ARDS: Complicated ICU Patients

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In the past year, over 1,000 nurses shared their expert knowledge to enhance AACN’s products and services. An additional corps of over 1,500 AACN Ambassadors worked as liaisons between AACN and their unit and/or facility, promoting cultures of certification, healthy work environments, clinical practice standards and educational offerings — including NTI.

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By working together, each AACN volunteer strengthens our profession and the vital contribution nurses make to patients and families. We look forward to partnering with you in the coming year.

For information about the Volunteer Program at AACN, please contact...
Introduction and Background
Acute Lung Injury
- 200,000 patients / year
- 10-15% of ICU admission
- 30-35% mortality

Acute Respiratory Distress Syndrome
- 100,000 patients / year
- 80% require intubation
- 30-60% mortality*
- Survivors have protracted reductions in quality of life

*Patients with refractory hypoxemia have highest mortality
Definitions

- Vietnam War
  - Shock Lung, Wet Lung, Da Nang Lung, Post Traumatic Respiratory Distress Syndrome

http://www.natgeotv-int.com
American-European Consensus Conference
- Acute onset of severe respiratory distress
- Bilateral infiltrates on frontal CXR
- Absence of LA hypertension
  - PAOP ≤ 18 mm Hg, or
  - No signs of left heart failure
- Severe hypoxemia
  - ALI: PaO₂/FIO₂ ratio ≤ 300 mm Hg
  - ARDS: PaO₂/FIO₂ ratio ≤ 200 mm Hg

**The Berlin Definition**

### Table 3. The Berlin Definition of Acute Respiratory Distress Syndrome

<table>
<thead>
<tr>
<th><strong>Acute Respiratory Distress Syndrome</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timing</strong></td>
</tr>
<tr>
<td><strong>Chest imaging</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Origin of edema</strong></td>
</tr>
<tr>
<td><strong>Oxygenation</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Mild</strong></td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
</tr>
<tr>
<td><strong>Severe</strong></td>
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</tbody>
</table>

Abbreviations: CPAP, continuous positive airway pressure; FiO<sub>2</sub>, fraction of inspired oxygen; PaO<sub>2</sub>, partial pressure of arterial oxygen; PEEP, positive end-expiratory pressure.

<sup>a</sup>Chest radiograph or computed tomography scan.

<sup>b</sup>If altitude is higher than 1000 m, the correction factor should be calculated as follows: $[\text{PaO}_2/\text{FiO}_2 \times \text{barometric pressure}]/760$.

<sup>c</sup>This may be delivered noninvasively in the mild acute respiratory distress syndrome group.

## Differences

<table>
<thead>
<tr>
<th></th>
<th>AECC</th>
<th>BERLIN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timing</strong></td>
<td>Acute onset</td>
<td>Within 1 week</td>
</tr>
<tr>
<td><strong>CXR</strong></td>
<td>Bilateral infiltrates</td>
<td>Bilateral opacities</td>
</tr>
<tr>
<td><strong>Origin</strong></td>
<td>Absence of LA Htn</td>
<td>RF not explained by cardiac or fluid overload</td>
</tr>
<tr>
<td><strong>Oxygenation</strong></td>
<td>ALI ≤ 300 mmHg</td>
<td>Mild ≤ 300 mmHg with PEEP ≥ 5 cm H₂O</td>
</tr>
<tr>
<td></td>
<td>ARDS ≤ 200 mmHg</td>
<td>Moderate ≤ 200 mmHg with PEEP ≥ 5 cm H₂O</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe ≤ 100 mmHg with PEEP ≥ cm H₂O</td>
</tr>
</tbody>
</table>
PaO₂/FIO₂ Ratio

- PaO₂ = 142 mm Hg
- FIO₂ = 60% or .60

\[
\frac{142}{.60} = 236
\]

- PaO₂ = 98 mm Hg
- FIO₂ = 100% or 1.0

\[
\frac{98}{1} = 98
\]
Pathogenesis

Insult → Cytokines → Cell Activation → Acute Inflammatory Response → Broncho-constriction

Insult → Complement Cascade → Acute Inflammatory Response → Pulmonary Hypertension

Insult → Acute Inflammatory Response → Increased Vascular Permeability
Alveoli at the Cellular level
Predisposing Factors

DIRECT INJURY
- Aspiration*2
- Trauma
- Pneumonia
- O₂ Toxicity
- Inhalation
- Near Drowning

INDIRECT INJURY
- Sepsis*1
- Shock
- Multiple Trauma
- Drug OD
- Multiple Transfusions
- DIC
- Embolisms
- Pancreatitis
- Bypass
- Eclampsia
Ventilatory Strategies
What the Research Shows

- Lung Protective Strategy
  - TV of 4 – 8 ml/kg ideal body weight (IBW)
  - Plateau pressure (Pplat) \( \leq 30 \text{ cm H}_2\text{O} \)
  - *Modest* level of positive end expiratory pressure (PEEP)
Plateau Pressure

