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Varying Patterns of Home Oxygen Use in Infants at 23–43 Weeks' Gestation Discharged from United States Neonatal Intensive Care Units

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Abstract

Objectives—To compare proportions of infants at different gestational ages discharged from the neonatal intensive care unit (NICU) on home oxygen, to determine how many were classified with chronic lung disease based on timing of discharge on home oxygen, and to determine the percentage discharged on home oxygen who received mechanical ventilation.

Study design—We evaluated a retrospective cohort of infants of 23–43 weeks' gestational age discharged from 228 NICUs in 2009, using the Pediatrix Clinical Data Warehouse. Multilevel logistic regression analysis identified predictors of home oxygen use among extremely preterm, early-moderate preterm, late preterm, and term infants. Duration of mechanical ventilation and median length of stay were calculated for infants discharged on home oxygen.

Results—For the 48 877 infants studied, the rate of home oxygen use ranged from 28% (722 of 2621) in extremely preterm infants to 0.7% (246 of 34 934) in late preterm and term infants. Extremely preterm infants composed 56% (722 of 1286) of the infants discharged on home oxygen; late preterm and term infants, 19% (246 of 1286). After gestational age, mechanical ventilation was the main predictor of home oxygen use; however, 61% of the late preterm and term infants discharged on home oxygen did not receive ventilation. The median length of hospital stay was 95 days (IQR, 76–114 days) for extremely preterm infants discharged on home oxygen, but only 15 days (IQR, 10–22 days) for late preterm and term ventilated infants discharged on home oxygen.

Conclusion—Although home oxygen use is uncommon in later-gestation infants, the greater overall numbers of later-gestation infants contribute significantly to the increased need for home oxygen for infants at NICU discharge. Neither respiratory failure nor lengthy hospitalization is a prerequisite for home oxygen use at later gestational age.

Infants discharged from the neonatal intensive care unit (NICU) have high rates of morbidities requiring extensive resource utilization postdischarge, as has been well studied in the extremely preterm population.^{1,2} Later-gestation infants that require NICU care also have increased use of medical resources after discharge.^{3–6} Although later-gestation infants have lower rates of medical complications compared with extremely preterm infants, they compose a substantial proportion of the infants who need specialized services after NICU discharge.^{6–8}

A common medical need after NICU discharge is home oxygen therapy for bronchopulmonary dysplasia (BPD). We recently reported on the prevalence and predictors of home oxygen use for infants at 23–31 weeks' gestation with BPD, as well as the significant intercenter variation in home oxygen use.⁹ There are other reasons besides BPD for the use of home oxygen therapy.¹⁰ Respiratory failure in late preterm and term infants can lead to chronic lung disease (CLD) and home oxygen use. Clinical trials for respiratory failure reported CLD in 3%–20% of late preterm and term infants and home oxygen use in 5%–11% of these infants.^{11–15} To date, there are no published data comparing proportions of infants discharged with home oxygen therapy across gestational ages.

Studies of late preterm and term infants with respiratory failure have reported average NICU lengths of stay of 17–29 days. Because CLD is defined as an oxygen requirement at 28 days of life or discharge, whichever comes first, we hypothesized that some infants in this age group would be discharged on home oxygen therapy before 28 days of life.^{12,14,15} These later-gestation infants would be classified with CLD according to the proposed National Institutes of Health consensus definition, based on the initiation of home oxygen therapy.¹⁶ This difference in timing of discharge on home oxygen therapy could have significant effects on reported rates of CLD outside of the extremely preterm population; however, there is no information about this practice.

Home oxygen therapy also may be used in infants without respiratory failure. In modern neonatal care, many extremely preterm infants do not require significant initial oxygen or mechanical ventilation support, yet develop BPD owing to arrest of lung development. These infants are at risk for use of home oxygen therapy despite not having a severe initial respiratory course.^{17,18} At later gestational ages, home oxygen also may be used in infants without respiratory failure as a means toward discharge for infants who have achieved other discharge readiness milestones. There are no data on the use of home oxygen therapy in infants who did not receive mechanical ventilation.

The goals of the present study were: (1) to compare the proportion of infants discharged from the NICU with home oxygen therapy who were born at extreme preterm, early-moderate preterm, late preterm, or term gestation; (2) to determine how many infants in each gestational age group were classified with CLD based on the timing of discharge on home oxygen therapy; (3) to identify clinical predictors of home oxygen use for each gestational age group; and (4) to determine the percentage of infants discharged on home oxygen who had received mechanical ventilation. This information could serve as a starting point to identify potential best practices for neonates of all gestational age groups with respiratory disease.

