Care of the NICU Graduate: Bronchopulmonary Dysplasia & Home Oxygen Therapy

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Medical Director, Bronchopulmonary Dysplasia Clinic
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I have no relationship to report.
Objectives

1. Understand the varied manifestations of bronchopulmonary dysplasia (BPD) (aka chronic lung disease of prematurity)
2. Become familiar with using home pulse oximetry to diagnose chronic hypoxemia in children
3. Understand the indications for home oxygen therapy (HOT), and when and how HOT should be weaned or discontinued
4. Know when to refer a child with BPD for further evaluation
What is bronchopulmonary dysplasia?

- Type of chronic lung disease that affects primarily children born prematurely
- Can also occur in children born at term who experience significant acute lung injury (e.g., pneumothorax, pneumonia, meconium aspiration)
- Etiology is multifactorial
  - Antenatal injury: fetal growth restriction, maternal smoking, chorioamnionitis, maternal preeclampsia
  - Postnatal factors: mechanical ventilation, oxygen toxicity, infection, patent ductus arteriosus, surgical NEC
Early Injury → Acute BPD → Chronic BPD → Resolution of BPD

23-28 Weeks 28-36 Weeks 36 Weeks - months years

Hits to Fetal Lung | Hits During Transition | Postnatal Hits

Proinflammation

Chronic Chorioamnionitis → Initiation of Ventilation → Ventilatory Support → Oxygen → Sepsis

Fetal Lung → Preterm Lung → BPD

Corticosteroids → Surfactant → Corticosteroids

Anti-Inflammation

BPD Incidence

- BPD incidence increases with lower gestational age and birthweight
  - 73% for GA 23 wks
  - 23% for GA 28 wks
- Approximately 1/3 of children with BW < 1000 gm develop BPD

LUNG PATHOPHYSIOLOGY OF BPD

Central airways:
- Tracheomalacia
- Subglottic stenosis, cyst
- Granulomas
- Bronchomalacia
- Bronchial stenosis

Small airways:
- Structural remodeling
- Mucus gland hyperplasia
- Epithelial injury, edema
- Smooth muscle hyperplasia
- Bronchoconstriction
- Hyper-reactivity

Distal airspace and vasculature:
- Decreased alveolarization, vascular growth
- Abnormal vascular remodeling, tone and reactivity
- Impaired lymphatic function, structure

Normal vs. BPD

5 mo old term infant

8 mo old infant born at GA 28 wks
- Enlarged alveolar ducts
- Fewer alveoli

How is BPD diagnosed?

TABLE 23-2 NIH Consensus Conference: Diagnostic Criteria for Establishing BPD

<table>
<thead>
<tr>
<th>Gestational Age</th>
<th>&lt; 32 Weeks</th>
<th>&gt; 32 Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time point of Assessment</td>
<td>36 weeks PMA or discharge to home, whichever comes first</td>
<td>&gt; 28 d but ≤ 56 d postnatal age or discharge to home, whichever comes first</td>
</tr>
<tr>
<td>Treatment with oxygen &gt; 21% for at least 28 d</td>
<td>Treatment with oxygen &gt; 21% for at least 28 d</td>
<td></td>
</tr>
<tr>
<td>Mild BPD</td>
<td>Breathing room air at 36 wk discharge, whichever comes first</td>
<td>Breathing room air by 56 d postnatal or discharge, whichever comes first</td>
</tr>
<tr>
<td>Moderate BPD</td>
<td>Need for &lt; 30% O₂ at 36 wks PMA or discharge, whichever comes first</td>
<td>Need for &lt; 30% O₂ to 56 d postnatal or discharge, whichever comes first</td>
</tr>
<tr>
<td>Severe BPD</td>
<td>Need for &gt; 30% O₂ +/- PPV or CPAP at 36 wks PMA or discharge, whichever comes first</td>
<td>Need for &gt; 30% O₂ +/- PPV or CPAP at 56 d postnatal age or discharge, whichever comes first</td>
</tr>
</tbody>
</table>

- Most commonly used consensus definition: 2001 NICHD Consensus Workshop
- Requirement: 28 days continuous O₂ therapy
- Mild, moderate and severe is based on level of support at 36 wks (for GA < 32 wks), or at discharge vs. 56 days (for GA > 32 wks).

