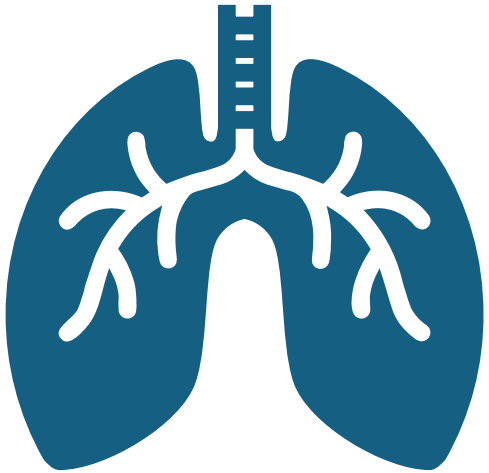
Bronchopulmonary Dysplasia Transitions: The Next Breath



OCHSNER'S 2025 PEDIATRIC UPDATE

JULY 18, 2025

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Ochsner Health-Baptist

Disclosure

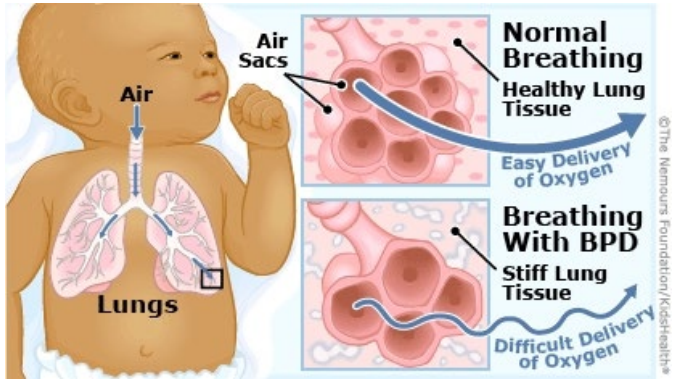
- I have no financial interest or affiliation concerning material discussed in this presentation

Objectives

At the end of this session, participants will be able to :

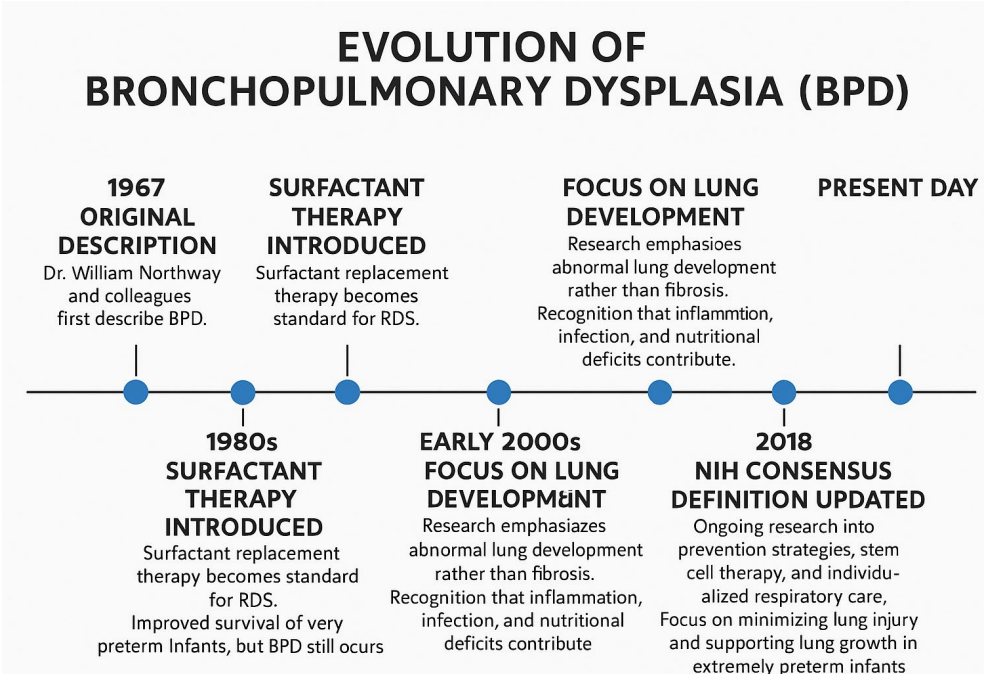
- Describe the evolution of BPD and pathophysiology
- Identify discharge readiness criteria
- Outline the role of Pediatricians in post-NICU care
- Understand the complexities of BPD care beyond the NICU
- Understanding the comorbidities associated with BPD
- Understand the barriers to care
- Understand current strategies
    - **SPOILER ALERT**
- Be aware of emerging treatments
- Summary

Bronchopulmonary Dysplasia (BPD)



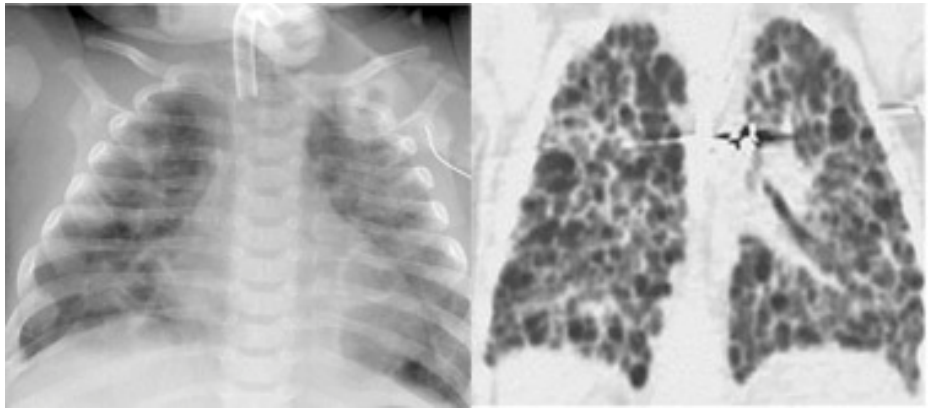
- Chronic lung disease primarily affecting extremely premature infants.
- The most common long-term morbidity of premature birth.
- 12,000–15,000 infants in the United States per year and 50% of infants with birth weights less than 1,000 g.
- Improved survival rates for premature infants have led to increased prevalence of BPD.

Brief History/Evolution of definition



- 1967 – Dr.Northway (coined the term) “classic BPD”

- “New BPD” – disrupted lung development
  - impaired alveolar and vascular growth



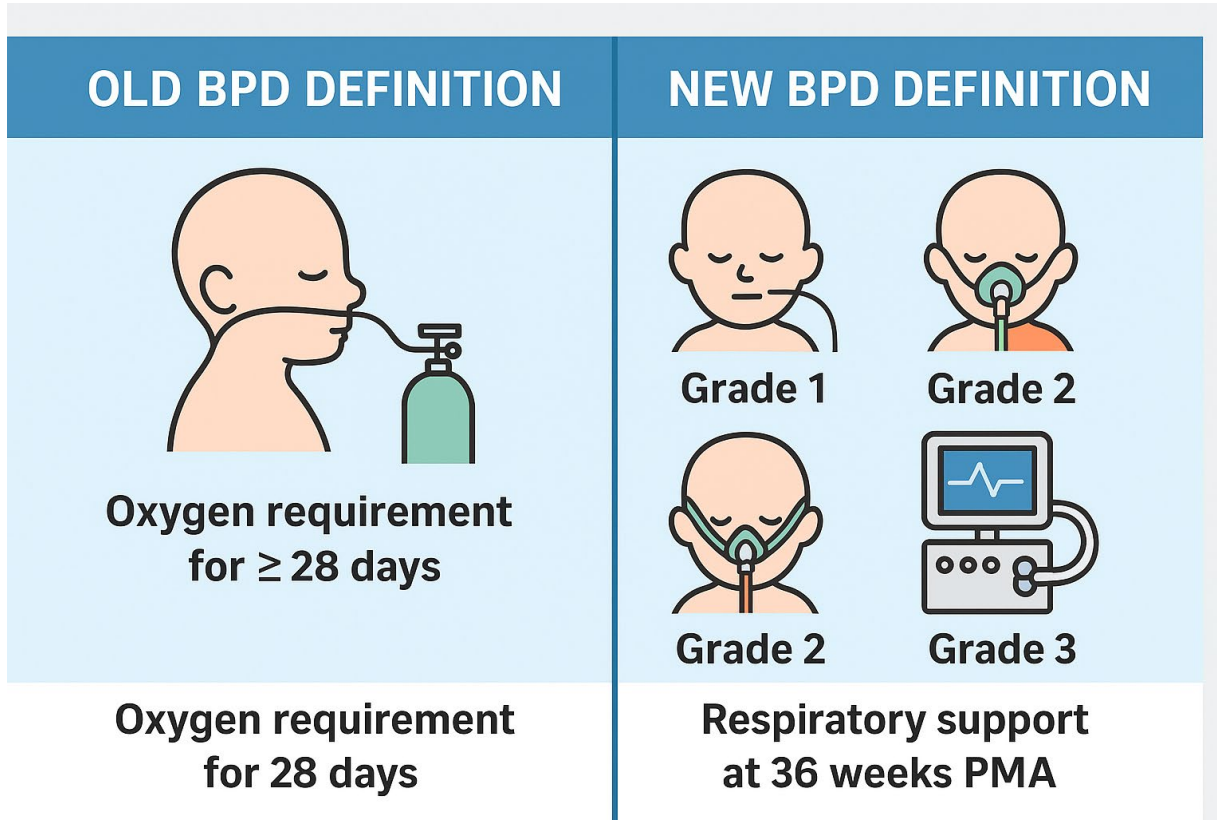
Disease in infants born at less than 32 weeks gestation who require ongoing respiratory support at 36 weeks post-menstrual age (PMA)

