

## Weaning Adults From Mechanical Ventilation

Arthur Jones, EdD, RRT

This Presentation is Approved for  
1 CRCE Credit Hour

## Learning Objectives

- Analyze data pertaining to readiness for weaning from mechanical ventilation
- Evaluate weaning strategies with respect to effectiveness & safety
- Explain common causes for weaning & extubation failure
- Describe strategies to prevent weaning & extubation failure

## Ventilator Discontinuance & Dependence

## Types of Ventilator Discontinuance

- Rapid & routine discontinuance
  - ❖ Postoperative patients
  - ❖ Drug overdoses
  - ❖ Acute illness, trauma

## Types of Ventilator Discontinuance

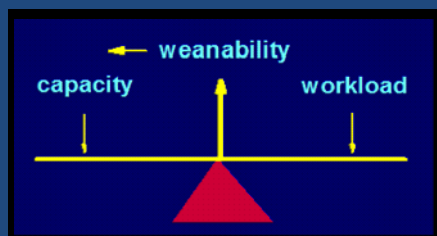
- Rapid & routine discontinuance
  - ❖ Postoperative patients
  - ❖ Drug overdoses
  - ❖ Acute illness, trauma
- Weaning: gradual reduction of support
  - ❖ Chronic or severe illness
  - ❖ Severe trauma
- Ventilator dependent patients

## Ventilator Discontinuance

- 20% of ventilated patients fail their first attempt at weaning
- 40% of the total duration of mechanical ventilation is occupied by weaning

## Causes of Ventilator Dependence

- > Function of balance between ventilation workload & capacity to work



## Causes of Ventilator Dependence

- > Ventilation workload exceeds capacity
  - ❖ Increased workload
    - Increased airway resistance
    - Decreased lung / thoracic compliance
    - Increased deadspace - demands greater spontaneous TV

## Causes of Ventilator Dependence

- > Ventilation workload exceeds capacity
  - ❖ Decreased work capacity
    - Impaired neurologic function - loss of ventilatory drive
    - Impaired muscular function
    - Debilitation, e.g. malnutrition

FYI see links below for abstract on ventilator-induced diaphragmatic dysfunction

## When Should Weaning Commence?

- > Evaluation for weanability should commence with decision to intubate, ventilate
- > Patient should be tested for reduced support when it is safe
- > Support should be reduced as it is determined safe to do so

## Weaning Readiness

## Determinants of Weaning Readiness

- > Primary factor: improvement or reversal of process that caused commitment to ventilation, i.e. the precipitating condition

## Determinants of Weaning Readiness

- > General clinical determinants
  - ❖ APACHE II score (acute physiology & chronic health evaluation)
  - ❖ Cardiovascular stability, e.g. vasopressors?

See links below for APACHE II score calculator

## Determinants of Weaning Readiness

- > General clinical determinants
  - ❖ APACHE II score (acute physiology & chronic health evaluation)
  - ❖ Cardiovascular stability, e.g. vasopressors?
  - ❖ Chest radiograph
  - ❖ Cough
  - ❖ Sputum production

## Determinants of Weaning Readiness

- > General clinical determinants
  - ❖ Mental status, e.g. cognition, attitude
  - ❖ Sleep - deprived?
  - ❖ CNS depressant requirements

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- > General clinical determinants
  - ❖ Mental status, e.g. cognition, attitude
  - ❖ Sleep - deprived?
  - ❖ CNS depressant requirements
  - ❖ Hemoglobin level - determines oxygenation, regardless of SaO<sub>2</sub>
  - ❖ Fluid balance - overload?
  - ❖ pH balance - ventilatory drive
  - ❖ Electrolyte balance - affects muscle contractility, dysrhythmias

## Determinants of Weaning Readiness

- > Oxygenation parameters
  - ❖ PaO<sub>2</sub> > 60 mm Hg
  - ❖ FiO<sub>2</sub> < 0.6
  - ❖ P(a/A)O<sub>2</sub> > 0.35

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  - ❖ P(A-a)O<sub>2</sub> < 350 on FiO<sub>2</sub> = 1.0
  - ❖ PaO<sub>2</sub>/FiO<sub>2</sub> > 200
  - ❖ SvO<sub>2</sub> > 60%
  - ❖ Oxygen index =  $\frac{FiO_2 \times MAP \times 100}{PaO_2}$

