360-degree Care for the Bronchopulmonary Dysplasia Infant with Pulmonary Hypertension: A Comprehensive Review

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Premature infants are at risk of developing bronchopulmonary dysplasia and associated pulmonary hypertension. These infants make up a complex group of patients with unique considerations regarding development of lung and vascular disease, comorbidities, and care plans. They are high risk for many complications and poor outcomes due to the severity and complexity of disease. Because of this, a comprehensive approach to care with consideration for multiple organ systems and with an interdisciplinary team of experts is the preferred approach. Here we describe in detail the major considerations in care for these infants.

INTRODUCTION

Bronchopulmonary dysplasia (BPD) following preterm birth is an increasingly common diagnosis in modern medicine. Many different definitions have been used and modified over the years, with various iterations to work toward the improved ability to predict later outcomes. The most recent definitions rely on an evaluation of respiratory support at 36 weeks postmenstrual age (PMA), have incorporated the most current respiratory support modalities, and can reliably predict respiratory, late death, and neurodevelopmental impairment outcomes.[1-3] BPD is defined as the continued need for respiratory support at 36 weeks PMA, in an infant born at ≤32 weeks of gestation and is stratified to reflect severity (Table 1).[1] The actual incidence of BPD is difficult to state with certainty because of differences in clinical practice and reporting, and it has been cited as 10% to 60%. However, incidence has generally been estimated at 40%, a figure which has remained stable despite advances in medical care.[4-6] Notwithstanding, the absolute number of affected infants has steadily increased, reflecting the increased number of preterm births and survival of these infants.[7]

Table 1. Stratification of BPD Severity by Oxygen Requirement and Age[a]

Severity	Definition
No BPD	Breathing room air at 36 wk PMA or discharge home, if earlier
Grade 1	Nasal cannula at less than or equal to 2 liters per minute at 36 wk PMA or discharge home, if earlier
Grade 2	Nasal cannula at greater than 2 L/min, "high flow" nasal cannula, CPAP, NIPPV at 36 wk PMA
Grade 3	Invasive PPV at 36 wk PMA

Abbreviations: BPD, bronchopulmonary dysplasia; CPAP, continuous positive airway pressure; NIPPV, non invasive positive pressure ventilation; PMA, postmenstrual age; PPV, poitive pressure ventilation.

[a] Adapted from Jensen et al.[1]

Although the definition of BPD is rooted in respiratory disease burden, the infant with BPD often suffers from associated comorbidities that contribute significantly to the child's clinical course and affect therapy and prognosis. Prematurely born infants are at particularly increased risk for neurologic sequelae, feeding difficulties, and developmental delays, all of which pose significant threat to overall stability and ultimately the child's respiratory prognosis. Therefore, it is of utmost importance that the pulmonary hyper-

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tension (PH) clinician assess the BPD infant in a comprehensive manner to minimize perturbation of PH-BPD and to ensure a robust outcome for the BPD survivor.

Respiratory Embryology

Embryologically, the developing fetus goes through 4 periods of lung growth: embryonic, pseudoglandular, canalicular, and saccular. A fifth stage, alveolar, begins near term and continues through birth and childhood. Most premature infants are born during the canalicular and saccular stages of lung development, rendering significant disruption to respiratory development. And since the airways act as a template for pulmonary vascular growth, vascular development is abnormal by association and angiogenesis is therefore significantly impaired in the preterm infant.[8] Postnatally, this abnormal lung is now subject to mechanical ventilation, oxygen toxicity, and altered fluid mechanics, creating a complex inflammatory environment that further impairs alveologenesis and angiogenesis.

Respiratory Burden of Bronchopulmonary Disease

The clinical pulmonary features of BPD include abnormalities in the lung parenchyma, small airways, large airways, and pulmonary vasculature. The most severe forms of the disease exhibit parenchymal heterogeneity with areas of air trapping, hyperinflation, atelectasis, and thickened septa, and can be complicated by severe tracheobronchomalacia, small airway obstruction, and PH.

