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Respiratory outcomes after initial hospital discharge in children with ventricular shunts and bronchopulmonary dysplasia

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Abstract

Introduction—Children born premature who require ventricular shunt placement for post hemorrhagic hydrocephalus are at increased risk for neurodevelopmental delay. We hypothesized that preterm infants with bronchopulmonary dysplasia (BPD) who require ventricular shunt (VS) placement are at additive risk for long-term respiratory morbidities due to their higher likelihood of neurodevelopmental delay. We also hypothesized that children with BPD and ventricular shunts would require frequent shunt revisions during early childhood following initial shunt placement.

Methods—All subjects were recruited from the Johns Hopkins Bronchopulmonary Dysplasia Clinic between January 2008 and November 2016. A review of demographic and clinical information was undertaken and a respiratory outcomes questionnaire was completed by the primary caregiver.

Results—Fifty-five (8.9%) of 623 subjects in the study population had ventricular shunts, with a mean 4.6 ± 2.3 years of follow-up data (range: 0.5–10.1). Subjects with VS were more likely to be born at earlier gestational ages and be discharged on supplemental oxygen compared to BPD subjects alone. Outpatient respiratory symptoms and acute care usage were similar between the two groups. BPD subjects with VS were more likely to have had gastric tubes placed. A total of 270 neurosurgical procedures were performed in subjects with VS with a mean of 4.9 ± 5.4 procedures/subject.

Conclusion—Children with ventricular shunts and BPD had similar outpatient respiratory outcomes compared to children with BPD alone; however respiratory morbidities may have been mitigated by the greater use of gastric tubes in the VS + BPD group. Multiple neurosurgical procedures were common in children with ventricular shunts.

Keywords

bronchopulmonary dysplasia (BPD); intraventricular hemorrhage; prematurity; respiratory outcomes; ventricular shunts

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1 | INTRODUCTION

Extremely low birth weight infants (ELBW) are at increased risk for intraventricular hemorrhages (IVH)¹ and bronchopulmonary dysplasia. Progressive hydrocephalus can develop in infants with high grade hemorrhages, necessitating the need for surgical placement of a ventricular shunt (VS). Limbrick et al² reported that 29.2% of infants with grades III–IV hemorrhages required a neurosurgical procedure to treat progressive post-hemorrhagic ventricular dilation. In another study by Radic et al³ 8.6% of preterm infants successfully resuscitated between 20 and 30 weeks of gestation underwent placement of a VS.

In preterm infants with VS and BPD, the combination of lung and CNS injuries may increase the severity of chronic respiratory symptoms in early postnatal life, due in part to a higher likelihood of neurological impairment in the infants who require ventricular shunts. However, it is unknown whether these children with VS + BPD, have more respiratory morbidities compared to children with BPD alone, after initial hospital discharge.

Although many infants who require ventricular shunts are not neurologically devastated, up to one-half of preterm infants with ventricular shunts have less than good neurodevelopmental outcomes.⁴ A recent meta-analysis of pooled rates of “good” neurodevelopmental outcomes in preterm children with ventricular shunts found rates of 58.7%, 50.1%, and 56.1% depending on the type of shunt.⁴ Children with CNS injury and neurodevelopmental impairment have been reported to have a higher risk for chronic respiratory symptoms.⁵ CNS injury can cause altered muscle tone, cerebral palsy, swallowing dysfunction, and/or dyscoordinated cough, which in turn can increase the risks of long-term respiratory morbidities.⁵ The added burden of dysphagia and/or aspiration in children with CNS injury may increase the severity of respiratory symptoms in children with underlying chronic lung disease⁶ such as BPD. Preterm infants with VS placement are at high risk for shunt obstructions and infections, particularly in infants who have shunts placed before six months of age,⁷ consequently recurrent shunt revisions may adversely affect CNS function.

