

## Mechanical Ventilation Modes and Weaning

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## Respiratory Failure

- Primary function of the respiratory system:
  - to remove CO<sub>2</sub> and to deliver O<sub>2</sub> to the pulmonary capillary bed
- Respiratory Failure
  - A condition that results in abnormally low PaO<sub>2</sub> with or without an abnormally increased PaCO<sub>2</sub>
  - Respiratory failure may be acute or chronic

## Classification of Acute Respiratory Failure

- Type I (Hypoxemic):
  - decreased PaO<sub>2</sub> w (< 55 mm Hg when FiO<sub>2</sub> ≥ 0.60) with PaCO<sub>2</sub> normal or low
  - usually represents a disease process that involves the lung itself (e.g. ARDS)

## Classification of Acute Respiratory Failure

- Type II (Hypercapnic):
  - increased PaCO<sub>2</sub> (with decreased PaO<sub>2</sub>)
  - usually results from decreased minute ventilation (V<sub>e</sub>) or increased dead space (V<sub>d</sub>/V<sub>t</sub>)

## Type I (Hypoxic) Respiratory Failure: Treatment

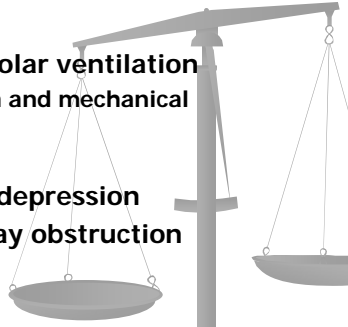
- Supplemental FiO<sub>2</sub>
- Increase mean airway pressure
  - 1) Mechanical ventilation with PEEP
  - 2) CPAP
- Correct extra-pulmonary shunt
- Hyperventilation (When hypoventilation cause)

## Type II (hypercapnic) respiratory failure

- increased PaCO<sub>2</sub> (with decreased PaO<sub>2</sub>)
- usually results from decreased minute ventilation (V<sub>e</sub>) or increased dead space (V<sub>d</sub>/V<sub>t</sub>)
- $P_aCO_2 = \frac{k \cdot VCO_2}{V_E (1 - \{V_d/V_t\})} = \frac{k \cdot VCO_2}{V_A}$
- A ↓ in V<sub>E</sub> is the most common mechanism of Type II failure

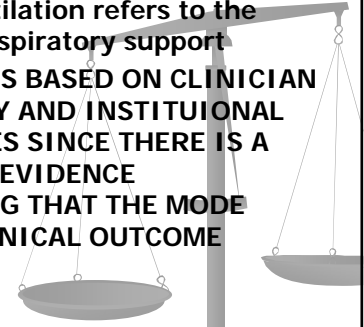
## Type II (hypercapnic) respiratory failure: Treatment

- Increase alveolar ventilation
  - 1) Intubation and mechanical ventilation
  - 2) BiPAP
- Reverse CNS depression
- Reverse airway obstruction



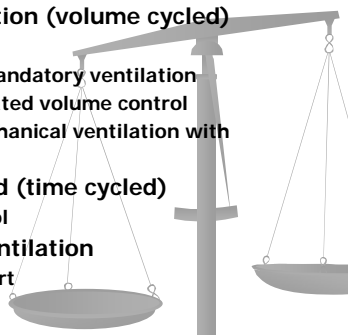
## Mechanical Ventilation

- Mode of ventilation refers to the method of inspiratory support
- SELECTION IS BASED ON CLINICIAN FAMILIARITY AND INSTITUTIONAL PREFERENCES SINCE THERE IS A PAUCITY OF EVIDENCE INDICATING THAT THE MODE AFFECTS CLINICAL OUTCOME