The diagnosis of BPD is not an acute event. Rather, it reflects a chronic series of exposures in the prenatal, perinatal, and postnatal periods.[9] Prenatal exposures such as preeclampsia, placental insufficiency, and growth restriction all modify and contribute to abnormal alveolarization and therefore angiogenesis in the developing fetus. However, gestational age and weight of the fetus at the time of birth have been cited as the greatest predictors of BPD development.[7] In the postnatal period, the preterm infant requires significant support, which negatively impact the developing lungs. Surfactant dysfunction, oxygen toxicity, barotrauma, nutritional failure, infection, and inflammation pose recurring challenges to the preterm infant, prevent normal pulmonary growth and repair, and result in a loss of alveolar surface area.[10] These challenges extend well beyond the postnatal period and/or discharge from the neonatal intensive care unit since the lungs continue to develop until early adulthood and remain at continual risk for insult and injury.

While the field of neonatology continues to push forward with advances in medical therapy and clinical approaches, the aging BPD population at any moment reflects the care of decades earlier.[6,11] Nevertheless, the study of current adult BPD populations may shed insight into continued lung development and therefore inform present-day strategies to minimize BPD development. Examination of lung disease in prematurely born adults reveals significant deficits in percent predicted values for forced expiratory volume in the first second and distorted architecture. However, these deficits are magnified when preterm birth is accompanied by severe BPD diagnosis.[6,12,13] Although serial evaluations of lung function in preterm infants, specifically forced expiratory volume in the first second, demonstrate catch-up growth, the metrics remain below matched subjects born at term. Children with BPD are more likely to present with asthma-like symptoms of wheezing, airway hyperreactivity, and exercise symptoms and are often treated with inhaled corticosteroid therapies.[12,14] The reversible airway obstruction may be related to a combination of abnormal airway tone, heterogeneity in inflation, and air trapping, reflecting the significant complexities of assessing the BPD infant with continued respiratory complaints.[7]

CARDIORESPIRATORY ASSESSMENT OF THE INFANT WITH BPD

Comprehensive cardiac assessments are crucial in the BPD infant because of the high risk of clinical complications associated with abnormal morphology.

The most widely employed tool for cardiac assessment is echocardiography, a valuable screening and diagnostic modality that should be part of every BPD clinician's toolkit. Echocardiography is seminal to verify cardiac anatomy, to assess for the presence of intracardiac and extracardiac shunts, and to confirm pulmonary venous drainage.

Shunt Lesions in the BPD Infant

Shunts are particularly problematic in the BPD infant as they increase volume load to simplified and stressed alveolovascular units and therefore when judged to be significant, they must be addressed. Patent ductus arteriosus and ventricular septal defects are typically accepted as potentially problematic in the BPD infant, especially if left atrial dilation is noted, and therefore discussion of closure has not typically been controversial. However, atrial septal defect (ASD) closure has been a particularly controversial topic among neonatologists, pulmonologists, and cardiologists.

Classically, the ASD is not considered to significantly increase pulmonary blood flow and therefore the risk of pulmonary overcirculation is judged to be low. However, there is now a growing understanding that for a child with developmental lung disease, the pulmonary vascular bed is typically reduced, simplified, and often abnormal. Therefore, any additional pulmonary blood flow is unlikely to be tolerated and can result in significant pulmonary vascular strain. This has been recognized in the BPD medical literature, with numerous case reports and case series about the morbidity associated with ASD and the improvement in the BPD infant after closure.[15-21] Persistent left-to-right atrial level shunts have been linked to failure to wean from respiratory support (oxygen, positive airway pressure), poor growth, and lack of clinical progress. In fact, in a large multicenter observational study, the presence of an ASD was associated with increased odds of BPD development in premature infants.[22] The mechanism for ASD-associated injury is not well-known but is thought to be related to the impaired capacitance of a maldeveloped pulmonary vascular bed. In the child who suffers ASD-associated morbidity, the positive pressure support, oxygen supplementation, and

use of diuretics may be significant and therefore contribute to the development of BPD. Therefore, in the BPD infant with an atrial level shunt, closure should be considered if the shunt is persistently left-to-right and the infant has significant associated respiratory morbidity.