Methods

The data for this analysis were acquired from the Pediatrix Clinical Data Warehouse, a deidentified electronic medical records database containing information on all patients cared for by the Pediatrix Medical Group. This group oversees 15%–20% of NICU admissions in the US across a range of sizes and types of hospitals.¹⁹ We conducted a retrospective cohort analysis of all infants at 23–43 weeks' gestational age discharged to home from a Pediatrix center in 2009. We excluded infants with major congenital anomalies, as identified by listed diagnoses. We also excluded infants who died or were transferred before discharge, along with infants reported from centers >4000 feet above sea level, because of differences in use of home oxygen therapy in those areas.^{20,21}

The primary outcome was home oxygen use. For infants of 23–31 weeks' gestation, we used the consensus definition of moderate-severe BPD as supplemental oxygen at 36 weeks' corrected age as our primary designation of BPD, because this better captures the subset of infants with the primary outcome of home oxygen use.^{9,16} The use of physiologic testing to diagnose BPD was not recorded in this data set.²² CLD (proposed) was defined as receipt of supplemental oxygen at 28 days of life or at discharge, whichever came first.¹⁶ Infants receiving mechanical ventilation at 36 weeks' corrected age or 28 days of life were classified with CLD, regardless of their supplemental oxygen requirement.

Gestational age was recorded as completed weeks of gestation based on obstetric estimate, and was divided into 4 groups: extreme preterm (23–28 weeks), early-moderate preterm (29–33 weeks), late preterm (34–36 weeks), and term (37–43 weeks). Birth weight was recorded as a continuous variable; small birth weight for gestational age was defined as below the 10th percentile for age based on published growth charts.²³

We collected information on sex, multiple birth versus singleton birth status, receipt of antenatal steroids, and race/ethnicity. To describe respiratory support, we recorded the days of mechanical ventilation, use of surfactant, and use of nitric oxide. Respiratory diagnoses were recorded as documented in the medical record, including pneumonia or sepsis, pneumothorax, persistent pulmonary hypertension of the newborn (PPHN), and meconium aspiration syndrome (MAS). Sepsis and pneumonia were considered a single diagnosis, as were PPHN and MAS owing to the overlap between these disorders.¹⁴ Because detailed reports, such as chest radiography findings, were not available, more granular categorizations were not considered. Length of stay was recorded as a continuous variable. Hospitals were assigned a random identification number to maintain deidentification. The altitude of each hospital's location was recorded as a continuous variable.

We compared demographics, respiratory diagnoses, and respiratory support requirements by gestational age, assessing differences in proportions by gestational age using the χ^2 test for differences in proportions and the Kruskal-Wallis test for differences in median values. Rates of missing data were assessed; infants with missing data were retained in the dataset. We calculated rates of home oxygen use for each gestational age group, as well as the gestational age distribution for the subset of infants discharged on home oxygen therapy. For infants with BPD or CLD, we calculated the proportion in each gestational age group who

were discharged to home before 36 weeks' corrected age or 28 days of life, comparing differences using the χ^2 test.

To determine clinical characteristics predicting home oxygen use across varying gestational ages, we fit 4 separate multilevel logistic regression models, 1 for each gestational age group studied. Each model was adjusted for hospital altitude, with hospitals as random intercepts. We included all variables in each model, with exceptions based on clinical relevance; antenatal steroids and patent ductus arteriosus were included only in models for infants <34 weeks' gestational age, whereas PPHN and MAS were included only in models for infants ≥ 34 weeks' gestational age. Variables, or categories within variables, were included only if they were present in at least 50 infants. Each model's fit was assessed with receiver operating characteristic (ROC) curves, including the full model and a reduced model that included only variables with $P < .05$. Differences between the area under the receiver operating characteristic curve (AUC) of the full and reduced models were compared using the χ^2 test. To assess the fit of clinical risk factors alone versus a model including hospital-level variation, we also calculated the AUC of corresponding full and reduced logistic regression models. Finally, for the infants discharged on home oxygen therapy, we compared the distribution of duration of mechanical ventilation by gestational age, evaluating differences using the χ^2 test. Statistical significance was accepted at $P < .05$ for all analyses.

This study was approved by the Medical College of Wisconsin's Institutional Review Board. The Pediatrix Clinical Data Warehouse was certified as Health Insurance Portability and Accountability Act compliant and approved for research use by the Western Institutional Review Board.

