FROM THE NICU AND BEYOND: RESPIRATORY CARE AT HOME

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6/7/25

AGENDA

Definitions

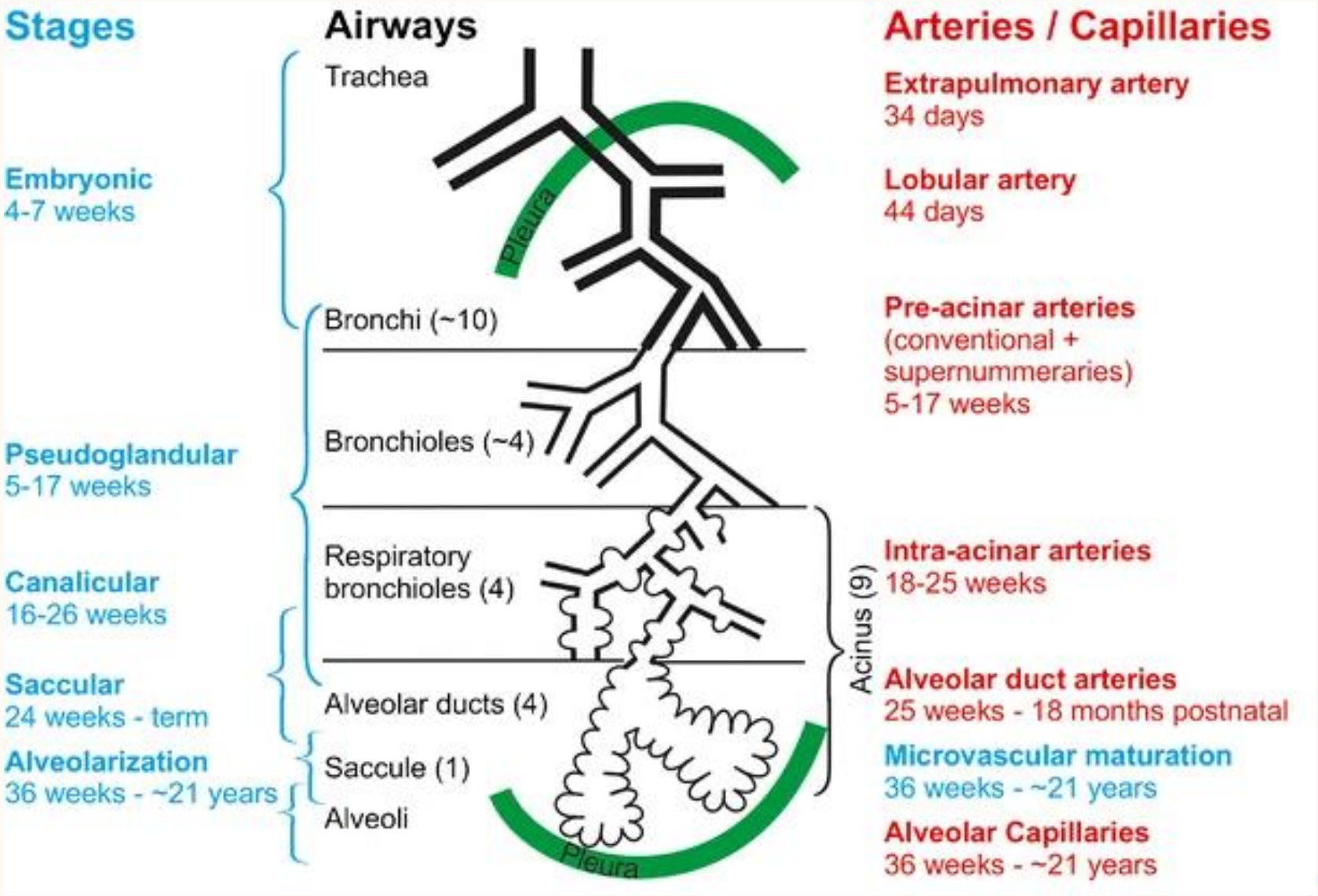
Pathophysiology

Outpatient Management

Long-term Outcomes

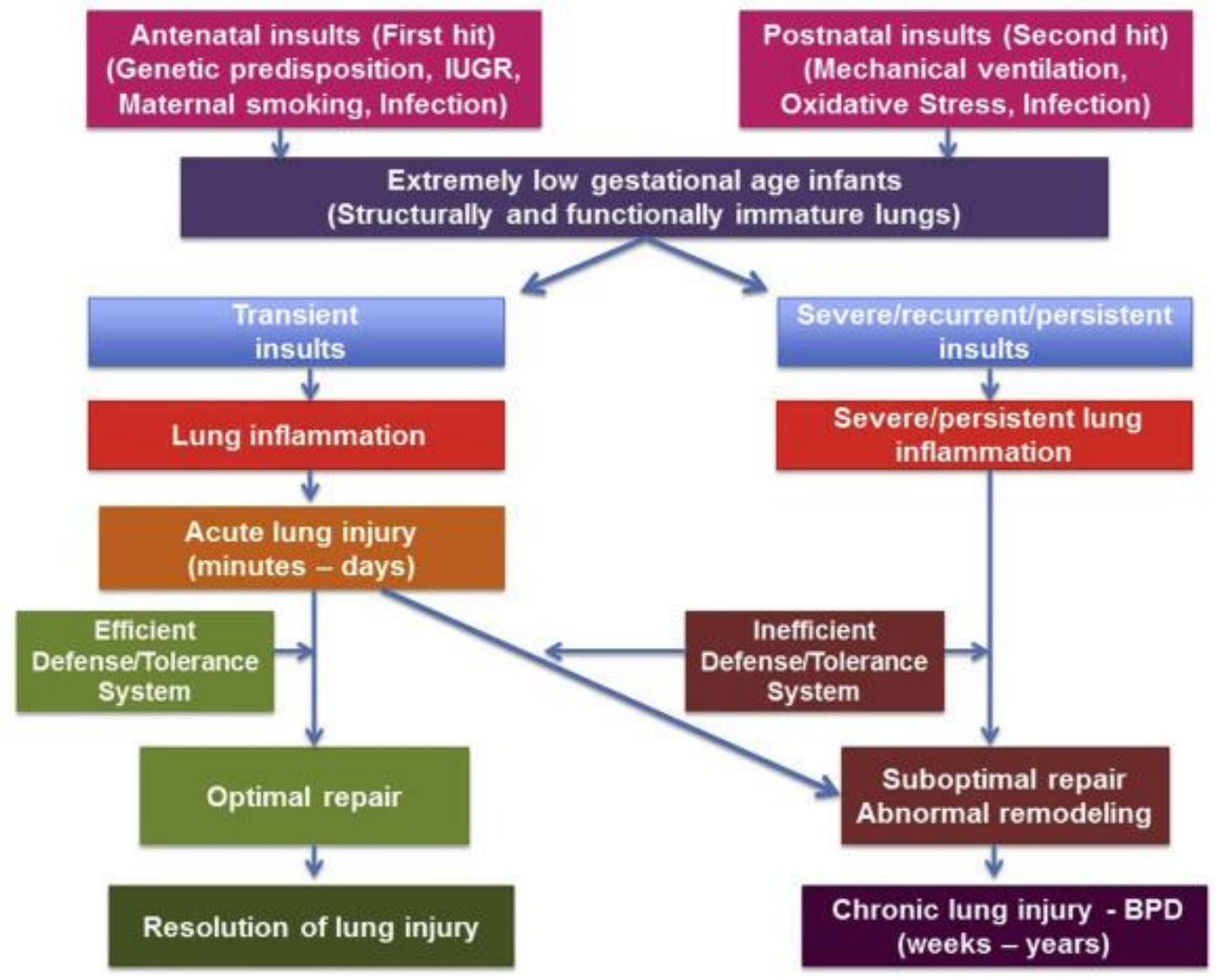
Multidisciplinary Approach

LUNG DEVELOPMENT & PATHOPHYSIOLOGY



Schnitty JC. Development of the lung. Cell Tissue Res 2017;367:427-444

Pathogenesis of BPD



Kalikkot Thekkeveedu R, et al. Bronchopulmonary dysplasia: A review of pathogenesis and pathophysiology, Respiratory Medicine, 2017, 132:170-177