Pulmonary Vein Stenosis

Pulmonary vein stenosis (PVS) may be congenital or acquired, and is often progressive, leading to recurrent pulmonary edema, failure to thrive, secondary PH, and right heart failure.[23] Unfortunately, PVS requires frequent intervention by cardiac catheterization because of recurrence and progression. Although PH is frequently noted on echocardiography and its development imparts a worse prognosis, the use of targeted pulmonary vasodilator therapy frequently results in exacerbation of the PVS disease and the child develops pulmonary edema. Therefore, these treatments are used sparingly in PVS, if at all. Therapies aimed at the mechanistic development of venous occlusion have been trialed in PVS with varying success: sirolimus, imatinib, bevacizumab, methotrexate, and vincristine.[23,24] The etiology of PVS in the preterm infant is not clear. The postnatal positive pressure used in the premature infant has been thought to create back pressure on the left heart that then induces pulmonary venous changes. Once the pulmonary veins are affected, pulmonary edema is a common development, which prompts use of increased positive pressure support, fostering a vicious cycle. The BPD infant with PVS is unfortunately at higher risk of death than the BPD infant without PVS, so the BPD clinician has the responsibility to be acutely aware of this condition, maintain a high index of suspicion, and support screening and intervention.[25,26]

Pulmonary Hypertension

In the modern era, one of the biggest threats to the survival of the BPD population is the development of PH.[27] PH is a condition of elevated pulmonary artery pressure, secondary to elevated pulmonary vascular resistance. In the BPD infant, it's further characterized by elevated abnormal vasoreactivity to even mild episodes of hypoxemia.[28,29] The development of PH in this vulnerable population is multifactorial and reflects derangements in alveolarization and the additive effect of prenatal and postnatal injuries on a delicate pulmonary vascular bed. The resulting vascular disorder in conjunction with abnormal respiratory units results in pulmonary vascular disease, which in its severe form can cause PH with right ventricular dysfunction.[4,7] This highly comorbid diagnosis is associated with a significant risk for adverse clinical outcome, with mortality rates cited as high as 14% to 38%.[4,30] Interestingly, while there is a steep mortality risk in the first 6 months after diagnosis, the cumulative mortality over the first 2 years of life suggests that these children remain at increased risk of death following discharge from the neonatal intensive care unit.[31]

A modifier of prognosis is early identification to help direct therapy.[32] Therefore, infants who acutely require increased support or have worsening hypoxemia should be evaluated for PH, even if it is before the 36 weeks PMA time point, as worsening pulmonary disease is often the harbinger of PH.[33] Unfortunately, PH-BPD screening criteria and methods of screening are inconsistent in the published literature, inconsistent at the bedside, and therefore inconsistent for diagnosis. These irregularities are reflected in the reported prevalence of PH-BPD.[34] PH guidelines released by the American Heart Association in conjunction with the American Thoracic Society recommend echocardiography screening of all PH-BPD infants with moderate to severe BPD at 36 weeks gestational age, and the Pediatric Pulmonary Hypertension Network expanded on this recommendation with clinical specifics.[33,35,36] Despite these consensus statements, implementation remains variable. Echocardiography is often done in response to clinical change.