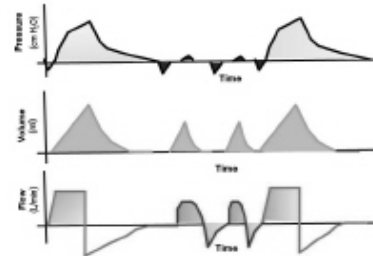


## Modes of Ventilation

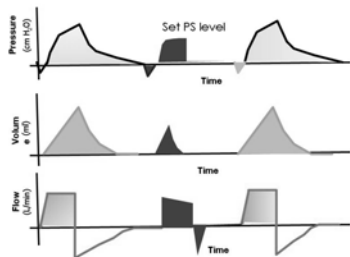
- Volume ventilation (volume cycled)
  - Volume control
  - Intermittent mandatory ventilation
  - Pressure regulated volume control
  - Controlled mechanical ventilation with autoflow
- Pressure limited (time cycled)
  - Pressure control
- Flow limited ventilation
  - Pressure support



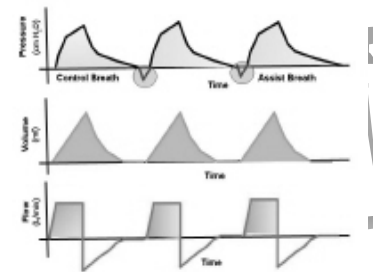
### SIMV (Volume-Targeted Ventilation)

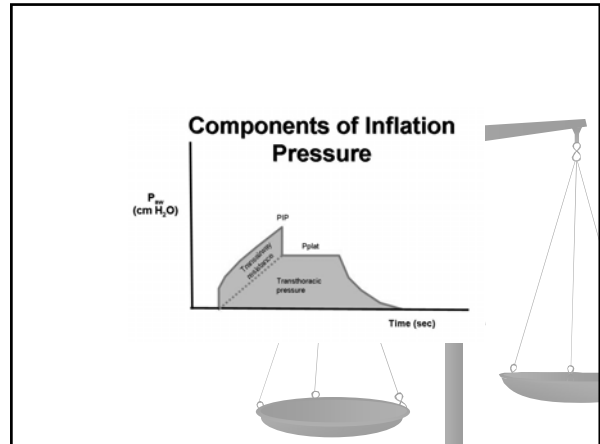
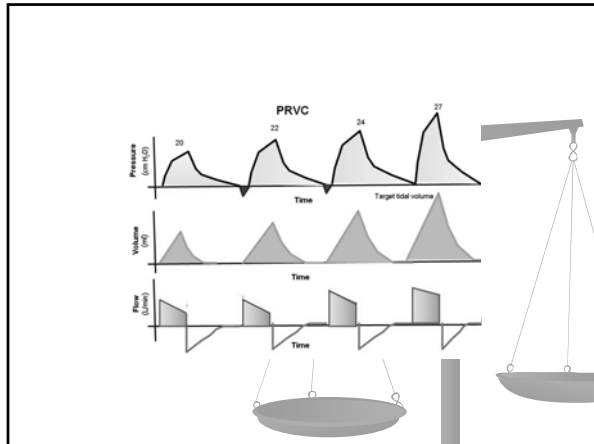


### SIMV+ PS (Volume-Targeted Ventilation)



### Assisted Mode (Volume-Targeted Ventilation)





### Volume vs Pressure Limited

- No difference in mortality, oxygenation or WOB
- Pressure limited is associated with lower peak airway pressures
- Volume limited guarantees tidal volume

### Pressure Support Ventilation

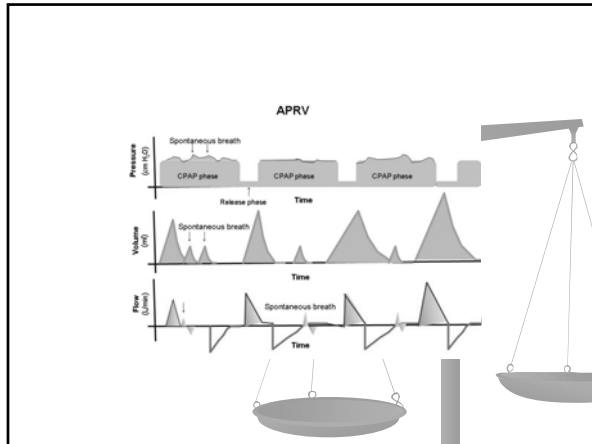
- Flow limited
- More comfortable (Patient determines inspiratory time)
- Poorly suited for full support
- Has not been shown to shorten weaning time