Jobe, Bancalari. Am J Respir Crit Care Med (2001)
Moderate BPD in a 5 mo old (CGA 1 mo) infant with 23 wk prematurity

Clinical Pearl:

CXR in a well child with mild, moderate or severe BPD can look similar to CXRs of children with viral airways disease or reactive airways disease.
Severe BPD in a 9 mo old (CGA 6 months) infant with history of 23 wk prematurity

Clinical Pearl:
- Severity grading for BPD is important
- Children with mild and moderate BPD have very different clinical trajectories and risk compared to children with severe BPD

Image: Abnormal airway and parenchymal architecture, hyperinflation, atelectasis, mediastinal shift secondary pulmonary hypoplasia, heterogeneous lung disease
Clinical Features

- Physical Exam:
  - Often normal
  - Sometimes lung findings: Tachypnea, retractions, rales, coarse crackles, intermittent wheezing

- CXR:
  - Clear → Diffuse haziness → Coarse interstitial pattern (from atelectasis, inflammation, and/or pulm edema)
  - Normal or low lung volumes

- Increased risk of ER visits and hospitalizations in the first 2 years of life
  - Respiratory infections triggering inflammation will lead to more mucus production, airflow obstruction, atelectasis, and hypoxemia

Clinical Pearl:
Monophasic or biphasic wheezing localized at the anterior chest is suspicious for tracheomalacia
Natural Hx of Chronic Lung Disease - Prematurity and Respiratory Outcomes Program (PROP)\(^1\)

- Multicenter observational prospective cohort study
  - Preterm infants < 29 wks GA up to 1 yr CGA
  - Questionnaires at 3, 6, 9, 12 mo CGA
- Prematurity respiratory disease (PRD)
- Severe disease = home supplemental O2 for > 3 months, multiple hospitalizations, systemic steroids or symptoms despite ICS
- Of 724 infants...
  - 68% had significant PRD at CGA 1 yr
  - 38% had severe PRD

Among 10-year-old children born extremely preterm, those who had BPD were at increased risk of:

- Cognitive, language, and executive dysfunctions
- Academic achievement limitations
- Social skill deficits
- Low scores on assessments of health-related quality of life.

Cognitive Development & QoL

- 2002-2004 Cohort: ELGAN (Extremely Low Gestational Age Newborns) study population
  - 863 children born preterm (<28 wks GA) +/- BPD (N=372, 43% O₂ dep at PMA 36 wks; N=78, 9% O₂ + vent dep)
- Assessed at 10 yo age
- IQ z-scores ≤-2 occurred 2x as much in children with BPD vs no BPD
- “Severe” BPD (O₂ + vent) had lowest scores for all measures

Approximately one-half of children with “severe” or “moderate” BPD had scores in the normal range for academic achievement.
Outcomes in adolescents

- Drummond 2019:
- Birth cohort 1996-1998 - Compared to 15 yo adolescents w/ h/o prematurity w/o BPD (N=249), h/o of BPD (N=55) was associated with:
  - Poorer academic performance:
    - Higher risk of attending a school for children with special needs (p<0.05)
    - Repeating a grade (p=0.01)
  - Higher healthcare utilization

Long-term Respiratory Outcomes

- Abnormal lung function in childhood, adolescence and adulthood
- Higher rates of asthma or reactive airways disease
- Hypoxemia and hypercapnia with exercise or respiratory illness
- Possible increased risk of chronic obstructive pulmonary disease
Lung function

Islam 2015:

- Preterm infants have reduced small airway flows compared to full-term matched control infants
- Infants with BPD has more severe airflow obstruction compared to those w/o BPD
- Trends persist into young adulthood
Lung function changes over time

