Acute Respiratory Failure

Physiologic Definition:
Inability of the lungs to meet the metabolic demands of the body
Can’t take in enough O₂ or Can’t eliminate CO₂ fast enough to keep up with production

Respiratory Failure

Mechanism
- Failure of Oxygenation: $P_aO_2<60$ mmHg
- Failure of Ventilation*: $P_aCO_2>50$ mmHg

* $P_aCO_2$ is directly proportional to alveolar minute ventilation

Acute Respiratory Failure

Physiologic Classification

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Type 1 Hypoxic</th>
<th>Type 2 Hypercarbic</th>
<th>Type 3 Post-op</th>
<th>Type 4 Shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shunt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airspace Flooding</td>
<td>Increased Respiratory load, Decreased ventilatory drive</td>
<td></td>
<td></td>
<td>Decreased FRC and increased Closing Volume</td>
</tr>
<tr>
<td>Water, Blood or Pus filling alveoli</td>
<td>CNS depression, Bronchospasm, Stiff respiratory system, respiratory muscle failure</td>
<td>Abdominal surgery, Pneumothorax, CTPN, ALS, Sepsis, MI, acute hemorrhage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ventilatory Failure

Inbalance between load on the lungs and the ability of bellows to compensate

Acute Hypoxemic Respiratory Failure

- Shunt disease - intracardiac or intrapulmonary
- Severe V/Q mismatch - asthma, PE
- Venous admixture due to low cardiac output states, severe anemia coupled with shunt and/or V/Q mismatch
Acute Respiratory Distress Syndrome (ARDS)

Leaky alveolar capillaries
Plasma fluid and leukocytes leak into the airspace
Shunt
Hypoxemia

Causes of ARDS

DIRECT LUNG INJURY
- Pneumonia
- Aspiration of gastric contents
- Pulmonary contusion
- Near-drowning
- Inhalation injury (Cl-, smoke)
- Reperfusion pulmonary edema after lung transplantation or pulmonary embolectomy

INDIRECT LUNG INJURY
- Non-pulmonary sepsis/SIRS
- Severe trauma with shock
- Cardiopulmonary bypass
- Drug overdose (Narcotics)
- Acute pancreatitis
- Transfusion (TRALE)
- Drug reaction (ARA-C, nitrofurantoin)
- Fat/air/amniotic fluid embolism, bypass

Acute Respiratory Distress Syndrome (ARDS)

American-European Consensus Definition:*

- Refractory hypoxemia
  \( P_{O_2}/F_{I_{O_2}} (P/F \text{ ratio}) \)
  - <300 for ALI
  - <200 for ARDS
- A disease process likely to be associated with ARDS
- No evidence of elevated left atrial pressure elevation (by clinical exam, echo or PA catheter)
- Bilateral airspace filling disease on X-ray

**ARDS**

**Fundamental Pathophysiology:**

*Increased alveolar permeability due to direct neutrophil-mediated injury to the alveolar epithelium*

Not a distinct disease - rather a sequelae of activation of lung and systemic inflammatory pathways

---

**Infiltration of the alveolar septum with neutrophils, macrophages, erythrocytes**

Presence of hyaline membranes, and protein-rich edema fluid in the alveolar spaces; capillary injury and disruption of the alveolar epithelium

---

**Optimal V/Q matching**

\[
\frac{1.36 \times 15 \times 100\%}{50\%} \approx 20\ vols\%
\]

\[
\frac{1.36 \times 15 \times 100\%}{150\%} \approx 15\ vols\%
\]

---

**Shunt**

\[
\frac{1.36 \times 15 \times 100\%}{50\%} \approx 15\ vols\%
\]

\[
\frac{1.36 \times 15 \times 100\%}{150\%} \approx 10\ vols\%
\]
Severe Hypoxemia

Therapeutic Goals

Maintain reasonable oxygen delivery
Find & fix the primary cause

"Baby Lungs"