Since infants with ventricular shunts and BPD have a greater risk of neurological impairment,^{8,9} and neurologic impairment by itself is associated with chronic respiratory symptoms,¹⁰ we hypothesized that children with both VS and BPD would have significantly more emergency room visits and hospitalizations, more symptoms of cough and wheeze, exercise limitation, nighttime respiratory symptoms and need for oral steroids and antibiotics for acute respiratory exacerbations after initial hospital discharge, compared to children with BPD alone. We also sought to determine the rate of shunt revision in our subjects with VS and BPD and whether the frequency of shunt revision was associated with adverse respiratory outcomes after initial hospital discharge.

To characterize chronic respiratory symptoms and acute respiratory care usage in BPD children with or without VS, a retrospective review of subjects recruited from an outpatient BPD clinic was performed and respiratory symptoms and acute care usage was quantified by

caregiver questionnaire.¹¹ Other determinants of BPD severity were examined including gestational age, birth weight, need for surgical PDA ligation, and supplemental oxygen requirement at initial hospital discharge.¹² Median household income and insurance status were also included in the analyses as measures of socioeconomic status. Finally, in BPD children with VS, the number of neurosurgical procedures following initial VS placement was quantified from a mean of 4.6 ± 2.3 years of follow-up data.

2 | METHODS

2.1 | Study population

All subjects ($n = 623$) in this study were recruited from the outpatient Johns Hopkins BPD Clinic between January 2008 and November 2016. Inclusion criteria included being born preterm (<32 weeks gestation), and being diagnosed with BPD by a neonatologist or pediatric pulmonologist per NICHD criteria.¹³ This study was approved by the Johns Hopkins University Institutional Review Board (Protocol#: NA_051884) with informed consent from parents/guardians.

2.2 | Demographic and clinical data

Birth weight percentile was derived from published U.S. norms.¹⁴ Race/ethnicity was self-reported. Median household income was derived from 2010 U.S. Census data based on residential zip code (U.S. median household income: \$50 502; State of Maryland median household income: \$70 004). Health insurance coverage (public vs private) was obtained from billing records. Clinical data were obtained through chart review, including the types and timing of neurosurgical procedures (VS placement, externalizations, fenestrations, cyst procedures, ventriculostomies, etc). Pulmonary hypertension was defined by the presence of pulmonary hypertension (pulmonary pressures $\geq$ 1/2 systemic pressures) after 2 months of age by echocardiogram.¹⁵

2.3 | Questionnaire data

At clinic visits, caregivers completed a questionnaire on respiratory outcomes with the aid of a data coordinator as necessary; caregivers may have completed additional questionnaires at subsequent visits as well. This questionnaire, which has not been validated, assessed the subject's history of emergency department visits, hospital admissions, systemic steroid use, and antibiotic use for respiratory reasons since the last BPD clinic visit (or since the initial hospital discharge if assessed at the first BPD clinic visit). Only questionnaires collected at ≥ 36 months of age were used for analysis. Chronic symptom morbidities assessed included the presence of cough/wheeze, inhaled rescue beta-agonist use, activity limitations owing to respiratory symptoms, and nighttime respiratory symptoms. The chronic outcomes were assessed as occurring 0 days, 1–3 days, and ≥ 4 days within the past week, but for the purposes of analysis, these outcomes were dichotomized into occurring or not occurring in the past week.

2.4 | Statistical methods

Demographic and clinical data between subjects with VS and those without were compared using chi-square and *t* tests (Table 1). The relationship between respiratory morbidities

(dependent variable) and a history of VS placement (independent variable) were assessed using logistic regression to generate odds ratios adjusted for potential confounders, including age of the subject at the time of questionnaire completion, gestational age, and birth weight percentile (as markers of prematurity), and the use of home supplemental oxygen (as a marker of BPD severity) (Table 2). As caregivers may have completed questionnaires at several clinic visits, the logistic regressions accounted for the possibility of more than one questionnaire per subject using Generalized Estimating Equations (GEE) methodology (clustered by subject).¹⁶ Kaplan-Meier methodology was used to analyze the ages at specified neurosurgical procedures (Figure 1; $n = 51$) and the age of oxygen weaning among patients on home supplemental oxygen via nasal cannula (Figure 2; $n = 212$). All analyses were conducted using STATA IC 11.0 (College Station, TX) and P values < 0.05 were considered statistically significant.