FYI see links below for OI calculator

## Determinants of Weaning Readiness

- > Weaning parameters
  - ❖ VC > 20 ml/kg
  - ❖ TV = 5 - 8 mL/kg

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- > Weaning parameters
  - ❖ VC > 20 ml/kg
  - ❖ TV = 5 - 8 mL/kg
  - ❖  $PE_{MAX} > 20$  cm H<sub>2</sub>O - assesses cough capability
  - ❖  $PI_{MAX@20\text{ sec}} > 20$  cm H<sub>2</sub>O - does not reflect endurance
  - ❖ Problem - inconsistent measurement technique

FYI see links below for article with predicted MIP & MEP values

## Determinants of Weaning Readiness

- > Weaning parameters - supported by evidence
  - ❖  $f > 38/\text{min}$  → failure
  - ❖  $PI_{100}/PI_{MAX} < 0.3$  → success
  - ❖ Rapid-shallow breathing index (RSBI) (f/TV)
    - $> 105$  → failure
    - $< 80$  → success
    - RSBI  $> 120$  may indicate need for NIPPV
    - Measurement - with / without CPAP, ATC, on or off ventilator?

## Determinants of Weaning Readiness

- > Measuring weaning parameters
  - ❖ All procedures must be standardized to ensure agreement among practitioners within a department

FYI see links below for article on evidence for RSBI

## Determinants of Weaning Readiness

- > CROP weaning index
  - ❖ Components
    - Dynamic compliance
    - Resistance
    - Oxygenation ( $PaO_2/PAO_2$ )
    - Pressure ( $PI_{MAX}$ )
    - Respiratory rate
  - ❖ Success threshold  $\geq 13$

## Determinants of Weaning Readiness

- > Integrative weaning index (IWI)
  - ❖ Components
    - Respiratory system compliance, resistance
    - $SaO_2$
    - RSBI
  - ❖ 2009 pilot study only - no comparisons

FYI see links below for article on IWI

## Determinants of Weaning Readiness

- > Workload evaluation
  - ❖ Static compliance (Cstat)
  - ❖ Airways resistance ( $R_{aw}$ )
  - ❖ Ventilator-generated WOB display
  - ❖ Electronic evaluation: measure workload
  - ❖  $V_d/V_t > 0.6$  is excessive because it indicates a high spontaneous TV required for alveolar ventilation

## Determinants of Weaning Readiness

- > Workload evaluation
  - ❖ Accessory muscle usage
    - Sternocleidomastoid - inspiration
    - Abdominal muscles - expiration
  - ❖ Intercostal retractions - may predict extubation failure
  - ❖ Paradoxical abdominal motion - diaphragmatic fatigue

## Determinants of Weaning Readiness

- > Hemodynamic status (noninvasive)
  - ❖ Brain natriuretic peptide (BNP) - elevation is associated with weaning failure
    - $> 712 \rightarrow$  weaning failure
    - $> 864 \rightarrow$  reintubation
  - ❖ Transthoracic echocardiography (TTE) - detects decreased left ventricular ejection fraction during SBT

FYI see links below for article on echocardiography & weaning

## Determinants of Weaning Readiness

- > Adrenal status
  - ❖ Adrenal insufficiency is associated with weaning failure
  - ❖ Deficiency - AM cortisol  $< 25$  mcg/dl
  - ❖ Hydrocortisone may enable weaning
- > Nutritional status - indirect calorimetry
  - ❖ Proteins  $\rightarrow$  muscle strength
  - ❖ Carbohydrates  $\rightarrow$  required minute ventilation

FYI see links below for article on weaning & calorimetry

## Weaning Strategies

## Optimize Patient Condition

- > Acid-base balance - Diamox for metabolic alkalemia?
- > Electrolyte balance - repletion
- > Nutrition
  - ❖ Minimize carbohydrates
  - ❖ Optimize proteins
- > Hemoglobin ( $> 9$  g/dL)
- > No systemic infection

FYI see links below for article on weaning

## Optimize Patient Condition

- Pain relief
- Sleep
- Sedation - dexmedetomidine (Precedex) - alpha2 agonist
  - ❖ Sedative, anxiolytic, analgesic
  - ❖ Minimal respiratory / cardiovascular depression
  - ❖ Easy arousal
  - ❖ Reduces requirements for other drugs
  - ❖ May facilitate weaning