Although cardiac catheterization is the gold standard for PH diagnosis, PH-BPD is usually diagnosed by echocardiography because of concerns for transport stability of the critically ill BPD infant and hemodynamic stability with anesthesia and catheterization procedure. The identification of PH by echocardiogram can be hampered by the hyperinflation, expansion of the thoracic cage, and alteration of the heart position, obscuring important measurements such as that of the tricuspid regurgitation jet velocity.[37] For these reasons, careful consideration for right heart catheterization may still be considered for the diagnosis of PH, while also allowing interrogation of important potential cardiac comorbidities.[38]

The echocardiogram must be reviewed carefully to exclude other causes of elevated right ventricular pressure, such as left heart disease, PVS, left-to-right shunts, and intrinsic cardiac conditions. A direct estimate of the systolic function of the right ventricle (RV) may not be possible because of inadequate tricuspid jet velocity. However, other indicators of RV pressure include the position of the interventricular septum, the appearance and function of the RV, changes in RV ejection time to pulmonary artery acceleration time ratio, and changes in direction of shunt flow. A useful calculation is the ratio of the estimated RV systolic pressure in relation to the systemic systolic pressure. An RV-systemic ratio > 1:2 is consistent with at least mild PH in the PH-BPD infant.[34,39] Cardiac catheterization should be considered in the PH-BPD infant with recurrent pulmonary edema to assess for concomitant PVS, the infant who has persistently elevated RV pressure estimate on echo, or the infant with shunt lesions.

Upon diagnosis of PH, the crux of PH-BPD treatment rests in the optimization of the infant's respiratory status as the single most impactful therapy that can be offered.[27] Modifiers of pulmonary vascular resistance include hypoxemia, acidosis, hypercarbia, hyperinflation, and atelectasis. Therefore, use of advanced imaging such as a chest computed tomography scan, VQ scan, dynamic airway computed tomography scan, or even newer modalities of magnetic resonance imaging may be useful in characterizing extent of pulmonary disease as targets for optimization.[33,35,37,40] Interventions include adjusting mechanical support to minimize extremes of inflation (hyper- and hypo-), titrating oxygen supplementation to reach appropriate targets for age and disease, judicious use of diuretics, and encouragement of growth

Table 2. Medications Used to Treat PH-BPD

Class	Action	Side effects	Generic names (USA)
Phosphdiesterase-5 inhibitor (PDE-5i)	Nitric oxide potentiators	Reflux, systemic hypotension, worsening hypoxemia	Sildenafil: can be given orally[41-47] or intravenously[48] Tadalafil: oral use only[49]
Soluble guanylyl cyclase stimulator	Enzyme in nitric oxide pathway	Hypotension, cannot be combined with PDE-5i class.	Riociguat[a]
Endothelin receptor antagonist (ERA)	Block binding of endothelin-1	Dose-related liver dysfunction (bosentan), teratogenicity, anemia (ambrisentan)	Bosentan: oral administration[46,50,51] Ambrisentan: oral administration*
Synthetic prostacyclins and prostacyclin receptor agonists	Increases levels of circulating prostacyclins	Systemic hypotension, nausea, vomiting, diarrhea Platelet dysfunction Infectious risks with indwelling central line Pain at subcutaneous site Cough, bronchospasm with inhalation	Treprostinil: can be given orally, by inhalation,[b] continuous subcutaneous infusion,[46] continuous intravenous infusion.[52] Iloprost: inhalation[46,53,54] Epoprostenol: inhalation, continuous intravenous infusion[46,52,55]

[a] Use has not been described in pulmonary hypertension associated with bronchopulmonary dysplasia.

[b] Inhaled treprostinil requires breath actuation by patient.

with adequate nutrition. Impact of these interventions should be characterized and closely monitored in a serial way with diagnostics such as blood gases and radiographs.[28] With close management of ventilation and respiratory mechanics, PH in severe BPD may even be adequately managed without PH-directed pharmacotherapy in cases. To achieve this, infants with severe lung disease and resultant PH may require chronic supplemental oxygen or chronic mechanical ventilation. For the infant with significant PH, PH-targeted therapies have been used in PH-BPD with good results and tolerance (Table 2).