Results

A total of 48 877 infants were identified who were at 23–43 weeks' gestational age, had no major congenital anomalies, and were discharged from the NICU in the hospital at which they were born in 2009 (Table I). Infants were treated in 228 hospitals across 30 states. No infants were missing information regarding the outcome of home oxygen use. Rates of BPD and CLD varied by gestational age, from 37% in extremely preterm infants to 0.7% in term infants. The median length of stay varied by gestational age, from 78 days in extremely preterm infants to 6 days in term infants.

Gestational Age Distribution of Home Oxygen Use

Only 1286 of the 48 877 infants (2.6%) were discharged on home oxygen therapy. The rates of home oxygen therapy varied by gestational age (Figure 1, A). The gestational age distribution of the infants discharged on home oxygen therapy is shown in Figure 1, B. Extremely preterm infants accounted for slightly more than one-half (56%), and latepreterm and term infants for nearly one-fifth (19%), of the infants discharged on home oxygen therapy.

Length of Stay, CLD, and Home Oxygen Use

The median length of stay for infants who received mechanical ventilation and were discharged on home oxygen therapy ranged from 97 days (IQR, 79–115 days) in extremely preterm infants to 14 days (IQR, 9–18 days) in term infants. Of the 1667 infants classified with BPD or CLD, 86% of late preterm and 89% of term infants were classified with CLD because of discharge on home oxygen before 28 days of life. In contrast, only 1.7% of extremely preterm infants were classified with BPD because of discharge on home oxygen before 36 weeks' corrected age.

Clinical Predictors of Home Oxygen Use

Table II lists clinical risk factors predicting the odds of home oxygen use for each gestational age group studied. At all gestational ages, longer duration of mechanical ventilation significantly increased the odds of home oxygen use. In term infants, the presence of PPHN and MAS increased the odds of home oxygen use. Among early-moderate preterm and term infants, non-Hispanic black and Hispanic infants had lower odds of home oxygen use than non-Hispanic white infants, adjusted for clinical risk factors. ROC AUC values ranged from 0.78 to 0.86 for the multilevel models and from 0.70 to 0.82 for the fixed-effects only models. In general, there were few significant differences in AUC among the models, including full and reduced models (Tables III–VI; available at www.jpeds.com).

Home Oxygen Therapy and Mechanical Ventilation

Figure 2 displays the distribution of the 1286 infants discharged on home oxygen therapy by gestational age and duration of mechanical ventilation. Although longer duration of mechanical ventilation increased the odds of home oxygen use, many infants in each gestational age group were not ventilated or were ventilated only briefly. Almost one-quarter (22%; 159 of 722) of the extremely preterm infants discharged on home oxygen therapy were ventilated for ≤ 7 days; 33% (103 of 318) of the early-moderate preterm infants and 62% (151 of 246) of the late preterm and term infants discharged on home oxygen therapy never received mechanical ventilation. Of the 151 late-preterm and term infants discharged on home oxygen therapy who never received mechanical ventilation, 126 (83%) had a respiratory-related diagnosis, such as respiratory distress or transient tachypnea of the newborn. Thirty-one of those infants had more a complex respiratory diagnosis, including respiratory failure, pneumothorax, or PPHN; 18 were infants of diabetic mothers, 19 were term infants with poor feeding, and 14 had apnea. Of the remaining 25 infants without a listed respiratory diagnosis, 22 underwent evaluation for sepsis or pneumonia; other diagnoses included poor feeding ($n = 7$), apnea ($n = 6$), and hypotonia or seizures ($n = 6$).

Hospital Rates of Home Oxygen Use in Late-Preterm and Term Infants

Home oxygen therapy for infants of later gestational ages was provided at discharge by many NICUs in the study cohort. Of the 228 centers, 164 discharged >100 infants. Of these 164 centers, 147 (90%) discharged at least 1 infant on home oxygen therapy; 104 of the 147 (71%) discharged at least 1 late-preterm or term infant on home oxygen therapy, and 76 (52%) discharged at least 1 late-preterm or term infant on home oxygen therapy who never

received mechanical ventilation. The 104 centers that discharged at least 1 late-preterm or term infant on home oxygen therapy had a median of 2 infants (IQR, 1–3) discharged on home oxygen therapy in 2009.