- Retrospective study of 24 patients with BPD & 355 PFTs:
  - 1st PFT: median 7.6 yrs; Last PFT: median 18.2 yrs
  - < 5th percentile:
    - FEV1 - 75% (18/24)
    - FEV1/FVC - 54% (13/24)
  - FEV1 and FEV1/FVC worsened over time:
    - mean ppFEV1 - 71.3% (SD 18.3) → 66.7% (SD 21.7) (p<0.05)
    - mean FEV1/FVC - 85.4% (SD 15.2) → 79.8% (SD 17.3) (p=0.01)

Lung function deterioration:
- FEV1 - 70% (17/24)
- FVC - 54% (13/24)
- FEV1/FVC - 70% (17/24)

Birth cohort:
- Born before 1990: None out of 11 pts improved in FEV1
- Born after 1990: 7 out of 13 pts born after 1990 showed improvement in FEV1 (p=0.006).

Lung function evolution towards adulthood was somewhat more favorable in children born after 1990 compared with those born earlier, probably reflecting improvements in neonatal care in subjects with new type BPD.

4 yo F with Hx of 32 wk prematurity

- Mild persistent asthma (previously RAD w/ viral triggers) - on low-medium dose fluticasone 110 mcg - 1 puff twice daily
- H/o RSV and Moraxella pneumonia and respiratory failure at age 2 months
- Maternal smoke exposure
- H/o choking, GERD, croup

Order Diagnosis:

H/O BPD(Z87.09), HISTORY OF PREMATURE (Z87.898), REACTIVE AIRWAY DISEASE (J45.909).

<table>
<thead>
<tr>
<th>Pre-Drug</th>
<th>Post-Drug</th>
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<tbody>
<tr>
<td></td>
<td>Actual</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>1.25</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>0.97</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>*78</td>
</tr>
<tr>
<td>FEF 25-75% (L/sec)</td>
<td>*0.82</td>
</tr>
<tr>
<td>FEF Max (L/sec)</td>
<td>1.98</td>
</tr>
<tr>
<td>FEF50%/FIF50% (%)</td>
<td>72</td>
</tr>
<tr>
<td>FIF Max (L/sec)</td>
<td>1.33</td>
</tr>
<tr>
<td>Expiratory Time (sec)</td>
<td>4.23</td>
</tr>
</tbody>
</table>

- SPIROMETRY ---
Asthma Interventions Matter

- After serial dose escalation from fluticasone 110 mcg - 1 puff twice daily to fluticasone/salmeterol 230/21 - 1 puff twice daily, lung function finally normalized.

- At 5 years of age: No obstructive pattern, no significant improvement with bronchodilator.

- Categorized now as moderate persistent asthma, well controlled.
Defining **Chronic** Hypoxemia

- Low SpO2 for 2+ weeks
- Chronic respiratory condition
- Clinically stable
Normative values come from 31 studies measuring oxygenation in healthy children, out of 1,711 articles on oxygenation in children.
Healthy Children < 1 year old - Awake

- Desaturation events were common in the first 48 hrs of life.
- Desaturations decrease with age.
  - Desaturations to SpO2 < 80%
    - 1 mo: median of 0.9/hr (range, 0-15.1/hr) for a median of 1.2 s (range, 0.3-2.2 s)
    - 6 wks: median 0.7/hr
    - 3 mo: median 0.4/hr
    - 6 mo: median 0.5/hr
  - Oxygen desaturation index (3% or more):
    - Age 1.4 yrs (range, 1.1-1.9 yr): median 0.1/hr (range, 0-2.2/hr)

Healthy Children < 1 year old - Sleep

- 5% of sleep time with median SpO2:
  - 2 wks: <92% (range, 73-99%)
  - 3 mo: <96% (range, 83-98%)
  - 6 mo: <95.5% (range, 69-99%)

- 10% of sleep time with median SpO2:
  - 2 wks: <96% (range, 77-99%)
  - 3 mo: <97% (range, 86-100%)
  - 6 mo: <97% (range, 75-99%)
Healthy Children ≥ 1 year old

