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The Role of Pulmonary Follow-up in Reducing Health Care Utilization in Infants With Bronchopulmonary Dysplasia

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Abstract

Objective. To determine whether pulmonary follow-up affects rates of rehospitalization and visitations to emergency departments (EDs) in preterm infants with bronchopulmonary dysplasia (BPD). *Methods*. In this retrospective cohort study, the authors identified all preterm infants born at ≤32 weeks' gestation with at least one outpatient visit to a pulmonary follow-up clinic at Children's Hospital Boston or a high-risk primary neurodevelopmental follow-up clinic for preterm infants. ED visits and rehospitalizations were identified through electronic medical records. *Results*. Infants with pulmonary follow-up compared with infants without pulmonary follow-up were, respectively, younger (mean gestational age 26.3 ± 2.3 vs 28.3 ± 2.3 weeks, $P < .0001$), smaller at birth (birth weight <1200 g, 87.6% vs 57.2%, $P < .0001$), and needed more supplemental oxygen (55.7% vs 2.6%, $P < .0001$) and diuretics (65.8% vs 4.7%, $P < .001$) at the time of discharge from the neonatal intensive care unit. Although rates of rehospitalization were higher in infants with pulmonary follow-up, rates of visits to an ED for respiratory causes were not statistically significant. After controlling for baseline differences in both groups, the rates of rehospitalization or ED visits were the same for both groups. *Conclusions*. Despite differences in lung disease status in infants with and without pulmonary follow-up, the rates of health care utilization were the same in both groups. Pulmonary follow-up may decrease the expected higher rates of ED visits and hospitalizations in preterm infants with more severe lung disease.

Keywords

bronchopulmonary dysplasia, prematurity

Introduction

Preterm birth (<37 weeks) is one of the most important factors leading to infant morbidity and mortality worldwide.[1,2] Bronchopulmonary dysplasia (BPD) is one of the most common morbidities associated with preterm birth.[3,4] BPD affects approximately 35% of very low-birth-weight infants (VLBW; <1500 g).[3] Although neonatal intensive care continues to improve, the rate of BPD is unchanged,[4] likely because of the increased survival of the earliest and smallest preterm infants.[5]

Newer definitions of BPD incorporate a scale of severity, reflecting the range of pulmonary injury that preterm infants may experience in their early weeks and months of life in the neonatal intensive care unit (NICU).[6] Later validation of this definition correlated higher levels of severity with worse respiratory outcomes.[7]

Previous studies have documented high rates of rehospitalization in all patients with BPD; even preterm infants with milder levels of BPD have significant respiratory morbidity.[7-11] In a study validating the National Heart Lung and Blood Institute (NHLBI) definitions of BPD, 23.9% and 26.7% of preterm infants with no and

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mild BPD, respectively, were rehospitalized within 18 to 22 months of gestational age (GA).

Referral for pulmonary follow-up for other lung diseases has been shown to improve respiratory outcomes.[12,13] Despite the potential to improve respiratory outcomes and the high background risk of respiratory morbidities in the BPD population, utilization of pulmonary follow-up seems inconsistent.

Attempts to ascertain predictors of utilization of health care resources have identified several potential factors but excluded the role of pulmonary follow-up.[14] In addition, many studies that have described rehospitalization in BPD do not reflect more recent changes in NICU management, including less systemic steroid use and different ventilator strategies. The purpose of this study was to describe health care utilization and its association with pulmonary follow-up during the first 2 years of life for a large regional cohort of preterm infants.

Methods

Study Population

All eligible infants were born at GA ≤32 weeks, independent of birth weight, and had at least one outpatient visit to a pulmonary follow-up clinic or a high-risk primary neurodevelopmental follow-up clinic for preterm infants at Children's Hospital Boston (CHB) between 2004 and 2009. The institutional review board of CHB approved this study.

Details of the NICU course were obtained from the NICU discharge summaries. Respiratory outcomes were determined by cross-referencing the list of preterm infants with all emergency department (ED) visits and hospitalizations at CHB from 2004 to 2009. We obtained the electronic records for each of the ED visits and determined whether the visit was for respiratory reasons and whether the infant was hospitalized. For all hospitalizations, we obtained discharge summaries for the patients who were hospitalized and determined their length of stay, need for ICU care, and supplemental oxygen use and intubation.