3 | RESULTS

3.1 | Demographic

The study population consisted of 623 subjects with bronchopulmonary dysplasia. Of these subjects, 55 (8.9%) had a history of VS placement for cerebrospinal fluid drainage (Table 1). The mean gestational age of subjects was 26.6 ± 2.2 weeks and the average birth weight was 908 ± 327 g. There were no differences by sex or self-reported sex/ethnicity on the basis of VS placement. Subjects with a history of VS were likely to be born at an earlier gestational age (25.5 vs 26.7 weeks; $P < 0.001$), but have a greater birth weight percentile adjusted for gestational age (47.4 vs 39.9; $P = 0.024$) compared to those without VS. Subjects with VS were more likely to have a longer initial hospitalization after birth (5.7 vs 4.1 months; $P < 0.001$) than subjects without VS. Additionally, subjects with VS were more likely to require other medical technologies/surgical procedures, including home supplemental oxygen (52.7% vs 35.2%; $P = 0.010$), patent ductus arteriosus ligation or device closure (34.6% vs 19.1%; $P = 0.007$), gastrostomy tubes (43.6% vs 23.9%; $P = 0.001$), and Nissen fundoplication (27.3% vs 15.5%; $P = 0.025$).

3.2 | Neurosurgical procedures

Fifty-five (8.9%) of the 621 subjects in the study population had a VS placed with a mean 4.6 ± 2.3 years of follow-up data (range: 0.5–10.1). A total of 270 neurosurgical procedures were performed in these subjects (Mean number of procedures per subject: 4.9 ± 5.4 [range: 1–27; median: 3]), Figure 1.

Overall, 12 (21.8%) had ventriculosubgaleal shunts only, 33 (60%) had ventriculosubgaleal shunts, which were later converted to ventriculoperitoneal (VP) shunts, and 10 (18.2%) had a VP shunt placed as the initial VS. Of the 41 patients with VP shunts, 7 (17.1%) were later converted to ventriculoatrial (VA) shunts. Where the age of first shunt placement was known, the median ages of first placement of ventriculosubgaleal shunts, VP shunts, and VA shunts were 1.0 months ($n = 41$; range: 0.2–3.0), 3.4 months ($n = 43$; range: 0.3–10.8), and 9.5 months ($n = 7$; range: 4.1–14.4), respectively. Figure 1 includes 51 subjects for whom complete data is available.

A total 25% of patients had at least one externalization of their VS, 58% had at least one VS revision or replacement, 22% had a procedure for cyst management (fenestration or catheter placement), and 9% had choroid plexus cautery. The median age of first externalization, revision, or replacement for the 58% of subjects who had at least one of these procedures was 6.7 months ($n = 32$; range: 1.5–57.2).

3.3 | Respiratory outcomes

A total of 1299 respiratory outcome questionnaires were collected on 546 subjects (Mean number of questionnaires per subject: 2.4 ± 1.8 ; range: 1–13). There were no differences in terms of having a completed questionnaire (chi square $P = 0.44$) or number of questionnaires (t test $P = 0.80$) between subjects with VS and those without. The average response rate per question was 97.3%. Adjusted clustered logistic regression was used to determine if respiratory morbidities were associated with any history of VS; regression diagnostics indicated that multicollinearity was not a substantial concern (all VIFs < 6.7). The presence of a VS was not associated with acute respiratory care use (ie, emergency department visits, inpatient hospitalizations, systemic steroid use, or antibiotic use) or chronic respiratory symptoms (ie, cough/wheeze, rescue β -agonist use, activity limitations, or nighttime symptoms) (Table 2). To determine if infants and children with VS had more severe respiratory disease and were more likely to have adverse outcomes, regression was repeated in the subset of subjects on home respiratory support (ie, supplemental oxygen, home ventilators and/or tracheostomy; $n = 207$). Again, no associations were seen between those with VS and those without in this subset (Table 2). For subjects who received supplemental oxygen via nasal cannula oxygen in the home setting, there was no difference in the age of weaning between those who had a VS and those who did not (Figure 2, log rank $P = 0.71$). Although, rescue medication and antibiotic use for respiratory illnesses were significantly associated with a greater number of neurosurgical procedures, when adjusted for gestational age, birthweight, supplemental oxygen, and age at discharge; there were no associations with respiratory outcomes when outliers who had greater than 12 neurosurgical procedures were eliminated from analyses.