- Awake:
  - Mean 97.6% (SD, 0.7%)
  - Median 97.5% (range, 97-98%)

- Sleep:
  - Mean 97.8% (SD, 0.7%)
  - Desaturation nadir:
    - Mean 94.6% (SD, 3.1%)
    - Median 93% (range, 91-94%)
  - ODI (desaturations of 3 or 4% or more):
    - Mean 0.6/hr (SD, 1.0)
    - Median 0.4/hr (range, 0.1-0.8)
  - <1% of sleep with SpO2 <95%
  - <0.03% of sleep with SpO2 <90%

Healthy Children ≥ 1 year old - High Altitude

- High Altitude:
  - Median SpO2:
    - 2,560 m - 92%
    - 3,200 mg - 87%

- SpO2 ranges:
  - 1,371 m - 95-96.7% (*SLC is 1,288 m)
  - 2,073 m - 93.9-95.4%
  - 2,393 m - 91.8-93.4%
  - 2,405 m - 93.4-96.1%
  - 2,484 m - 93.7-96.2%
Healthy Children ≥ 1 year old - High Altitude

- High Altitude:
  - Desaturation events are more frequent but less common with age
  - Age 1-6 yrs:
    - 1,600 m - ODI (4%) - 4.0/hr (*SLC is 1,288 m)
  - Age 6+:
    - 4,000 m - ODI (4%) - 1.6/hr

Chronic Hypoxemia Consensus Definition

- **Age <1 yr:**
  - 5% of recording time with SpO2 ≤ 90%
  - 3 intermittent, independent measurements of SpO2 ≤ 90%
- **Age ≥1 yr:**
  - 5% of recording time with SpO2 ≤ 93%
  - 3 intermittent, independent measurements of SpO2 ≤ 93%
- Normal intermittent measurements do not exclude chronic hypoxemia. Only continuous oximetry monitoring, which includes a period of sleep, can exclude chronic hypoxemia.

Criteria A & B must be met.

A. PSG, OCST, or nocturnal oximetry shows the arterial oxygen saturation (SpO2) during sleep \( \leq 88\% \) in adults or \( \leq 90\% \) in children for \( \geq 5 \) minutes.

B. Sleep related hypoventilation is not documented.
Untreated hypoxemia $\rightarrow$ Pulmonary Vascular Disease

- Hypoxic pulmonary vasoconstriction
- BPD & PH: Home O2 therapy helps to resolve RVH when SpO2 is maintained above 94-95%
- Effects of Alveolar hypoxia
  - Minimal effects in many children
  - In some susceptible children, there is heightened pulmonary vascular reactivity and remodeling
    - Infants with BPD
    - Young adults with h/o perinatal aphymia
- Mild chronic alveolar hypoxia $\rightarrow$ significant PH

Hypoxemia & Neurodevelopment - Infants

- In RCT of infants born < 30 wks GA (N=358) who required supplemental O2 at 32 wks PMA:
  - No significant developmental benefit at age 1 yr between targeting SpO2 91-94% vs. 95-98%.
- Systematic review of 55 studies of CHD, SDB, asthma, chronic vent impairment and infants with resp instability:
  - Chronic intermittent hypoxemia negatively influences development, behavior, and academic achievement.

Hypoxemia & Neurodevelopment - Children & adolescents

- 4-6th graders with overnight pulse oximetry - Hypoxemia was associated with impaired math performance.

- Children & adolescents - Short and long-term exposures to high altitude (3,500 m) impaired executive function, memory, and processing speed.

Hypoxemia & Sleep - Apneas & BRUE’s

- Hypoxemia during sleep predisposes infants to:
  - Increased periodic breathing, hypoventilation, central apneas, increased risk of BRUEs

- Severe BRUEs risk factors in premature infants:
  - Central apnea > 30 s
  - SpO2 < 80% for 10 s
  - HR < 50-60 bpm for 10 s
  - URIs

- Infants with BPD have lower SpO2 and more central apneas compared to preterm infants w/o BPD.