Discussion

Here we report rates of home oxygen use in a group of infants of all gestational ages, particularly late-preterm and full-term infants. Based on our data, we can draw 4 main conclusions. (1) Extremely preterm infants accounted for slightly more than one-half of infants discharged on home oxygen therapy. One-fifth of the infants without a major congenital anomaly discharged on home oxygen therapy were late preterm and term infants. (2) Unlike extreme preterm infants with BPD, 86%–89% of late preterm and term infants classified with CLD were discharged on home oxygen therapy before 28 days of life, complicating the definition of CLD in this gestational age group. (3) Similar to what has been reported in extremely preterm infants, clinical risk factors, such as duration of mechanical ventilation and presence of PPHN or MAS, predicted the likelihood of home oxygen use in later-gestation infants, with ROC values of 0.78–0.86. (4) Despite the increased odds of home oxygen use in infants who received mechanical ventilation, mechanical ventilation is not a prerequisite for home oxygen use at any gestational age.

Home oxygen therapy is commonly used in extremely preterm infants with BPD.¹⁰ Consequently, in the analysis for our previous report on home oxygen use in infants of 23–31 weeks' gestational age, we were surprised to find that restricting gestational age omitted a large proportion of the infants discharged on home oxygen therapy. That observation prompted the present study. Home oxygen use has been reported in late preterm and full-term infants in clinical trials of nitric oxide and surfactant for severe respiratory failure.^{12,14,15} Fortunately, respiratory failure requiring mechanical ventilation is uncommon in later-gestation infants, occurring in only 25 of 1000 live births of normal birth weight infants.⁸ Extreme prematurity is also uncommon, however, occurring in only 8 of 1000 live births.^{8,24} The greater overall proportion of infants at later gestational ages contributes to the number of later-gestation infants receiving home oxygen therapy.

We found that 86%–89% of late preterm and term infants classified with CLD were discharged to home with oxygen therapy before 28 days of life rather than being kept in the NICU with an oxygen requirement. This differs from our previous finding in preterm infants with BPD, nearly all of whom were still hospitalized at 36 weeks' corrected age.⁹ The length of stay reported here is consistent with that found in major clinical trials enrolling late preterm and term infants with severe respiratory failure. Konduri et al¹⁴ reported a median length of stay of 17–18 days for term infants receiving inhaled nitric oxide, and Lotze et al¹⁵ reported a 17- to 18-day median length of stay in a trial of surfactant for severe respiratory failure. The present study is a retrospective study, and as such our findings require prospective validation. But if corroborated, they may prompt consideration of revising the classification of CLD in later-gestation infants to better describe this heterogeneous patient population.¹⁶

Our previous study detailed predictors of home oxygen therapy in preterm infants at 23–31 weeks' gestation.⁹ In later-gestation infants, we found that infections, PPHN, and MAS increased the odds of home oxygen therapy, in agreement with previous literature regarding reasons for respiratory failure in neonates.⁸ We also noted decreased odds of home oxygen use in non-Hispanic black and Hispanic infants compared with non-Hispanic white infants in some gestational age groups, after adjusting for clinical predictors. This finding may represent varying discharge preferences from providers, families, or insurance companies; previous studies have found lower rates of home oxygen and apnea monitor use in infants with public insurance or living in areas with less access to home nursing services.^{25,26} Because home oxygen use in late-preterm and term infants occurs infrequently in a single center, we were unable to determine the extent of institutional variation in home oxygen use for later-gestation infants, as we showed in our previous report on home oxygen use in extremely preterm infants. Future research should explicitly address these issues, to ensure that best practices are applied and individualized optimally across populations.

It is not surprising that a small proportion of extremely preterm infants discharged on home oxygen therapy received only a brief period of mechanical ventilation; this fits with the current literature on BPD resulting from alveolar arrest rather than severe respiratory failure requiring intensive support.¹⁸ Nonetheless, it is striking that 93% of the late preterm and term infants discharged with home oxygen therapy never received mechanical ventilation. We did not examine the use of noninvasive positive pressure support in this study, owing to differences in coding these therapies among centers; future research is planned to address this issue. Regardless, our finding that the majority of late preterm and full-term infants discharged on home oxygen never had respiratory failure underscores the need for further discussion regarding the use of home oxygen therapy in this population.