BronchopulmonaryDysplasia

- Bronchopulmonary dysplasia (BPD) is a chronic lung disease that primarily affects premature infants who require prolonged respiratory support

Evolution of Definitions

Definition	Main Criteria	Key Limitation
Classic (1967)	Radiographic & clinical	Based on old treatment methods
NIH (2001)	Oxygen use ≥28 days + severity at 36w PMA	Practice variability; doesn't reflect support
Jensen/NICHD (2018–19)	Type of respiratory support at 36w PMA	Simpler and outcome-predictive



2019 NICHD Neonatal Research Network definition of BPD

BPD severity grade	Mode of respiratory support administered at 36 weeks PMA or discharge to home if earlier
No BPD	• Room air (no support)
Grade 1	• Nasal cannula ≤2L/min
Grade 2	• Nasal cannula >2L/min, • Nasal continuous positive airway pressure, *or* • Non-invasive positive pressure ventilation
Grade 3	• Invasive mechanical ventilation

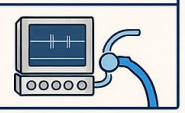
Jensen et al. AJRCCM 2019

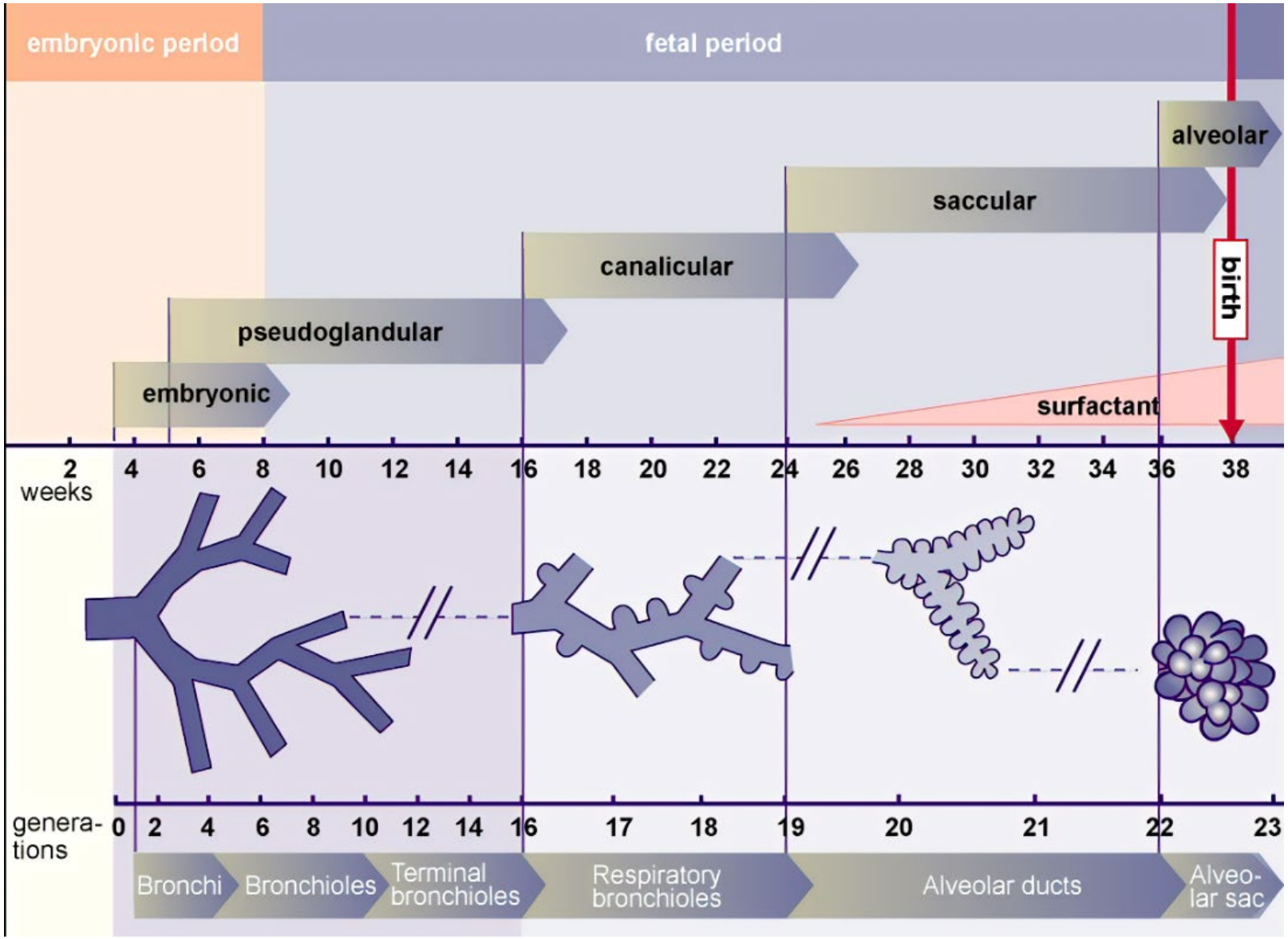
UPDATED NICHD BPD DEFINITION

(Jensen 2019)

For infants <32 weeks gestation age, assessed at 36 weeks PMA

- Diagnosis: need for ≥21% oxygen for ≥28 days
- Severity graded by type of respiratory support at 36 weeks PMA

BPD Grade	Respiratory Support at 36	Example
Grade 0	Breathing in room air (no support)	None
Grade 1	Nasal cannula ≤2 L/min	
Grade 2	≥2 L/min aasal cannula or noninvasive positive pressure 	High-flow  CPAP, NIPPV
Grade 3	Invasive mechanica ventilation	


embryonic period
fetal period
alveolar
saccular
canalicular
pseudoglandular
embryonic
birth
surfactant
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
weeks
genera-tions
0 2 4 6 8 10 12 14 16 17 18 19 20 21 22 23
Bronchi
Bronchioles
Terminal bronchioles
Respiratory bronchioles
Alveolar ducts
Alveo-lar sac