- Central apneas resolve with supplemental O2.

Hypoxemia & Sleep

- Infants with BPD:
  - SpO2 90% was associated with sleep fragmentation, and less REM sleep
  - Supplemental O2 improved sleep fragmentation
  - No change in sleep architecture in infants with BPD with SpO2 > 93%

Hypoxemia & Growth

- Infants with BPD:
  - Improved growth when SpO2 during sleep > 92% compared with SpO2 88-91%
  - Another study showed growth promotion when SpO2 > 93%.
  - Negative effect on growth when supplemental O2 was stopped.

- NEHI:
  - Some had improved growth velocity with starting supplemental O2 therapy

Indications for Home Oxygen Therapy in BPD

- Chronic hypoxemia: 5% of recording time with SpO2 < 93%; 3 separate measurements of SpO2 < 93%
- Sleep disordered breathing (eg, OSA, CSA) complicated by severe nocturnal hypoxemia who cannot tolerate PAP or are awaiting surgical treatment
- Severe nocturnal hypoxemia: 5% of recording time with SpO2 < 90% during sleep
Home Oxygen Therapy in Pulmonary Hypertension and Interstitial Lung Disease

- Pulmonary Hypertension w/o CHD:
  - Chronic hypoxemia: 5% with SpO2 \(< 93\%\) or 3 separate measurements of SpO2 \(< 93\%\)

- Pulmonary Hypertension w/ CHD before or after surgery: Do not prescribe HOT w/o consultation with Cardiology or Pulmonology with “expertise in management of PH”
  - Chronic hypoxemia: 5% with SpO2 \(< 93\%\) or 3 separate measurements of SpO2 \(< 93\%\)

- Interstitial Lung Disease:
  - Severe chronic hypoxemia (SpO2 \(<90\%\) for 5% recorded time; 3 separate occasions)
  - Both mild chronic hypoxemia (SpO2 90-93\%) & either dyspnea on exertion or desaturation during sleep or exertion (exercise for children, feeding for infants)

Limitations of pulse oximetry accuracy

- Improper probe placement
  - Movement artifact
    - Nail color
    - Ambient light
  - Reduced distal extremity perfusion
    - Hypothermia
    - Skin pigmentation
  - Dysfunctional hemoglobin
Discontinuing Home Oxygen Therapy

- Assessing Readiness:
  - Stable health (no current or recent acute illness)
  - Age- and condition-appropriate growth, including positive trends in weight gain, linear growth, and head circumference
  - Meeting developmental milestones as expected for clinical condition
  - Acceptably low frequency and/or severity of illnesses requiring hospitalization
  - Reassuring physical exam
  - Oxygen saturation at steady state (not “spot check”) on room air; Pulse oximetry while awake does not correlate with nocturnal oxygenation in infants with BPD
  - Consider echocardiogram to assess for absence or improvement of pulmonary hypertension

Successful Discontinuation of Home Oxygen Therapy

- Preterm infants with BPD 6 month post-discharge:
  - More successful weaning to room air if receiving ≤ 20 mL/kg/min of supplemental O2.
    - 3 kg: 0.06 L/min (1/16 LPM)
    - 4 kg: 0.08 L/min
    - 5 kg: 0.1 L/min
    - 6 kg: 0.12 L/min (1/8 LPM)

- Room air challenges if clinically stable:
  - Age < 1 yr: <0.1 L/min
  - Age 1-4 yrs: <0.1-0.25 L/min
  - School-age: 0.25-0.5 L/min

Example 1: Almost normal pulse oximetry in a 3 year old F with sleep difficulties

**Oximetry: Summary Report**

Comments: Overnight study breathing room air.

