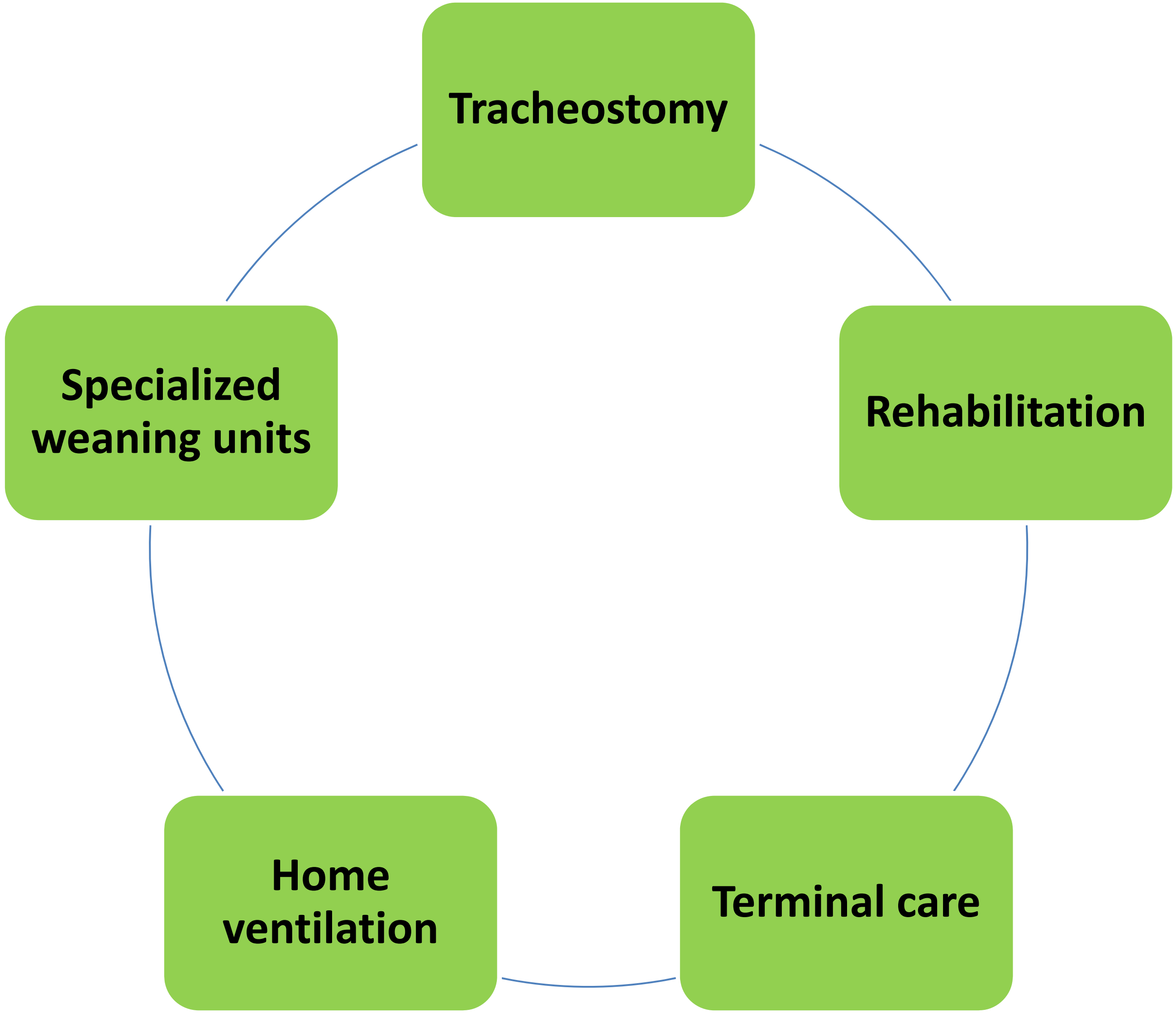
- ***Proportional assist ventilation***
- Application sometimes regarded as difficult.
- Not been investigated thoroughly in weaning trials.

- ***Servo-controlled ventilation***
- Automatic ventilatory modes
- Tool to achieve optimal ventilatory support and an individual level of PS with the aim of rapid extubation.
- Rapid adaptation of the ventilatory support to the changing situations of a patient.

- **ASV** – Adaptive support ventilation
- Manage the spectrum of ventilatory support ranging from controlled mechanical ventilation to PS, up to the pre-extubation weaning trial.
- No studies specifically in prolonged weaning.