THE FATHER OF BRONCHOPULMONARY DYSPLASIA: DR. WILLIAM NORTHWAY

The New England
Journal of Medicine

Volume 276 FEBRUARY 16, 1967 Number 7

PULMONARY DISEASE FOLLOWING RESPIRATOR THERAPY OF HYALINE-MEMBRANE DISEASE*

Bronchopulmonary Dysplasia

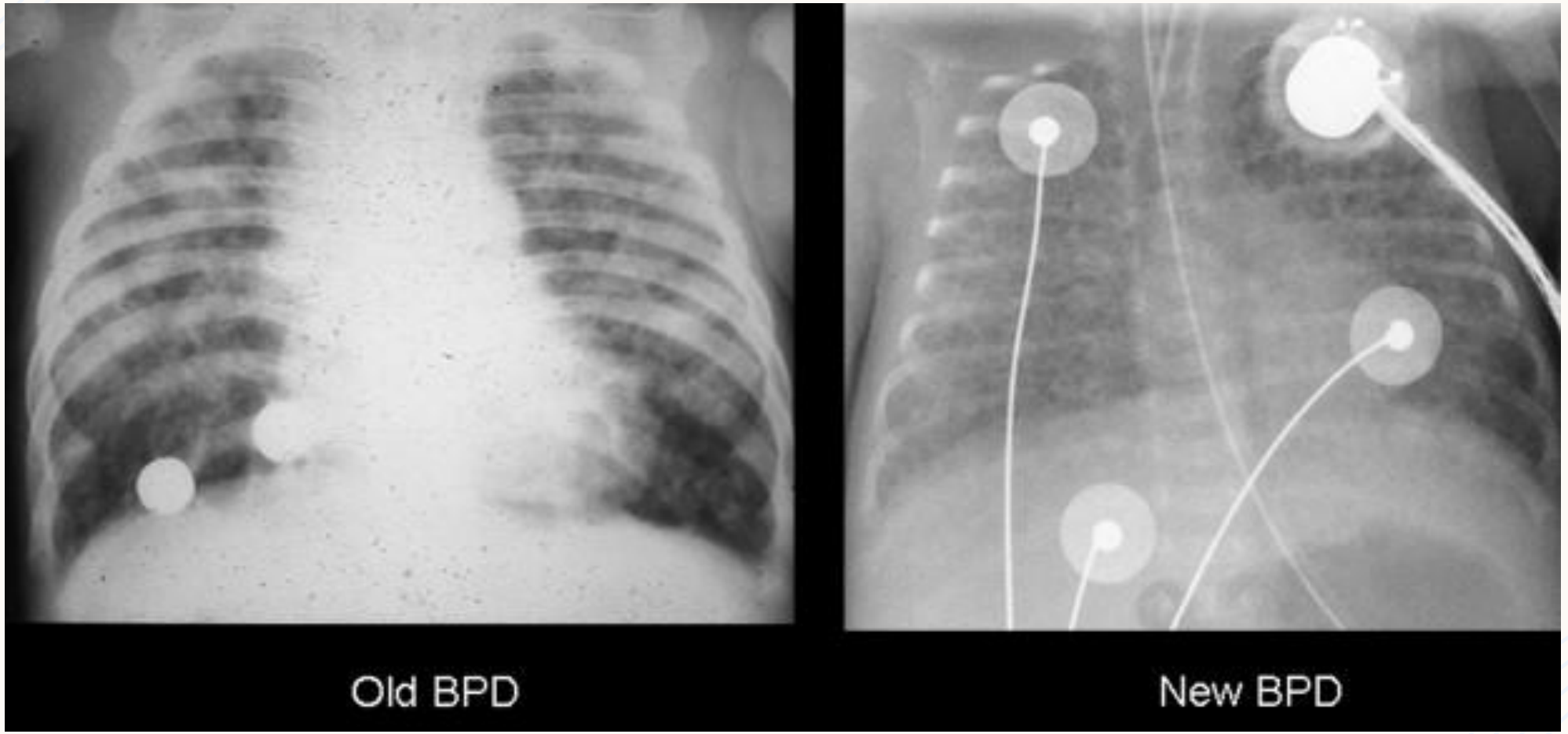
WILLIAM H. NORTHWAY, JR., M.D.,† ROBERT C. ROSAN, M.D.,‡ AND DAVID Y. PORTER, M.D.§

PALO ALTO, CALIFORNIA

NEW VS OLD BPD

Old BPD	New BPD
Larger preterm infants	Extremely premature infants
High ventilation and oxygen needs	Modest ventilation and oxygen needs
Severe large airway injury	Minimal large airway disease
Interstitial and alveolar edema	Arrested alveolarization
Extensive small airway disease with alternating areas of overinflation and fibrosis	Minimal small airway disease with less inflammation and fibrosis
Pulmonary artery muscularization	Fewer and abnormal pulmonary arteries

Cerny, Laura & Torday, John & Rehan, Virender. (2008). Prevention and Treatment of Bronchopulmonary Dysplasia: Contemporary Status and Future Outlook. Lung. 186. 75-89. 10.1007/s00408-007-9069-z.


Old BPD
New BPD

BRONCHOPULMONARY DYSPLASIA-DEFINED

Classic definition:	2001 NICHD definition:

• Need for supplemental O2 at 28 days of life
• Radiographic evidence of chronic lung disease
	• 28 days of supplemental O2
	• Severity classification
	  • Mild
	  • Moderate
	  • Severe
	• Based on O2/respiratory support needs at 36 weeks post menstrual age.