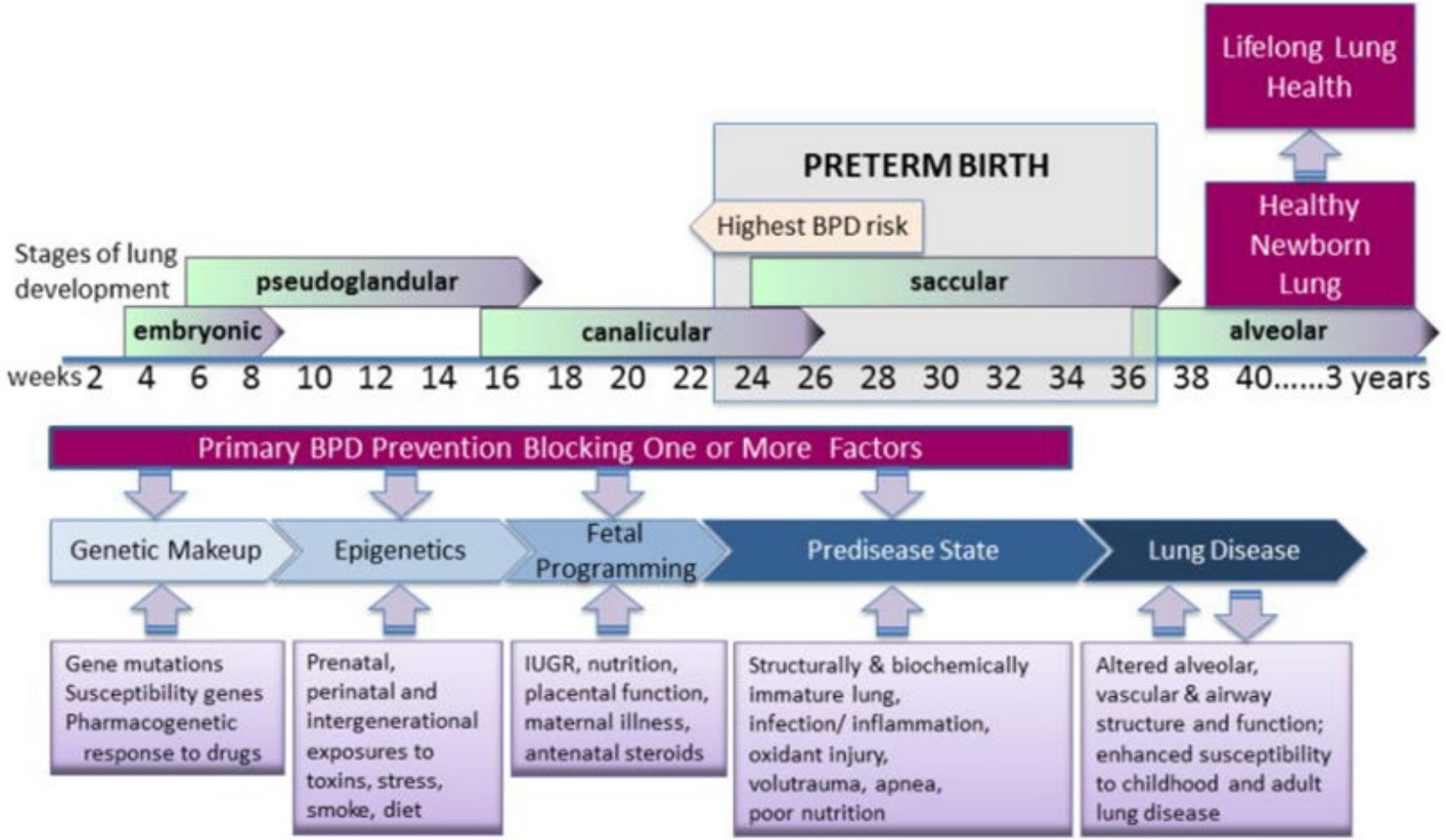
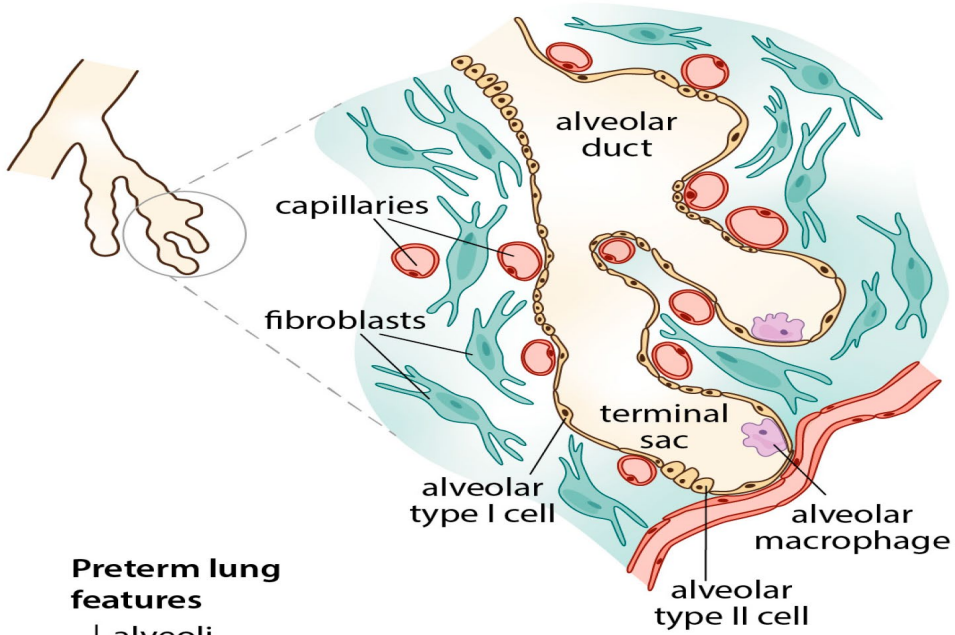


Figure 1 The pulmonary injury sequence representing the stages of lung development and factors contributing to BPD which should be the focus of prevention of the disease. Reprinted with permission of the American Thoracic Society. Copyright © 2014 American Thoracic Society. All rights reserved. McEvoy CT, Jain L, Schmidt B, Abman S, Bancalari E, Aschner JL. NHLBI Workshop on the primary prevention of chronic lung disease: Bronchopulmonary dysplasia. *Ann Am Thorac Soc.* 2014;11: S146–S153. *Annals of the American Thoracic Society* is an official journal of the American Thoracic Society.[6]

Adapted from Journal of Experimental Pharmacology 2021:13378Roberts et al Dovepress

LUNG IN CANALICULAR/SACCULAR PERIOD (23/26 GW)



Preterm lung features

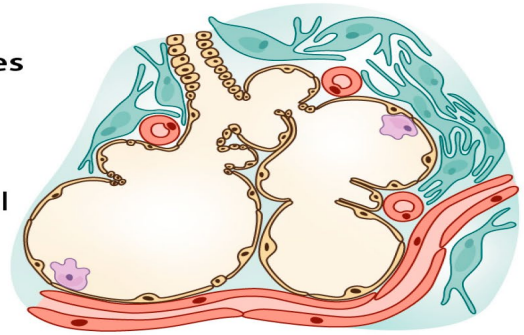
- ↓ alveoli
- ↓ immune response
- ↓ antioxidant defense
- ↓ surfactant
- ↓ compliance
- ↓ lung skeletal/matrix function

