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ARTICLE

# Prospective Multicenter Study of Bronchiolitis: Predicting Safe Discharges From the Emergency Department

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**What's Known on This Subject**

Bronchiolitis is the leading cause of hospitalization for infants. Nonetheless, there is variability in the disposition and care of children with bronchiolitis. Clinicians must differentiate children who need to be hospitalized from those children who could be safely discharged home.

**What This Study Adds**

Few studies have investigated the low-risk end of the bronchiolitis severity spectrum. This large multicenter study of children presenting to the ED with bronchiolitis identified several factors associated with safe discharge, including cutpoints for respiratory rate and oxygen saturation.

## ABSTRACT

OBJECTIVE. Bronchiolitis is the leading cause of hospitalization for infants. Our objective was to identify factors associated with safe discharge to home from the emergency department.

METHODS. We conducted a prospective cohort study during 2 consecutive bronchiolitis seasons, from 2004 to 2006. Thirty US emergency departments contributed data. All patients were <2 years of age and had a final emergency department attending physician diagnosis of bronchiolitis. Using multivariate logistic regression, a low-risk model was developed with a random half of the data and then validated with the other half.

RESULTS. Of 1456 enrolled patients, 837 (57%) were discharged home from the emergency department. The following factors predicted safe discharge to home: age of ≥2 months, no history of intubation, a history of eczema, age-specific respiratory rates (<45 breaths per minute for 0–1.9 months, <43 breaths per minute for 2–5.9 months, and <40 breaths per minute for 6–23.9 months), no/mild retractions, initial oxygen saturation of ≥94%, fewer albuterol or epinephrine treatments in the first hour, and adequate oral intake. The importance of each factor varied slightly according to age, but the comprehensive model (developed and validated for all children <2 years of age) yielded an area under the receiver operating characteristic curve of 0.81, with a good fit of the data.

CONCLUSIONS. This large multicenter study of children presenting to the emergency department with bronchiolitis identified several factors associated with safe discharge, including cut points for respiratory rate and oxygen saturation. Although the low-risk model requires further study, we believe that it will assist clinicians evaluating children with bronchiolitis and may help reduce some unnecessary hospitalizations.

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**Key Words**
bronchiolitis, discharge, emergency department, risk factors, guideline

**Abbreviations**
ED—emergency department
CI—confidence interval
RSV—respiratory syncytial virus

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BRONCHIOLITIS IS THE leading cause of hospitalization for infants,[1,2] and hospitalization rates increased 2.4-fold from 1980 to 1996.[1] When children with bronchiolitis are admitted to the hospital, it is not for specific therapies but rather for supportive care and monitoring of respiratory functioning.[3] Although most children with bronchiolitis have a mild course, some children have severe outcomes and are admitted to an ICU, are intubated, or die.[4–7] One of the key roles for clinicians is to differentiate children who need to be hospitalized for supportive care from children who could be safely discharged to home.

The disposition decision is clear for certain patients, but the difficulty and uncertainty of determining the appropriate level of supportive care is documented by the variability in the disposition and care of children with bronchiolitis.[8,9] Admission rates for infants with bronchiolitis are significantly different between pediatric and general emergency departments (EDs)[10] and even among pediatric ED attending physicians.[11] Moreover, one study documented that, among 10 hospitals, the thresholds for PICU admission and intubation varied widely.[5]

Researchers have analyzed historical, clinical, and laboratory data from children with respiratory syncytial virus (RSV) lower respiratory tract infection to understand the relative effects of these variables on a child's severity of illness,[4,12] monthly risk of hospitalization,[13] or bronchiolitis-associated deaths.[6,7] These studies provide clinicians with some data to help determine which children with bronchiolitis may have a severe outcome; children, however, who have bronchiolitis of mild-to-moderate severity may be admitted to the hospital for observation because clinicians do not want to discharge to home children who may experience unanticipated clinical deterioration.

Few studies have investigated prediction rules for the low-risk end of the bronchiolitis severity spectrum, either predictors of safe discharges to home or predictors of unnecessary hospitalizations (ie, admitted infants who ultimately do not require a hospital level of care). One single-center study classified cases of bronchiolitis in children presenting to an ED as mild or severe[14] but did not address specifically safe discharges to home. If low-risk children could safely avoid unnecessary hospitalizations, then such children would avoid risks of medical errors,[15] being exposed to other infectious diseases in the hospital, and unnecessarily exposing other hospitalized children to their infectious respiratory pathogens.[16,17] Evidence-based discharge decisions also might decrease the more than $500 million now spent on bronchiolitis hospitalizations each year.[18]

Therefore, we conducted a prospective, multicenter, observational study of almost 1500 children <2 years of age who presented to the ED with bronchiolitis. Our objective was to identify factors associated with safe discharge to home from the ED and then to develop a comprehensive low-risk model for children with bronchiolitis.