- **Knowledge-based expert system** (Evita XL; Drager, Lubeck, Germany) Smartcare
- No studies in difficult weaning.

Management of patients with prolonged weaning failure



Tracheostomy

- ***Proposed 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 events***
- Misplacement, haemorrhage, obstruction, displacement, impairment of swallowing reflexes and late tracheal stenosis.

- **Issues of patient comfort and sedation**

- **Technical, mechanical and safety aspects**
- More secure airway - Fewer accidental extubations
- May reduce WOB - No evidence that this is linked to reductions in weaning time or length of stay.
- VAP – Effects are inconsistent.

- **Timing of tracheostomy**
- Little evidence to guide optimal timing .
- Methodological diversity.
- Need for better predictors of ventilator dependence.
- Need for studies on long term outcome.

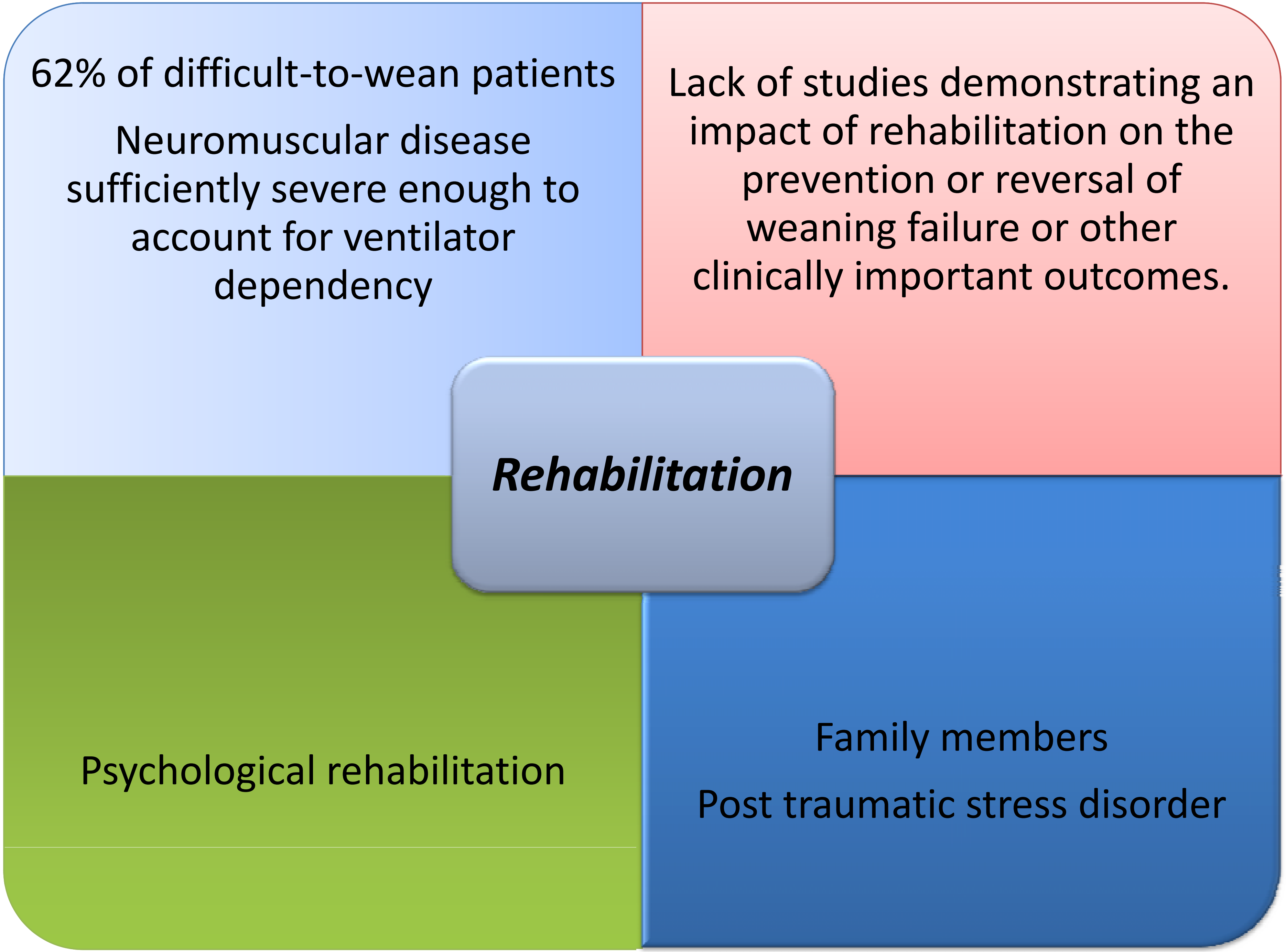
Percutaneous tracheostomy

Meta-analysis - Fewer complications compared with surgical tracheostomy .