FRC can be reduced by 80% or more in ARDS

ARDS Network Trial

<table>
<thead>
<tr>
<th>Day 1 Ventilatory Characteristics</th>
<th>Low Vt, Group n=432</th>
<th>Traditional Vt, Group n=429</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vt:</td>
<td>6.2 ± 0.9</td>
<td>11.8 ± 0.8</td>
</tr>
<tr>
<td>PEEP:</td>
<td>9.4 ± 3.6</td>
<td>8.6 ± 3.6</td>
</tr>
<tr>
<td>F,O2:</td>
<td>0.56 ± 0.19</td>
<td>0.51 ± 0.17</td>
</tr>
<tr>
<td>Pplat:</td>
<td>25.7 ± 7</td>
<td>33 ± 9</td>
</tr>
<tr>
<td>Ppeak:</td>
<td>32.8 ± 8</td>
<td>39 ± 10</td>
</tr>
<tr>
<td>P,o2/ F,O2:</td>
<td>158 ± 73</td>
<td>176 ± 76</td>
</tr>
<tr>
<td>P,CO2:</td>
<td>40 ± 10</td>
<td>35 ± 8</td>
</tr>
<tr>
<td>pH:</td>
<td>7.38 ± 0.08</td>
<td>7.41 ± 0.07</td>
</tr>
</tbody>
</table>
ARDS Network Trial

Mortality: 39.8% in traditional tidal volume group, 31% in low tidal volume group (P=0.007)

Also: at 28 days: more ventilator-free days (12 vs. 10), more days without organ failure (15 vs 12), higher rate of liberation from ventilation rate (65.7% vs 55%)

What happens to alveoli in ARDS?

Edema accumulates in alveoli

Diluting & disaggregating surfactant

Surface tension increases

Alveoli collapse

Alveolar collapse decreases FRC and contributes to hypoxemia

Positive End-Expiratory Pressure (PEEP)

• Beneficial Effects
  - Increases FRC, CI, P,O2
  - Recruits Atelectatic Units
  - Decreases Qs/Qt
  - Allows Reduction in FiO2

• Detrimental Effects
  - Volutrauma
  - Alveolar Overdistention
  - Hemodynamic Derangements
PEEP

Oxygen is:
- A) good for you
- B) bad for you
- C) all of the above

F$_O_2$ > 0.6 for 24 hours or more may cause lung injury

PEEP recruits collapsed alveoli, improves FRC and improves oxygenation

An essential therapy for patients with ARDS

Does Mechanical Ventilation Contribute to MSOF?


Controls (n=19): Rate 10-15 bpm, V$_t$ targeted to maintain PaCO$_2$ 35-40 mmHg (mean: 11 ml/kg), PEEP titrated to SaO$_2$ (mean: 6.5), P$_{plat}$ maintained < 35 cmH$_2$O

Lung protective ventilation (n=18): Rate 10-15 bpm, V$_t$ targeted to keep P$_{plat}$ less than upper inflexion point (mean: 7 ml/kg), PEEP 2-3 cmH$_2$O above LIP (mean: 14.8)

FIO$_2$ > 0.6 for 24 hours or more may cause lung injury

An essential therapy for patients with ARDS

ARDS Network Trial

The standard of care

Assist Control
V$_t$ 6 cc/kg ideal body weight
PEEP of ≈ 8-10

Cause of Death in ARDS Patients?

Generally not due to respiratory failure

Biotrauma
Goals for Management of ARDS

The American-European Consensus Conference on ARDS, Part 2

- Ensure appropriate $O_2$ delivery to vital organs
- Minimize oxygen toxicity/tolerate mediocre ABG’s
- Reduce edema accumulation
- Minimize airway pressures
- Prevent atelectasis/Recruit alveoli
- Use sedation and paralysis judiciously

Survival from “pure” ARDS

1979: 20-50%

2002: 50-90%