DEFINITION ISSUES

Definition	Oxygen at 36 weeks		Mild	Moderate	Severe
% Meeting criteria	No 56.3%	Yes 43.7%	30.8%	29.7%	16.7%
% Pulmonary medications	28.5%	43.4%	29.7%	40.8%	46.6%
% Pulmonary re-hospitalization	25.6%	36.1%	26.7%	33.5%	39.4%
Bottom line:	No BPD: Almost 1/3 still had pulmonary morbidity				Severe BPD: Over half did not have pulmonary morbidity

Ehrenkranz RA, et al, National Institutes of Child Health and Human Development Neonatal Research Network. Pediatrics 2005;116:1353-1360

BRONCHOPULMONARY DYSPLASIA-DEFINED

NICHD Updated Definition (2019)

- Prospective study (n=2677)
- Preterm infants <32 weeks GA
  - 90% were extremely preterm (<27 weeks GA)
- Proposed 18 different pre-specified definitions
- Outcomes: Death or severe morbidity through 26 months CGA
- Best definition based on mode of respiratory support at 36 weeks PMA (regardless of supplemental O2 use)

Jensen EA, et al. The Diagnosis of Bronchopulmonary Dysplasia in Very Preterm Infants: An Evidence Based Approach. Am J Respir Crit Care Med 2019;200:751-759.

MANAGEMENT/ TREATMENT

CORNERSTONES OF TREATMENT

Respiratory support: Supplemental O2, PPV
Nutrition
Limiting total fluid intake
Diuretics
Corticosteroids- Inhaled/systemic
Pulmonary hypertension

POSITIVE PRESSURE VENTILATION

Differs for established BPD compared to RDS
• Heterogeneity/regional differences
  • Compliance
  • Resistance
  • Time constants

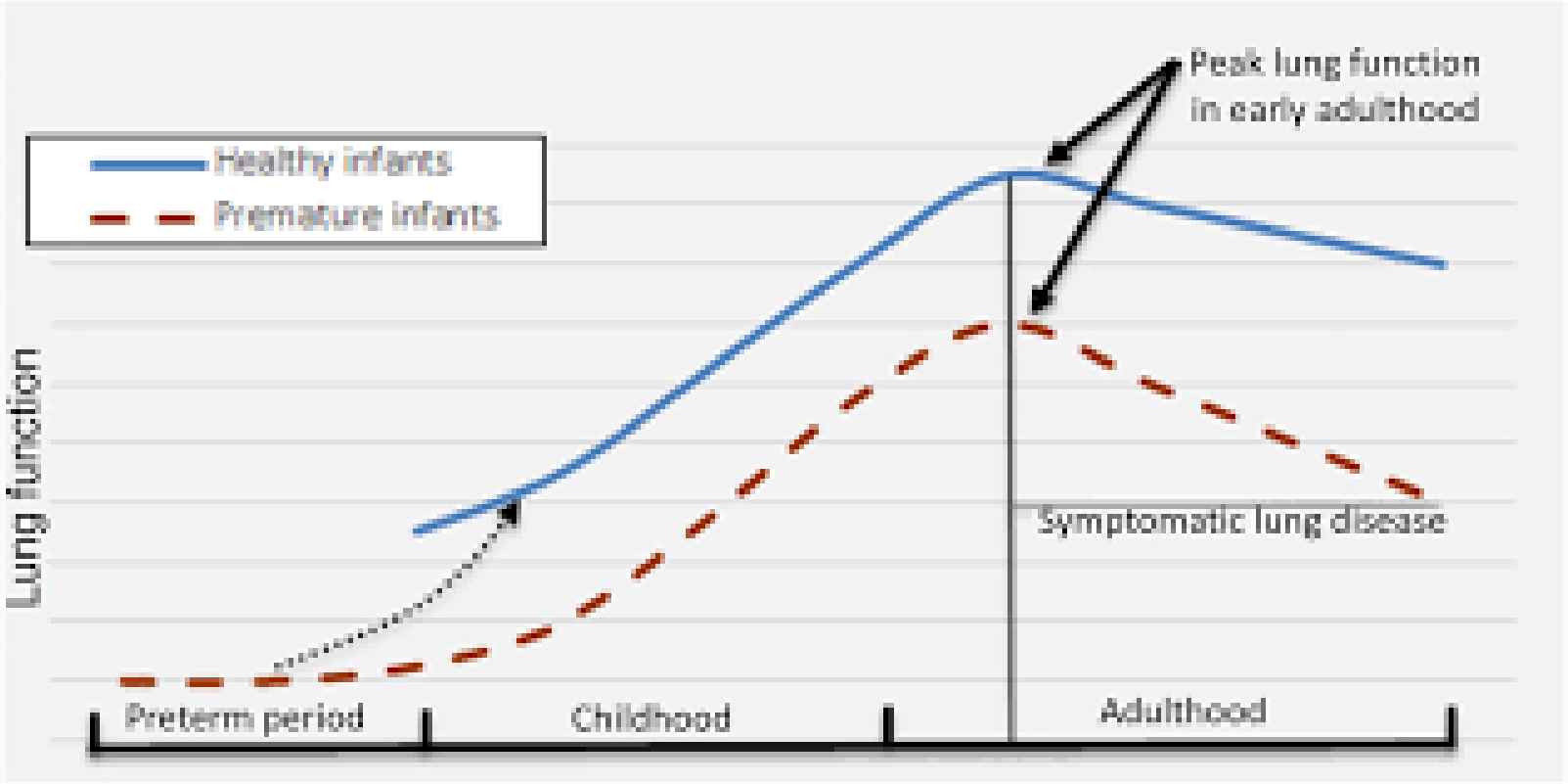
No studies to guide SpO2 target • BPD Collaborative recommends 92-95%
Frequent blood gases less useful
Goal is to provide adequate respiratory support • Growth and development
Noninvasive and invasive options