4 | DISCUSSION

In this study, children with ventricular shunts and BPD had similar respiratory outcomes after initial hospital discharge, compared to children with BPD alone. This was found even though children with ventricular shunts had risk factors associated with more severe BPD, including a greater likelihood of shorter gestational age, supplemental oxygen at discharge, and longer length of initial hospitalization.¹⁷ Children with ventricular shunts and BPD however, were more likely to have a gastric tube placed during infancy. Placement of a gastric tube in infants with BPD who are at high risk for dysphagia and poor weight gain, may have mitigated long-term pulmonary complications associated with aspiration and malnutrition, in part by minimizing lung injury and enhancing “catch up” lung growth. We also found in this study that children with VS and BPD have a high ventricular shunt revision rate with a mean of 4.9 neurosurgical procedures per child over a mean of 4.6 years, indicating that children with BPD and ventricular shunts continue to have significant morbidity from shunt placement that continues into early childhood.

In this study, the VS and BPD children were more likely to be on supplemental oxygen at initial hospital discharge, indicating more severe BPD. Nevertheless they had similar outpatient respiratory outcomes, compared to children with BPD alone. However, the VS + BPD children were more likely to have had a gastric tube place for nutritional support during infancy. Placement of gastric tubes during infancy may have been more common in the children with ventricular shunts and BPD, due in part to their greater likelihood of neurodevelopmental delay and dysphagia. A recent study found that preterm infants who needed gastric tube placement prior to discharge from the NICU, were more likely to have a severe IVH and to have neurodevelopmental delay at 18–24 months of age.¹⁸ Another study evaluating children at risk for dysphagia found that aspiration, gastroesophageal reflux, and age one year or less were significant risk factors for subsequent pneumonia.¹⁹ It is possible that early gastric tube placement and/or Nissen fundoplication in our study population may have mitigated the potential adverse effects of dysphagia and aspiration on long-term respiratory outcomes in the VS children. Gastric tube placement has been used to modify aspiration risk, reduce respiratory fatigue, and support weight gain when conservative therapies fail. Minimizing aspiration and promoting adequate weight gain in BPD infants with ventricular shunts may have promoted catch up lung growth and attenuated progression of lung injury.²⁰ Therefore the early placement of gastric tubes in the children with VS + BPD may have accounted in part for the similar respiratory outcomes found, compared to the children with BPD alone. However, this will need to be studied, further in a prospective manner.

Children with ventricular shunts in this study were also found to have a high likelihood of requiring subsequent neurosurgical procedures for shunt revision. Risk factors for ventricular shunt failure and need for shunt revision in preterm infants include earlier gestational age (<than 27 weeks gestation) and low birth weight (<1.5 kg).²¹ These risk factors were also found in our subjects with VS and BPD. Ventricular shunt revisions are performed most commonly for shunt obstruction or infection and have been reported to occur most frequently in children during the first 3 years of life, nevertheless, shunt failures can continue to occur throughout the lifetime of an individual.^{21,22}

There are limitations to this study. Participants included only subjects with VS and BPD who attended a BPD outpatient clinic. Respiratory outcomes in children with VS and BPD who do not attend an outpatient BPD clinic may not be similar to those of children who attend a BPD clinic. Attending a BPD clinic may modify some of the adverse effects on respiratory health that children with VS and BPD may encounter. Nevertheless, outpatient treatments between the two groups were similar as were respiratory outcomes despite the VS + BPD children having a greater likelihood of being discharged on supplemental oxygen indicating more severe lung disease.