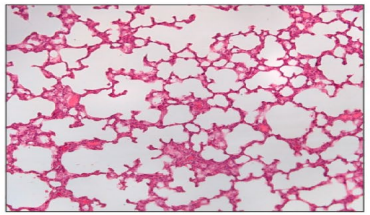
PRETERM BIRTH → *PATHOGENETIC INSULTS*

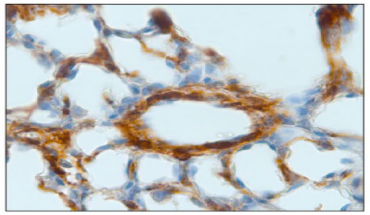
POST-NATAL LUNG DEVELOPMENT

BDP lung features

- Emphysema
- Fibrosis
- Increased arteriolar medial thickness







no intervention

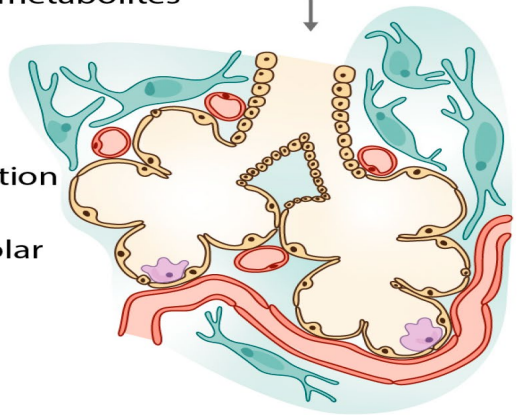
Pathogenetic pathways activation

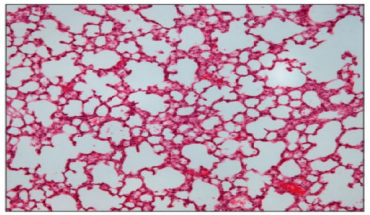
proteins, DNA, RNA, metabolites

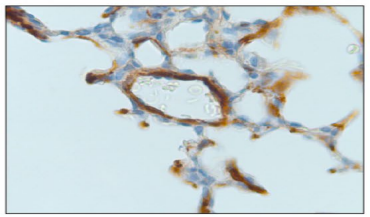
extracellular vesicles administration

Treated lung improvements

- Better alveolarization
- Less fibrosis
- Decreased arteriolar medial thickness







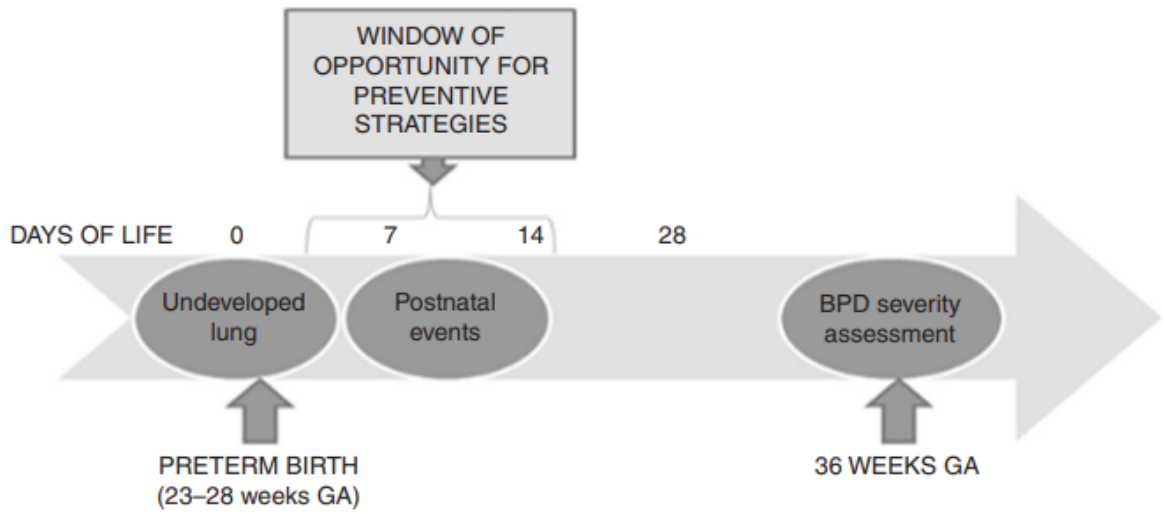
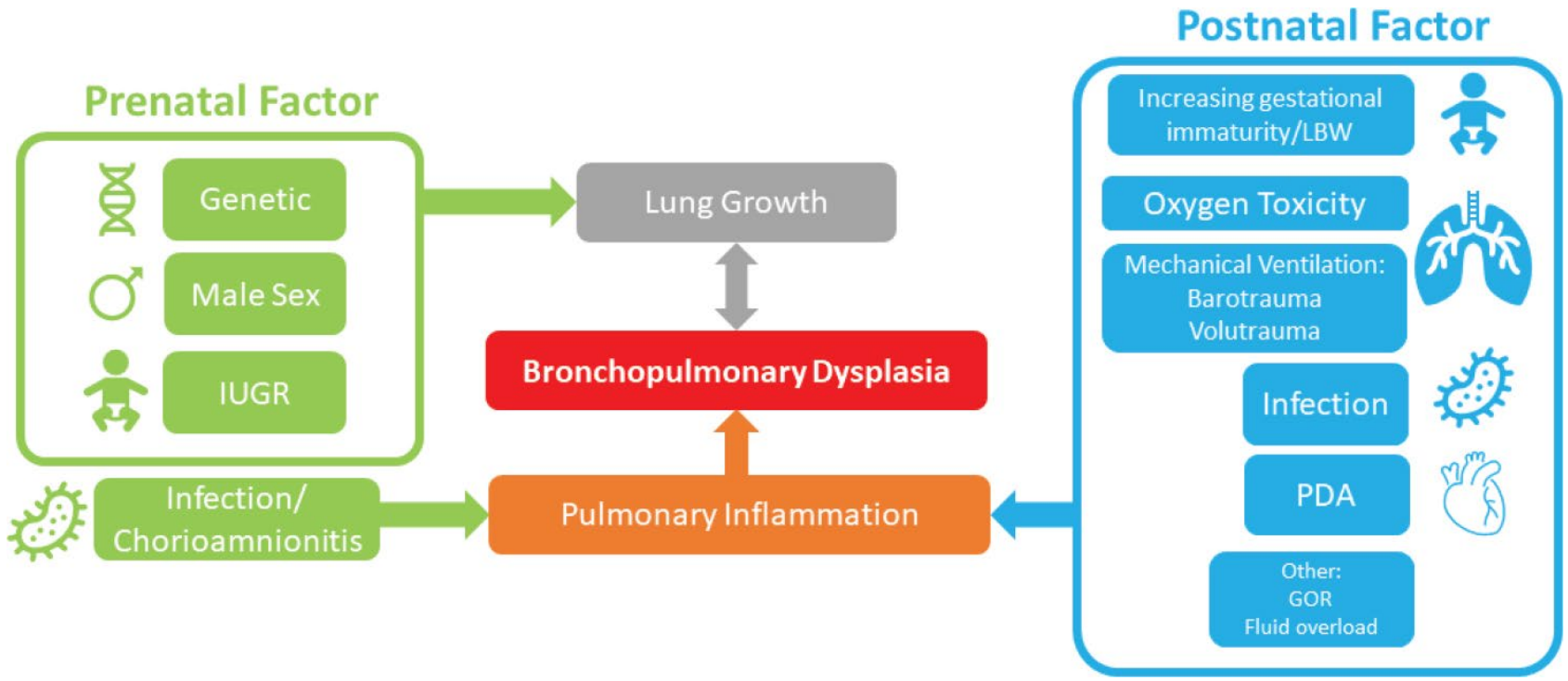


Fig. 1 Timeline of bronchopulmonary dysplasia (BPD) development, since birth until 36 weeks gestational age. At preterm birth (23–28 weeks) the lung is still immature, at the sacular stage of development. During the first month the premature lung is damaged by postnatal neonatal intensive care unit (NICU)-related factors that increase the risk of developing BPD. At 36 weeks postmenstrual age the damage is already established. Therefore, the optimal time for preventive treatment with mesenchymal stromal cells (MSC) is in the first 2 weeks of life

Risk factors



The respiratory consequences of preterm birth: from infancy to adulthood
Christopher W. Course, Ella A. Kotecha, Kate Course, Sailesh Kotecha

Adequately supported infant

- Quiet and alert
- Good eye contact
- No evidence of respiratory distress
- Stable oxygen saturations
- Good linear growth

Discharge readiness

- Considered when the infant with BPD achieves overall “**physiologic stability**”

- Stable respiratory status
- Stable supplemental oxygen need
- Adequate growth trend with appropriate nutritional intake

- Coordinated discharge planning across multiple disciplines
- Home medical equipment and caregiver training in place
- For infants with tracheostomy : extensive home educations and equipment setup

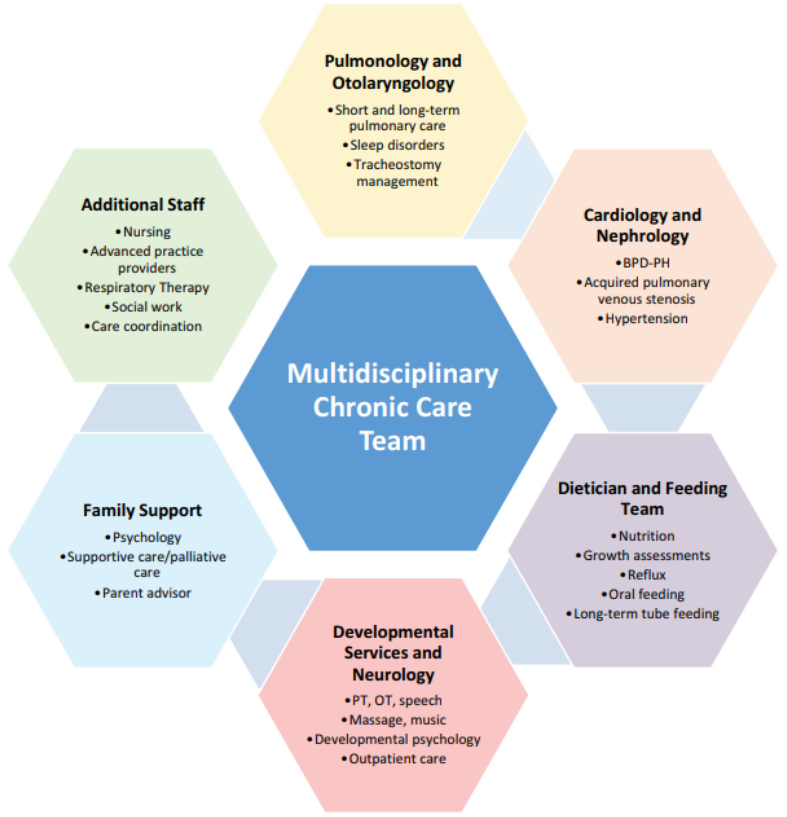


Figure 2. Multidisciplinary team members needed for a comprehensive approach to chronic care management in established BPD, in addition to the primary intensive care team.

