Acute Respiratory Failure & ARDS

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Objectives

- Define respiratory failure & discuss types of respiratory failure
- Brief introduction to mechanical ventilation
- Define ARDS, its epidemiology & basic pathophysiology
- Discuss clinical aspects of ARDS
- Discuss treatment of ARDS
Respiratory Failure

- An inability to adequately oxygenate or ventilate
  - $\text{PaO}_2 < 60 \text{ mm Hg}$
  - $\text{PaCO}_2 > 45 \text{ mm Hg}$
# Respiratory Failure

<table>
<thead>
<tr>
<th></th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
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</thead>
<tbody>
<tr>
<td><strong>Mechanism</strong></td>
<td>Shunt</td>
<td>Hypoventilation</td>
<td>Atelectasis</td>
<td>Hypoperfusion</td>
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<tr>
<td><strong>Etiology</strong></td>
<td>Alveolar flooding- low or high pressure pulmonary edema</td>
<td>Increased dead space, decreased minute ventilation</td>
<td>Decreased FRC, Increased closing volume</td>
<td>Decreased mixed venous oxygen</td>
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<tr>
<td><strong>Clinical Scenario</strong></td>
<td>ARDS, CHF, Pneumonia, Alveolar hemorrhage</td>
<td>Airway Obstruction, Impaired Lung or Chest Wall Compliance, Neuromuscular weakness, Impaired CNS drive</td>
<td>Postoperative, Obesity</td>
<td>Shock, MI</td>
</tr>
</tbody>
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Respiratory Failure - Type I
Acute Hypoxemic Respiratory Failure

- Cardiogenic
  - “High-pressure” edema
- ARDS
  - “Low-pressure”/increased permeability edema
- Focal lung lesions
  - Pneumonia, Contusion
- Alveolar Hemorrhage syndromes
  - Goodpasture’s, Wegener’s disease
- Miscellaneous
Respiratory Failure: Type I

100% FiO2

PAO2 = 650 mm Hg
CcO2 = 22 mL/100 mL

PvO2 = 40 mm Hg
CvO2 = 15 mL/100 mL

PaO2 = 60 mm Hg
CaO2 = 18.5 mL/100 mL
Respiratory Failure- Type I
Starling Equation

\[ \* J_v = K_f \left[ (P_c - P_i) - \sigma (\pi_c - \pi_i) \right] \]

- \( K_f \) = filtration coefficient
- \( P_c \) = hydrostatic capillary pressure
- \( P_i \) = interstitial capillary pressure
- \( \pi_c \) = oncotic capillary pressure
- \( \pi_i \) = oncotic interstitial pressure
- \( \sigma \) = reflection coefficient
Respiratory Failure - Type II

\[ \text{Pa}_{\text{CO}_2} = \frac{\dot{V}_{\text{CO}_2} \times k}{\dot{V}_A} \]

- \( \text{Pa CO}_2 \) rises if:
  - CO2 production increases
  - Alveolar ventilation decreases
Strength/ Drive

CNS Drive
Sedation
Metabolic encephalopathy
OHS

NM Transmission Impaired
ALS
Guillain-Barre Syndrome
Paralytic

Muscle Weakness
Malnutrition
Fatigue
Electrolyte
Hypoperfusion

Load

Resistive
Bronchospasm
OSA
Secretions

Lung & Chest Wall Elastic
Pneumonia
Pulmonary Edema
Pleural Effusion
Ascites

Minute Ventilation
Sepsis
Pulmonary Embolism
Metabolic Acidosis
Respiratory Failure - Type II

* PaO2 corrects readily with supplemental oxygen
Respiratory Failure - Type IV

- Hypoperfusion
- Cardiac output “steal”
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Indications for Mechanical Ventilation

- Inadequate Oxygenation
- Inadequate Ventilation
- Shock
- Airway Protection
- Elective (e.g. Sx)
Mechanical Ventilation

Preset Volume or Pressure

Inspiration

Expiration

Normal Respiration

Positive Pressure Ventilation
Principles of Mechanical Ventilation

Equation of Motion

- Driving Pressure

\[ \text{Resistive load} + \text{Elastic load} = \text{Airways Resistance} + (\text{lung and chest wall}) \]

Elastance
Mechanical Ventilation

- **Ventilation**
  - Volume or Pressure Modes
  - Compliance determines:
    - Alveolar pressure
    - Tidal volume