### Ventilator Triggering

- Pressure triggering
  - Traditional
  - Used on Siemens ventilators
- Flow triggering
  - May decrease WOB
  - Used on newer ventilators

### Airway Pressure Release Ventilation

- High continuous positive airway pressure (p high) is delivered for a long duration (T high) and then falls to a lower pressure (P low) for a shorter duration (T low)
- Transition from p high to p low deflates the lungs and eliminates carbon dioxide
- Alveolar recruitment is maximized by high continuous positive airway pressure
- T high and low determine the frequency of inflation and deflation
- Spontaneous breathing occurs at p high and p low.
- Has not been shown to alter mortality
- Small studies have suggested shorter times of mechanical ventilation
- No clear indication



## Inverse Ratio Ventilation

- Not a mode of ventilation per se
- Normal I:E = 1:2
- Lengthens I relative to E to increase mean airway pressure and alveolar recruitment
- No improvement in mortality or shorter length of time on mechanical ventilator
- Requires heavy sedation

## High Frequency Oscillatory Ventilation

- Delivers respiratory rate of 3-15 hertz
- Airway pressures oscillates around a constant mean airway pressure
- TV = amplitude is less than anatomic dead space
- mPaw determines oxygenation (> 24 mm hg)
- Main determinants of PCO<sub>2</sub> is delta P (pressure amplitude) and RR (Hz)
  - Increase in delta P decreases PCO<sub>2</sub>
  - Decrease in Hz decreases PCO<sub>2</sub>
- No universal indications

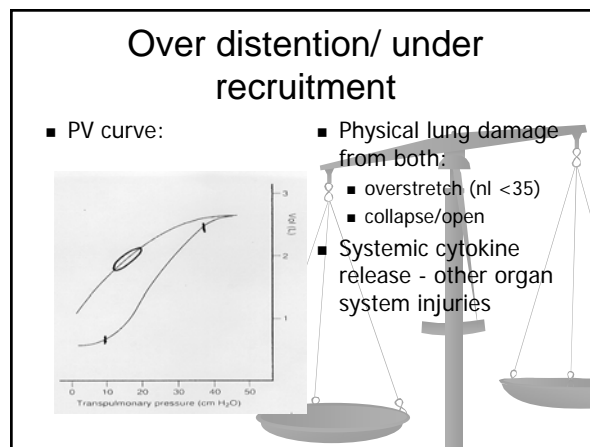
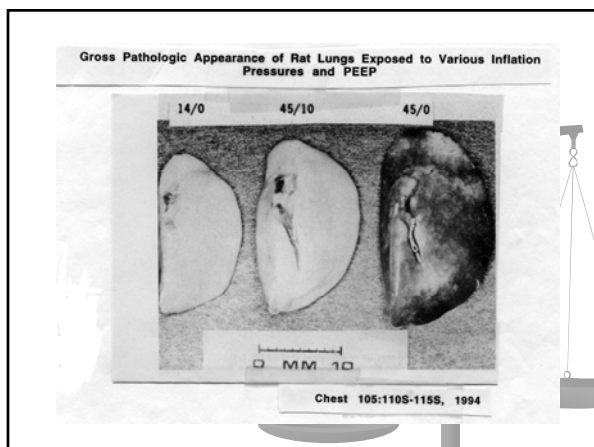
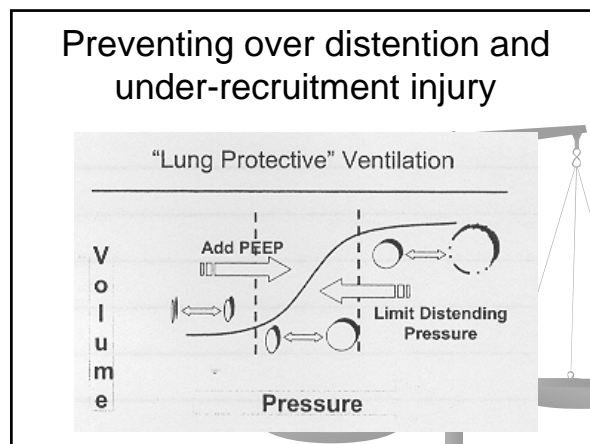
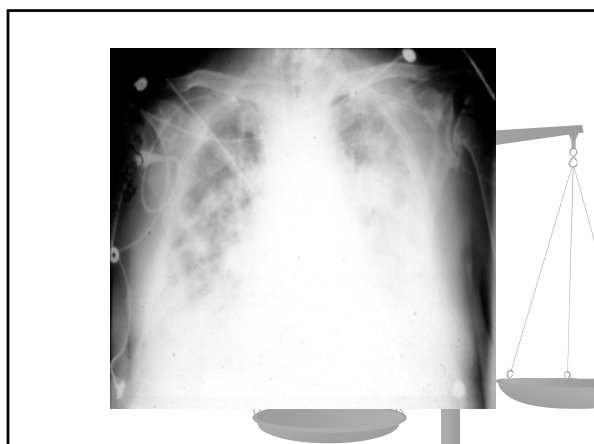