Early PCP follow up 48-72 hours of discharge

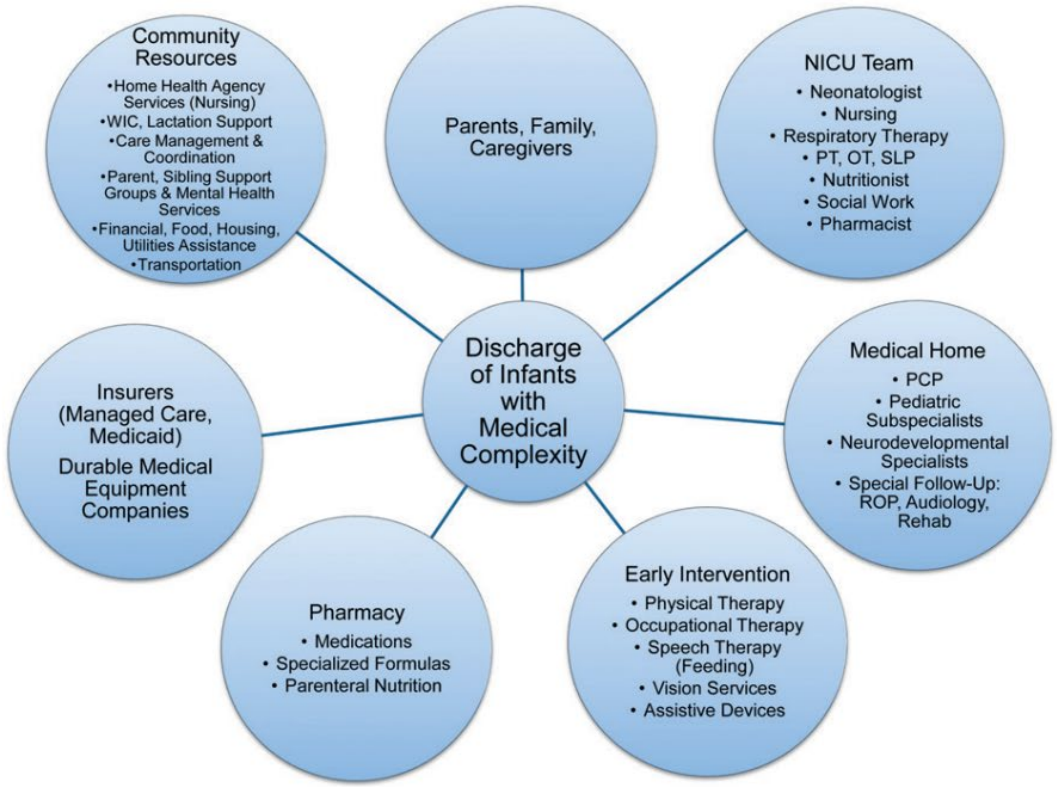


Figure. Multidisciplinary team required for effective discharge coordination. OT=occupational therapy; PCP=primary care physician; PT=physical therapy; SLP=speech-language pathology; WIC=Women, Infants, and Children.

Role of a Pediatrician

- **“Central coordinators**” of care- monitoring growth, development, and respiratory stability

Highlights of the discharge summary

- BPD severity
- Oxygen/ventilator needs
  - Goal saturations **92-95%** when discharged on oxygen
- Feeding regimen (PO/NG/G tube, calories)
- Medications-inhalers/nebulizers, sildenafil

Follow-up referrals

- Pulmonology
- ENT
- Cardiology
- Surgery
- Nephrology
- Nutrition/Feeding therapy
- Early intervention and developmental pediatrics

Common challenges post discharge

Oxygen weaning delays

GERD, oral aversion, poor feeding

Pulmonary hypertension

High parental anxiety

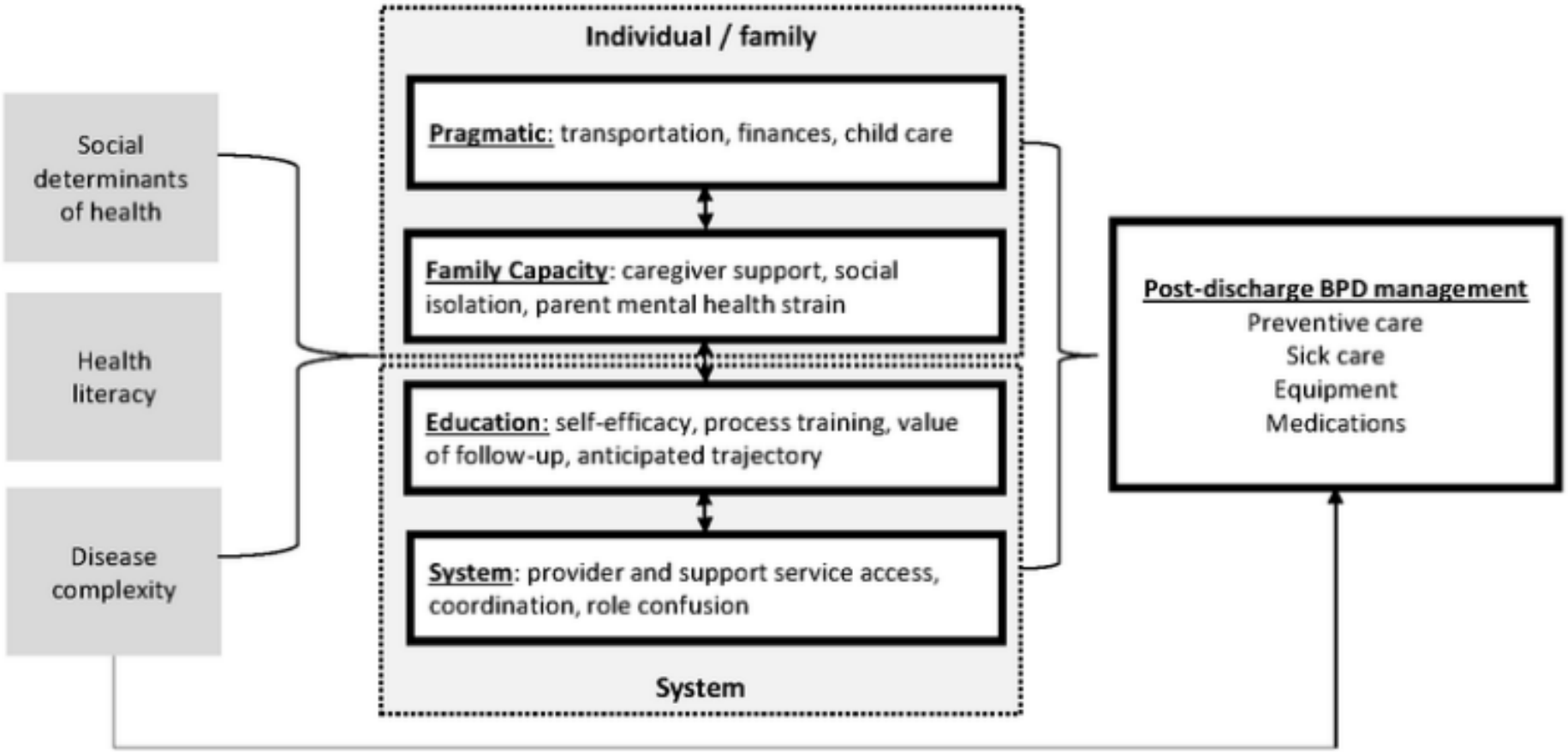
Missed appointments/poor care coordination

Key comorbidities to monitor

- Pulmonary Hypertension – surveillance ECHO is important
- Growth failure: caloric needs increased due to work of breathing
- Feeding issues/aspiration: GERD, oropharyngeal dysfunction is common
- Neurodevelopmental delays: CP, language delay, sensory issues

Barriers

Figure 1. Conceptual framework of barriers to care impacting infants with BPD.