MANAGEMENT OF PULMONARY DISEASE

Respiratory Support Strategies

Infants with severe BPD and associated PH benefit from the optimization of oxygenation, ventilation, atelectasis, and hyperinflation, as physical factors and inflammatory factors increase pulmonary vascular resistance in response to perturbations in these physiologic parameters.[56] For infants who are oxygen dependent, it is essential to ensure that the oxygen support is adequate to maintain oxygen saturations above 92% and that the infant can achieve somatic growth with no signs of PH worsening.[35]

Ventilation of the BPD infant is challenging. In the first few weeks of life, a premature infant's lung disease is characterized by low compliance and relatively homogeneous lung involvement. However, as BPD develops, bedside clinicians will note more pronounced evidence of the abnormal parenchyma that hallmarks this disease: heterogeneous lung disease with air trapping, interspersed with atelectatic segments and high airways resistance. As the lung disease evolves over the course of the infant's life, the mechanical support strategy must also evolve to minimize hyperinflation and atelectasis, worsening gas exchange, and increased work of breathing with ventilator asynchrony. The currently recommended model of ventilation includes high tidal volume, long inspiratory time, and low respiratory rate to adequately ventilate the lung unit with heterogenous time constants.[57,58] Optimization of ventilation is the cornerstone of BPD-PH management and must be taken seriously to prevent further PH exacerbation.

Tracheostomy

With severe BPD, tracheostomy is often considered to facilitate long-term mechanical ventilation. These infants are overall a small proportion of total BPD patients, but they are a high-risk population with high morbidity and mortality, requires specialized care, and has grown in recent years.[59] An interdisciplinary team including neonatology, otolaryngology, pulmonology, respiratory therapy, and palliative care may be helpful in determining which patients would benefit from tracheostomy placement and best determine the timing for this intervention.

There is often more than one indication for tracheostomy.[60] Indications include neurologic impairment, secretion management, upper airway obstruction, and abnormal ventilatory drive. Chronic respiratory failure or respiratory insufficiency, especially with associated PH should be considered as an indication for tracheostomy for chronic long-term ventilation.[35] This may manifest as a failure of extubation, increased work of breathing, or carbon dioxide retention with invasive or noninvasive ventilator support once at term.[57] Importantly, tracheobronchomalacia increases the likelihood that tracheostomy will be necessary for infants with respiratory failure and PH.[61]

The decision to place a tracheostomy should not be taken lightly, as there are risks associated with tracheostomy placement that must be weighed with the benefit of long-term respiratory support. Risks include complications such as mucus plug, accidental decannulation, tracheostomy-associated

infections, and bleeding, any of which can lead to neurologic devastation and death.[60] While the decision to pursue tracheostomy may begin around term gestation, the timing of surgery is still debated in the literature and there are no established criteria or guidelines. Reports of surgical placement range from 40 to 51 weeks PMA, and timing of this has not been shown to impact mortality, time to liberation from ventilator, or time to decannulation.[62,63] Tracheostomy placement, however, has been associated with improved proportional growth, improved participation in developmental therapies, and developmental progress, which may be a consideration in earlier trach placement.[64] While chronic mechanical ventilation via tracheostomy is initially an overwhelming idea for many families, the natural history of ventilator-dependent severe BPD infants (even those whose courses are complicated by PH) is that most patients are able to reach liberation from the ventilator and decannulation between 3 and 5 years of age.[65] Risk of neurodevelopmental impairment in this population is high, however, and neurologic disorder increases the likelihood that decannulation is delayed.[66]

Neurodevelopmental Concerns

Neurodevelopmental outcomes (cognitive, language, and motor) are important considerations for the BPD infant as there is considerable risk for significant deficits compared to non-BPD infants: cerebral palsy, neurosensory deficits, changes in academic performance, language delays, and disorders of visuospatial perception.[67] Conditions that favor hypoxic brain injury (recurrent hypoxemic events, chronic hypercapnia, and respiratory acidosis) set the infant up for impaired oxygen delivery to the cerebral tissues. The use of postnatal corticosteroids has also been implicated as a risk factor for neurodevelopmental deficits in this population, a treatment that is commonly used in this population to facilitate extubation. The exact mechanism by which glucocorticoids affect neuromotor impairments is not clear but may have to do with abnormal growth and maturation of the brain (decreased gray matter, brain-cell hypoxic division, differentiation, myelination, and electrophysiological reactions.)[68]

Unfortunately, the PH-BPD infant is at particularly increased risk for developmental delays compared to the BPD infant without PH.[69,70] This underscores the critical illness of these children and associated interventions that are required for support, the considerable histologic derangements of the alveolovascular units, and the ultimate effects on oxygen delivery to a vulnerable neurologic system.