## METHODS

### Study Design

We conducted a prospective cohort study during the 2004 to 2006 winter seasons, as part of the Multicenter Airway Research Collaboration. The Multicenter Airway Research Collaboration is a division of the Emergency Medicine Network (www.emnet-usa.org). Using a standard protocol, investigators at 30 EDs in 14 US states provided 18- to 24-hour/day coverage for a median of 2 weeks from December to March, to coincide with large numbers of bronchiolitis visits. All patients were treated at the discretion of the treating physician. Inclusion criteria were an attending physician diagnosis of bronchiolitis, age of <2 years, and the ability of the parent/guardian to give informed consent. As defined by the American Academy of Pediatrics in its 2006 position statement, children with bronchiolitis typically have "rhinitis, tachypnea, wheezing, cough, crackles, use of accessory muscles, and/or nasal flaring."[3] We applied (retrospectively) the American Academy of Pediatrics definition to the children in this cohort, and 98% satisfied this definition. The only exclusion criterion was previous enrollment. The institutional review board at each of the 30 participating hospitals approved the study, and informed consent was obtained for all participants.

### Data Collection

The ED interview assessed patients' demographic characteristics, medical and environmental history, details of the acute illness (including medications used during the week leading up to the ED visit), and duration of symptoms. Median household income was estimated by using patients' home zip codes.[19] Children were considered to be premature if they were born at <35 weeks of gestation. ED chart review provided clinical data, including respiratory rate at triage, clinical assessment of degree of retractions (collapsed for analysis into none/mild versus moderate/severe), oxygen saturation, management, and disposition. Follow-up data regarding relapse were collected in a telephone interview 2 weeks after the ED visit. For purposes of the current analysis, the outcome of interest was discharge to home after an ED visit for bronchiolitis. A relapse event was defined as any urgent visit to an ED or clinic because of worsening of bronchiolitis during the 2-week follow-up period. To examine the reproducibility of the relapse classification, 2 authors (Drs Mansbach and Camargo) independently reviewed the 2-week follow-up data for 100 randomly sampled cases ($\kappa = 0.98$).

All forms were reviewed by site principal investigators (physicians) before submission to the Emergency Medicine Network coordinating center in Boston. At the coordinating center, the data were further reviewed by trained personnel and underwent double data entry.

### Statistical Analyses

All analyses were performed by using Stata 9.0 (Stata Corp, College Station, TX). Data are presented as proportions (with 95% confidence intervals [CIs]), means (with SDs), or medians (with interquartile ranges). The association of factors was examined by using $\chi^2$ tests, Student's *t* tests, and Kruskal-Wallis rank tests, as appropriate. All *P* values are 2-tailed, with $P < .05$ being considered statistically significant.

Multivariate logistic regression was used to evaluate the association between the candidate predictors and the discharge decision. The 1456 enrolled patients were assigned randomly to 1 of 2 data sets (a derivation data set and a validation data set). Factors associated with discharge in univariate analyses were assessed for inclusion in the multivariate model if they were associated with the outcome at $P < .20$. The following factors were also included because of their potential clinical significance: gender, race, parental history of asthma, ED visit during the week before the index ED visit, and duration of symptoms. Continuous variables were assessed for linearity. Factors that did not show a linear relationship with ED disposition were further evaluated in quintiles, to assess where the factor should be categorized. On the basis of this process, oxygen saturation was dichotomized at 94% when included in the multivariate model. Age-specific normal values for respiratory rate were assigned as follows: 0 to 1.9 months, 45 breaths per minute; 2 to 5.9 months, 43 breaths per minute; 6 to 23.9 months, 40 breaths per minute.[20–22] When oxygen saturation was evaluated in the multivariate model, both lowest oxygen saturation and triage oxygen saturation were examined; they were found to be similarly predictive of ED disposition (data not shown). Concomitant medical disorders, being born premature, and having a history of eczema were evaluated for interactions in the final model. The final model is presented for the 1012 children with complete data on all factors in the model. Creating dummy variables for missing responses and including them in the multivariate model to include children with complete data and those with missing data yielded similar results; therefore, we present the model for children with complete data. Results are presented as odds ratios with 95% CIs.