Variables

We used the NHLBI definition of BPD for infants with GA <32 weeks. Specifically, mild BPD was defined as treatment with oxygen >21% for at least 28 days and breathing room air at 36 weeks postmenstrual age (PMA) or discharge. Moderate BPD was defined as treatment with oxygen >21% for at least 28 days and need for <30% oxygen at 36 weeks PMA or discharge. Severe BPD was defined as treatment with oxygen >21% for at least 28 days and need for >30% oxygen and/or positive pressure (ventilation or continuous positive airway pressure) at 36 weeks PMA.

Primary outcomes included rehospitalizations before the first birthday and then before the second birthday (including the event before the first birthday). Additional primary outcomes included ED visits, using identical time assessments as those used for rehospitalizations.

Neonatal variables included information about the infant (GA, birth weight, sex), treatment (antenatal steroids, postnatal steroids, supplemental oxygen at NICU discharge, diuretics at NICU discharge, and surfactant), and medical complications (medical, surgical, or suspected necrotizing enterocolitis, any grade of intraventricular hemorrhage, and patent ductus arteriosus).

Because infants with BPD who contract respiratory syncytial virus (RSV) infection are far more likely than infants without infection to be admitted to the hospital, we accounted for discharge during RSV season, defined as the period between November 1 and March 31.

Statistical Analysis

We compared demographic and physiological factors among infants with and without pulmonary follow-up. Then, we examined those same demographic and physiological factors as predictors of rehospitalization among infants with and without pulmonary follow-up in several steps. First, we studied rehospitalizations before the first birthday for any reason and then focused specifically on rehospitalization before the first birthday for respiratory diagnoses. Next, we studied rehospitalizations before the second birthday for any reason and then focused specifically on rehospitalization before the second birthday for respiratory diagnoses. Finally, we repeated this whole series of analyses replacing rehospitalization with ED visits as the outcome.

These analyses used *t* tests for continuous normal data and χ^2 tests for categorical data. Multivariate logistic regression analysis was used to examine the independent effects of those variables that were significantly associated with rehospitalization in the bivariate analyses. In a manual model-building process, variables were entered in categories. We conducted separate multivariate analyses for rehospitalization before the first birthday and before the second birthday for any reason and then specifically for a respiratory reason. Then we conducted separate multivariate analyses for ED visits before the first birthday and the second birthday for any reason and then specifically for a respiratory reason. These models provided odds ratios and 95% confidence intervals adjusted for potential confounding variables. In all analyses, *P* values less than .05 were considered significant.

Table 1. Baseline Characteristics of the Participants[a]

Characteristic	Entire Cohort	Pulmonary Follow-up	No Pulmonary Follow-up	*P*
Gestational age in weeks; mean (SD)	27.2 (4.3)	25.9 (5.2)	28.6 (2.6)	<.0001
Male; n (%)	261 (55.5)	148 (62.5)	113 (48.5)	.0029
Birth weight <1200 g; n (%)	300 (71.1)	169 (87.6)	131 (57.2)	≤.0001
Antenatal steroids; n (%)	190 (40.4)	80 (33.8))	110 (47.2)	.0035
Postnatal steroids; n (%)	38 (8.1)	33 (13.9)	5 (2.4)	≤.0001
Surfactant; n (%)	325 (69)	171 (72.2)	154 (65.8)	.16
PDA; n (%)	285 (60.5)	170 (71.7)	115 (49.2)	≤.0001
BPD (total); n (%)	276 (60.7)	217 (98.2)	59 (25.2)	≤.0001
Mild; n (%)	58 (12.8)	27 (12.2)	31 (13.3)	≤.0001
Moderate; n (%)	142 (31.2)	132 (59.7)	10 (4.3)	≤.0001
Severe; n (%)	76 (16.7)	58 (26.2)	18 (7.7)	≤.0001
IVH; n (%)	104 (22.1)	51 (21.5)	53 (22.7)	.82
NEC; n (%)	42 (8.9)	27 (11.4)	15 (6.4)	.075
Home on diuretics; n (%)	167 (35.5)	156 (65.8)	11 (4.7)	≤.0001
Home on oxygen; n (%)	138 (29.3)	132 (55.7)	6 (2.6)	≤.0001
Home during RSV season; n (%)	100 (21.2)	48 (20.3)	52 (22.2)	.65
Rehospitalizations per infant <1st year; mean (SD)	0.25 (0.70)	0.32 (0.79)	0.20 (0.60)	.057
Rehospitalizations per infant <2nd year; mean (SD)	0.35 (0.91)	0.45 (1.06)	0.25 (0.73)	.012
ED visits per infant <1st year; mean (SD)	0.63 (1.55)	0.73 (1.65)	0.53 (1.4)	.15
ED visits per infant <2nd year; mean (SD)	0.96 (2.10)	1.13 (2.28)	0.8 (1.9)	.07