Components of Inflation Pressure

$P_{aw}$ (cm H$_2$O)

Time (sec)

- PIP
- Transairway resistance
- Transthoracic pressure
- Pplat

Maintained < 30-35 cm H$_2$O

Minimizes Barotrauma

Increasing PEEP
- ↑Aleveolar recruitment
- ↓Decreased shunt
- ↑PaO₂

How much is too much PEEP?
- 3 trials; ALVEOLI, LOV, EXPRESS
- Modest levels of PEEP (12-18)
  - Higher PaO₂/FIO₂ ratio; no survival advantage
  - 2/3 studies reported ↓refractory hypoxemia, death with refractory hypoxemia, and ↓use or rescue therapy

Grasso, et al, Am J Respir Crit Care Med. 2007;176:761-767
### PEEP

<table>
<thead>
<tr>
<th>FIO2</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.3</th>
<th>0.4</th>
<th>0.4</th>
<th>0.5</th>
<th>0.5</th>
<th>0.5-0.8</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

Dependent on Alveolar Recruitment

• When not successful
  • Minimal improvement or worsening of PaO₂
  • Increase in dead space (increasing PaCO₂)
  • Worsening compliance
Lung Recruitment Maneuvers

- Transient increase in transpulmonary pressure intended to promote reopening of collapsed alveoli; improving gas exchange

- What are recruitment maneuvers?
  - Manipulation of PEEP
  - Prone positioning
  - HFOV
Recruitment and PEEP

Recruitment and PEEP

Pressure Control Ventilation

- Lower peak inspiratory pressure (PIP)
- Improved patient-ventilator synchrony
- Improved gas exchange

↑Mean airway pressure
↓end – inspiratory flow
Laminar vs Turbulent Flow
Initial Settings

- **PIP (Peak Inspiratory Pressure)**
  - 30-35 cmH$_2$O
  - Maintain Vt ~6 ml/kg
- **PEEP**
  - Maintain current PEEP
- **RR**
  - Maintain current RR
- **I:E**
  - Start at 1:1
Pressure Control Inverse Ratio Ventilation

- Inspiratory time > expiratory time
  - $\uparrow$ mean airway pressure
  - Improve arterial oxygenation
  - Prolongs time for recruitment
  - Limits time for derecruitment
Airway Pressure Release Ventilation

- Allows spontaneous breathing
- High airway pressure
- Intermittent pressure release
- APRV = PCIRV in absence of spontaneous breathing
### Initial Setting

<table>
<thead>
<tr>
<th></th>
<th>Time High – $T_{\text{high}}$</th>
<th>Time Low – $T_{\text{low}}$</th>
<th>Pressure High – $P_{\text{high}}$</th>
<th>Pressure Low – $P_{\text{low}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value</strong></td>
<td>4 - 6 seconds</td>
<td>0.5 – 1 seconds</td>
<td>25 – 30 seconds</td>
<td>0 -3 seconds</td>
</tr>
</tbody>
</table>

- Optimize recruitment by higher total time at high airway pressure
- Minimize derecruitment by less time at low airway pressure
High Frequency Oscillatory Ventilation

- FDA approved in US 2001
- Vibration of the lung around constant airway pressure
- “Low stretch ventilation” or “Opening the lung and keeping it open”
“Safe Window”

Inai Y, Slutsky AS. *Crit Care Med*, 2005;33:S129-S134..
How Does It Work?

- Piston pump-driven diaphragm to push gas in and out of the lung
Initial Settings

- Bias Flow – 30 L/min
- Frequency – 5 Hz (300 breaths/min)
- MAP – equal or > 5 cm H$_2$O the MAP on conventional ventilation
- $\Delta P/\text{Amplitude}$ – start at 4-6 and adjust Chest Wiggle Factor (CWF) with Amplitude ~ 70-90%
- FIO$_2$ – 1.0
- I Time – 33%
High Frequency Percussive Ventilation

- Volumetric Diffusive Respirator
  - Flow-regulated
  - Pressure limited
  - Time cycled
- High frequency (200-900 cycles/min) small volumes in a stepwise stacking pattern

http://www.percussionaire.com
Non-Ventilatory Strategies
Neuromuscular Blocking Agents

1. Ventilator asynchrony
2. Improve oxygenation
3. Decreased vent days
   - 48 hours early in severe ARDS
4. Risks
   - Critical care myopathy with or without steroid use

Inhaled Nitric Oxide

- Inhaled, selective vasodilator of pulmonary vasculature
  - Improved ventilation-perfusion mismatch
  - ↑ oxygenation
  - ↓ pulmonary arterial pressure
- Cost
Research
- Some oxygenation improvement
- No effect on mean PAP
- No effect on survival or duration of mechanical ventilation

Recommendations
- Rescue therapy for refractory hypoxemia

Phenylephrine

- Non-selective $\alpha$ receptor agonist
  - Pulmonary and systemic vasoconstriction