OUTCOMES

LONG TERM OUTCOMES

- Pulmonary
- Cognitive/developmental
- Quality of life and caregiver mental health
- Financial

LUNG FUNCTION



Jordan BK, McEvoy CT. Trajectories of lung function in infants and children: setting a course for lifelong lung health. Pediatrics 2020;146:4

LUNG FUNCTION IN BPD

- Lung function tracks over time when measured at different time points (24 mos, 8 years)
- Compliance is reduced and resistance is increased, but this improves over the first 2 years of life
- Lung volumes are low, but FRC increases over time; VmaxFRC remains low.
- FEV1 remains low into childhood and adulthood
- Severe BPD is associated with 3 phenotypes of lung function:
  - Obstructive (51%)
  - Restrictive (9%)
  - Mixed (40%)

Jordan BK, McEvoy CT. Trajectories of lung function in infants and children: setting a course for lifelong lung health. Pediatrics 2020;146:4

LUNG FUNCTION: BPD VS. PREMATURITY

- Few studies comparing healthy preterm to infants with BPD
- Those with BPD had lower lung function compared with age-matched controls
  - At 6 to 8 years, 10 to 11 year, and 18 years
- Effect of BPD on lung function is separate from prematurity

Jordan BK, McEvoy CT. Trajectories of lung function in infants and children: setting a course for lifelong lung health. Pediatrics 2020;146:4

COGNITIVE AND NEURODEVELOPMENTAL OUTCOMES

- Compared to other preterm infants and controls, infants with BPD have increased:
  - Risk of cerebral palsy, neurodevelopmental impairment and cognitive delay
  - Lower Mental Development Index on Bayley
  - Poorer motor (gross and fine) performance
    - Worse for those exposed to postnatal steroids
  - Increased need for early intervention services
    - PT (71 vs 44%), OT (71 vs 41%), Speech

Doyle et al. An update on pulmonary and neurodevelopmental outcomes of bronchopulmonary dysplasia. Seminars in Perinatology 42 (2018) 478-484

COGNITIVE AND NEURODEVELOPMENTAL OUTCOMES

- Neurodevelopmental and cognitive delays persist from early childhood to school age
  - Worse performance on intelligence, reading, mathematics, motor performance, memory, and attention
- Comparing performance of 3 yo with BPD, without BPD and controls:
  - Cognitive delay 21% vs 11% vs 4%
  - Motor delay was 20% vs 9% vs 1%
  - Language delay (<2 SD below the mean) in 24.2% with BPD and 12.3% without
- Similar results found at 8 years

Doyle et al. An update on pulmonary and neurodevelopmental outcomes of bronchopulmonary dysplasia. Seminars in Perinatology 42 (2018) 478-484