Home oxygen therapy is likely used similarly as a means to facilitate earlier discharge in infants of all gestational ages. This application has been reported in infants with BPD who would otherwise require weeks to months of additional hospital care,⁹ but it may be an underrecognized phenomenon for infants of all gestational ages with less severe lung disease. Bakewell-Sachs et al²⁷ reported that infants may acquire feeding, apnea, and temperature stability milestones before successful weaning from oxygen. Such infants, even those without severe lung disease, may be considered good candidates for home oxygen therapy. At a system level, variation in hospital practices, such as the use of cardiorespiratory monitors or home use of methylxanthines for apnea of prematurity, have been shown to affect length of stay and may indirectly affect the use of home oxygen therapy by changing the time of readiness for discharge.²⁸ Owing to the infrequent nature of home oxygen use in late-preterm and term infants in a single center, we were unable to identify high-oxygen-use centers vs low-oxygen-use centers to test this hypothesis. Future studies are planned to explicitly compare hospital practices that affect the use of home oxygen therapy and length of stay.

The present study has several limitations. A deidentified data warehouse was not sufficient for a detailed analysis of many factors that might affect an individual infant's diagnosis of lung disease, such as whether a physiological test for BPD was used, attempts to wean from oxygen, or specific chest radiography findings. Reported variables might not adequately

reflect a patient's severity of illness. Despite our attempt to exclude infants with major congenital anomalies by manually checking recorded diagnoses, some misclassification bias may still be present. We also were unable to capture varying processes of care across a heterogeneous group of NICUs. Despite these limitations, however, our findings can help identify important patterns for future research. Strengths of this study include the large number of infants available for analysis, the recent single-year data collection that minimizes changes in treatment patterns over time, and the broad variety of types and sizes of NICUs represented in the dataset.

Although home oxygen use is less common in later-gestation infants, the greater overall number of later-gestation infants contributes significantly to the home oxygen needs of infants at NICU discharge. Neither respiratory failure nor lengthy hospitalization is a prerequisite to homeoxygen use. Appropriate discharge planning requires research that addresses best practices for all infants, identifying NICU discharge practices and outpatient follow-up structures that optimize outcomes for infants and their families.

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Glossary

AUC	Area under the curve
BPD	Bronchopulmonary dysplasia
CLD	Chronic lung disease
MAS	Meconium aspiration syndrome
NICU	Neonatal intensive care unit
PPHN	Persistent pulmonary hypertension of the newborn
ROC	Receiver operating characteristic

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Figure 1.

A, Rates of home oxygen use by gestational age. Numbers above the bars indicate the number of infants in each group who were discharged with home oxygen therapy divided by the total number of infants in that gestational age group, along with the corresponding percentage. **B**, Gestational age distribution of the 1286 infants who were discharged on home oxygen therapy. The graphs show the gestational age group, number of infants in that gestational age group discharged with home oxygen therapy, and percentage of the total number of infants discharged with home oxygen therapy.

Figure 2.

Distribution of gestational age and days of mechanical ventilation for the 1286 infants discharged on home oxygen therapy. The number in each stacked-column box indicates the number of infants at each gestational age and each duration of mechanical ventilation. The duration of mechanical ventilation for infants discharged with home oxygen therapy was significantly different by gestational age group ($P < .001$, χ^2 test).

Table 1

Description of surviving neonates discharged to home in 2009

	ALL	Gestational age			
		23–28 weeks	29–33 weeks	34–36 weeks	37–43 weeks
Number	48 877	2621	11 322	16 561	18 378
Demographic and birth characteristics					
Birth weight, g, median (IQR)	2444 (1868–3160)	920 (752–1100)	1710 (1442–1964)	2350 (2069–2661)	3310 (2950–3670)
SGA, %	13	9	10	18	11
Male sex, %	55	51	53	55	58
Multiple birth, %	19	25	33	26	2
Antenatal steroid use, %	32	83	77	-	-
Race/ethnicity, %					
Non-Hispanic white	48	45	50	52	45
Non-Hispanic black	19	31	22	18	17
Hispanic	23	16	18	21	29
Other	5	5	5	5	5
Respiratory support, %					
Duration of mechanical ventilation					
0 days	85	17	77	92	94
1–3 days	7	20	13	5	4
4–7 days	3	10	6	2	2
8–28 days	2.4	23	3	0.6	0.6
29–56 days	1.2	20	0.6	<0.1	<0.1
>56 days	0.6	10	0.1	<0.1	<0.1
Surfactant use	16	77	30	11	4
Inhaled nitric oxide	0.4	3	0.3	0.1	0.4
Respiratory diagnoses, %					
Pneumothorax	4	6	2	2	6
Pneumonia or sepsis	15	40	13	9	18
Patent ductus arteriosus, not ligated	7	44	10	-	-
Patent ductus arteriosus, surgically ligated	0.7	11	0.3	-	-

	Gestational age				
	ALL	23–28 weeks	29–33 weeks	34–36 weeks	37–43 weeks
PPHN or MAS	3			1	6
CLD*	3	37	4	0.8	0.7
Length of stay, days, median (IQR)	10 (6–21)	78 (63–98)	27 (19–39)	11 (8–15)	6 (4–8)

SGA, small for gestational age.