Finally, we performed 3 sensitivity analyses to address ambiguities in the clinical definition of bronchiolitis, that is, (1) restricting the sample to the 98% of children who met the American Academy of Pediatrics definition,[3] (2) restricting the sample to the 82% of children <1 year of age, and (3) restricting the sample to the 92% of children without a previous diagnosis of reactive airways disease. These analyses excluded 33, 269, and 120 children, respectively. The final model did not differ materially from the overall study results for any of these 3 clinical subgroups (data not shown).

## RESULTS

### Study Group

Of 2129 eligible children presenting to the ED with bronchiolitis, 1459 (68%) were enrolled. Among eligible children not enrolled in the study, 89% were missed by the site personnel and 11% were missed for other reasons, including refusal to participate. Two patients who left against medical advice and 1 patient who did not have disposition recorded as part of the ED record or in administrative records were excluded from analysis. Of 1456 analyzed patients, 837 (57%; 95% CI: 55%–60%) were discharged to home. The remaining 619 children were admitted to an observation unit ($n$ = 96; 7%), regular ward ($n$ = 479; 33%), or ICU ($n$ = 44; 3%).

### Enrolled Versus Nonenrolled

Enrolled and nonenrolled children were similar with respect to demographic factors, with no significant differences in terms of age, gender, or race/ethnicity (all $P > .10$). Enrolled children were more likely to have a history of wheezing (30% vs 23%; $P = .001$) and a history of eczema (18% vs 5%; $P < .001$), and they also had a slightly lower mean initial respiratory rate (47 breaths per minute vs 45 breaths per minute; $P = .002$). Although enrolled children were more likely to be admitted (43% vs 28%; $P < .001$), they did not differ from nonenrolled children with respect to other medical history factors, ED presentation, or clinical management (data not shown).

### Derivation and Validation Models

In the derivation data set, significant predictors of being sent home from the ED were age of ≥2 months, no history of intubation, history of eczema, respiratory rate less than normal for age, no/mild retractions, initial oxygen saturation of ≥94%, fewer albuterol or epinephrine treatments in first hour, and adequate oral intake. Gender, race/ethnicity, parent history of asthma, ED visit during the past week, and duration of symptoms were included in the model because of their potential clinical significance. The area under the receiver operating characteristic curve for the multivariate model in the derivation data set was 0.84, with a Hosmer-Lemeshow test statistic of 14.03 (8 *df*; $P = .08$). The same factors were found to be significant when the derivation results were applied to the validation data set. The model also performed well in the validation data set. The area under the receiver operating characteristic curve for the multivariate model in the validation data set was 0.78, with a Hosmer-Lemeshow test statistic of 6.40 (8 *df*; $P = .60$). Because the multivariate model performed well in both the derivation and validation data sets, we present the results hereafter for the entire cohort ($n$ = 1456).

### Demographic Factors

The children's demographic characteristics are shown in Table 1. Discharged children were older than those who were admitted and were more likely to be of nonwhite race/ethnicity. The 2 groups did not differ with respect to gender, median household income, insurance status, or primary care provider status.

### Medical History

Medical history also is shown in Table 1. Children who were discharged were less likely to have any concomitant medical disorder. Looking at specific concomitant medical disorders (including asthma, seizure disorder, spastic diplegia/quadriplegia, chronic lung disease, immunodeficiency, reflux, and congenital heart disease), we found that children with congenital heart disease were less likely to be discharged (0.8% vs 3%; $P = .002$).

Table 1 also shows that discharged children were more likely to weigh ≥5 lb at birth, to be born >35 weeks of gestation, and to have a history of wheezing, eczema, and a family history of asthma. Previous hospitalization was not associated with a child's discharge, but children who had never been intubated were more likely to be discharged. Medication use during the week leading up to the ED visit also differed between the groups; discharged children were less likely to use inhaled or systemic corticosteroids during the week leading up to the ED visit. Discharged children also had fewer primary care provider and ED visits during the week leading up to the index ED visit.