Another limitation to our study is that the majority of the children in our clinic were non-white and lived in urban settings, thus our results may not be generalizable to children living in other regions of the country or at other centers. We also did not quantify cognitive or motor defects in our groups of subjects with and without VS. It is possible that both groups of children had similar cognitive and motor development and degree of dysphagia. However, this would not be expected, since children with grade III and IV IVH with VS placement

have been reported to have an increased prevalence of cognitive defects and cerebral palsy^{23,24} and the VS subjects were more likely to receive gastric tubes. In addition a survival bias in the VS and BPD group could account for similar respiratory outcomes since our BPD registry only included children who survived until discharge from the hospital, whereas infants who died before discharge, including those who received palliative care management, were excluded from our analyses.

In summary, children with VS and BPD had similar respiratory outcomes as children with BPD alone, after initial hospital discharge, despite early risk factors that would suggest poorer respiratory outcomes. However, it was also noted that children with ventricular shunts and BPD were more likely to have gastric tubes placed during infancy. Early GT placement may have mitigated the potential for more adverse respiratory outcomes in the VS and BPD children despite the higher risk for neurodevelopmental delay and dysphagia. A prospective study is needed to determine if early gastric tube placement in BPD infants with VS can attenuate long-term respiratory morbidities by minimizing early aspiration risk and improving overall nutrition and lung function.

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References

1. Vento M, Cheung PY, Aguar M. The first golden minutes of the extremely-low-gestational-age neonate: a gentle approach. *Neonatology*. 2009; 95:286–298. [PubMed: 19052475]
2. Limbrick DD Jr, Mathur A, Johnston JM, et al. Neurosurgical treatment of progressive posthemorrhagic ventricular dilation in preterm infants: a 10-year single-institution study. *J Neurosurg Pediatr*. 2010; 6:224–230. [PubMed: 20809705]
3. Radic JA, Vincer M, McNeely PD. Temporal trends of intraventricular hemorrhage of prematurity in Nova Scotia from 1993 to 2012. *J Neurosurg Pediatr*. 2015; 15:573–579. [PubMed: 26030328]
4. Badhiwala JH, Hong CJ, Nassiri F, Hong BY, Riva-Cambrin J, Kulkarni AV. Treatment of posthemorrhagic ventricular dilation in preterm infants: a systematic review and meta-analysis of outcomes and complications. *J Neurosurg Pediatr*. 2015; 16:545–555.
5. Winfield, NR., Barker, NJ., Turner, ER., Quin, GL. Non-pharmaceutical management of respiratory morbidity in children with severe global developmental delay; Cochrane Database Syst Rev. 2014. p. CD010382<https://doi.org/10.1002/14651858.CD010382.pub2>
6. Gerdung CA, Tsang A, Yasseen AS III, Armstrong K, McMillan HJ, Kovesi T. Association between chronic aspiration and chronic airway infection with *pseudomonas aeruginosa* and other gram-negative bacteria in children with cerebral palsy. *Lung*. 2016; 194:307–314. [PubMed: 26883134]
7. Riva-Cambrin J, Kestle JR, Holubkov R, et al. Risk factors for shunt malfunction in pediatric hydrocephalus: a multicenter prospective cohort study. *J Neurosurg Pediatr*. 2016; 17:382–390. [PubMed: 26636251]
8. Radic JA, Vincer M, McNeely PD. Outcomes of intraventricular hemorrhage and posthemorrhagic hydrocephalus in a population-based cohort of very preterm infants born to residents of Nova Scotia from 1993 to 2010. *J Neurosurg Pediatr*. 2015:580–588. [PubMed: 26030329]
9. Bolisetty S, Dhawan A, Abdel-Latif M, Bajuk B, Stack J, Lui K. Intraventricular hemorrhage and neurodevelopmental outcomes in extreme preterm infants. *Pediatrics*. 2014; 133:55–62. [PubMed: 24379238]