BPD is an independent predictor of motor delays above that of prematurity alone.[71] Motor delays in particular can be difficult for infants with severe BPD, as they rely on musculoskeletal strength to power the respiratory system that is at a mechanical disadvantage compared to healthy children, limiting their ability to participate in effective therapies and tolerate interactions with the ventilator. The length and severity of critical illness in these infants often necessitates significant time with sedation and neuromuscular blockade to maintain stability in the setting of severe lung disease and frequent ventilator asynchrony, which contributes to the motor delay.[72] In addition, the nutritional deficiencies noted to be associated in infants with BPD and associated PH impacts the growth of the skeletal muscle.[69] This impact on skeletal muscle strength can last through childhood and into adulthood with weakness of peripheral muscle groups and posture reported to be affected.[73] Careful assessment and early detection and treatment of neurologic impairment can improve quality of life for children and families.[71]

Nutritional and Gastrointestinal Concerns

Nutrition is a key contributor to the overall health of the infant with BPD. The approach to nutrition should be multifaceted, with input from experienced speech therapists, dieticians, and gastrointestinal specialists as needed to optimize growth and safe feeding options.[3,28] Unfortunately, BPD infants often begin life at a nutritional disadvantage. Small size at birth (small for gestational age) and inadequate perinatal somatic growth impact the risk of BPD development and confer higher mortality in comparison to appropriate-for-gestational-age counterparts.[74,75] The effect of poor nutrition has been noted to affect neurodevelopmental and pulmonary outcomes, reflected in postnatal growth failure at 36 weeks and inadequate linear growth as risk factors for negative outcome.[75-76] The importance of caloric and protein intake despite critical illness in this at-risk population therefore cannot be overstated and must be a focus of the BPD clinician.

Infants with BPD have higher energy needs than infants without BPD, impacted by work of breathing, stress, inflammation, and the need for catch-up growth. Estimates show that the energy needs of infants with BPD are 15% to 25% higher than healthy controls.[78] Optimal nutrition, and particularly protein intake, is necessary for lung growth, repair, and recovery over time.[28] Achieving optimal lung growth is often difficult in the setting of fluid restriction, diuretic use, and avoidance of excessive mineral intake, all of which need to be accounted for in planning feeds for these infants.[79]

In addition to careful consideration of growth parameters in the impact of lung health, safe feeding is of utmost concern. BPD is strongly associated with oral feeding problems such as oral aversion, disturbed suck-swallow-breathing coordination, aspiration, and gastroesophageal reflux disease, which all contribute to poor oral feeding and dependence on tube feeding.[80] Reflux and aspiration are risks for ongoing lung injury in patients with BPD and are associated with episodic worsening of respiratory status, so there should be a low threshold to proceed with diagnostic studies such as an upper gastrointestinal series, pH probe, impedance probe, and videofluoroscopic swallow studies to assess the infant's reflux and/or aspiration risk.[28,81,82] To manage these symptoms and ensure a reliable feeding method, many infants with severe BPD require an alternate enteral feeding option such as gastrostomy tube, anti-reflux surgery, or a gastrojejunal tube.[83] Infants with severe BPD-PH are more likely to have anti-reflux surgery than those without PH, and there seems to be an improvement in respiratory status in many of these infants after surgery.[84]

DISCHARGE OF THE COMPLEX BPD PATIENT

Children diagnosed with BPD remain at increased risk for hospital readmissions particularly in the first several years of life, and it is estimated that nearly 50% of infants born prematurely are readmitted during their first years of life.[85] Reducing hospital readmissions in this patient population can significantly improve patient and family stressors, health care costs, and reduce the use of community and hospital resources.