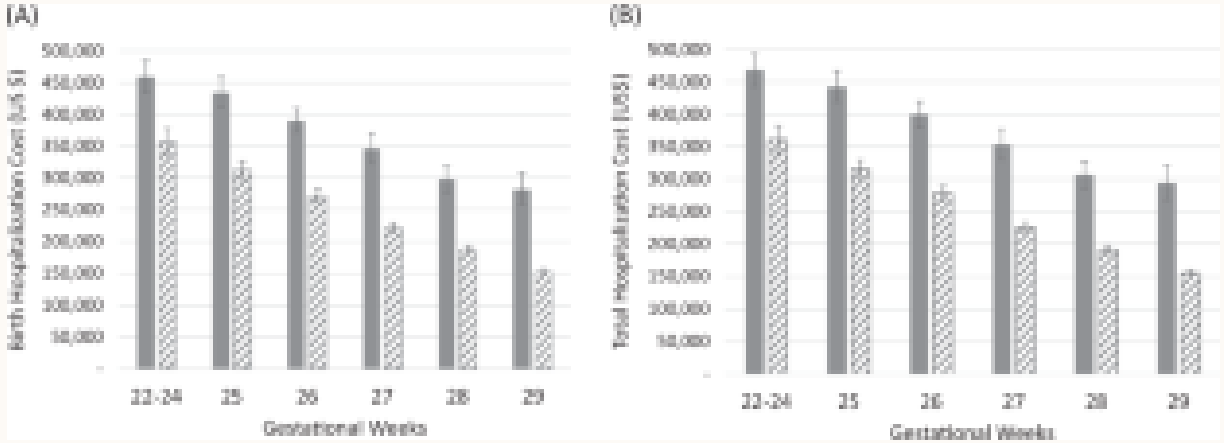
CAREGIVER MENTAL HEALTH OUTCOMES

Potential Positives	Potential Negatives
• Unification of the family • Watch child thrive at home • Sense of accomplishment and confidence in parenting abilities • Less anxiety	• Caregiver fatigue • Social isolation • Marital conflict • Anxiety about medical care and complications • Financial stress • Balancing work and child-care
• Lower healthcare related quality of live scores for families who reported more respiratory symptoms and acute care usage • Significant improvement as children aged	

Collaco et al. The impact of BPD on caregiver health related quality of life during the first 2 years of life. Pediatric Pulmonology 48:579-586 (2023)

FINANCIAL OUTCOMES

- Infants with BPD are more likely to require rehospitalization and increased acute care usage in the first year of life
  - Longer stays, higher cost hospitalizations



Lapcharoensap, W., Bennett, M.V., Xu, X. *et al.* Hospitalization costs associated with bronchopulmonary dysplasia in the first year of life. *J Perinatol* **40**, 130–137 (2020)

FINANCIAL OUTCOMES

- A Canadian simulation study of lifetime costs of BPD estimates:
  - Lifetime costs $716,912 CAD (95% CI $416,000-$1,275,000
    - 28% incurred in the first year
    - Gradual decline
  - Costs dependent on BPD severity and complications/comorbidities

Van Katwyk et al. Lifetime patient outcomes and healthcare utilization for BPD and extreme preterm infants: a microsimulation study. BMC Pediatrics (2020) 20:136

OUTCOMES SUMMARY

- BPD increases the risk for worse neurodevelopmental and pulmonary outcomes and increased healthcare utilization throughout life
- Increased stress and financial burdens on families
- Families require lots of support in caring for children with BPD