10. Blackmore AM, Bear N, Blair E, et al. Prevalence of symptoms associated with respiratory illness in children and young people with cerebral palsy. *Dev Med Child Neurol*. 2016; 58:780–781. [PubMed: 27307196]
11. Collaco JM, Aherrera AD, Breyse PN, Winickoff JP, Klein JD, McGrath-Morrow SA. Hair nicotine levels in children with bronchopulmonary dysplasia. *Pediatrics*. 2015; 135:e678–e686. [PubMed: 25647675]
12. Ehrenkranz RA, Walsh MC, Vohr BR, et al. Validation of the National Institutes of Health consensus definition of bronchopulmonary dysplasia. *Pediatrics*. 2005; 116:1353–1360. [PubMed: 16322158]
13. Jobe AH, Bancalari E. Bronchopulmonary dysplasia. *Am J Respir Crit Care Med*. 2001; 163:1723–1729. [PubMed: 11401896]
14. Oken E, Kleinman KP, Rich-Edwards J, Gillman MW. A nearly continuous measure of birth weight for gestational age using a United States national reference. *BMC Pediatr*. 2003; 3:6. [PubMed: 12848901]
15. Stuart BD, Sekar P, Coulson JD, Choi SE, McGrath-Morrow SA, Collaco JM. Health-care utilization and respiratory morbidities in preterm infants with pulmonary hypertension. *J Perinatol*. 2013; 33:543–547. [PubMed: 23328926]
16. Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*. 1986; 42:121–130. [PubMed: 3719049]
17. Laughon MM, Langer JC, Bose CL, et al. Prediction of bronchopulmonary dysplasia by postnatal age in extremely premature infants. *Am J Respir Crit Care Med*. 2011; 183:1715–1722. [PubMed: 21471086]
18. Jadcherla SR, Khot T, Moore R, Malkar M, Gulati IK, Slaughter JL. Feeding methods at discharge predict long-term feeding and neurodevelopmental outcomes in preterm infants referred for gastrostomy evaluation. *J Pediatr*. 2017; 181:125–130. [PubMed: 27939123]
19. Taniguchi MH, Moyer RS. Assessment of risk factors for pneumonia in dysphagic children: significance of videofluoroscopic swallowing evaluation. *Dev Med Child Neurol*. 1994; 36:495–502. [PubMed: 8005360]
20. Boesch RP, Daines C, Willging JP, et al. Advances in the diagnosis and management of chronic pulmonary aspiration in children. *Eur Respir J*. 2006; 28:847–861. [PubMed: 17012631]
21. Bir SC, Konar S, Maiti TK, Kalakoti P, Bollam P, Nanda A. Outcome of ventriculoperitoneal shunt and predictors of shunt revision in infants with posthemorrhagic hydrocephalus. *Childs Nerv Syst*. 2016; 32:1405–1414. [PubMed: 27278283]
22. Wang JY, Jackson EM, Jallo GI, Ahn ES. Shunt revision requirements after posthemorrhagic hydrocephalus of prematurity: insight into the time course of shunt dependency. *Childs Nerv Syst*. 2015; 31:2123–2130. [PubMed: 26248674]
23. Tsai AJ, Lasky RE, John SD, Evans PW, Kennedy KA. Predictors of neurodevelopmental outcomes in preterm infants with intraparenchymal hemorrhage. *J Perinatol*. 2014; 34:399–404. [PubMed: 24556980]
24. Calisici E, Eras Z, Oncel MY, Oguz SS, Gokce IK, Dillmen U. Neurodevelopmental outcomes of premature infants with severe intraventricular hemorrhage. *J Matern Fetal Neonatal Med*. 2015; 28:2115–2120. [PubMed: 25354288]

FIGURE 1.
Number of Neurosurgical Procedures per child in children with ventricular shunts and bronchopulmonary dysplasia