### ED Presentation and Course

ED presentation and course are shown in Table 2. Discharged children were more likely to have symptoms for >7 days before presenting to the ED. At triage, discharged children, as expected, had a lower initial respiratory rate, were more likely to have no or mild retractions and higher initial oxygen saturation, and were less likely to have the presence of a cough in the ED. However, the 2 groups did not differ with respect to the presence of wheezing. During the ED stay, discharged children continued to have higher oxygen saturations,

TABLE 1 **Demographic Characteristics and Medical History of Children Presenting to the ED With Bronchiolitis, According to Disposition**

| | Admitted ($n$ = 619) | Sent Home ($n$ = 837) | $P$ |
|---|---|---|---|
| Demographic characteristics | | | |
| Age, median (IQR), mo | 4.3 (1.9–8.5) | 6.9 (4.2–11.3) | <.001 |
| Age of <2 mo, % | 27 | 6 | <.001 |
| Age of mother, mean ± SD, y | 28 ± 6 | 27 ± 6 | .65 |
| Male, % | 59 | 58 | .81 |
| Nonwhite race/ethnicity, % | 59 | 68 | <.001 |
| Estimated median household income, median (IQR), US$ | 45 414 (33 339–58 001) | 43 193 (30 281–56 685) | .20 |
| Insurance, % | | | .11 |
| Private HMO/commercial | 32 | 30 | |
| Medicaid | 59 | 63 | |
| Other public | 5 | 3 | |
| None | 4 | 4 | |
| Has PCP, % | 96 | 97 | .13 |
| Medical history | | | |
| Concomitant medical disorder, % | 21 | 16 | .02 |
| Weight when born, % | | | .02 |
| <3 lb | 4 | 2 | |
| 3–5 lb | 8 | 5 | |
| ≥5 lb | 89 | 92 | |
| Premature, %[a] | 12 | 8 | .006 |
| Breastfed, % | 55 | 53 | .36 |
| History of wheezing, % | 27 | 33 | .008 |
| History of eczema, % | 13 | 22 | <.001 |
| Attends day care, % | 19 | 29 | <.001 |
| Has siblings in home, % | 97 | 97 | .78 |
| Family history of asthma, % | | | .03 |
| Mother only | 15 | 18 | |
| Father only | 14 | 12 | |
| Both parents | 3 | 5 | |
| Neither parent | 69 | 65 | |
| Maternal smoking during pregnancy, % | 18 | 18 | .69 |
| Secondhand smoke exposure, % | 15 | 16 | .75 |
| Ever hospitalized, % | 23 | 20 | .12 |
| Ever intubated, % | 10 | 5 | <.001 |
| Inhaled $\beta$-receptor agonist use in past week, % | 36 | 32 | .08 |
| Antibiotic use in past week, % | 18 | 15 | .20 |
| Medication use during past week, % | | | |
| Inhaled/nebulized corticosteroid | 10 | 6 | .006 |
| Systemic corticosteroid | 11 | 6 | .001 |
| Health care utilization during past week | | | |
| No. of PCP visits, median (IQR) | 1 (0–1) | 0 (0–1) | <.001 |
| No. of ED visits, median (IQR) | 0 (0–1) | 0 (0–0) | <.001 |

IQR indicates interquartile range; HMO, health maintenance organization; PCP, primary care provider.
[a] Premature was defined as gestation of <35 weeks.

received fewer antibiotics and laboratory tests, and were more likely to have adequate oral intake. Among children who underwent viral testing, discharged children were less likely to test positive for RSV. Among children who received chest radiographs, discharged children were less likely to have abnormal radiographic findings.

### Outcomes of Children Discharged to Home

Among the 837 children who were sent home, 722 (86%) presented for follow-up evaluation within 2 weeks. Among these 722 children, 49 (7%) had worsening bronchiolitis that led to hospital admission. Twenty-seven (55%) of these hospitalizations took place within 24 hours of ED discharge. One child (4%) had apnea, no child was admitted to the ICU, and no child was intubated.

