Ventilator Liberation and Weaning
Objectives

- Discuss physiologic variables that are used to indicate readiness to wean from mechanical ventilation
- Contrast the approaches used to wean patients from mechanical ventilation
- Discuss the use of protocols to wean patients from ventilatory support
- Discuss the criteria used to indicate readiness for extubation
- Describe the most common reasons why patients fail to wean from mechanical ventilation
Introduction

- 75% of mechanically ventilated patients are easy to be weaned off the ventilator with simple process
- 10-15% of patients require a use of a weaning protocol over a 24-72 hours
- 5-10% require a gradual weaning over longer time
- 1% of patients become chronically dependent on MV
Readiness To Wean

- Improvement of respiratory failure
- Absence of major organ system failure
- Appropriate level of oxygenation
- Adequate ventilatory status
- Intact airway protective mechanism (needed for extubation)
Oxygenation Status

- $\text{Pa}_O_2 \geq 60 \text{ mm Hg}$
- $\text{Fi}_O_2 \leq 0.40$
- $\text{PEEP} \leq 5 \text{ cm H}_2\text{O}$
Ventilation Status

- Intact ventilatory drive: ability to control their own level of ventilation
- Respiratory rate < 30
- Minute ventilation of < 12 L to maintain $\text{Pa}_{\text{CO}_2}$ in normal range
- Functional respiratory muscles
Intact Airway Protective Mechanism

- Appropriate level of consciousness
- Cooperation
- Intact cough reflex
- Intact gag reflex
- Functional respiratory muscles with ability to support a strong and effective cough
Function of Other Organ Systems

- Optimized cardiovascular function
  - Arrhythmias
  - Fluid overload
  - Myocardial contractility

- Body temperature
  - 1° degree increases CO$_2$ production and O$_2$ consumption by 5%

- Normal electrolytes
  - Potassium, magnesium, phosphate and calcium

- Adequate nutritional status
  - Under- or over-feeding

- Optimized renal, Acid-base, liver and GI functions
## Predictors of Weaning Outcome

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of ventilatory drive:</td>
<td></td>
</tr>
<tr>
<td>- P 0.1</td>
<td>&lt; 6 cm H2O</td>
</tr>
<tr>
<td>Ventilatory muscle capability:</td>
<td></td>
</tr>
<tr>
<td>- Vital capacity</td>
<td>&gt; 10 mL/kg</td>
</tr>
<tr>
<td>- Maximum inspiratory pressure</td>
<td>&lt; -30 cm H₂O</td>
</tr>
<tr>
<td>Ventilatory performance</td>
<td></td>
</tr>
<tr>
<td>- Minute ventilation</td>
<td>&lt; 10 L/min</td>
</tr>
<tr>
<td>- Maximum voluntary ventilation</td>
<td>&gt; 3 times $V_E$</td>
</tr>
<tr>
<td>- Rapid shallow breathing index</td>
<td>&lt; 105</td>
</tr>
<tr>
<td>- Respiratory rate</td>
<td>&lt; 30 /min</td>
</tr>
</tbody>
</table>
Maximal Inspiratory Pressure

- Pmax: Excellent negative predictive value if less than –20 (in one study 100% failure to wean at this value)

An acceptable Pmax however has a poor positive predictive value (40% failure to wean in this study with a Pmax more than –20)
Frequency/Volume Ratio