The severity of the child's BPD determines the type of respiratory support and therapy the child may need as they go home.[86] Discharge planning should be individualized to the specific needs of the child and family. Adoption of a smooth discharge process in institutions caring for these children can reduce the risk of hospital readmissions. This process can help ensure that all necessary tasks are completed and that follow-ups are arranged before discharge.

Discharge Checklist

Discharge planning for these children usually begins weeks to months in advance of the actual discharge. Families progress in proficiency in administration of oxygen supplementation, medical therapies, and airway treatments, if appropriate for the child. They may also start classes to learn the care needed for a technology-dependent child (ie, for a tracheostomy, ventilator, and/or gastrostomy) and work with home health agencies for care arrangements at home. One potential approach to more successful discharge management is the creation of a discharge checklist to ensure all appropriate aspects for care management are completed before the child's discharge. While the outpatient clinical care of the child varies from child to child, a discharge checklist can ensure that necessary tasks such as specific ventilator training for parents and/or appropriate vaccinations are given before going home.

Checklist Components

Pharmacotherapy Management: Before discharge, the timing of medications should be adjusted to ensure that the schedule is reasonable for families and the child's schedule at home (for example, to coincide with scheduled feedings.) Children who are discharged home with PH medications should understand the appropriate timing of these medications and how to refill them. When educating families before discharge, it is imperative to understand the caregivers' best learning style, if they can read, and their preferred language. Neglecting to identify this can create misunderstanding and confusion once the child is discharged home.

Immunizations: Every BPD-PH child should receive routine pediatric vaccinations as recommended by the Centers for Disease Control and Prevention based on their chronological age and immunological state.[87] For those who are at least 6 months or over, the influenza vaccine should be given before discharge with the second vaccine given by the primary care provider about 1 month after the initial dose. The palivizumab vaccine is recommended for the child's first respiratory syncytial virus season by the American Academy of Pediatrics for preterm infants younger than 32 weeks gestational age and required oxygen supplementation for the first 28 days of life.[88] Often, the first dose is given before discharge as well. The American Academy of Pediatrics extended recommendations for the 23-valent pneumococcal polysaccharide vaccine beginning at age 2 years and could be considered for those with BPD given their chronic lung disease status once they reach that age mark.[89]

Outpatient Medical Care: Infants with BPD require ongoing outpatient medical care depending on their severity of BPD as well as other associated comorbidities with prematurity. Consultants may include specialists from neurology, cardiology, pulmonology, developmental pediatrics, gastroenterology, and nutrition. Some BPD centers may offer collaborative clinics to facilitate a comprehensive care plan and minimize burden of care for families. Outpatient efforts should be focused on making continued global progress, with the primary goals of care being the development of a well-developed child with good growth parameters and minimal burden of comorbid disease. The discharge checklist should ensure these appropriate follow-ups are made before discharge and that families know how to contact these teams should issues arise at home.

Other Discharge Elements: Other discharge elements to be considered for a thorough checklist include home supplies, developmental therapy referrals (early childhood intervention), and car seat testing. Additional elements will vary for each neonatal intensive care unit, reflecting local culture and practice. While these elements are not specific to the BPD infant, failure to complete these routine discharge tasks could also be significant risk factors for readmissions.

CONCLUSION

Infants with BPD-PH are a particularly vulnerable group of patients with multiple comorbidities, increased risk of mortality, and are often technology dependent. A comprehensive view of their care in the setting of a multidisciplinary team is necessary to meet the varied needs that these patients present. The complex nature of their care unfortunately leaves these patients at high risk for recurrent hospitalizations, poor neurologic and developmental outcomes, and serious or life-threatening events in the many transitions that they face between inpatient and outpatient services. Therefore, these infants should be cared for by a team who has special knowledge of medically complex children and PH to best support them in a global and comprehensive manner.

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