<table>
<thead>
<tr>
<th>Time with SpO2&lt;90:</th>
<th>0:00:00,  0.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time with SpO2&lt;80:</td>
<td>0:00:00,  0.0%</td>
</tr>
<tr>
<td>Time with SpO2&lt;70:</td>
<td>0:00:00,  0.0%</td>
</tr>
<tr>
<td>Time with SpO2&lt;60:</td>
<td>0:00:00,  0.0%</td>
</tr>
<tr>
<td>Time with SpO2&lt;88:</td>
<td>0:00:00,  0.0%</td>
</tr>
<tr>
<td>Highest pulse:</td>
<td>117</td>
</tr>
<tr>
<td>Lowest pulse:</td>
<td>60</td>
</tr>
<tr>
<td>Mean pulse:</td>
<td>77</td>
</tr>
<tr>
<td>1 S.D.:</td>
<td>5.8</td>
</tr>
<tr>
<td>Highest SpO2:</td>
<td>99%</td>
</tr>
<tr>
<td>Lowest SpO2:</td>
<td>91%</td>
</tr>
<tr>
<td>Mean SpO2:</td>
<td>96.1%</td>
</tr>
<tr>
<td>1 S.D.:</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The mean length of desaturation events that were >=10 sec & <=3 mins was: 54.8 sec.

Desaturation event index (events >=10 sec per sampled hour): 1.3
Desaturation event index (events >= 0 sec per sampled hour): 1.3
Oximetry: 8 hours per page
Comments: Overnight study breathing room air.
Example 2: 6 mo old (CGA 4 mo) female w/ history of 31 wk prematurity, twin, h/o IUGR, feeding difficulties, on NG feeds, moderate BPD complicated by chronic hypoxemia

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**Oximetry: Summary Report**

Comments: Overnight study breathing room air.

- Recording time: 12:23:40
- Excluded sampling: 00:01:04
- Total valid sampling: 12:22:36

<table>
<thead>
<tr>
<th>Condition</th>
<th>Time</th>
<th>Duration</th>
<th>SpO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpO2&lt;90</td>
<td>0:03:16</td>
<td>0.4%</td>
<td>99.6%</td>
</tr>
<tr>
<td>SpO2&lt;80</td>
<td>0:00:08</td>
<td>0.0%</td>
<td>99.6%</td>
</tr>
<tr>
<td>SpO2&lt;70</td>
<td>0:00:00</td>
<td>0.0%</td>
<td>99.6%</td>
</tr>
<tr>
<td>SpO2&lt;60</td>
<td>0:00:00</td>
<td>0.0%</td>
<td>99.6%</td>
</tr>
<tr>
<td>SpO2&lt;56</td>
<td>0:00:56</td>
<td>0.1%</td>
<td>99.6%</td>
</tr>
</tbody>
</table>

The longest continuous time with saturation <=88 was 00:00:12, which started at 01/17/20 06:18:01.

The mean length of desaturation events that were >=10 sec & <=3 mins was: 32.2 sec.

Desaturation event index (events >=10 sec per sampled hour): 8.6

Desaturation event index (events >= 0 sec per sampled hour): 15.4
Clinical features

- Chronic tachypnea (RR 70’s)
- Room air during awake, desaturations while sleeping (on 1/8 LPM while sleeping)
- Abnormal CXRs (patchy perihilar & bibasilar opacities)
- GER, chronic vomiting, on PPI
- h/o poor growth, improved with NG tube feeds, oral aversion
- h/o PDA closure (occlusion device)
- No h/o pulmonary hypertension
Serial chest imaging: PDA closure + time

3 mo old (CGA 7 wks)

6 mo old (CGA 4 mo)
Polysomnography – 6 mo (CGA 4 mo)

1. Mild obstructive sleep apnea more pronounced during REM sleep (OAHI 3.3/hr, REM-OAHI 7/hr) was exhibited on room air. Frequency of obstructive events decreased with 1/8 LPM O2, likely due to masking effect of O2 therapy.

2. Central sleep apnea (CAI 9.4/hr) was exhibited while patient was on room air. Central apnea improved with 1/8 LPM O2.

3. Respiratory events were associated with mild to moderate desaturations.

4. CO2 measurements were normal while the patient was on room air and O2 therapy.

Total sleep time with SpO2 < 90% was 7.9 minutes.