- Index of rapid and shallow breathing RR/Vt
- Single study results:
  - RR/Vt > 105  95% wean attempts unsuccessful
  - RR/Vt < 105  80% successful
- One of the most predictive bedside parameters.
**Measurements Performed Either While Patient Was Receiving Ventilatory Support or During a Brief Period of Spontaneous Breathing That Have Been Shown to Have Statistically Significant LRs To Predict the Outcome of a Ventilator Discontinuation Effort in More Than One Study**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Studies, No.</th>
<th>Threshold Values</th>
<th>Positive LR Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured on ventilator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \dot{V}E )</td>
<td>20</td>
<td>10–15 L/min</td>
<td>0.81–2.37</td>
</tr>
<tr>
<td>NIF</td>
<td>10</td>
<td>(-20–30) cm (H_2O)</td>
<td>0.23–2.45†</td>
</tr>
<tr>
<td>P_{max}</td>
<td>16</td>
<td>(-15–30) cm (H_2O)</td>
<td>0.98–3.01</td>
</tr>
<tr>
<td>P_{o.1}/P_{max}</td>
<td>4</td>
<td>0.30</td>
<td>2.14–25.3</td>
</tr>
<tr>
<td>CROP score</td>
<td>2</td>
<td>13</td>
<td>1.05–19.74</td>
</tr>
<tr>
<td>Measured during a brief period of spontaneous breathing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR</td>
<td>24</td>
<td>30–38 breaths/min</td>
<td>1.00–3.89</td>
</tr>
<tr>
<td>VT</td>
<td>18</td>
<td>325–408 mL (4–6 mL/kg)</td>
<td>0.71–3.83</td>
</tr>
<tr>
<td>f/VT ratio</td>
<td>20</td>
<td>60–105/L</td>
<td>0.84–4.67</td>
</tr>
</tbody>
</table>
Liberation Methods

- Spontaneous breathing trials
- Pressure support ventilation (PSV)
- SIMV
- New weaning modes
DO NOT WEAN TO EXHAUSTION
Spontaneous Breathing Trials

- SBT to assess extubation readiness
  - T-piece or CPAP 5 cm H2O
  - 30-120 minutes trials
  - If tolerated, patient can be extubated

- SBT as a weaning method
  - Increasing length of SBT trials
  - Periods of rest between trials and at night
**Frequency of Tolerating an SBT in Selected Patients and Rate of Permanent Ventilator Discontinuation Following a Successful SBT**

<table>
<thead>
<tr>
<th>Study</th>
<th>Pts Receiving SBT</th>
<th>Pts Tolerating SBT</th>
<th>Pts Discontinuing Ventilation</th>
<th>Pts Having Ventilation Reinstituted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esteban et al(^{107})</td>
<td>546</td>
<td>416 (76)</td>
<td>372</td>
<td>58 (16)</td>
</tr>
<tr>
<td>Ely et al(^{108})</td>
<td>113</td>
<td>88 (78)</td>
<td>65</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Dojat et al(^{110})</td>
<td>38</td>
<td>22 (58)</td>
<td>22</td>
<td>5 (23)</td>
</tr>
<tr>
<td>Esteban et al(^{101})</td>
<td>246</td>
<td>192 (78)</td>
<td>192</td>
<td>36 (19)</td>
</tr>
<tr>
<td>Esteban et al(^{102})</td>
<td>270†</td>
<td>237 (89)</td>
<td>237</td>
<td>32 (14)</td>
</tr>
<tr>
<td></td>
<td>256‡</td>
<td>216 (84)</td>
<td>216</td>
<td>29 (13)</td>
</tr>
</tbody>
</table>

*Values given as No. (%). Pts patients.
†30-min SBT.
‡120-min SBT.
## Criteria Used in Several Large Trials To Define Tolerance of an SBT*  

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective measurements indicating tolerance/success</td>
<td>Gas exchange acceptability (SpO₂ ≥ 85–90%; P₀₂ ≥ 50–60 mm Hg; pH ≥ 7.32; increase in PaCO₂ ≤ 10 mm Hg); Hemodynamic stability (HR &lt; 120–140 beats/min; HR not changed &gt; 20%; systolic BP &lt; 180–200 and &gt; 90 mm Hg; BP not changed &gt; 20%, no pressors required)</td>
</tr>
<tr>
<td>Subjective clinical assessments indicating intolerance/failure</td>
<td>Stable ventilatory pattern (eg, RR ≤ 30–35 breaths/min; RR not changed &gt; 50%); Change in mental status (eg, somnolence, coma, agitation, anxiety); Onset or worsening of discomfort; Diaphoresis; Signs of increased work of breathing (use of accessory respiratory muscles, and thoracoabdominal paradox)</td>
</tr>
</tbody>
</table>

*HR  heart rate; Spo2  hemoglobin oxygen saturation.
Pressure Support

- Gradual decrease in the level of PSV on regular basis (hours or days) to minimum level of 5-8 cm H2O
- PSV that prevents activation of accessory muscles
- Once the patient is capable of maintaining the target ventilatory pattern and gas exchange at this level, MV is discontinued
SIMV