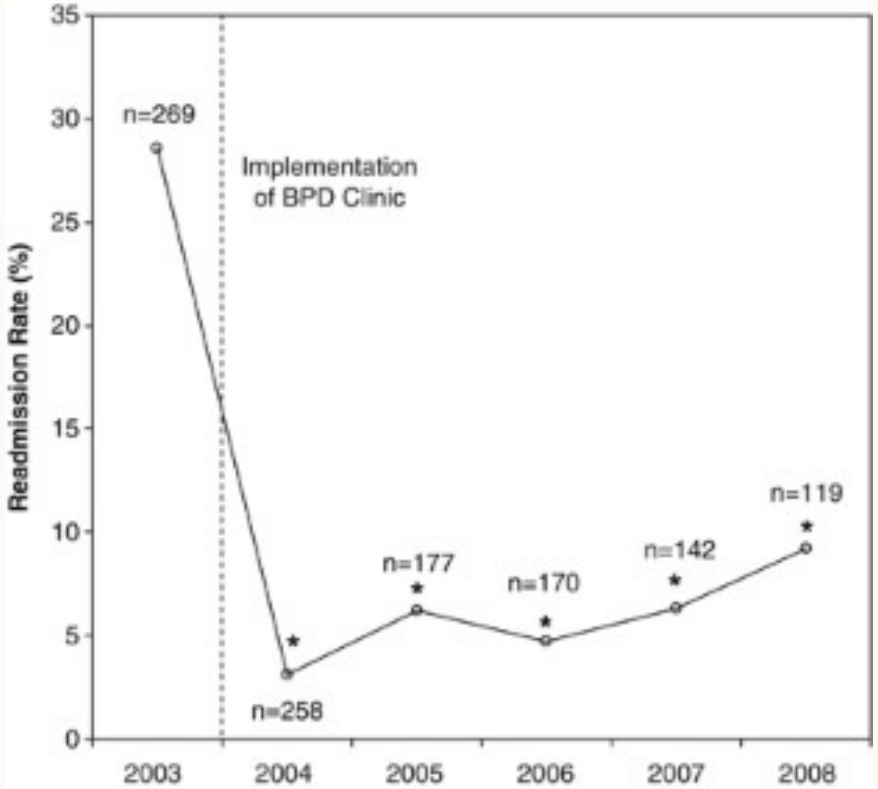
MULTIDISCIPLINARY APPROACH

MULTIDISCIPLINARY APPROACH: SHEPHERD ET AL, 2012

Interdisciplinary Team:	Goals:
• Neonatologists • Pulmonologists • OT/PT/ST • Pharmacists • Respiratory therapists • Parental support staff • Pediatricians	• Improve evidence-based care • Empower families to actively participate in care

Shepherd EG, et al. An interdisciplinary bronchopulmonary dysplasia program is associated with improved neurodevelopmental outcomes and fewer rehospitalizations. J Perinatol. 2012 Jan;32(1):33-8

SHEPHERD ET AL, 2012



Shepherd EG, et al. An interdisciplinary bronchopulmonary dysplasia program is associated with improved neurodevelopmental outcomes and fewer rehospitalizations. J Perinatol. 2012 Jan;32(1):33-8

MULTIDISCIPLINARY APPROACH: MCKINNEY ET AL 2019

Table 2.

Mean NICU length of stay (LOS), postmenstrual age (PMA) at discharge and corrected Z-score weight and length at time of discharge between the three groups with 95% confidence intervals.

	BIT:s *N* = 69	Pre-BIT:s *N* = 37	mBPD *N* = 37	*p* value BIT:s vs Pre-BIT:s
Mean NICU LOS (days)	140 (CI 131–149)	170 (150–192)	109 (CI 102–116)	0.007
PMA at discharge (wks)	46 (44–47)	50 (47–53)	41 (40–42)	0.01
Weight at discharge z-score	−0.80 (−1.03 to −0.57)	−1.35 (−1.72 to −0.98)	−0.73 (−1.07 to −0.40)	0.02
Length at discharge z-score	−1.78 (−2.19 to −1.37)	−2.31 (−2.90 to −1.72)	−1.32 (−1.77 to −0.88)	0.15

Open in a new tab

P values represent comparison between BIT:s and Pre-BIT:s.

McKinney RL, Schmidhoefer JJ, Balasco AL, Machan JT, Hirway P, Keszler M. Severe bronchopulmonary dysplasia: outcomes before and after the implementation of an inpatient multidisciplinary team. J Perinatol. 2021 Mar;41(3):544-550.

OXYGEN WEANING AFTER HOSPITAL DISCHARGE IN CHILDREN WITH BPD YEH, ET AL 2016 [30]

420 infants with BPD

154 infants discharged with O2

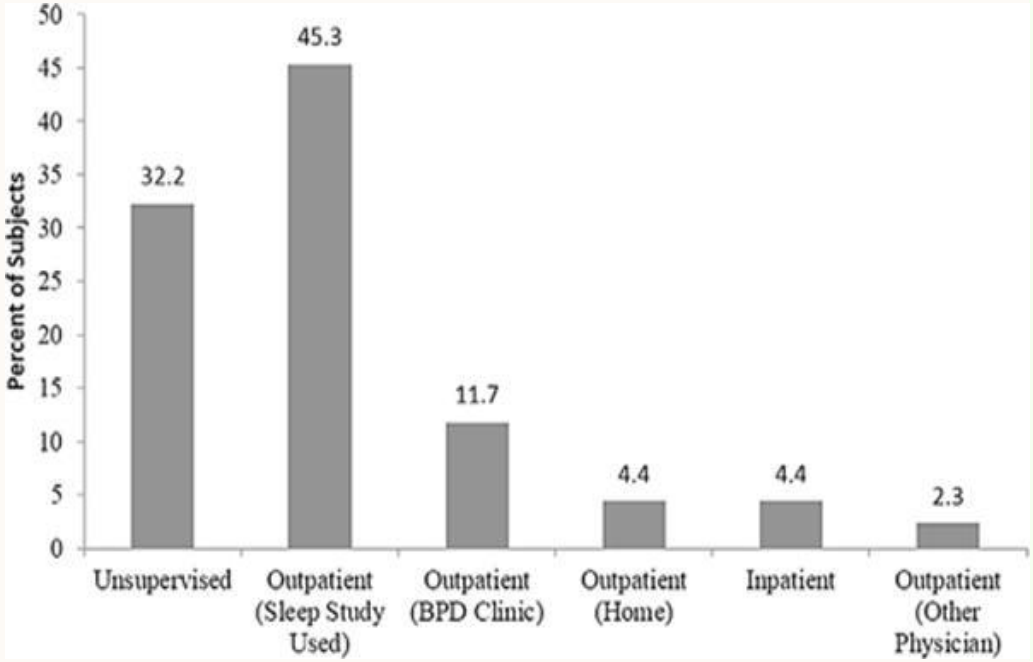


TABLE 2.