## Optimize Patient Condition

- Depression → negative attitude
  - ❖ Affects 40% of cognizant ventilator patients
  - ❖ Approximately doubles risk of weaning failure

FYI see links below for articles on daily sedation interruption plus depression & weaning

## Optimize Patient Condition

- Maximize communication
- Comfortable positioning
- Decrease FiO<sub>2</sub> to 0.4
- Decrease PEEP to ≤ 5 cm H<sub>2</sub>O

## Rapid Ventilator Discontinuance

- Criteria
  - ❖ Less than 72 hours on ventilator
  - ❖ No underlying cardiovascular problems

## Rapid Ventilator Discontinuance

- Procedure
  - ❖ Evaluate, e.g. RSBI, etc.
  - ❖ Spontaneous breathing trial (SBT)
    - Any ventilation mode without machine-triggered breaths
    - 30 minutes is as good as 2 hours
  - ❖ Blood gas?
  - ❖ Extubate
  - ❖ Monitor - O<sub>2</sub>, WOB, stridor

## Weaning Strategies

- T-piece trials
- SIMV
- PSV
- CPAP
- Special modes: Automode, ASV, PAV, SmartCare, NAVA, ATC
- Noninvasive positive pressure ventilation (NPPV)
- Weaning protocols

## T-Piece Trials

- > Advantages of T-piece
  - ❖ Rapid weaning
  - ❖ Provides exercise of ventilatory muscles
  - ❖ Zero ventilator-imposed WOB
  - ❖ Assesses ventilatory capability without PEEP
  - ❖ Requires minimal technology

## T-Piece Trials

- > Disadvantages
  - ❖ More staff time
  - ❖ Lack of alarms → less safe
  - ❖ Imposed WOB from ETT
  - ❖ Greater endocrine stress on patient
  - ❖ Greater risk for infection

FYI see links below for article on weaning modes & stress

## Synchronized Intermittent Mandatory Ventilation (SIMV)

- > Machine-triggered breaths, with intermittent spontaneous breaths
- > Advantages
  - ❖ Less staff time
  - ❖ Presence of alarms
  - ❖ Can incorporate PSV & PEEP
  - ❖ Psychological support: ventilator remains in place

## Synchronized Intermittent Mandatory Ventilation (SIMV)

- > Disadvantages
  - ❖ Slower?
  - ❖ Some obsolete ventilators & circuits increase WOB
  - ❖ Inappropriate application

## Pressure Support Ventilation (PSV)

- > Advantages
  - ❖ Compensates for imposed WOB
  - ❖ At least as fast as T-piece
  - ❖ Presence of alarms, backup ventilation
  - ❖ Can be combined with SIMV, CPAP
  - ❖ Flow pattern: physiologic, comfortable
  - ❖ Permits titration of workload

## Pressure Support Ventilation (PSV)

- > Disadvantages
  - ❖ High mean airway pressures: may be misleading for extubatability
  - ❖ Flow cycling problematic with system leaks
  - ❖ Inappropriate adjustment of expiratory trigger may impede weaning

### Continuous Positive Airway Pressure (CPAP)

- > Advantages
  - ❖ Prevents atelectasis: emulates epiglottic closure
  - ❖ Presence of alarms, apnea backup ventilation
  - ❖ Compatible with SIMV, PSV
  - ❖ Same as T-piece with respect to outcomes

### Continuous Positive Airway Pressure (CPAP)

- > Disadvantages - CPAP can produce artifactual improvement
  - ❖ Lung mechanics may deteriorate when CPAP is discontinued
  - ❖ Pulmonary edema may develop when CPAP is discontinued
- > SBT without CPAP or prepare for mask CPAP?