- Gradual decrease in mandatory breaths
- It may be applied with PSV
- Has the worst weaning outcomes in clinical trials
- Its use is not recommended
New Modes

- Volume support
- Automode
- MMV
- ATC
Protocols

- Developed by multidisciplinary team
- Implemented by respiratory therapists and nurses to make clinical decisions
- Results in shorter weaning times and shorter length of mechanical ventilation than physician-directed weaning
Daily SBT

Mechanical Ventilation

PaO2/FiO2 ≥ 200 mm Hg
PEEP ≤ 5 cm H2O
Intact airway reflexes
No need for continuous infusions of vasopressors or inotrops

RSBI

Stable Support Strategy
Assisted/PSV

RSBI

24 hours

Daily SBT

RR > 35/min
Spo2 < 90%
HR > 140/min
Sustained 20% increase in HR
SBP > 180 mm Hg, DBP > 90 mm Hg
Anxiety
Diaphoresis

Extubation

Yes

No

Rest 24 hrs

> 100

<100

Low level CPAP (5 cm H2O),
Low levels of pressure support (5 to 7 cm H2O)
“T-piece” breathing

24 hours

30-120 min
Failure to Wean

- **Respiratory:**
  - Increased resistance
  - Decreased compliance
  - Increased WOB and exhaustion
  - Auto-PEEP
- **Cardiovascular:**
  - Backward failure: left ventricular dysfunction
  - Forward heart failure
- **Metabolic/Electrolytes:**
  - Poor nutritional status
  - Overfeeding
  - Decreased magnesium and phosphate levels
  - Metabolic and respiratory alkalosis
- **Infection/fever**
- **Major organ failure**
- **Stridor**
Weaning to Exhaustion

- RR > 35/min
- SpO2 < 90%
- HR > 140/min
- Sustained 20% increase in HR
- SBP > 180 mm Hg, DBP > 90 mm Hg
- Anxiety
- Diaphoresis
Work-of-Breathing

- Pressure = Volume/compliance + flow X resistance
- High airway resistance
- Low compliance
- Aerosolized bronchodilators, bronchial hygiene and normalized fluid balance assist in normalizing compliance, resistance and work-of-breathing
Auto-PEEP

- Increases the pressure gradient needed to inspire
- Use of CPAP is needed to balance alveolar pressure with the ventilator circuit pressure
- Start at 5 cm H₂O, adjust to decrease patient stress
- Inspiratory changes in esophageal pressure can be used to titrate CPAP
Left Heart Failure

- Increased metabolic demands that are associated with the transition from mechanical ventilation to spontaneous breathing
- Increases in venous return as that is associated with the negative pressure ventilation and the contracting diaphragm which results into an increase in PCWP and pulmonary edema
- Appropriate management of cardiovascular status is necessary before weaning will be successful
Post Extubation Stridor

- **The Cuff leak test:**
  - The expired tidal volume is measured with the cuff inflated on Assist Control mode with a tidal volume of 10-12ml/kg.
  - The cuff is then deflated, four to six consecutive breaths are used to compute the average value for the expiratory tidal volume.
  - The difference in the tidal volumes with the cuff inflated and deflated is the leak.
  - A value of 130ml (12% of inspiratory tidal volume) gave a sensitivity of 85% and a specificity of 95% to identify patients with an increased risk of post extubation stridor.

- **Cough / Leak test: In spontaneously breathing patients**
  - The tracheal cuff is deflated and monitored for the first 30 seconds for cough.
  - Only cough associated with respiratory gurgling (heard without a stethoscope and related to secretions) is taken into account.
  - The tube is then obstructed with a finger while the patient continues to breath. The ability to breathe around the tube is assessed by the auscultation of a respiratory flow.
Critical Care is A Promise

ان الله يحب العبد اذا عمل عملا أن يتقنه
If you are admitted and ventilated in our ICU we will:

- Assess your readiness for extubation on a daily basis
- Optimize oxygenation, ventilation, the function of all organ systems, electrolytes, nutrition before weaning is attempted
- Use spontaneous breathing trials (SBT) in the assessment
- Use RSBI <100 and Maximum inspiratory pressure of < -30 to predict weaning failure
- Discontinue ventilatory support if you tolerate SBT for 30-120 minutes
- Use of liberation and weaning protocol to facilitate process and decreases the ventilator length of stay
Discontinuation of Mechanical Ventilation