## Improvement of Oxygenation on Ventilator

- Oxygenation Index = FiO<sub>2</sub> x mean airway pressure
- Increased mean airway pressure converts collapsed (shunted) alveoli to open (V/Q mismatched areas) which are now responsive to FiO<sub>2</sub>
- Mean airway pressure may be increased by increasing PEEP, IRV, APRV, HFOV

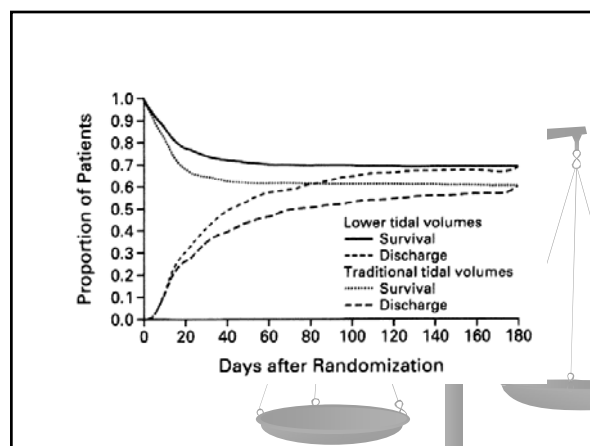
## Worsening Oxygenation: What to do?

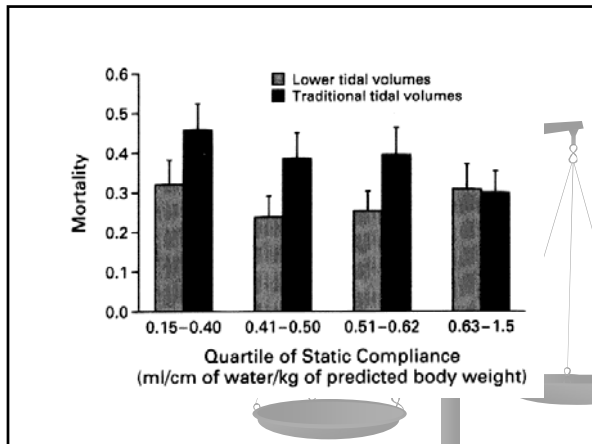
- Maximize FiO<sub>2</sub> and mean airway pressure
- Look for intracardiac or intrapulmonary shunt with "bubble" echo
- Utilize salvage modes/treatments
  - Flolan vs Nitric oxide
  - APRV
  - High frequency ventilation
  - ECMO



### The ARDS NIH Network

- Prospective, randomized study comparing traditional (12 ml/kg) vs low (6 ml/kg) tidal volumes in ARDS
- Stopped after enrollment of 861 patients
- Mortality 40% in traditional TV group vs 31% in the low TV group
  - NEJM 342:1301-8, 2000.