Nutrition and growth

- Nutrition is essential for lung development, maturation, and healing –**maternal milk an ideal source of enteral nutrition**
- Growth failure in BPD infants is predominantly due to malnutrition
- Compromise of lung development and function
- Feeding difficulties can further affect nutrition

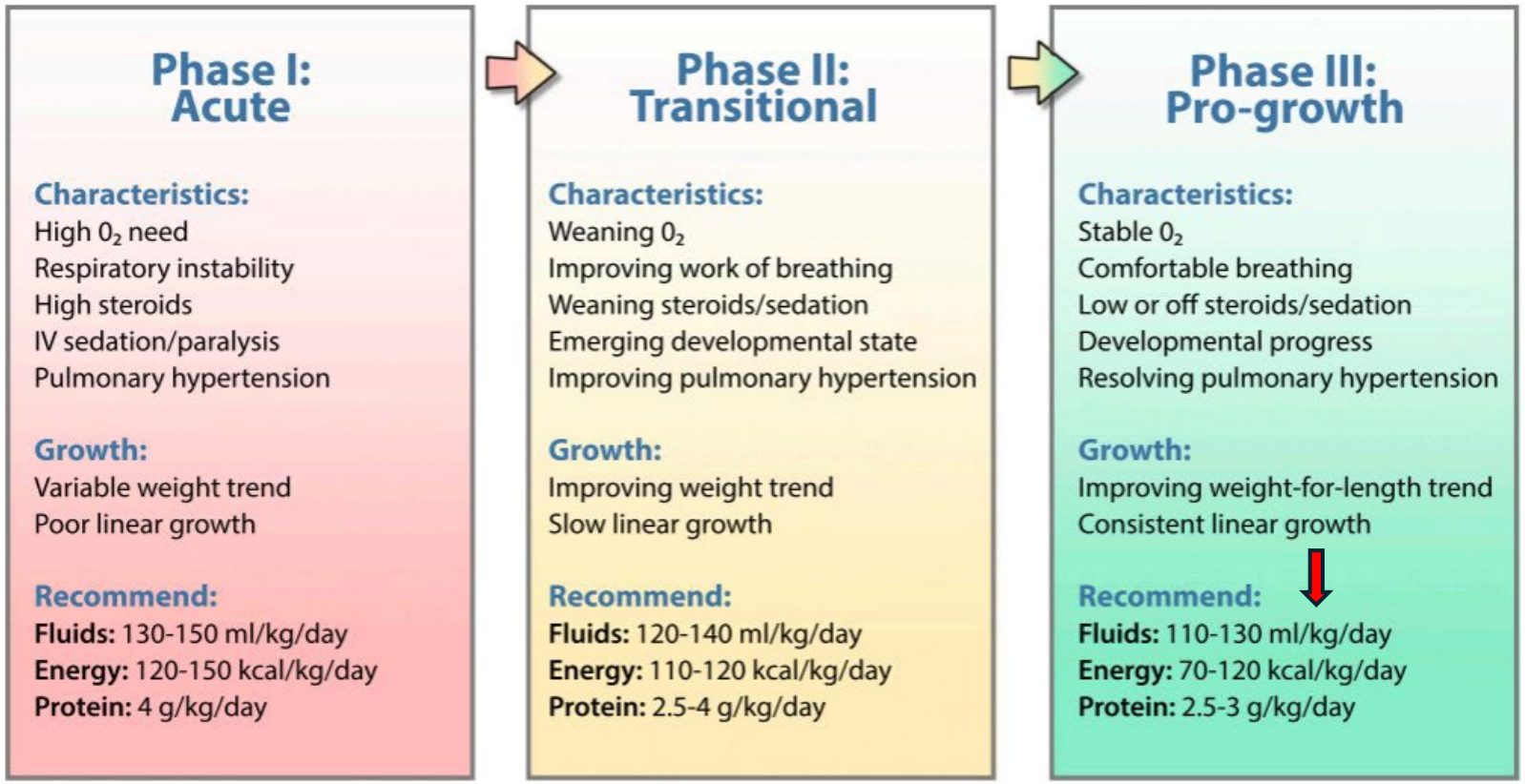
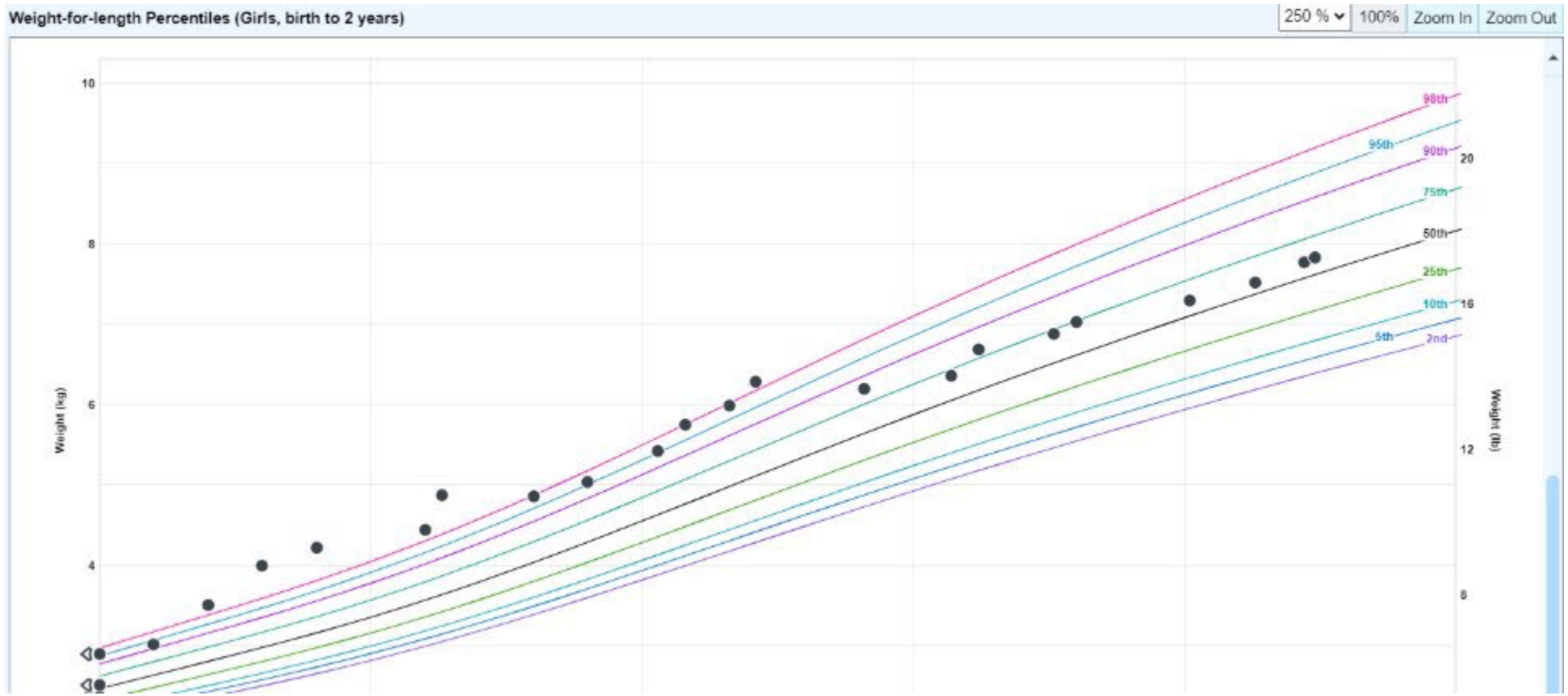


Figure 2. Characteristics, growth observations, and basic nutrition guidelines for infants with severe bronchopulmonary dysplasia based on disease severity. Reproduced from Miller et al (4) originally published in the *Journal of Perinatology*.


Weight-for-length Percentiles (Girls, birth to 2 years)
250 %
100%
Zoom In
Zoom Out
Weight (kg)
Weight (lb)
10
8
6
4
20
16
12
8
98th
95th
90th
75th
50th
25th
10th
5th
2nd

Linear growth

Table. Age-based Recommendations for Weight Gain Velocity and Linear Growth (101)

Weight gain	**Age (mo)**	**Recommendation (g/d)**
	0–3	24–34
	3–6	13–21
	6–12	8–11
Linear growth	**Age (mo)**	**Recommendation (cm/wk)**
	0–3	0.8–0.88
	3–6	0.46–0.48
	6–12	0.29–0.34

- Linked to lean body mass gains, brain, and organ growth
- Arguably the **BEST** indicator of nutritional status
- Linear growth velocity is closely associated to increase in lung function during the first 2 yrs
- Length boards or stadiometer = gold standard

Current strategies

At present there is **no specific individual treatment** available for patients with developing BPD or for established BPD

CLINICAL PRACTICE GUIDELINE

Summary for Clinicians: Clinical Practice Guidelines for Outpatient Respiratory Management of Infants, Children, and Adolescents with Post-Prematurity Respiratory Disease

Laurie C. Eldredge[1], Jonathan C. Levin[2], Michael C. Tracy[3], A. Ioana Cristea[4], Christopher D. Baker[5], Joseph K. Ruminjo[6], and Carey C. Thomson[7,8]

ATS American Thoracic Society

2021

Table 2. Summary of recommendations for medication use in infants, children, and adolescents with post-prematurity respiratory disease

Medication	Indication	Recommendation	Strength of Recommendation	Quality of Evidence
Short-acting inhaled bronchodilator	No recurrent or chronic respiratory symptoms	Not routinely prescribed	Conditional	Very low certainty
	Recurrent respiratory symptoms	Trial of therapy with assessment	Conditional	Very low certainty
Inhaled corticosteroid	No chronic cough or recurrent wheezing	Not routinely prescribed	Conditional	Very low certainty
	Chronic cough or recurrent wheezing	Trial of therapy with assessment	Conditional	Very low certainty
Diuretics	Infants, children, and adolescents with PPRD	No routine use	Conditional	Very low certainty
	Infants discharged from NICU on chronic diuretic therapy	Discontinuation in a judicious manner	Conditional	Very low certainty

Definition of abbreviations: NICU = neonatal intensive care unit; PPRD = post-prematurity respiratory disease.