All differences in gestational age groups were significant at $P < .01$ by χ^2 analysis or the Kruskal-Wallis test of medians as appropriate. Infants missing data were retained in the analysis, and constituted <3% of each gestational age group.

* CLD refers to moderate-severe BPD in infants 23–31 weeks' gestation, or the proposed National Institutes of Health consensus definition of CLD for infants 32–43 weeks' gestation.

Table II

Predictors of home oxygen use in infants at 23–43 weeks' gestation

Risk factor	23–28 weeks			29–33 weeks			34–36 weeks			37–43 weeks		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Mechanical ventilation, days												
0	0.4	0.3–0.7	<.001	0.4	0.3–0.6	<.001	0.2	0.1–0.4	<.001	0.4	0.2–0.7	.004
1–3	1.0			1.0			1.0			1.0		
4–7	1.0	0.7–1.6	.904	1.5	1.0–2.3	.060	1.8	0.8–3.6	.129	1.0	0.3–2.6	.928
8–28	1.3	0.9–1.9	.119	5.8	3.9–8.7	<.001	11.2	5.5–22.8	<.001	4.9	2.0–11.6	<.001
29–56	3.7	2.5–5.3	<.001	15.8	8.2–30.4	<.001	-	-	-	-	-	-
>56	7.5	4.7–12.1	<.001	-	-	-	-	-	-	-	-	-
Surfactant use												
No				1.0								
Yes				1.7	1.2–2.4	.001						
PPHN or MAS												
No	-	-	-	-	-	-				1.0		
Yes	-	-	-	-	-	-				2.8	1.6–4.8	<.001
Gestational age, wk												
23–24	2.1	1.4–3.0	<.001	-	-	-	-	-	-	-	-	-
25–26	1.6	1.3–2.1	<.001	-	-	-	-	-	-	-	-	-
27–28	1.0			-	-	-	-	-	-	-	-	-
29–31	-	-	-	1.5	1.2–2.0	.003	-	-	-	-	-	-
32–33	-	-	-	1.0			-	-	-	-	-	-
Patent ductus arteriosus												
None	1.0			1.0			-	-	-	-	-	-
Not ligated	1.2	0.9–1.5	.229	1.5	1.1–2.0	.010	-	-	-	-	-	-
Ligated	2.0	1.4–2.1	<.001	-	-	-	-	-	-	-	-	-
Birth weight												
SGA	1.8	1.3–2.6	.001	1.6	1.1–2.3	.003						
AGA	1.0			1.0								
Sex												

Risk factor	23–28 weeks			29–33 weeks			34–36 weeks			37–43 weeks		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Male	1.3	1.0–1.5	.037									
Female	1.0											
Infection												
No							1.0					
Yes							0.4	0.2–0.9	.018			
Race/ethnicity												
Non-Hispanic white				1.0						1.0		
Non-Hispanic black				0.6	0.4–0.8	.001				0.6	0.3–1.0	.096
Hispanic				0.9	0.6–1.3	.462				0.6	0.3–1.0	.037
ROC AUC												
Multilevel		0.83			0.86						0.78	
Fixed effects		0.78			0.82						0.73	

AGA, appropriate for gestational age.

Four separate multilevel logistic regression models of predictors of home oxygen use within gestational age groups, 23–28 weeks, 29–33 weeks, 34–36 weeks, and 37–43 weeks. Dashes (–) indicate variables or categories that were not considered in that regression model, owing either to small number (the longer-duration mechanical ventilation categories at later gestational ages) or clinical relevance (gestational age, patent ductus arteriosus, PPHN, or MAS). Blank spaces indicate variables that were not significant in a full model for that gestational age group. Unadjusted percent of home oxygen use for each risk factor, χ^2 tests of differences in proportions of home oxygen use, full multilevel regression models, and comparisons of ROC AUC between full and reduced models are reported in Tables III–VI.