### Multivariate Predictors of Discharge

The final multivariate model for children discharged to home is shown in Table 3. The area under the receiver operating characteristic curve for the final model was 0.81, with a Hosmer-Lemeshow test statistic of 3.93 (8 *df*; $P$ = .86). In the final model, potential interactions were evaluated for concomitant medical disorders, premature birth, and history of eczema, and no statistically significant interactions were observed (all $P$ > .20). Because of the potential differences in children across age groups, the final model was stratified with 4 age groups, that is, 0 to 1.9 months, 2 to 5.9 months, 6 to 11.9

**TABLE 2 ED Presentation and Clinical Course Among Children With Bronchiolitis, According to Disposition**

| | Admitted ($n = 619$) | Sent Home ($n = 837$) | $P$ |
|---|---|---|---|
| Duration of symptoms of ≥7 d, % | 16 | 23 | .001 |
| Respiratory rate, mean ± SD, breaths per min | 51 ± 15 | 44 ± 14 | <.001 |
| Respiratory rate less than normal for age, %[a] | 28 | 46 | <.001 |
| Retractions, % | | | <.001 |
| None/mild | 68 | 90 | |
| Moderate/severe | 32 | 10 | |
| Oxygen saturation in room air, mean ± SD, % | 95 ± 4 | 97 ± 2 | <.001 |
| Lowest room air oxygen saturation, mean ± SD, % | 93 ± 6 | 97 ± 2 | <.001 |
| Presence of cough, % | 87 | 82 | .006 |
| Presence of wheeze, % | 76 | 74 | .31 |
| Given inhaled $\beta$-receptor agonist treatment, % | 88 | 92 | .01 |
| No. of inhaled $\beta$-receptor agonist treatments in first hour, median (IQR) | 1 (0–1) | 1 (0–1) | .001 |
| No. of inhaled $\beta$-receptor agonist treatments over entire ED stay, median (IQR) | 1 (1–2) | 1 (1–2) | .02 |
| Given epinephrine treatment, % | 39 | 17 | <.001 |
| No. of epinephrine treatments in first hour, median (IQR) | 0 (0–0) | 0 (0–0) | <.001 |
| No. of epinephrine treatments over entire ED stay, median (IQR) | 0 (0–1) | 0 (0–0) | <.001 |
| Given corticosteroids, % | 15 | 16 | .65 |
| Given antibiotics, % | 17 | 10 | <.001 |
| Any laboratory tests, % | 92 | 66 | <.001 |
| Oral intake, % | | | <.001 |
| Adequate oral intake | 60 | 84 | |
| Inadequate oral intake | 32 | 8 | |
| Unknown | 8 | 7 | |
| Viral test results, %[b] | | | |
| RSV positive | 42 | 18 | <.001 |
| Influenza A positive | 2 | 1 | .07 |
| Influenza B positive | 0.3 | 0.2 | .77 |
| Adenovirus positive | 0.3 | 0.1 | .40 |
| Abnormal chest radiographic findings, %[c] | 70 | 59 | .001 |
| ED length of stay, median (IQR), min | 240 (155–355) | 165 (119–239) | <.001 |

IQR indicates interquartile range.

[a] Normal values for age groups were as follows: 0 to 1.9 months of age, 45 breaths per minute; 2 to 5.9 months of age, 43 breaths per minute; 6 to 11.9 months of age, 40 breaths per minute; 12 to 23.9 months of age, 40 breaths per minute.

[b] Among children who underwent viral testing ($n = 721$).

[c] Abnormal radiographic findings included atelectasis, infiltrate, hyperinflated, or other findings ($n = 975$ children with chest radiographs).

months, and 12 to 23.9 months. Stratified results are shown in Table 4. One variable, adequate oral intake, was a significant predictor of safe discharge across all ages.

### Performance of Multivariate Model

We used a cutoff value of .50 for the predicted probability from the multivariate model to predict discharge to home from the ED. Among the 1012 children with data on all factors included in the multivariate model, there were 163 (17%) children who were misclassified with the multivariate model (ie, the child was predicted as being discharged from the hospital when the child was actually admitted to the hospital). Among those 163 children, 33 (20%) were admitted to an observation unit and 130 (80%) were admitted to a regular medical ward. None of the misclassified children was admitted to the ICU. The median hospital length of stay among those children was 2 days (interquartile range: 1–3 days), which is shorter than the length of stay of children who were admitted and were classified appropriately by the model (2 vs 3 days; $P < .001$).

When criteria from the low-risk model were applied individually to those 163 patients, as a clinician would in the ED setting, there were only 3 remaining patients (0.3%) who were truly missed (ie, predicted to be at low risk but hospitalized directly from the ED). All 3 patients were admitted to a regular ward, and each was hospitalized for 2 days. Twenty-one patients (2%) were predicted to be low risk and were discharged to home but then were hospitalized within 24 hours after ED discharge. None of those 21 patients had apnea, ICU admission, or intubation during the follow-up period.