<table>
<thead>
<tr>
<th>TABLE OF O2 SUMMARY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP level</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Off</td>
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<tr>
<td>Off: 1/8</td>
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</tbody>
</table>

PAP= Positive airway pressure, TST= Total sleep time, SE= Sleep efficiency, OAHI= Obstructive apnea hypopnea index (Events per hour), CAI= Central apnea index (Events per hour), ODI= Oxygen desaturation index (Events per hour).
BPD Continuum of Care
<table>
<thead>
<tr>
<th>Screening</th>
<th>Interventions</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spirometry</td>
<td>Assessing lung function</td>
</tr>
<tr>
<td></td>
<td>Overnight polysomnography</td>
<td>Screening for sleep-disordered breathing</td>
</tr>
<tr>
<td></td>
<td>Chest CT with contrast enhancement</td>
<td>Assessing for parenchymal disease/cystic disease</td>
</tr>
<tr>
<td></td>
<td>Echocardiograms (with or without cardiac catheterization)</td>
<td>Screening for pulmonary hypertension</td>
</tr>
<tr>
<td></td>
<td>Airway endoscopy</td>
<td>Assessing for upper airway lesions and/or tracheobronchomalacia</td>
</tr>
<tr>
<td></td>
<td>Exercise studies</td>
<td>Assessing pulmonary reserve</td>
</tr>
<tr>
<td>Preventive Care</td>
<td>Avoidance of active smoking, secondhand smoke, air pollution</td>
<td>Decreasing inhalational injury</td>
</tr>
<tr>
<td></td>
<td>Prevention of aspiration</td>
<td>Preventing lung injury</td>
</tr>
<tr>
<td></td>
<td>Palivizumab</td>
<td>Decreasing RSV disease severity</td>
</tr>
<tr>
<td></td>
<td>Influenza vaccination</td>
<td>Preventing influenza infections</td>
</tr>
<tr>
<td></td>
<td>Preoperative anesthesia consults for pulmonary hypertension</td>
<td>Reducing pulmonary hypertensive crises</td>
</tr>
<tr>
<td></td>
<td>Interdisciplinary care team</td>
<td>Improving outcomes with coordination of care</td>
</tr>
<tr>
<td></td>
<td>Promoting linear growth</td>
<td>Improving lung growth</td>
</tr>
</tbody>
</table>
BPD Clinic - Severe BPD, Mild or Moderate BPD + risk factors, Chronic hypoxemia (2+ mo after NICU)

- **1st Visit:**
  - CBG if on continuous supplemental O2
  - 2 view CXR
  - Review history & and post-NICU growth and events
  - Assess for appropriateness of further diagnostic work-up: home pulse oximetry, polysomnography, swallow study, echocardiograms, CT(A) chest, etc.
  - Assess parental understanding of BPD & gaps in knowledge
  - Review preventative care
  - Create a sick care plan

- Medications: Albuterol PRN, wean off diuretics (if possible), discuss potential benefits of inhaled steroids in future

- If imaging, history or physical exam are concerning (eg, atelectasis, poor growth, tachypnea) - consider manual CPT education for caregivers
  - Typically helpful in the short-term and PRN illnesses

- Create shared goals and plans (eg, weaning off supplemental O2, improved nutrition & growth)

- Provide resources where appropriate - Neonatal Follow-up Program, Early Intervention, Nutrition Clinic, HEFT Clinic, etc.
BPD Clinic - Lesson #1

Always get a baseline 2 view CXR
Preterm infants are high risk for NAT

- High medical complexity
- Small size
- Osteopenia of prematurity
- Iatrogenic calcium depletion (diuretics, steroids, antacids)
BPD Clinic Follow-up Visits

Follow-up visits:
- 1\textsuperscript{st} year: every 1-3 months
- 2\textsuperscript{nd} year: every 3-6 months
- 3+ year: every 3-12 months

Goals:
- Improve caregiver education/care
- Wean off unnecessary medications
- Provide support & resources
- Optimize growth & development
Thank you!