Abbreviations: SD, standard deviation; PDA, patent ductus arteriosus; BPD, bronchopulmonary dysplasia; IVH, intraventricular hemorrhage; NEC, necrotizing enterocolitis; RSV, respiratory syncytial virus; ED, emergency department.
[a]Infants with pulmonary follow-up compared with infants without were younger, were smaller at birth, and needed more supplemental oxygen and diuretics at discharge from the newborn intensive care unit.

Statistical analyses were done using the SAS version 9.1 (SAS Institute, Inc, Cary, NC).

Results

Study Sample

The study cohort consisted of 2 groups of preterm infants born at less than 32 weeks' gestation: those who received at least one pulmonary subspecialty follow-up appointment at Children's Hospital Boston (PULM) and those who received at least one appointment at a high-risk neurodevelopmental specialty clinic but did not receive pulmonary follow-up (NO-PULM). There were 252 PULM patients and 247 NO-PULM infants.

There were significant differences between baseline characteristics of the PULM and NO-PULM infants (Table 1). PULM infants were of substantially younger gestation and lower birth weight. Significantly more PULM infants were discharged from the NICU on diuretics and oxygen. As expected, the rates of BPD (using the NHLBI definition) were significantly higher in the PULM group. However, both groups had similar receipt of surfactant and rates of discharge from the NICU during the RSV season. The rates of necrotizing enterocolitis and intraventricular hemorrhage were similar between the 2 groups, but more of the PULM infants had a patent ductus arteriosus.

Rates of Hospitalization

We then compared rates of hospitalization between the 2 cohorts of patients. Rates of total hospitalization were higher in PULM patients than in NO-PULM at both 1 and 2 years of life (13.5% vs 6.9% and 19.0 vs 10.9 %, respectively; Figures 1 and 2). Similarly, rates of hospitalization for respiratory causes increased from 9.9% during the first year of life to 13.9% during the first 2 years of life in the PULM cohort (Figure 2) All differences in the rates of hospitalization between groups were statistically significant, with the exception of respiratory hospitalizations at 1 year of life. There was no statistically significant difference in the mean number (standard deviation) of rehospitalizations per infant between PULM patients (1.3 at 1 year and 1.4 at 2 years) and the NO-PULM cohort (1.3 at 1 year and 1.4 at 2 years) for total hospitalization. Similarly, there were no differences in respiratory hospitalizations between the cohorts.

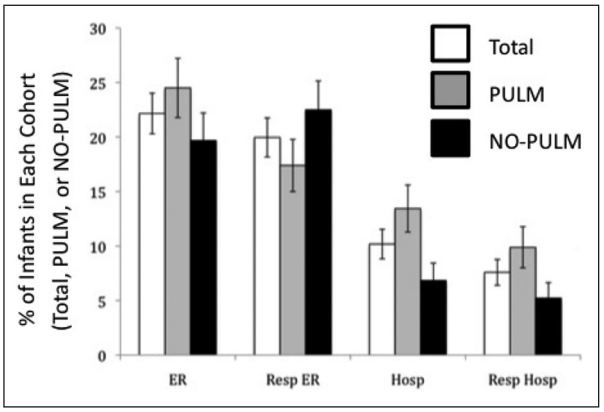

Figure 1. Emergency department visits and hospitalizations at 1 year of age in preterm infants
Infants with pulmonary follow-up (PULM) had slightly higher, but comparable, rates of emergency room (ER) visits and hospitalizations at 1 year of age than infants without pulmonary follow-up (NO-PULM).