Finally, 99 children who did not meet the factors in the low-risk guideline criteria were discharged to home. Of those 99 children, 8 (8%; 95% CI: 4%–15%) were admitted to the hospital within 24 hours after ED discharge. None of those children proceeded to have apnea, to be admitted to the ICU, or to be intubated (0%; 95% CI: 0%–4%).

## DISCUSSION

In providing care to a child with bronchiolitis, one of the main objectives is to decide the level of support the child

TABLE 3 **Predictors of Being Discharged to Home Among Children Treated in the ED for Bronchiolitis**

| | Odds Ratio (95% CI) | *P* |
|---|---|---|
| Age of ≥2 mo | 5.19 (3.13–8.60) | <.001 |
| Female | 0.96 (0.71–1.29) | .78 |
| Nonwhite race/ethnicity | 1.13 (0.82–1.54) | .45 |
| ≥1 parent with asthma | 0.97 (0.71–1.34) | .87 |
| No history of intubation | 2.25 (1.25–4.08) | .007 |
| Eczema | 1.87 (1.27–2.77) | .002 |
| No ED visit during past week | 1.21 (0.84–1.75) | .31 |
| Duration of symptoms of >7 d | 1.14 (0.78–1.67) | .50 |
| Respiratory rate less than normal for age[a] | 2.02 (1.46–2.80) | <.001 |
| Mild retractions | 2.78 (1.91–4.06) | <.001 |
| Initial room air oxygen saturation of ≥94% | 2.28 (1.56–3.34) | <.001 |
| Lower no. of $\beta$-receptor agonist treatments during first hour | 1.60 (1.30–1.98) | <.001 |
| Lower no. of epinephrine treatments during first hour | 1.92 (1.30–2.84) | .001 |
| Oral intake | | |
| Adequate | 6.02 (3.87–9.35) | <.001 |
| Inadequate | 1.00 (reference) | |
| Unknown | 3.80 (1.89–7.63) | <.001 |

Area under the receiver operating characteristic curve: 0.81; Hosmer-Lemeshow test statistic (8 *df*): 3.93 ($P = .86$).

[a] Normal values for age groups were as follows: 0 to 1.9 months of age, 45 breaths per minute; 2 to 5.9 months of age, 43 breaths per minute; 6 to 11.9 months of age, 40 breaths per minute; 12 to 23.9 months of age, 40 breaths per minute.

will need, which ranges from care at home to intensive care. Because no clinician wants to discharge a child to home who might have an unanticipated clinical deterioration, many children are admitted to the hospital for observation. Using prospective multicenter data, we have identified several historical and clinical factors that are associated with a child's safe discharge to home. When all of these factors are combined, the resulting model reliably predicts a child's safe discharge to home from the ED. Although this low-risk model requires additional study, and future studies of predictors of unnecessary hospitalizations are needed, we think that this model will assist clinicians in evaluating children with bronchiolitis and may help reduce some unnecessary hospitalizations. Safely reducing unnecessary hospitalizations would not only reduce health care costs but children discharged to home would avoid the risks of medical errors, being exposed to other infectious diseases in the hospital, and exposing other children and staff members in the hospital to respiratory pathogens.

Previous studies have identified demographic, environmental, and medical history variables associated with severe bronchiolitis. One of these variables is age, specifically the relationship between age and apnea.[23] Previous data indicated that younger infants are at a high-risk of having bronchiolitis-associated apnea,[23,24] and our multicenter data support an age of ≥2 months as a protective factor for safe discharge to home. Regardless of age, male patients with bronchiolitis have been found to have a greater likelihood of being hospitalized than female patients,[1,25] and male patients have been found to be more likely to die as a result of bronchiolitis.[7] Other potentially important variables that increase severity of illness include household crowding,[26–28] child care attendance,[29] passive smoke exposure,[30] low socioeconomic status,[29,31] and days of illness.[14] We evaluated all of these demographic, environmental, and medical history factors and, although some were associated significantly with discharge in univariate analyses, only age of ≥2

