Mechanical Ventilation of Infants with Severe BPD: An Interdisciplinary Approach

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Disclosures

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Learning Objectives

- To review physiologic differences in lung disease during the progression from acute to chronic respiratory failure in severe BPD;
- To understand the goals and strategies of long-term mechanical ventilator support in severe BPD;
- To appreciate the need for interdisciplinary teams to enhance late outcomes of infants with severe BPD.
Case Study: Lessons Learned

- Surprising resilience of the developing lung;
- Progressive stages of clinical respiratory course requiring different goals and strategies: acute, transitional, and long-term care;
- Need for better insights into “life span” issues (e.g., more relevant clinical endpoints beyond “36 weeks PMA on oxygen therapy”);
- Need for more interdisciplinary collaborations (neonatology, pulmonary medicine, others) to better understand and enhance long-term outcomes

Relationship of Gestational Age to BPD Severity

Re-Admissions of Preterm Infants to Pediatric ICUs During Early Childhood

(* n = 296 patients)
Impact of Early Impairment of Lung Growth on COPD

(McGeachie et al. NEJM 2016)

BPD Severity: NIH Workshop *

<table>
<thead>
<tr>
<th>BPD Severity</th>
<th>Definition (Modified from)</th>
<th>Relative Incidence (Data from)</th>
<th>Post-Discharge Mortality (Data from)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>O₂ treatment ≤28 days and breathing room air at 36 weeks PMA or discharge home, whichever comes first</td>
<td>23.1%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Mild</td>
<td>O₂ treatment at least 28 days and breathing room air at 36 weeks PMA or discharge home, whichever comes first</td>
<td>30.3%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Moderate</td>
<td>O₂ treatment at least 28 days and receiving &lt;30% oxygen at 36 weeks PMA or discharge home, whichever comes first</td>
<td>30.2%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Severe (Type 1)</td>
<td>O₂ treatment at least 28 days and receiving ≥30% oxygen or ≥CPAP/HNC at ≥36 weeks PMA</td>
<td>16.4%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Severe (Type 2)</td>
<td>O₂ treatment at least 28 days and receiving mechanical ventilation at ≥36 weeks PMA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* NIH Workshop Point Prevalence Study from the BPD Collaborative: Severe BPD*

<table>
<thead>
<tr>
<th>Mean ± SD (range) (correct)</th>
<th>Frequency of ≥BPD* (%)</th>
<th>Birth weight (g)</th>
<th>Birth weight (percentile)</th>
<th>Birth length (cm)</th>
<th>Gestational age (wks)</th>
<th>Current postmenstrual age (wks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57.7%</td>
<td>313 ± 247</td>
<td>34 ± 28</td>
<td>31.1 ± 1.6</td>
<td>25.2 ± 2.4</td>
<td>32.1 ± 1.7</td>
</tr>
<tr>
<td>2</td>
<td>44.6%</td>
<td>318 ± 267</td>
<td>34 ± 28</td>
<td>31.1 ± 1.6</td>
<td>25.2 ± 2.4</td>
<td>32.1 ± 1.7</td>
</tr>
<tr>
<td>3</td>
<td>25.9%</td>
<td>328 ± 271</td>
<td>38 ± 28</td>
<td>32.2 ± 3.7</td>
<td>25.5 ± 2.6</td>
<td>32.5 ± 2.6</td>
</tr>
<tr>
<td>4</td>
<td>16.9%</td>
<td>332 ± 280</td>
<td>39 ± 28</td>
<td>31.1 ± 1.6</td>
<td>26.3 ± 2.6</td>
<td>32.6 ± 2.6</td>
</tr>
<tr>
<td>5</td>
<td>32.3%</td>
<td>327 ± 267</td>
<td>46 ± 26</td>
<td>32.8 ± 3.7</td>
<td>26.1 ± 2.6</td>
<td>32.3 ± 2.6</td>
</tr>
<tr>
<td>6</td>
<td>39.3%</td>
<td>327 ± 267</td>
<td>46 ± 26</td>
<td>32.8 ± 3.7</td>
<td>26.1 ± 2.6</td>
<td>32.3 ± 2.6</td>
</tr>
<tr>
<td>7</td>
<td>48.8%</td>
<td>327 ± 267</td>
<td>46 ± 26</td>
<td>32.8 ± 3.7</td>
<td>26.1 ± 2.6</td>
<td>32.3 ± 2.6</td>
</tr>
<tr>
<td>8</td>
<td>31.6%</td>
<td>327 ± 267</td>
<td>46 ± 26</td>
<td>32.8 ± 3.7</td>
<td>26.1 ± 2.6</td>
<td>32.3 ± 2.6</td>
</tr>
</tbody>
</table>

* denominator: infants with GA < 32 weeks; presence of any BPD, range: 20 – 77%

Point Prevalence Study:
Respiratory Support in sBPD

<table>
<thead>
<tr>
<th>Percentage (%)</th>
<th>N</th>
<th>Fgy ≥ 30% (% pop)</th>
<th>Invasive positive pressure ventilation* (% pop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>center</td>
<td>16</td>
<td>28 wks PMA Current</td>
<td>36 wks PMA Current</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>77%</td>
<td>64%</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>100%</td>
<td>70%</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>56%</td>
<td>63%</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>100%</td>
<td>50%</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>78%</td>
<td>11%</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>59%</td>
<td>59%</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>64%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Early Prevention: Maternal Factors
- Prenatal care
- Preterm birth Rx
- Environmental
- Prenatal Steroids
- Delivery room practice
- Surfactant delivery

Modulation: Ventilation
- Oxygen use
- Surfactant delivery
- nCPAP? HFV?