- Research
  - 1 study showed oxygenation improvement with NO

- Recommendations
  - More research, not endorsed

Inhaled Prostacyclins

- Inhalation of prostanoids
  - Selective pulmonary vasodilation
- Research
  - Most of the studies have been done on PAH or Right Heart Failure patients
- Recommendations
  - May offer lower cost alternative to NO
  - Epoprostenol as continuous inhalation
    - Inhaled iloprost or treprostinil can’t be used with mechanical ventilation due to specialized devices
  - Additional research needed
Prone Positioning
Prone Positioning

- **Improved oxygenation**
  - Alveolar recruitment
  - Redistribution of ventilation towards dorsal regions with enhanced ventilation/perfusion matching
  - Elimination of lung compression by the heart

- **No documented survival benefits**
## Meta Analysis 10 trials

### Results
- 16% risk reduction mortality in severely hypoxemic subgroup (PaO2/FIO2 ≤ 100) only
- Improved PaO2/FIO2 in 7 trials
- No effect on vent days
- No differences between short duration vs long

### Increased risk
- HAPU in 7 trials
- ETT obstruction in 7 trials
- Inadvertent CT removal in 8 trials

### No difference
- Unplanned extubations
- Inadvertent CVC or Aline removal
- Pneumothorax
- Cardiac Arrest

Recommendations

- Reasonable short term therapy for patients with severe refractory hypoxemia

www.kci.com

www.vollman.com
Extracorporeal Life Support

- Registry 2008
  - ~2000 adults at 145 centers in the world
- Goal
  - Support gas exchange
  - ↓ the intensity of mechanical ventilation
  - Rescue therapy for refractory life-threatening hypoxemia

http://www.elso.med.umich.edu/
ECLS

- Research
  - CESAR Trial – *Conventional Ventilatory Support vs Extracorporeal Membrane Oxygenation for Severe Adult Respiratory Failure*
  - RCT 180 intent to treat patients
  - Survival
    - 63% ECLS
    - 47% Control (p = 0.03)
Recommendations

- Include as option for severe refractory hypoxemia
- Weigh
  - Likelihood of survival
  - Feasibility and safety of transport and therapy
  - Inconclusive outcome data
Fluid Management

- Conservative fluid management “dry lungs”
  - Lower intravascular pressures
  - Higher oncotic pressure
  - ↓ extravascular lung water
  - Shorter duration of mechanical ventilation
  - Shorter ICU LOS
Fluid Management Strategy

- **Expert Consensus**
  - Diuresis unless
    - Hypotensive
    - < 12 hours received vasopressors
    - CVP < 4 mm Hg
    - Oliguric with CVP 4-8

- **Research**
  - Albumin for hypoproteinemic patients
Corticosteroids

- Research
- Meta analysis (5 cohort, 4 RCT)
  - Trends
    - Improved mortality
    - Improved morbidity
      - Ventilator free days
      - ICU los
      - PaO2/FIO2

Recommendations

- Moderate-dose glucocorticoids should be considered in early severe ARDS and before day 14 in patients with unresolving ARDS.
Nutrition

- Recent Omega 3 and antioxidant ARDS net study closed for futility
  - Lacked evidence for benefit
  - Showed trends for worse results regarding survival, ventilator-free days, an ICU-free days

- Other Research
  - Meta analysis – 3 RCT
    - ↓ risk of mortality
    - ↓ morbidity (vent days, organ failure, ICU los)

ARDS/ALI Algorithm

Conventional Management

PaO2/FIO2 < 100
OR
Pplat > 30 cm H2O
on VT 4 ml/kg IBW
OR
OI > 30

ARDSnet Guidelines

Nonventilatory Strategies

yes

Ventilatory Strategies

yes

FIO2 (%) X MAP X 100
PaO2

no
## Strategies

<table>
<thead>
<tr>
<th>VENTILATORY</th>
<th>NON-VENTILATORY</th>
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</thead>
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<tr>
<td>1. PEEP</td>
<td>1. Neuromuscular blocking agents</td>
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<tr>
<td>2. Lung Recruitment</td>
<td>2. Vasoactive therapies</td>
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<tr>
<td>3. PCV</td>
<td>3. Prone Positioning</td>
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<tr>
<td>4. PCIRV</td>
<td>4. Conservative fluid management</td>
</tr>
<tr>
<td>5. APRV</td>
<td>5. Corticosteroids</td>
</tr>
<tr>
<td>6. HFOV</td>
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<tr>
<td>7. HFPV</td>
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</table>
ARDS/ALI Algorithm (cont)

PaO2/FIO2 ↑ 20%

- yes: Continue Therapy
- no: PaO2/FIO2 < 60, Consider ECLS
Long Term Effects Survivors

- Neuropsychological Function ALI
  - Prospective, multicenter, subset of FACTT
  - Validated telephone standardized neuropsychological tests at 2(122) and 12(102) months
  - Hypoxemia potential risk factor
    - 55% long-term cognitive impairment
    - 36% depression
    - 39% post-traumatic stress disorder
    - 62% anxiety

http://www.ardsusa.org
Thank You
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