TABLE 4 **Predictors of Being Discharged to Home Among Children Treated in the ED for Bronchiolitis, According to Age Group**

| | Odds Ratio (95% CI) | | | |
|---|---|---|---|---|
| | Age 0–1.9 mo ($n = 226$) | Age 2–5.9 mo ($n = 518$) | Age 6–11.9 mo ($n = 446$) | Age 12–23.9 mo ($n = 269$) |
| Female | 1.1 (0.3–3.7) | 0.8 (0.5–1.4) | 1.3 (0.7–2.2) | 0.7 (0.3–1.4) |
| Nonwhite race/ethnicity | 0.6 (0.2–2.0) | 1.2 (0.7–2.0) | 1.6 (0.9–2.9) | 1.1 (0.5–2.5) |
| ≥1 parent with asthma | 0.5 (0.1–1.8) | 1.1 (0.7–1.8) | 0.9 (0.5–1.7) | 0.9 (0.4–2.0) |
| No history of intubation | 1.2 (0.03–47) | 1.4 (0.3–6.2) | 6.3 (2.3–17) | 1.8 (0.5–6.0) |
| Eczema | 18.0 (1.3–257.4) | 1.3 (0.7–2.6) | 1.9 (0.9–3.7) | 2.3 (0.9–5.8) |
| No ED visit during past week | 1.0 (0.2–4.1) | 1.6 (0.9–3.0) | 0.9 (0.5–1.8) | 1.4 (0.5–3.9) |
| Duration of symptoms of >7 d | 5.3 (0.8–37.7) | 1.1 (0.6–1.9) | 1.7 (0.8–3.4) | 0.3 (0.1–1.0) |
| Respiratory rate less than normal for age[a] | 7.3 (1.9–28.0) | 1.5 (0.9–2.5) | 2.9 (1.5–5.9) | 2.4 (0.9–6.0) |
| Mild retractions | 1.1 (0.2–5.0) | 2.1 (1.1–4.0) | 3.4 (1.7–6.7) | 5.5 (2.2–14) |
| Initial room air oxygen saturation of ≥94% | 4.4 (0.6–29) | 1.4 (0.7–3.0) | 4.4 (2.2–8.7) | 2.9 (1.3–6.8) |
| Lower no. of $\beta$-receptor agonist treatments during first hour | 3.0 (1.0–9.4) | 1.8 (1.3–2.6) | 1.4 (1.0–2.1) | 1.4 (0.8–2.4) |
| Lower no. of epinephrine treatments during first hour | 12.1 (1.5–96.4) | 1.7 (0.9–3.2) | 1.4 (0.7–3.0) | 2.2 (0.8–6.3) |
| Oral intake | | | | |
| Adequate | 14 (2.1–88.8) | 5.1 (2.6–10.2) | 4.3 (2.0–9.4) | 11.1 (3.1–41) |
| Inadequate | 1.0 (reference) | 1.0 (reference) | 1.0 (reference) | 1.0 (reference) |
| Unknown | 7.8 (0.4–170.0) | 1.2 (0.4–3.7) | 8.4 (1.9–37.8) | 14.4 (2.8–121.5) |

[a] Normal values for age groups were as follows: 0 to 1.9 months of age, 45 breaths per minute; 2 to 5.9 months of age, 43 breaths per minute; 6 to 11.9 months of age, 40 breaths per minute; 12 to 23.9 months of age, 40 breaths per minute.

months independently predicted safe discharge in the multivariate model.

Previous data also identified children with comorbid medical conditions, including chronic lung disease, hemodynamically significant congenital heart disease, and immunocompromised status, as being at high risk for severe bronchiolitis.[1,4,32–34] In the final model, none of these factors independently predicted safe discharge to home from the ED, but it is important to note that, despite our large numbers, we had small numbers of children with immunodeficiency and congenital heart disease.

In the overall model, the historical/physical examination factors that predicted safe discharge included no history of intubation and the child having eczema. Although premature and low birth weight infants have been identified as risk factors for more severe bronchiolitis,[6,35] these 2 factors were not retained in the low-risk multivariate model. A child's intubation status may be a more clinically oriented proxy for premature birth, low birth weight, and/or chronic lung disease.

We were surprised by the apparent "protective" effect of a child having eczema, especially for age of $<2$ months. Considering that the numbers are smaller when the results are stratified according to age and there is a risk of inaccurate parental report, our eczema results must be interpreted with caution. However, this finding is not new. For example, Law et al,[26] in a multicenter study of predictors of hospitalization attributable to RSV for children born between 33 and 35 weeks of gestation, found in their multivariate analyses that having a family history of eczema protected children against hospitalization. In addition, Bradley et al[36] found that less-severe RSV infections were associated with maternal atopy. The explanation for these results is unclear, but several studies have now demonstrated the same finding, that is, having eczema or a family history of eczema may protect against severe bronchiolitis. This finding merits further investigation.