—Study Subjects by Oxygen Weaning Age

	Ever On Home Oxygen (n = 154)	Weaned off ≤12 months of age (n = 72)	Weaned off >12 months of age or still on oxygen (n = 82)	*P*-value
Demographics				
Sex (% male)	61.7	69.4	54.9	0.06
Race/ethnicity (% non-white)	65.6	66.7	64.6	0.79
Gestation (weeks)	26.1 ± 2.4 [23.0, 35.5]	26.2 ± 2.2 [23.0, 35.5]	26.0 ± 2.6 [23.0, 35.0]	0.69
Birth weight (g)	836 ±437 [380, 3181] (n = 146)	832 ± 410 [390, 3150] (n = 68)	840 ± 461 [380, 3181] (n = 78)	0.91
Clinical characteristics				
Age at discharge from NICU (months)	4.9 ± 3.0 [0.1, 24.5] (n = 153)	3.8 ± 1.3 [0.1, 7.2]	5.9 ± 3.7 [2.0, 24.5] (n = 81)	**<0.001**
Age at first visit to pulmonary clinic (months)	7.4 ± 5.4 [2.5, 51.3]	5.5 ± 1.7 [2.5, 10.0]	9.1 ± 6.8 [2.5, 51.3]	**<0.001**

WEANING OF SUPPLEMENTAL OXYGEN

RHO Trial 2020

Duration of Home Oxygen Therapy
(as influenced by study group, reporting frequency, and initial O_2 requirement)

Influence	Duration, days*	Change, %†	p‡
Study group: Intervention	78 ± 6		0.03
Standard care	100 ± 8		
Reporting frequency		−10.3 (−15.2 to −5.3)	0.0001
Initial O_2: ≤125 cc/min	73 ± 5		<0.0001
250 cc/min	98 ± 11		
≥500 cc/min	149 ± 21		
Nocturnal	80 ± 46		

*Adjusted mean ± standard error, retransformed from log scale.
†Percentage change in duration per report per month, with 95% confidence interval. Standard care participants attributed 0 reports per month.
‡Testing for equal means, or for zero rate of change.

- Unmasked RCT
  - N=166
  - Preterm infants <37 weeks
- Intervention: Use of recorded home oximetry (RHO) data
- Mean GA 26.9 weeks
- Primary outcome: Time to discontinue home supplemental O2
- Use of RHO significantly reduced duration of home O2 use

Rhein L, et al. Transmitted Home Oximetry and Duration of Home Oxygen in Premature Infants. *Pediatrics* August 2020; 146 (2): e20200079. 10.1542/peds.2020-0079

POTENTIAL BENEFITS OF MULTIDISCIPLINARY CARE

- Decreased cost and time of multiple subspecialty appointments
- Improved communication between providers
- Improved coordination of care
- Decreased patient utilization of resources
- Improved patient satisfaction
- Improved growth and nutritional outcomes
- Use of fewer systemic steroids
- Improved developmental outcomes
- Ventilator management
- More effective/efficient supplemental oxygen and diuretic weaning

TRACH VENT CLINIC AT ST. LUKE'S HEALTH SYSTEM

- Pediatric Pulmonology (myself, Dr. Ben Tippets, DO)
- Pediatric ENT (Dr. Jacob Robison, MD)
- Pediatric GI (Dr. Henry Thompson, MD)
- Pediatric PM&R (Dr. Erin Conlee, MD)
- Speech therapy (Kristin Booton, MS CCC SLP)
- Dietician (Tracy Varner, RD)

- The pediatric pulmonary team rounds with the NICU once a week with RT, nursing staff, speech therapy, PT, OT, care coordinators, and families in attendance

TAKE HOME POINTS

- BPD is a common complication of extreme prematurity
- BPD has long-lasting effects into adulthood and there is a heavy care burden on families
- Multidisciplinary care in patients with BPD leads to improved clinical outcomes, including decreased length of supplemental oxygen use and improved neurocognitive outcomes
- Further research is needed to support specific therapies and interventions

THANK YOU

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