- **Oxygenation**
  - PEEP & FiO2
Mechanical Ventilation

GOALS
- Maximal Rest
- Meet minute ventilatory requirements
- Patient-Ventilator Synchrony

Avoid
- Respiratory Alkalosis
- Barotrauma/Volutrauma
- Auto-PEEP
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ALI & ARDS
Definition

- Acute onset
- Bilateral infiltrates
- PaO$_2$/FiO$_2$
  - $< 300$ mm Hg for ALI
  - $\leq 200$ mm Hg for ARDS
- No evidence of pulmonary venous congestion
  - PCWP $\leq 18$ mm Hg

ALI & ARDS
Epidemiology

- 64 to 86.2 cases/100,000 person-years
- ~142,000 - 191,000 annual cases

Risk factors
- EtOH abuse
- Poor nutritional status
- Increased age
- Increased APACHE score

MacCallum NS; Evans TW. *Curr Opin Crit Care* 2005;11(1):43-9
ARDS Causes

**Direct**
- Pneumonia
- Aspiration
- Inhalational injury (e.g. heroin/crack)
- Lung contusion
- Near-drowning

**Indirect**
- Sepsis
- Trauma
- Pancreatitis
- Burns
- Air, Amniotic fluid or Fat Emboli
- Drug Reaction
- Transfusion of Blood Products
- D.I.C.

ARDS - Basic Pathophysiology

- Alveolar flooding
  - ↑ permeability alveolar-capillary barrier
  - Endothelial & epithelial injury
  - Surfactant depletion
- Inflammatory injury
  - TNFα, IL1, IL6
- Coagulation abnormalities

Ware LB, Matthay MA. *NEJM* 2000;342(18):1334-1349.
ARDS - Histopathology

Hyaline Membranes
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ARDS - Clinical Presentation

- **History:**
  - Acute onset: 4-48 hrs

- **Symptoms:**
  - Tachypnea, Dyspnea

- **Exam**
  - Severe, refractory hypoxemia
  - Diffuse “wet” crackles on lung exam
ARDS - Radiographically

- Bilateral infiltrates
- Consolidation
  - May be patchy
  - Often dependent
- Kerley B lines absent
- +/- pleural effusions & atelectasis
ARDS - Radiographically
ARDS - Differential Diagnosis

- Congestive heart failure
- Diffuse alveolar hemorrhage
- Acute eosinophilic PNA
- Acute interstitial PNA

Less commonly:
- Pulmonary alveolar proteinosis
- Hypersensitivity pneumonitis
- Cryptogenic organizing PNA
ARDS- Dx Evaluation

- Basic Labs (CBC, BMP)
- Chest X-ray
- ECG & Echocardiogram
- Bronchoalveolar lavage
ARDS - Clinical Course

- Exudative Stage
  - Refractory hypoxemia
  - Intrapulmonary shunt
  - Decreased compliance

- Proliferative Stage
  - Increased dead space & $V_E$
  - Pulmonary HTN

- Resolution

ARDS- Clinical Course

Exudative

Fibroproliferative

Resolution
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ARDS- Treatment

Treat the Underlying Cause!!!
ARDS- Treatment

- Maintain “adequate” oxygenation
  - O₂Sat ~ 88-90%
- Avoid “toxic” F₁O₂ exposure
- Lung protective ventilation
ARDS - PEEP & Oxygenation

ARDS - “Volutrauma”

- High-tidal volumes lead to ALI
- “Baby Lungs”

Gatinnoni L, Pesenti A. *Inten Care Med* 2005 31:776-784

ARDS- Low tidal volume ventilation

- 9% reduction in mortality
- Lower IL-6 levels
- > days without nonpulmonary organ failure

ARDS Network. NEJM 2000;342:1301-8
ARDS Mortality & Prognosis

**Mortality**
- Underlying Dz
- Multiorgan failure
- < often due to refractory hypoxemia

**Long-Term Sequelae**
- Neurocognitive deficits
- Neuromuscular weakness
- Neuropsychologic effects
- Decreased HRQL

**Risk Factors for Death**
- Age
- > physiologic severity of illness
- + Shock on admit
- Immunosuppression

**Pulmonary Function**
- Decreased diffusing capacity
- Obstructive & Restrictive Deficits observed

Thank you
Questions...?