No difference was observed between the two techniques regarding overall procedure-related complications or death.

Cost effectiveness.

Chest 2000; 118; 1412–1418.


62% of difficult-to-wean patients
Neuromuscular disease sufficiently severe enough to account for ventilator dependency
Lack of studies demonstrating an impact of rehabilitation on the prevention or reversal of weaning failure or other clinically important outcomes.
Rehabilitation
Psychological rehabilitation
Family members
Post traumatic stress disorder

Specialized teams
Nurses, physiologists, respiratory therapists, nutritionists

Bridge to home / ICU pressure relievers

Step down units
Regional weaning centres

Specialized weaning units
SWU's

Unresolved issues

34-60 % Successfully weaned

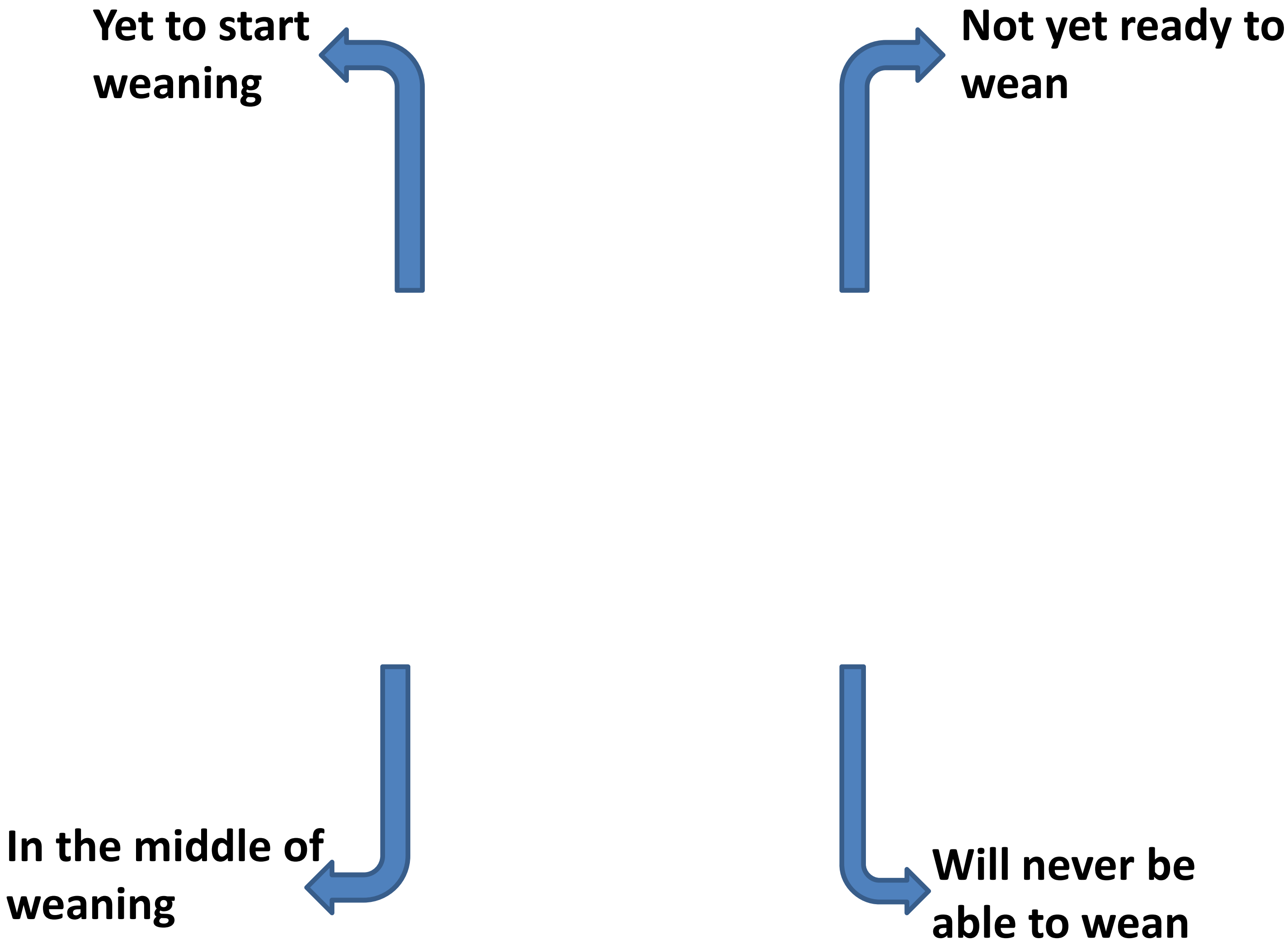
Up to 3 months after admission to these units