To discontinue mechanical ventilation requires:

- Patient preparation
- Assessment of readiness
  - For independent breathing
  - For extubation
- A brief trial of minimally assisted breathing
  - An assessment of probable upper airway patency after extubation
- Either abrupt or gradual withdrawal of positive pressure, depending on the patient’s readiness
### Preparation: Factors Affecting Ventilatory Demand

<table>
<thead>
<tr>
<th><strong>TABLE 10-1 FACTORS AFFECTING VENTILATORY DEMAND</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ PRODUCTION</strong> &amp; <strong>↑ Vₐ/Vₕ</strong> &amp; <strong>↑ DRIVE</strong></td>
</tr>
<tr>
<td>Fever</td>
</tr>
<tr>
<td>Lung disease</td>
</tr>
<tr>
<td>Neurogenic</td>
</tr>
<tr>
<td>Shivering</td>
</tr>
<tr>
<td>Hypovolemia</td>
</tr>
<tr>
<td>Psychogenic</td>
</tr>
<tr>
<td>Pain/agitation</td>
</tr>
<tr>
<td>Vascular occlusion</td>
</tr>
<tr>
<td>Metabolic acidosis</td>
</tr>
<tr>
<td>Trauma/burns</td>
</tr>
<tr>
<td>External apparatus</td>
</tr>
<tr>
<td>Hypoxemia</td>
</tr>
<tr>
<td>Sepsis</td>
</tr>
<tr>
<td>Excessive PEEP</td>
</tr>
<tr>
<td>Sepsis</td>
</tr>
<tr>
<td>Overfeeding</td>
</tr>
<tr>
<td>Hypotension</td>
</tr>
<tr>
<td>Work of breathing</td>
</tr>
</tbody>
</table>
**TABLE 10-4  THERAPEUTIC MEASURES TO ENHANCE WEANING PROGRESS**

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>HYPOXEMIA</th>
<th>↑ IMPEDANCE</th>
<th>↑ V_E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning</td>
<td>Positioning</td>
<td>Sedation</td>
<td></td>
</tr>
<tr>
<td>↓ Secretions</td>
<td>↑ Secretion clearance</td>
<td>↓ Fever</td>
<td></td>
</tr>
<tr>
<td>Bronchodilation</td>
<td>Bronchodilation</td>
<td>↓ Pain</td>
<td></td>
</tr>
<tr>
<td>Diuresis</td>
<td>Diuresis</td>
<td>↓ V_D/V_T</td>
<td></td>
</tr>
<tr>
<td>CPAP</td>
<td>Relieve cardiac ischemia</td>
<td>Correct acidosis</td>
<td></td>
</tr>
<tr>
<td>↑F_{1}O₂</td>
<td>↓ V_E</td>
<td>Allow ↑ PaCO₂</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↓Circuit resistance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>↓ DRIVE</th>
<th>↓ ENDURANCE</th>
<th>PSYCHOLOGICAL FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑Nutrition</td>
<td>Rest periods</td>
<td>Reassure patient</td>
<td></td>
</tr>
<tr>
<td>↓Loading</td>
<td>Ensure sleep</td>
<td>Convey plan</td>
<td>Anxiolytics</td>
</tr>
<tr>
<td>↓Alkalosis</td>
<td>Optimal positioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>↓Sedatives</td>
<td>Correct electrolytes</td>
<td>Encourage normal activity</td>
<td></td>
</tr>
<tr>
<td>↑Sleep</td>
<td>↑ Calories</td>
<td>Ambulation/physical R_X</td>
<td>Adjust steroid dose</td>
</tr>
<tr>
<td>↑Thyroid</td>
<td>Optimize heat function</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steroid replacement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correct anemia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

↑, increased; ↓, decreased.
* Partial listing.
Extubation Criteria

- Ability to protect upper airway
  - Effective cough
  - Alertness
- Improving clinical condition
- Adequate lumen of trachea and larynx
  - “Leak test” during airway pressurization with the cuff deflated


Thank You