FIGURE 2.
Age at nasal cannula oxygen weaning

TABLE 1

Study population

Mean±S.D. [range]	Study population (n = 623)	Ventricular shunt (n = 55)	No ventricular shunt (n = 568)	P value
Demographics				
Gender (% female)	40.9	32.7	41.7	0.20
Race (% non-white)	66.9	74.6	66.2	0.21
Gestation (weeks)	26.6 ± 2.2 [22.7–32.0]	25.5 ± 1.7 [23–31.3]	26.7 ± 2.2 [22.7–32.0]	<0.001
Birth weight (grams)	902 ± 324 [380–2188] (n = 611)	833 ± 292 [390–1770]	908 ± 327 [380–2188] (n = 556)	0.10
Birth weight (percentile)	40.6 ± 23.2 [1–95] (n = 611)	47.4 ± 22.7 [4–89]	39.9 ± 23.2 [1–95] (n = 523)	0.024
Median household income (\$000's)	63.4 ± 22.4 [15.6–156.6]	58.5 ± 18.7 [21.9–108.6]	63.9 ± 22.7 [15.6–156.6]	0.09
Public insurance (% yes)	58.6	70.9	57.4	0.052
Clinical data				
Age at discharge from NICU (months)	4.3 ± 2.7 [0.5–24.5] (n = 621)	5.7 ± 4.0 [1.8–24.5]	4.1 ± 2.5 [0.5–24.4] (n = 566)	<0.001
Age at first pulmonary clinic visit (months)	7.8 ± 5.9 [1.9–51.3]	8.0 ± 4.3 [2.5–25.7]	7.8 ± 6.0 [1.9–51.3]	0.83
Home supplemental oxygen (% yes)	36.8	52.7	35.2	0.010
Tracheostomy (% yes)	4.0	5.5	3.9	0.57
Home ventilator (% yes)	3.1	5.5	2.8	0.28
PDA ligation or device closure (% yes)	20.5	34.6	19.1	0.007
Pulmonary hypertension after 2 months of age (% yes)	15.6	20.0	15.1	0.34
Gastrostomy tube (% yes)	25.7	43.6	23.9	0.001
Nissen (% yes)	16.5	27.3	15.5	0.025
Inhaled corticosteroid use prior to age 2 yr (% yes)	78.2	88.3	77.3	0.09

TABLE 2

History of ventricular shunt as a predictor of selected respiratory outcomes

	All subjects			Subjects on home respiratory support ^b		
	Odds ratio ^a [95% C.I.]	N	P value	Odds Ratio [95% C.I.]	N	P value
Emergency department visit	1.07 [0.63, 1.83]	543 (1286 forms)	0.79	1.15 [0.52, 2.53]	205 (575 forms)	0.73
Inpatient hospitalization	1.52 [0.93, 2.46]	544 (1287 forms)	0.09	1.60 [0.80, 3.19]	206 (575 forms)	0.18
Systemic steroid use	1.14 [0.66, 1.98]	541 (1279 forms)	0.63	1.17 [0.52, 2.62]	205 (574 forms)	0.70
Antibiotic use	0.73 [0.41, 1.31]	543 (1284 forms)	0.29	0.61 [0.25, 1.50]	206 (575 forms)	0.28
Cough or wheeze	1.21 [0.78, 1.87]	537 (1252 forms)	0.40	1.10 [0.57, 2.14]	203 (559 forms)	0.77
Rescue β -agonist use	1.33 [0.83, 2.14]	537 (1252 forms)	0.24	0.87 [0.40, 1.88]	201 (554 forms)	0.72
Activity limitations	1.20 [0.58, 2.49]	531 (1227 forms)	0.62	0.65 [0.29, 1.47]	200 (548 forms)	0.30
Nighttime symptoms	1.63 [0.93, 2.85]	535 (1248 forms)	0.09	1.19 [0.47, 3.03]	202 (557 forms)	0.71

^a Odds ratios for respiratory outcomes (dependent variable) given a history of a ventricular shunt (independent variable) were generated through logistic regression and adjusted for potential confounders, including gestational age, birth weight percentile, home supplemental oxygen use, and age at the time of questionnaire completion.

^b Of the 207 subjects in this study with questionnaire data on home respiratory support, 187 were on supplemental oxygen via nasal cannula, 17 were on home ventilators, and three had tracheostomies without home ventilators. Odds ratios were calculated in a similar manner to the all subjects regressions, except there were not adjusted for supplemental oxygen.