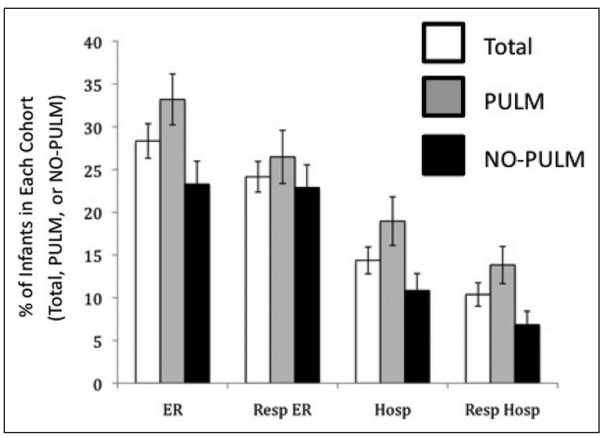

Figure 2. Emergency department visits and hospitalizations at 2 years of age in preterm infants
Infants with pulmonary follow-up (PULM) also had slightly higher, but comparable, rates of emergency room (ER) visits and hospitalizations at 2 years of age than infants without pulmonary follow-up (NO-PULM).

Multivariate Analysis

To account for baseline differences between the 2 groups, multiple logistic regression analysis was performed to determine the factors associated with hospitalization. After adjusting for the differences between the 2 cohorts, none of the differences in hospitalizations remained statistically significant (Table 2).

Rates of Emergency Department Visits

Of the PULM infants, 24.6% visited the ED during the first year of life compared with 19.8% of the NO-PULM infants (Figure 1). As expected, the rates of ED visits increased slightly when assessed during the first 2 years of life; 33.3 % of PULM infants visited the ED compared with 23.5% of the NO-PULM infants. When we examined only ED visits due to respiratory causes, the results were similar. Among all the comparisons, only the difference in rate for total ED visits within the first 2 years of age was statistically significant. The mean number (standard deviation) of ED visits per infant was 2 at both 1 and 2 years in the PULM cohort and 1.65 at 1 year and 1.85 at 2 years in the NO-PULM group (P = .15 and .07, respectively) for total ED visits. The number of ED visits for respiratory causes was 1.6 at both 1 and 2 years for the PULM infants and 1.5 at 1 year and 1.4 at 2 years in the NON-PULM group.

Multivariate Analysis

To account for baseline differences between the 2 groups, multiple logistic regression analysis was performed to determine the factors associated with ED visits. After adjusting for the differences between the 2 cohorts, none of the differences in ED visits remained statistically significant (Table 2).

Discussion

In this regional cohort study, we compared health care utilization rates in preterm infants who received at least one pulmonary subspecialty follow-up visit and those who received at least one visit at a high-risk preterm neurodevelopmental specialty clinic but did not receive pulmonary follow-up. After controlling for baseline differences in population, we found that there were no statistically significant differences in either hospitalization or ED visits rates between the 2 groups of infants.

Although other studies have described outcomes in BPD patients who received pulmonary follow-up,[14] our study is the first to attempt to quantify the role of pulmonary subspecialty follow-up in potentially decreasing resource utilization for former preterm infants. Considering the baseline differences between the 2 cohorts, we expected significantly greater percentages of visits to the ED and hospitalizations, especially for respiratory causes. Unexpectedly, the rates of respiratory ED visits at both 1 and 2 years of follow-up and the rates of respiratory hospitalizations at 1 year were not statistically different. For respiratory hospitalizations at 2 years of age, health care utilization was in fact more prevalent in the patients followed by pulmonary subspecialists. However, after adjusting for the significant differences between the 2 cohorts, none of the differences in health care utilization remained statistically significant. Our data therefore suggest that pulmonary follow-up may attenuate expected increases in health care utilization

Table 2. Multivariate Adjusted Odds Ratios (ORs) and 95% Confidence Intervals (CIs) of Rehospitalization and Emergency Department (ED) Visits in Patients With Pulmonary Subspecialty Follow-up[a]