SEMINARS IN PERINATOLOGY 42 (2018) 471–477

Available online at www.sciencedirect.com

Seminars in Perinatology

www.seminperinat.com

An update on the post-NICU discharge management of bronchopulmonary dysplasia

Anita Bhandari*, and Howard Panitch

Division of Pulmonary Medicine, Department of Pediatrics, Children's Hospital of Philadelphia, Perelman School of Medicine at the University of Pennsylvania, 11th floor Colket Building, 3501 Civic Center Boulevard, Philadelphia, PA 19446, United States

Table 1 – Suggested post-NICU therapy in patients with BPD.

Drug	Initial/maintenance dosing	Weaning	Comments
Diuretics			
Furosemide	PO/IV, 1–2 mg/kg/24 h or every other day	Consider wean to every other day therapy if on daily therapy	Prefer to discontinue before weaning chlorothiazide and spironolactone given side effects with chronic therapy
Chlorothiazide	PO/IV, 20–40 mg/kg/24 h, alone or with spironolactone	May wean by 25% at each visit if at higher end of the dosing range or discontinue if at the lower end of the range.	Wean if respiratory status is stable. Prefer to wean after patient is off oxygen
Spironolactone	PO, 2–4 mg/kg/24 h	May wean by 25% at each visit if at higher end of the dosing range or discontinue if at the lower end of the range.	Wean if respiratory status is stable. Prefer to wean after patient is off oxygen
Corticosteroids			
Systemic	PO, 2 mg/kg/24 h × 5 days, then 1 mg/kg/24 h × 3 days, then 1 mg/kg/24 h every other day for 3 doses) PO, 2 mg/kg/24 h × 5 days	May help wean off supplemental oxygen May use as therapy to decrease work of breathing with intercurrent viral illness	
Inhaled	Budesonide 500 mcg, 1 vial 1–2 times a day Fluticasone propionate 110 mcg, 1–2 puff 2 times a day	Consider if patient has wheezing or documented response to albuterol or oral steroids and has a strong family history of asthma	Other inhaled steroids such as Beclomethasone and Mometasone can be used. Dose based on severity of symptoms
Bronchodilators	Albuterol 1.25–2.5 mg given via nebulizer or 2 puffs [180 mcg] given via MDI with spacer device, every 3–4 h as needed Ipratropium bromide 250–500 mcg via nebulizer or 18 mcg/puff via MDI with spacer device, every 6–8 h as needed		Use for patients with wheezing or past history reversible bronchospasm. May be a useful adjunctive therapy especially in patients who are not responsive to albuterol alone. It may be better tolerated than albuterol in patients with significant tracheomalacia.
Oxygen	Majority of patients are discharged on up to 1LPM of oxygen via nasal cannula	Initiate weaning during the day time first and then wean night time oxygen. Monitor work of breathing, oxygen saturations and weight gain during weaning	Wean in consultation with cardiology when patient has pulmonary hypertension.

PO: per os (oral); IV: intravenous; MDI: metered dose inhaler; LPM: liters per minute.

Current Treatment Options in Pediatrics (2025) 11:20
https://doi.org/10.1007/s40746-025-00334-8

PEDIATRIC NEONATOLOGY (T THORKELSSON, SECTION EDITOR)

Recent Advances in the Management of Bronchopulmonary Dysplasia

Elin Cosgrove[1] · Lieve Boel[1] · Sailesh Kotecha[2]

Accepted: 20 June 2025

Table 2 Summary of ERS [55] and ATS [56] guidelines on outpatient management of children with BPD

	ERS 2020	ATS 2021
Investigations		
Imaging	Subgroup only	Subgroup only
Lung function	Recommended	
Polysomnography		Subgroup
Video fluoroscopic swallow study		Subgroup
Airway endoscopy		If unexplained symptoms
Management		
Bronchodilators	Optional for subgroup	Trial in subgroup
Inhaled corticosteroids	Trial in subgroup	Trial in subgroup
Diuretics	Natural weaning	Discontinuation in a judicious manner
Supplemental oxygen	Saturation target 90–95%	
Daycare attendance	Individual advice	

BPD clinics – smooth transition from NICU to outpatient care

- Provide longitudinal care throughout childhood with multiple disciplines
- Multidisciplinary team approach
- Additional follow up with other specialties depending on other co morbidities
- All infants need evaluation and participation in early intervention programs

Source: Jobe AH. The new BPD: an arrest of lung development. Pediatr Res. 1999

Source: Jensen EA et al. Outpatient Respiratory Management of Infants with BPD. ATS Clinical Practice Guidelines. 2023..

Benefits: coordinated care, reduced hospitalizations, improved outcomes

Table 4. Articles that summarize the discharge process and outpatient multidisciplinary management for infants and children with BPD.

Reference Number	Primary Author (year)	Study Design	Main Findings
[19]	Bonadies (2023)	Review article	A summary and review of the main characteristics of infants and children with BPD and a history of preterm birth to optimize general pediatrician care and multidisciplinary complex follow-up.
[45]	VanderVeen (2020)	Perspective article	Discharge coordination regarding respiratory support, medications, immunizations, nutrition.
[46]	Collaco (2020)	Review article and clinical recommendations	A review and clinical guidelines to multidisciplinary outpatient management of infants with established BPD.
[20]	Duijts (2020)	Practice guideline	European Respiratory Society practice guideline for long-term management of children with established BPD.
[47]	Hayes (2019)	Practice guideline	American thoracic society practice guideline for children on home supplemental oxygen therapy.
[48]	Sterni (2016)	Practice guideline	American Thoracic Society practice guideline for pediatric chronic home mechanical ventilation.
[49]	Groothius (2012)	Review and clinical recommendations	A review of multidisciplinary outpatient management of infants and children with BPD.
[50]	O'Shea (2007)	Prospective randomized trial	Premature infants with chronic lung disease were randomized to either a community-based or multidisciplinary center-based follow up program, and outcomes for development, growth, and hospital readmission were monitored. The community-based center difference in Bayley mean mental developmental index was 3.4 (95% CI: −2.7 to 9.5) and the difference in mean psychomotor developmental index was −0.1 (95% CI: −6.7 to 6.9). Weight for length less than the fifth percentile was found more frequently among infants in the community-based center, although the difference was not statistically significant.
[51]	Allen (2003)	Review and clinical recommendations	An American Thoracic Society statement on the management of the child with chronic lung disease of infancy and childhood, including multisystem longitudinal care recommendations.

Key benefits

- Individualized oxygen weaning plans
- Close monitoring for growth failure, pulmonary hypertension, and reactive airway disease
- Parental guidance for home care, equipment, and red flags
- Better preparedness for illness and admission planning

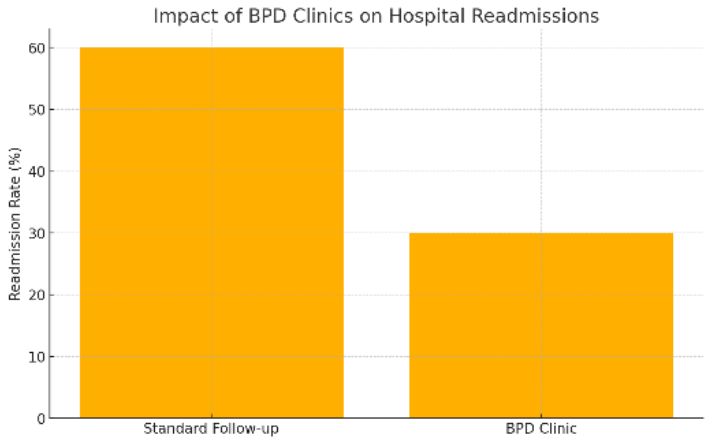
Source: Natarajan G et al. Weaning of respiratory support in BPD. Clin Perinatol. 2022.

Improved outcomes

- Reduces readmission rates
- Fewer acute exacerbations and improved symptoms control
- Streamlines referrals to early intervention and specialists
- Improves caregiver confidence and adherence

Source: Eber E, Midulla F. Structural and functional outcome of BPD. Eur Respir Rev. 2021

Reduced Readmissions with BPD Clinics



Source: Data adapted from NICHD Neonatal Research Network, 2022.