Treatment: Ventilation
- Oxygen use
- Surfactant delivery
- nCPAP? HFV?

Changing Care Issues During the Progression of BPD

Birth: Prevention
7 - 10 days: Modulation
> 2 - 3 weeks: Treatment

Severe BPD:

Adult ARDS: Ventilating the “Baby Lung”

- Small tidal volumes
- Increased PEEP
- Prone positioning

“A TWO COMPARTMENT MODEL”
Management of Ventilator-Dependent Infants with Severe BPD

- Heterogeneity of lung disease:
  - marked variability in regional time constants
  - mixed airways and parenchymal disease, with decreased surface area ("hypoplasia"), edema, atelectasis;
- Tracheomalacia, diffuse bronchomalacia
- Airway Secretions
- Aspiration
- Pulmonary Hypertension

Severe Bronchopulmonary Dysplasia
(GA 25 weeks, BW 698 g, oligohydramnious; CT at 6 months)

Heterogeneity of Lung Disease in Established BPD: Role of Variable Time Constants

Adverse Effects:
- Worse distribution of gas
- Increased dead space ventilation
- Higher PCO₂
- Higher FiO₂
- Progressive atelectasis
- Regional overdistension

Benefits:
- Improved Gas Distribution
- Lower Vd/Vt
- Lower PCO₂
- Lower FiO₂
- Less atelectasis
Acute PEEP Study in Severe BPD

High PEEP, 25 cm H₂O

No PEEP, 0 cm H₂O

(Rob Castile, Columbus Children’s Hospital)

Dynamic Hyperinflation in Severe BPD

Interim Summary: Ventilator Strategies in BPD

**Early (Preventive):**
- Low tidal volumes (4 - 6 ml/kg)
- Short inspiratory times
- Increase PEEP as needed for lung recruitment without over-distension (as reflected by high peak airway pressures)
- Achieve lower FiO₂
- **Goals for Gas Exchange:**
  - Adjust FiO₂ to target lower O₂ saturations (88 - 92%)
  - Permissive hypercapnea

**Late (Established BPD):**
- **Due to Regional Heterogeneity:**
  - Larger tidal volumes (10 - 12 ml/kg)
  - Longer inspiratory times (> 0.6 sec)
- **Airway Obstruction**
  - Slower rates (better emptying)
  - Complex role for PEEP (due to dynamic airway collapse)

Basic Questions for Invasive Chronic Respiratory Care for Infants with BPD

- When to transition strategies from lung protective to chronic support?
- What is “stable” disease?
- When stable, what to wean?
- When to commit to chronic ventilation and place a tracheostomy for supportive care?
Problems with the Care of Ventilator-Dependent BPD Infants

- Severe, acute illness takes precedence over chronic patients in ICU settings;
- Differences in pace of illness, response to therapy
- High staff turnover leads to inconsistencies in care
- Consistent communication between attendings, nurses, RTs, consultants, other providers and family is complex
- Need for interdisciplinary approaches

Successful Treatment of BPD is Synonymous With Good Supportive Care

- Minimal Impact Respiratory Support
- Prevention of Infection
- Prevention of Right Heart Failure
- Excellent Nutrition for Growth and Repair
- Developmental Assistance

(Stephen Welty, Baylor University)

What is “stable” in ventilated BPD infants?

- Tolerance of therapies, cares and handling with minimal episodes of desaturation and distress
- Less reliance on blood gas tensions (pCO2)
- Demonstrating consistent growth including weight and length
- When stable, initially wean FiO2 and not tidal volume or pressures
Conclusions

- Factors that contribute to the development of **severe BPD** and modulate long-term outcomes are incompletely understood;
- Ventilator goals and strategies for **chronic care** of ventilator-dependent children are strikingly different than current approach to acute respiratory failure;
- Improvements in long-term outcomes require greater and earlier integration of **interdisciplinary teams** that link inpatient with ambulatory care.
The “BPD Collaborative”

- Leif Nelin, Nationwide Children’s Hospital
- Stephen Welty, Texas Children’s Hospital
- Haresh Karpalani, CHOP
- Martin Keszler/Barbara Stonestreet, Brown
- Paul Moore, Vanderbilt
- Mike Collaco, Hopkins
- Jason Gien/Chris Baker, Colorado
- Bill Truog, Children’s Mercy, Kansas City
<table>
<thead>
<tr>
<th>Changes in clinical care after implementation of VCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic respiratory insufficiency</td>
</tr>
<tr>
<td></td>
</tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
</tr>
<tr>
<td>Colonization with virulent organisms</td>
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<tr>
<td>Reflux and aspiration</td>
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Abbreviations: PCA, Patient Controlled Analgesia; PEEP, positive end-expiratory pressure; VCP, ventilator care program.