### The Difficult to Wean Patient

- Represents ~10% of all mechanically ventilated patients
- Consumes 35-50% of ICU patient days and resources
- Huge economic drain
- Great source of frustration for staff
- No one method of weaning has proved superior

### A Comparison of Four Methods of Weaning Patients From Mechanical Ventilation

- Prospective, randomized, multicenter study of 546 patients
- Median duration of weaning:
  - 1) 5 days for IMV
  - 2) 4 days for pressure support
  - 3) 3 days for intermittent trials of spontaneous breathing
  - 4) 3 days for once daily trial of spontaneous breathing
- Esteban et al. N Engl J Med 1995; 332:345-350

### Causes of Ventilatory Dependency

- Hypoxemic respiratory failure
  - Impaired pulmonary gas exchange
  - Decreased oxygen content of venous blood
  - Hypoventilation
- Respiratory Muscle Pump Failure
  - Decreased neuromuscular capacity
  - Increased respiratory pump load
- Psychological Factors
  - Tobin. Postgrad Med 1991; 89:171-179

### Problems with Ventilatory Weaning

- Weaning too slowly or too aggressively
- Lack of consistency in communication
- Weaning started "too late" in day
- Patients left on ventilator overnight and during weekends
- Excessive arterial blood gas determinations
- Lack of consistency in performing and recording variables
- Oversedation

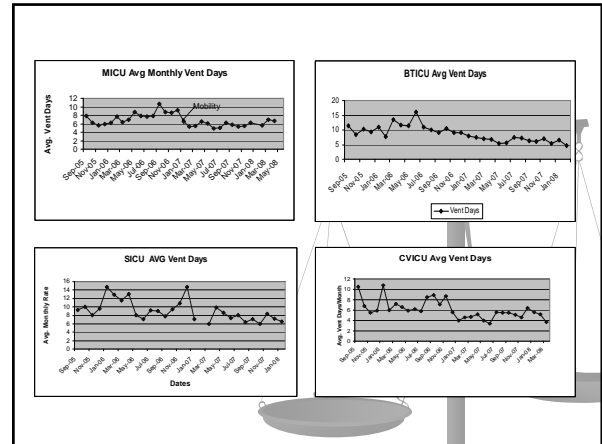
### Steps in Managing Patients Who Have Difficulty During Mechanical Ventilation

- Determine cause of ventilatory dependency
- Rectify correctable problems
- Develop weaning plan
- Use team approach
- Consider psychological factors
- Optimize posture
- Optimize pulmonary care
- Ensure adequate nutritional support
- Provide minerals and electrolytes
- Optimize general patient care
- Provide ambulation
  - Tobin. Postgrad Med 1991; 89:171-179

### A Randomized, Controlled Trial of Protocol-Directed Versus Physician-Directed Weaning From Mechanical Ventilation

- 179 protocol-directed patients versus 178 physician-directed patients
- Median duration of mechanical ventilation was 35 hours for the protocol-directed patients versus 44 hours for the physician-directed patients (p=.057)
- Hospital cost savings \$42,960
- Protocol-guided weaning (by respiratory therapists and nurses) is safe and led to extubation more rapidly than physician-directed weaning

■ Kollef et al. CCM 1997; 25:567-574



### Goals of Mechanical Ventilation

- Support patient in a non-toxic manner on ventilator while improving underlying condition
  - PIP < 40
  - FiO2 ≤ 60
  - Triggering ventilator
- No mode of ventilation has proved superior
- Get patient to oxygenation criteria for extubation (FiO2 50% or less, PEEP 8 or less)
- Daily trials of spontaneous breathing
- Daily sedation interruption and mobility

### Mechanical Ventilator Modes and Weaning: Conclusions

- Mechanical ventilation not therapeutic...its supportive
- Don't worsen lung injury with ventilator
- Reverse underlying process and patient is weaned!
- Weaning probably a misnomer
- Identify patient ready to extubate with daily trials of spontaneous breathing
- Low tidal volumes in ARDS saves lives!