### Special Ventilation Modes

- > PS with volume guarantee (most current ventilators)
  - ❖ Appropriate minimum tidal volume
  - ❖ Hyperpnea - PS is decreased
  - ❖ Obstruction - PS is increased
- > Auto-mode™ (Maquet) - alternating pressure control & pressure support, both with volume guarantee

### Special Ventilation Modes

- > Adaptive support ventilation™
  - ❖ Adjusts rate, pressure
  - ❖ Input - patient mechanics
- > Proportional assist ventilation™
  - ❖ Adjusts pressure
  - ❖ Input - patient effort
- > SmartCare™
  - ❖ Adjusts pressure support
  - ❖ Input - comfort - rate, TV, ETCO<sub>2</sub>

FYI see links below for abstract on automated weaning modes

### Special Ventilation Modes

- > WOB graphic
 

spontaneous breaths

FYI see links below for article on ventilator weaning modes

### Special Ventilation Modes

- > Neurally adjusted ventilatory assist NAVA™ (Maquet)
  - ❖ Gastric catheter detects & transmits diaphragmatic electrical activity to the ventilator
  - ❖ Ventilator uses the strength of the signal to adjust the level of support for the patient



### Special Ventilation Modes

- > Tube compensation - provides PSV level based on tube size & inspiratory flow
  - ❖ Theoretically, WOB same as if patient is extubated
  - ❖ "Electronic extubation"
- > Evidence for newer weaning modes?
- > Negative pressure ventilation
  - ❖ Cuirass
  - ❖ Iron lung

### Noninvasive Positive Pressure Ventilation (NPPV)

- > For patients with borderline parameters
- > For patients likely to become ventilator-dependent, e.g. those with COPD

FYI see links below for abstract on weaning with NPPV & COPD

### NPPV & Weaning

- > Rationales
  - ❖ Shorten intubation time
    - Decreased sedation
    - Decrease infection
    - Decrease ICU & hospital length-of-stay (LOS)
  - ❖ Prevent reintubation
  - ❖ Prevent tracheotomy

### NPPV & Weaning

- > Evidence from research
  - ❖ Decreased mortality
  - ❖ Decreased duration of invasive mechanical ventilation
  - ❖ Decreased ventilator-associated pneumonia
  - ❖ Decreased ICU & hospital length of stay (LOS)

See links below for abstract of meta-analysis of NPPV & weaning

### NPPV & Weaning

- > Disadvantages / complications
  - ❖ Gastric insufflation - high pressures
  - ❖ Aspiration
  - ❖ Mucus plugging
  - ❖ Patient intolerance
  - ❖ Caregiver time

### NPPV & Weaning

- > Supportive evidence is moderate, when applied to selected patients who
  - ❖ Meet criteria to initiate SBT
  - ❖ Meet criteria for extubation
    - Do not have excessive secretions
    - Have an effective cough
    - Have acceptable mental status
    - Are not a difficult intubation

## NPPV & Weaning

- Supportive evidence is moderate, when applied to selected patients who
  - ❖ Have no impediments for interface, e.g. can tolerate a mask
  - ❖ Tolerate short term spontaneous breathing for mask adjustments, etc.

## NPPV & Post-Extubation Failure

- Evidence does not support efficacy of NPPV in **treating** post-extubation respiratory failure
- Evidence supports that NPPV may be effective in **preventing** post-extubation respiratory failure where high-risk patients are identified in advance
- NPPV is not recommended as a routine intervention for post-extubation situations

## Weaning Protocols

- **Protocol:** clinical algorithm to guide decisions regarding progression of weaning, based on clinical data & observations
- Apply combinations of techniques

See links below for weaning algorithm example

## Weaning Protocols

- **Advantages**
  - ❖ Evidence - faster extubation, equal safety
  - ❖ Exercises therapists' knowledge & skills - motivating
  - ❖ Decreased demand for physician time

See links below for abstract on effectiveness of protocols  
FYI see links below for AARC adult weaning protocol

## Weaning Protocols

- **Barriers to adoption / implementation**
  - ❖ Physician resistance to loss of decision-making
  - ❖ Inadequate knowledge, skills, & professionalism of therapists

## Weaning Protocols

- **Daily screening (DS)**
- **Spontaneous breathing trial (SBT)**
- **Continuation of ventilation or extubation**

FYI see links below for article on weaning with evidence-based protocols

## Weaning Protocol (Ely, 2000)

- > Daily screening: 2 min test
  - ❖ Patient coughs when suction catheter inserted
  - ❖ Intact gag reflex
  - ❖ Patient not receiving continuous infusions of vasopressors or sedatives
  - ❖  $\text{PaO}_2/\text{FiO}_2 \geq 200$  mm Hg
  - ❖  $f/\text{TV}$  (RSBI)  $\leq 105$
  - ❖ PEEP  $\leq 5$  cm  $\text{H}_2\text{O}$