The more-objective clinical parameters predicting safe discharge were respiratory rate, degree of retractions, and oxygen saturation. We are not aware of previous studies establishing age-specific, low-risk respiratory rates for children with bronchiolitis in the ED. Indeed, normal respiratory rates for this age group are not well established,[21] although there are data for children when asleep.[20,37] One caveat of the identified cutpoints for respiratory rate is that a child may have a low respiratory rate and, instead of being well, actually be tiring and in extremis. Other clinical parameters (eg, oxygen saturation, retractions, and air entry) may identify such a child.

Although the clinical value of pulse oximetry has been established, particularly as an adjunct to respiratory rate data,[38] there are no specific predictive data regarding a safe level of oxygen saturation. A case vignette study demonstrated that pediatric ED attending physicians would admit many more 6-month-old infants with bronchiolitis with an oxygen saturation of 92%, compared with 94%.[11] The clinical significance of this 2% oximetry difference is not clear, but our model identifies 94% oxygen saturation as a cutoff point for a safe level of oxygen saturation and supports the clinical intuition of those ED attending physicians.

In addition to the previously discussed factors that can be determined at triage, the model contained 3 factors that required clinical judgment, that is, oral intake and the administration of nebulized albuterol or epinephrine in the first hour. If a patient does not have sufficient oral intake, then hospitalization is the correct disposition; when the model was stratified according to age, this factor was maintained across all ages. More complicated than interpretation of oral intake is interpretation of the clinical relevance of administering nebulized albuterol or epinephrine. There are some data suggesting that using these medications may reduce the length of the ED stay[39] and possibly reduce hospitalizations from the ED.[40] Although our data are not meant to investigate the effectiveness of nebulized albuterol or epinephrine, it is likely that clinicians used more nebulized treatments in the first hour for sicker children, with the hope of some benefit. The corollary is that children who receive fewer nebulized treatments during the first hour of the ED stay may be less ill and more likely to be discharged to home.

Our study has several potential limitations. The study participants were children presenting to urban EDs for bronchiolitis. Consequently, the results are not necessarily generalizable to other outpatient clinical settings, such as primary care offices. Similarly, the oxygen saturation results may not be generalizable to EDs at high altitudes.[41] The population in this cohort was admitted more frequently (43%; 95% CI: 40%–45%) than in a previous, observational, multicenter, ED study in Canada (31%)[42] and in a national US data set (19%).[43] When we included both enrolled and nonenrolled children, the overall admission rate remained high at 38% (95% CI: 36%–40%). We did not investigate the risk attitudes of physicians about hospitalization, but in one study this factor was not associated with hospitalization rates.[44] The values for respiratory rate, oxygen saturation, and degree of retractions used in the model were the initial values collected in the ED. These initial values were used in an effort to identify predictors and to create a model that could be applied at triage. Over the course of the ED stay, patients would have had variations in all of these values, of unclear relevance. However, when oxygen saturation was evaluated in the multivariate model, lowest oxygen saturation and triage oxygen saturation were both assessed and found to be similarly predictive of ED disposition (data not shown). The present study does not include information about the infectious etiology cause because the infectious pathogen is not currently considered valuable for diagnosis or acute management.[3] Nevertheless, there is a growing literature base indicating that bronchiolitis attributable to certain viruses (specifically rhinovirus) may affect long-term outcomes,[45–48] an important question that goes beyond the scope of our model predicting safe discharge to home.

Two final issues with any clinical model are the clarity of the outcome (admission) and the generalizability of the model. Although ED disposition can be subjective, we identified several predictive characteristics (eg, age-specific respiratory rates and safe room air oxygen saturation) from >1000 children from 30 hospitals, and we created a multivariate model predicting ED disposition with good test characteristics. Although the overall low-risk model was derived from a randomly selected half of the prospective multicenter data and validated with the other half, this model would benefit from additional validation and impact analyses.[49]

## CONCLUSIONS

On the basis of these prospective multicenter data of children presenting to the ED with bronchiolitis, we have identified several protective factors and developed a comprehensive model that predicts which children are safe for discharge to home. Although additional testing of this model is required, using these data to assist in clinical decision-making may help safely reduce some unnecessary bronchiolitis hospitalizations and ultimately may reduce nosocomial infections and costs. Future work should delineate predictors of unnecessary hospitalizations and also validate the individual factors, the low-risk model, and the potential beneficial effects of its use on patient care, health care costs, and family satisfaction.

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