Long-term mortality rate is not adversely affected

Of the successfully weaned~ 70 % discharged home alive
1-yr survival rate - 38–53%
Only 5 – 25 % - Admitted to SWU – Ventilator free and at home alive

What can we do ??

- Perform a daily screeen to assess readiness to wean.
- Thorough and systematic search for potentially reversible pathologies.
- Use of a sedation protocol.
- SBT should be repeated frequently (daily) in order to determine the earliest time at which the patient can be successfully extubated.
- PDT
- Eventual outcome depends on long term trajectory of underlying disease. (NM vs COPD).


Yet to start weaning
Not yet ready to wean
In the middle of weaning
Will never be able to wean

Abstract *Objective:* While "weaning parameters" are commonly used to guide removal of mechanical ventilation devices, little information exists concerning their prognostic value. We evaluated whether passing weaning parameters was associated with survival.

Design: A prospectively followed cohort of mechanically ventilated patients.

Setting: Medical and coronary adult intensive care units of an 806-bed medical center.

Patients: 300 consecutively enrolled mechanically ventilated patients.

Measurements and results: 216 patients who passed a daily screen of weaning parameters were more likely to be extubated successfully (87 vs 30 %, $p = 0.0001$), less likely to require ventilation for > 21 days (3 vs 30 %, $p = 0.0001$), and had a higher survival to hospital discharge (74 vs 29 %, $p = 0.0001$) than 84 patients who never passed the screen. The overall accuracy of the daily screen for predicting successful extubation and in-hospital survival was 82 and 73 %, respectively. Multivariate proportional hazards analysis of time until hospital death confirmed the beneficial effect of passing the daily screen ($p = 0.01$) and of duration of mechanical ventilation ($p = 0.001$) even after adjustment for differences in severity of illness, age, race, gender, diagnosis, and treatment assignment. While liberation from mechanical ventilation was predictive of survival at any time during the hospital stay ($p = 0.001$), the prognostic significance of the daily screen for hospital survival was related to how early after intubation it was passed. The difference in survival between patients who had passed and those who had not passed the daily screen was significant for $1\frac{1}{2}$ weeks postintubation but progressively decreased over time. The average time to extubation after passing the daily screen increased from 3 days (range 0 to 56), for those passing within 5 days of intubation, to 8 days (0 to 35), for those passing after 10 days of intubation ($r = 0.26$, $p = 0.001$).

Conclusions: Passing a daily screen of weaning parameters is an independent predictor of successful extubation and survival, but its prognostic value decreases over time. Time spent on mechanical ventilation after passing the daily screen presents an important opportunity to optimize liberation from the ventilator.

Key words Ventilator weaning · Respiration · Artificial · Critical care · Outcomes

PASSED

All of the following five criteria:

(1) PaO2/FIO2 > 200

(2) PEEP < 5 cm H2O

(3) f/Vt < 105 breaths/min per l

(4) An adequate cough durin

(5) No vasopressor

or sedative infusions

The prognostic significance of passing a daily screen of weaning parameters

Intensive Care Med (1999) 25: 581±587

Assessing readiness to wean

CLINICAL ASSESSMENT	*Adequate cough*
	Absence of excessive tracheobronchial secretion
	Resolution of disease acute phase for which the patient was intubated
OBJECTIVE ASSESSMENT	*Clinical stability*
	Adequate oxygenation
	Adequate pulmonary function
	Adequate mentation

Conclusions

- Evaluate readiness for weaning early.
- Be aggressive and search for reversible causes in difficult to wean patients.
- Weaning protocols - Most valuable where physicians otherwise do not adhere to standardised weaning guidelines.
- PSV – Preferred mode in difficult to wean. T- piece trials also appropriate. Do not use SIMV.
- NIV – Select subgroups. “Weaning in progress”
- ***DIFFICULT TO WEAN PROTOCOL / CHECK LIST ??***