## Weaning Protocol (Ely, 2000)

- > SBT
  - ❖ Recommended by RT
  - ❖ Ordered by MD
  - ❖ 120 minutes flowby without PS
  - ❖ Monitored by RN

## Weaning Protocol (Ely, 2000)

- > Termination of SBT
  - ❖  $f > 30$  for 5 min
  - ❖  $\text{SpO}_2 < 90\%$  for 30 sec
  - ❖ 20% change in HR for  $> 5$  min
  - ❖  $\text{P}_{\text{SYS}} > 180$  or  $< 90$  for 1 min
  - ❖ Anxiety, agitation, or diaphoresis for 5 min

## Weaning Protocol (Ely, 2000)

- > Termination of SBT
  - ❖ Successful after 120 min  $\rightarrow$  90% chance of staying off MV for 48 hours

## Weaning & Extubation Failure

## Causes of Weaning Failure

- > Underlying disease(s) unresolved - patient not ready
- > Poor lung mechanics, i.e. compliance, resistance
- > Muscular atrophy - immobility & prolonged support
- > Ventilatory muscle fatigue - overdoing weaning

FYI see links below for article on weaning failure

## Causes of Weaning Failure

- Inadequate / inappropriate respiratory care
  - ❖ PSV expiratory trigger maladjustment
  - ❖ Mechanical deadspace - HME
  - ❖ Inadequate humidification

## Causes of Weaning Failure

- Inadequate / inappropriate respiratory care
  - ❖ PSV expiratory trigger maladjustment
  - ❖ Mechanical deadspace - HME
  - ❖ Inadequate humidification
  - ❖ Bronchial hygiene
  - ❖ Bronchodilators
  - ❖ Inadequate monitoring, e.g. for fatigue

## Causes of Weaning Failure

- Malnutrition
- Anemia
- Psychological dependence
- CNS depressants
  - ❖ Propofol - associated with increased RSBI & decision not to wean
  - ❖ Precedex may facilitate weaning

FYI see links below for article on Precedex & weaning

## Causes of Weaning Failure

- Cardiovascular disease, e.g. CHF
  - ❖ Extubation failure predicted with pre- post SBT comparison of BNP
  - ❖ Monitor high-risk patients with transthoracic echocardiogram?

FYI see links below for articles on weaning failure of cardiac origin plus echocardiography & weaning

## Causes of Weaning Failure

- Cardiac failure or ischemia
- Discontinuation of CPAP
- Respiratory failure - load exceeds capacity
- Excessive secretions & inadequate cough
- Inability to swallow, inadequate gag - aspiration

## Causes of Weaning Failure

- Upper airway obstruction
  - ❖ Edema that may be preventable with steroids
  - ❖ Administer four hours before extubation
  - ❖ For high-risk patients, as detected by cuff leak test

FYI see links below for article on steroids & extubation failure

## Summary & Review

- > Types of ventilator discontinuance
- > Ventilatory work, capacity
- > Weaning readiness
  - ❖ General status
  - ❖ Oxygenation
  - ❖ Ventilatory parameters
  - ❖ Cardiac / hemodynamic status
  - ❖ Evaluation of ventilatory workload
  - ❖ Adrenal status

## Summary & Review

- > Weaning strategies
  - ❖ T-piece
  - ❖ SIMV
  - ❖ PSV
  - ❖ CPAP
  - ❖ Special modes, e.g. VAPS, PAV, NAVA
  - ❖ NPPV
  - ❖ Weaning protocols

## Summary & Review

- > Weaning failure
  - ❖ Unresolved precipitating condition
  - ❖ Poor lung mechanics
  - ❖ Inappropriate respiratory care, e.g. deadspace, bronchodilators, hygiene
  - ❖ Cardiac disease, e.g. CHF

## Summary & Review

- > Weaning failure
  - ❖ Muscular atrophy
  - ❖ Malnutrition
  - ❖ CNS depressants
  - ❖ Anemia
  - ❖ Psychological dependence

## Summary & Review

- > Extubation failure
  - ❖ Upper airway obstruction
  - ❖ Discontinuation of CPAP
  - ❖ Cardiac failure - edema
  - ❖ Excessive secretions
  - ❖ Inability to swallow, inadequate gag reflex

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