	Unadjusted OR (95% CI)	*P*	Adjusted OR (95% CI)	Adjusted *P*[b]
ED visits (total) within 1st year of life	1.1 (0.7-1.6)	.72	1.1 (0.5-2.5)	.89
ED visits for a respiratory cause within 1st year of life	0.7 (0.5-1.1)	.15	0.6 (0.3-1.6)	.35
Hospitalizations (total) within 1st year of life	2.1 (1.1-3.8)	.02	1.4 (0.4-4.8)	.58
Hospitalizations due to a respiratory cause within 1st year of life	1.9 (0.95-3.8)	.06	2.9 (0.6-13.5)	.18
ED visits (total) within 2nd year of life	1.6 (1.1-2.5)	.03	2.1 (0.9-5.1)	.11
ED visits for a respiratory cause within 2nd year of life	1.1 (0.71-1.8)	.61	1.2 (0.4-3.1)	.75
Hospitalizations (total) within 2nd year of life	1.9 (1.1-3.3)	.03	2.0 (0.7-6.0)	.21
Hospitalizations due to a respiratory cause within 2nd year of life	2.3 (1.1-4.6)	.02	4.0 (0.9-17.7)	.07

[a]Adjusting for severity of illness, the odds of rehospitalization or ED visit were comparable for infants with pulmonary follow-up and those who did not have such follow-up.
[b]The analysis was adjusted for presence of bronchopulmonary dysplasia, discharge on home oxygen, discharge on diuretics, gestational age, male sex, birth weight less than 1200 g, use of antenatal steroids, use of postnatal steroids, and presence of patent ductus arteriosus.

because of the published correlation between increased BPD severity and risk of rehospitalization.

To put our finding in the context of the current literature, in our study, rates of rehospitalization at both 1 year and 2 years of life were substantially lower than prior published reports.[8-11,15,16] Our rates of rehospitalization in these infants at less than 32 weeks' gestation were 11% and 16% at 1 and 2 years, respectively, compared with rates of 38% to 53% in other studies.[8-11,15,16] For example, Gregoire et al[11] described 24- to 28-week GA infants at 18 months of age and found that 56% of the infants with BPD and 43% of the infants without BPD were readmitted, whereas Smith et al[15] reported a rehospitalizaton rate of 49% in the first year of life for a cohort of patients with BPD.

Some of the differences in outcomes in our study compared with prior studies may be due to differences in methodology. Variability in methods of outcome assessment (parental questionnaire vs hospital records),[16] definitions of BPD,[11,12] timing of outcome assessment (ie, 1 year vs 18-22 months),[8] and choice of outcomes themselves (total hospitalizations vs hospitalizations for respiratory cause)[9,12] may all have contributed to the differences.

The lower rates of rehospitalization at both time points in our cohorts compared with the reported literature also could be due to improvements in local neonatal care. However, studies suggest that the rates of BPD in Boston are not lower than the national rates.[17] Furthermore, the local or national rates of BPD do not seem to have decreased from the time of earlier reports to our study (personal communication of VON [Vermont Oxford Network] data). Our findings suggest that the pulmonary follow-up could explain the perceived improvement in outcomes.

This study has several significant limitations. ED visit and hospitalizations were evaluated, but other important measures of health care utilization, including urgent unscheduled primary care visits, Synagis administration, and respiratory medication use, were not examined. We only accounted for hospitalizations and ED visits to the main tertiary care facility where the infants receive their follow-up care, although a chart review of 30 patients from each cohort confirmed that >95% of all hospitalizations or ED visits for these patients were to this facility. We were also limited in that we do not have health care utilization outside CHB or any means of measuring which infants were exclusively followed by CHB. It could be that the infants were readmitted or visited ED somewhere else besides CHB, for which we did not have data. Thus, our results should be generalized to other populations with caution.

Further studies should attempt to elucidate whether pulmonary follow-up, in addition to minimizing the expected increase in health care utilization in preterm infants with severe lung disease, may also affect additional parameters of respiratory quality of life. This study also suggests that the use of pulmonary subspecialty follow-up may be an important variable to consider when evaluating respiratory outcomes in patients with BPD. Pulmonary follow-up seems to improve outcomes in the most severe BPD patients; evaluation of its role in patients with less severe disease, who are currently underreferred but who still face significant risk of rehospitalization, is needed. The establishment of guidelines to describe indications for pulmonary follow-up in premature infants, followed by rigorous evaluation to refine such guidelines, can potentially improve outcomes for these patients. Our study helps clarify the role

of pulmonary follow-up in improving respiratory outcomes in patients with BPD, and highlights the need to account for this follow-up as an important variable when assessing outcomes in this population.

Authors' Note

LR and LK contributed equally to this project and are co–first authors.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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