Table III

Rates and predictors of home oxygen use in infants at 23–28 weeks' gestation

Risk factor	Home oxygen, %	P	aOR	95% CI	P
Total	28				
Mechanical ventilation, days					
0	8	<.001	0.4	0.3–0.7	<.001
1–3	15		1.0		
4–7	17		1.0	0.7–1.6	.904
8–28	23		1.3	0.9–1.9	.119
29–56	48		3.7	2.5–5.3	<.001
>56	64		7.5	4.7–12.1	<.001
Gestational age					
23–24 weeks	56	<.001	2.1	1.4–3.0	<.001
25–26 weeks	37		1.6	1.3–2.1	<.001
27–28 weeks	17		1.0		
Patent ductus arteriosus					
None	19	.001	1.0		
Treated medically	28		1.2	0.9–1.5	.229
Surgically ligated	56		2.0	1.4–2.1	<.001
Birth weight					
SGA	46	<.001	1.8	1.3–2.6	.001
AGA	26		1.0		
Sex					
Male	29	.13	1.3	1.0–1.5	.037
Female	26		1.0		
Race					
Non-Hispanic white	29	.098	1.0		
Non-Hispanic black	28		0.9	0.7–1.2	.545
Hispanic	23		0.7	0.5–0.9	.024
Pneumothorax					
No	26	<.001	1.0		

Risk factor	Home oxygen, %	P	aOR	95% CI	P
Yes	47		1.5	1.0–2.2	.059
Antenatal steroid use					
No	28	.773	1.0		
Yes	27		1.3	1.0–1.7	.104
Elevation above sea level					
<1000 feet	27	.023	1.0		
Each additional 1000 feet	27–42		1.2	0.9–1.5	.197
Sepsis or pneumonia					
No	22	<.001	1.0		
Yes	36		1.1	0.9–1.4	.275
Multiple birth					
No	28	.778	1.0		
Yes	27		0.9	0.7–1.1	.384
Surfactant use					
No	18	<.001	1.0		
Yes	30		1.1	0.8–1.4	.626
Multilevel model					
Full model AUC	0.836 (0.819–0.853)		0.776 (0.756–0.796)		
Reduced model AUC	0.834 (0.817–0.851)		0.769 (0.748–0.789)		
P	.095				.006

The “Home oxygen, %” column represents the unadjusted percent of home oxygen use for each risk factor; the *P* value for this variable compares differences in the proportion of home oxygen use by the χ^2 test. The “aOR” column presents the results of multilevel logistic regression, with hospitals treated as a random intercept. For each model, all variables were retained in the model; a reduced model was then fit including only variables significant at *P* < .05 (reported in Table II). Full and reduced multilevel models were compared by the AUC, as well as the AUC for fixed-effects only full and reduced models.

Table IV

Rates and predictors of home oxygen use in infants at 29–33 weeks' gestation

Risk factor	Home oxygen, %	P	aOR	95% CI	P
Total	2.8				
Mechanical ventilation, days					
0	1.2	<.001	0.4	0.3–0.6	<.001
1–3	4		1.0		
4–7	6.8		1.5	1.0–2.3	.060
8–28	20.4		5.8	3.9–8.7	<.001
29–56	38.1		15.8	8.2–30.4	<.001
>56	-		-	-	-
Surfactant use					
No	1.3	<.001	1.0		
Yes	6.4		1.7	1.2–2.4	.001
Birth weight					
SGA	2.6	<.001	1.6	1.1–2.3	.003
AGA	4.5		1.0		
Gestational age					
29–31 weeks	4.8	<.001	1.5	1.2–2.0	.003
32–33 weeks	1.6		1.0		
Patent ductus arteriosus					
None	2.1	<.001	1.0		
Treated medically	8.3		1.5	1.1–2.0	.010
Surgically ligated	-		-	-	-
Race					
Non-Hispanic white	3.2	.007	1.0		
Non-Hispanic black	1.9		0.6	0.4–0.8	.001
Hispanic	2.9		0.9	0.6–1.3	.462
Sex					
Male	3.2	.004	1.3	1.0–1.6	.068
Female	2.3		1.0		

Risk factor	Home oxygen, %	P	aOR	95% CI	P
Elevation above sea level					
<1000 feet	2.6	<.001	1.0		
Each additional 1000 feet	3.3–7.6		1.1	0.9–1.4	.215
Sepsis or pneumonia					
No	2.5	<.001	1.0		
Yes	5		1.1	0.8–1.5	.530
Antenatal steroid use					
No	2.9	.699	1.0		
Yes	2.8		0.9	0.7–1.3	.675
Pneumothorax					
No	2.7	<.001	1.0		
Yes	8.6		1.0	0.5–1.8	.939
Multiple birth					
No	2.8	.758	1.0		
Yes	2.7		1.0	0.8–1.3	.977
Multilevel model					
Fixed effects only					
Full model AUC	0.862 (0.841–0.882)		0.821 (0.796–0.846)		
Reduced model AUC	0.862 (0.841–0.882)		0.815 (0.790–0.841)		
P	.910			.086	

Multilevel logistic regression model for infants 29–33 weeks gestation. Labeling and methods are as described in Table III.