Additional counseling for families

- Secondhand smoke
- Electronic cigarette exposure
- Major roadway proximity
- Daycare attendance

Vaccinations and prophylaxis

- Routine vaccination per chronological age
- RSV
- Influenza and Covid vaccine starting at 6 months
- PPSV23 at age 2 if severe BPD
- Red flags : when a cold= a hospital admission

RSV

- Palivizumab 1998-RSV prophylaxis

  - Humanized mouse immunoglobulin monoclonal antibody –monthly during winter period (IM route)

- Beyfortus-Nirsevimab

  - One dose monoclonal antibody < 8m age entering first RSV season-Recommended if maternal vaccination did not occur before delivery

- Enflonasia-Clesrovimab

  - Newly approved monoclonal antibody (June 2025) < 8m age entering first RSV season

Wheezing

- Beyond infancy, children with BPD have higher rates of wheezing and asthma compared with preterm survivors without BPD and are more likely to use bronchodilators up to the age of 2 years, with more persistent wheezing between 2 and 5 years

- Children with BPD are 4.5 times more likely to have wheezing and chronic cough than matched preterm controls without BPD at 9.5 years of age

Sleep Disorders

- Increased risk of sleep-disordered breathing, including obstructive sleep apnea, central sleep apnea, hypoventilation, and nonapneic hypoxemia

- May require polysomnography as an outpatient prior to being weaned off supplemental oxygen

Impact on Early Childhood

- Increased hospital readmissions, respiratory symptoms, and poor growth.
- Higher rates of wheezing, coughing, and emergency room visits.
- Growth failure = poor developmental and lung recovery outcomes.

Impact at School Age

- BPD leads to worse lung function, frequent respiratory symptoms, and increased use of bronchodilators.
- Lower IQ scores and worse academic performance compared to peers.
- BPD is linked to motor impairments, such as developmental coordination disorder, affecting daily activities.

Developmental Outcomes

- Preterm children with BPD have worse developmental outcomes compared to preterm peers without BPD.
- BPD increases the risk of neurodevelopmental disabilities, including motor and cognitive delays.
- Severity of lung disease (e.g., duration of mechanical ventilation) is strongly correlated with developmental outcomes

Emerging treatments

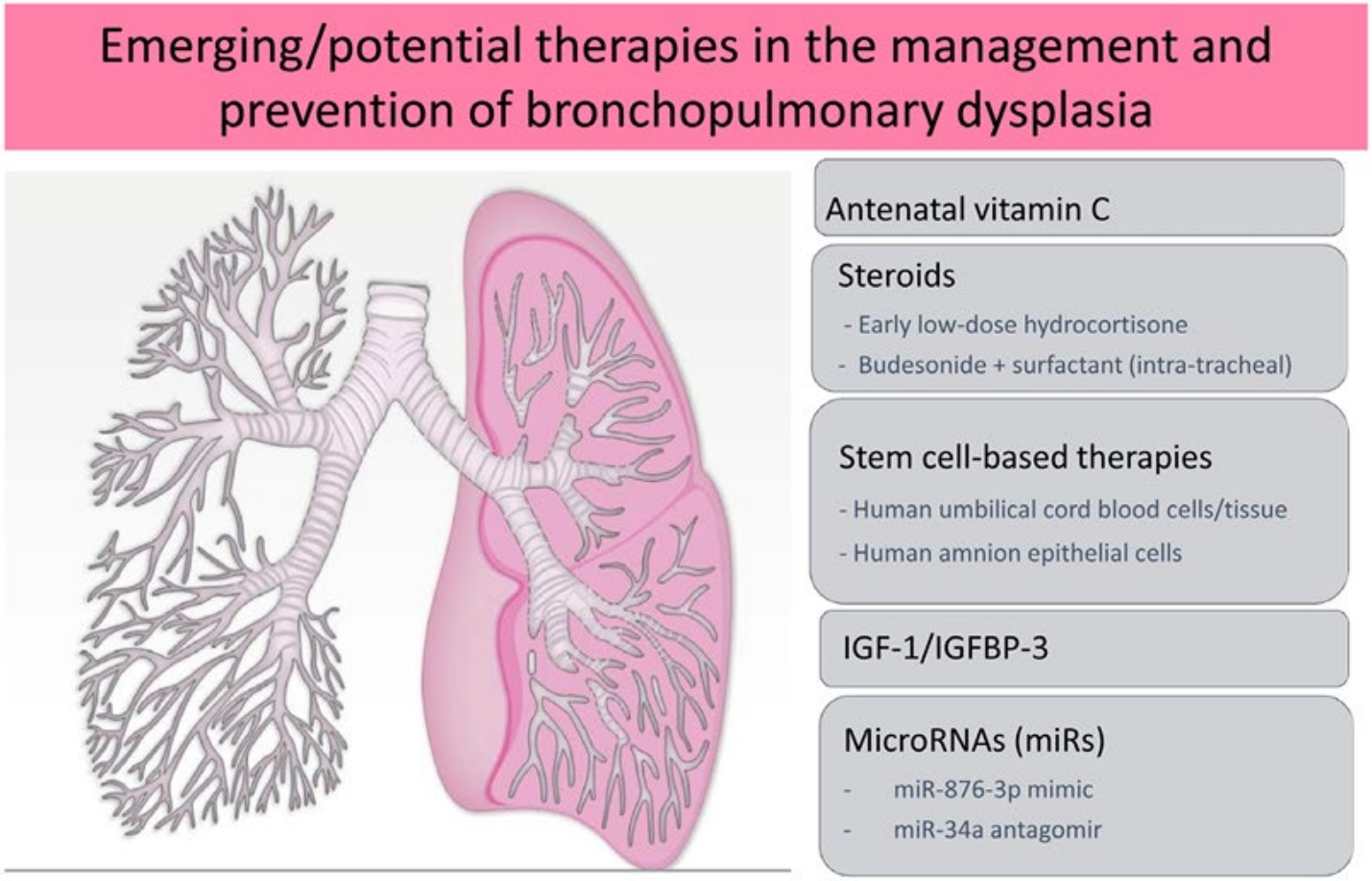
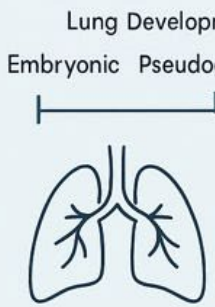


Figure 2. Emerging/potential therapies in the management and prevention of bronchopulmonary dysplasia. These include antenatal vitamin C, steroids, stem cell-based therapies, insulin-like growth factor-1 (IGF-1) in combination with IGF-binding protein-3 (IGFBP-3), and microRNAs.

Therapy Type	Mechanism of Action	Stage of Evidence
Mesenchymal Stem Cells	Anti-inflammatory and regenerative	Early Clinical Trials
IGF-1 + IGFP-3	Promotes alveologenesis and vascular Development	Phase II Trials
microRNA Modulation	Regulates gene expression involved in lung growth	Preclinical (animal models)
Antenatal Vitamins (e.g., Vitamin C)	Reduces oxidative stress in fetal lungs	Limited Clinical Data

BPD Snapshot



- Pulmonary Hypertension
- Growth Failure
- GERD/Aspiration
- Neurodeveloomental Risk

Respiratory Management

- **Home Oxygen**
- Monitor, Weaning Strategy
- **Medications**
- Bronchodilators
- Inhaled Corticosteroids
- Diuretics

Growth & Nutrition

- Caloric Needs Often 120–150 kcal/kg/day
- **Strategies**
  - High-Calorie Formula or Fortified Feeds
  - G-Tube Support
- Regular Growth Monitoring

Immunizations & Prophylaxis

- Routine
- RSV Prophylaxis
- Influenza Vaccine
- PPSV23 at Age 2 If Severe BPD

Summary

- Management is challenging due to multifactorial etiology
- Suboptimal intrauterine and postnatal growth is associated with an increased risk of bronchopulmonary dysplasia (BPD)
- Premature infants with BPD are at high risk for poor growth attainment after discharge from the neonatal intensive care unit.
- Infants with BPD are at risk for early onset COPD in adult life
- A multidisciplinary approach to post discharge management is critical to optimize nutrition, growth, and medical outcomes
- Monitor weight, length, head circumference, weight for length at each visit
- It is best to keep the diagnosis of prematurity and BPD in the problem list
- Dedicated BPD clinics enhance care quality, coordination, and outcomes for high-risk infants.

BPD clinic transition flowchart

- NICU Discharge

- Referral to BPD clinic

- Initial Multidisciplinary Assessment

- Ongoing follow-up :
  - Oxygen management
  - Growth and nutrition
  - Pulmonary hypertension monitoring
  - Developmental surveillance

- Transition to Pediatrician (1-2 years)

Q&A

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THANK YOU