Table V

Rates and predictors of home oxygen use among infants 34–36 weeks' gestation

Risk factor	Home oxygen, %	P	aOR	95% CI	P
Total	0.8				
Mechanical ventilation, days					
0	0.5	<.001	0.2	0.1–0.4	<.001
1–3	2.3		1.0		
4–7	4.2		1.8	0.8–3.6	.129
8–28	21.5		11.2	5.5–22.8	<.001
29–56	-		-	-	-
>56	-		-	-	-
Sepsis or pneumonia					
No	0.8	.902	1.0		
Yes	0.8		0.4	0.2–0.9	.018
PPHN or MAS					
No	0.7	<.001	1.0		
Yes	6.3		1.9	0.9–4.0	.093
Elevation above sea level					
<1000 feet	0.7	<.001	1.0		
Each additional 1000 feet	0.2–3.0		1.2	1.0–1.6	.095
Multiple birth					
No	0.9	.027	1.0		
Yes	0.5		0.8	0.5–1.2	.284
Pneumothorax					
No	0.7	<.001	1.0		
Yes	3.1		1.4	0.7–2.8	.333
Race					
Non-Hispanic white	0.9	.345	1.0		
Non-Hispanic black	0.6		0.8	0.5–1.5	.571
Hispanic	0.7		0.7	0.4–1.2	.155
Surfactant use					

Risk factor	Home oxygen, %	P	aOR	95% CI	P
No	0.6	<.001	1.0		
Yes	2.7		1.1	0.7–2.0	.665
Sex					
Male	0.9	.135	1.1	0.7–1.6	.723
Female	0.7		1.0		
Birth weight					
SGA	0.6	.226	1.0		
AGA	0.8		1.0	0.6–1.6	.897
Multilevel model					
Fixed effects only					
Full model AUC	0.851 (0.819–0.884)		0.760 (0.714–0.807)		
Reduced model AUC	0.851 (0.818–0.883)		0.697 (0.652–0.743)		
P	.927				<.001

Multilevel logistic regression model for infants 34–36 weeks gestation. Labeling and methods are as described in Table III.

Table VI

Rates and predictors of home oxygen use in infants at 37–43 weeks' gestation

Risk factor	Home oxygen, %	P	aOR	95% CI	P
Total	0.6				
Mechanical ventilation, days					
0	0.5	<.001	0.4	0.2–0.7	.004
1–3	2		1.0		
4–7	2.2		1.0	0.3–2.6	.928
8–28	12.7		4.9	2.0–11.6	<.001
29–56	-		-	-	-
>56	-		-	-	-
PPHN or MAS					
No	0.5	<.001	1.0		
Yes	3.1		2.8	1.6–4.8	<.001
Elevation above sea level					
<1000 feet	0.5	<.001	1.0		
Each additional 1000 feet	0.6–1.8		1.4	1.1–1.8	.002
Race					
Non-Hispanic white	0.7	.319	1.0		
Non-Hispanic black	0.6		0.6	0.3–1.0	.096
Hispanic	0.5		0.6	0.3–1.0	.037
Pneumothorax					
No	0.6	<.001	1.0		
Yes	1.6		1.8	1–3.2	.051
Sepsis or pneumonia					
No	0.6	.514	1.0		
Yes	0.7		0.8	0.5–1.3	.405
Sex					
Male	0.6	.623	0.8		
Female	0.7		1.0	0.6–1.3	.456
Surfactant use					

Risk factor	Home oxygen, %	P	aOR	95% CI	P
No	0.5	<.001	1.0		
Yes	3.3		1.2	0.6–2.5	.555
Birth weight					
SGA	0.6	.966	1.0	0.6–1.9	.924
AGA	0.6		1.0		
Multiple birth					
No	0.6	.824	1.0		
Yes	0.5		1.0	0.2–4.0	.956
			Multilevel model	Fixed effects only	
Full model AUC			0.778 (0.731–0.825)	0.733 (0.680–0.786)	
Reduced model AUC			0.783 (0.737–0.829)	0.723 (0.668–0.777)	
P			.518	.364	

Multilevel logistic regression model for infants 37–43 weeks gestation. Labeling and methods are as described in Table III.