

---

# Prospective Multicenter Bronchiolitis Study: Predicting Intensive Care Unit Admissions

Dorothy Damore, MD, Jonathan M. Mansbach, MD, Sunday Clark, MPH, ScD, Maria Ramundo, MD, Carlos A. Camargo Jr, MD, DrPH

---

## Abstract

**Objectives:** The authors sought to identify predictors of intensive care unit (ICU) admission among children hospitalized with bronchiolitis for  $\geq 24$  hours.

**Methods:** The authors conducted a prospective cohort study during two consecutive bronchiolitis seasons, 2004 through 2006, in 30 U.S. emergency departments (EDs). All included patients were aged  $< 2$  years and had a final diagnosis of bronchiolitis. Regular floor versus ICU admissions were compared.

**Results:** Of 1,456 enrolled patients, 533 (37%) were admitted to the regular floor and 50 (3%) to the ICU. Comparing floor and ICU admissions, multivariate ED predictors of ICU admission were age  $< 2$  months (26% vs. 53%; odds ratio [OR] = 4.1; 95% confidence interval [CI] = 2.1 to 8.3), an ED visit the past week (25% vs. 40%; OR = 2.2; 95% CI = 1.1 to 4.4), moderate/severe retractions (31% vs. 48%; OR = 2.6; 95% CI = 1.3 to 5.2), and inadequate oral intake (31% vs. 53%; OR = 3.3; 95% CI = 1.6 to 7.1). Unlike previous studies, no association with male gender, socioeconomic factors, insurance status, breast-feeding, or parental asthma was found with ICU admission.

**Conclusions:** In this prospective multicenter ED-based study of children admitted for bronchiolitis, four independent predictors of ICU admission were identified. The authors did not confirm many putative risk factors, but cannot rule out modest associations.

ACADEMIC EMERGENCY MEDICINE 2008; 15:887-894 © 2008 by the Society for Academic Emergency Medicine

**Keywords:** bronchiolitis, risk factors, multivariate predictors, ICU admission

---

**B**ronchiolitis is the leading cause of hospitalization for infants age  $< 1$  year<sup>1</sup> and is estimated to cause 500 deaths per year.<sup>2</sup> From 1992 to 2000,

From the Department of Emergency Medicine, New York Presbyterian Hospital/Weill Cornell Medical Center (DD, SC), New York, NY; the Department of Medicine, Children's Hospital Boston, Harvard Medical School (JMM), Boston, MA; the Department of Emergency Medicine, Akron Children's Hospital/Northeast Ohio University College of Medicine (MR), Akron, OH; and the Department of Emergency Medicine, Massachusetts General Hospital, Harvard Medical School (CAC), Boston, MA. Dr. Clark is currently with the Division of General Internal Medicine, University of Pittsburgh, Pittsburgh, PA.

Received May 5, 2008; revision received June 28, 2008; accepted July 10, 2008.

Presented at the Pediatric Academic Societies/Academic Pediatric Association/Society for Pediatric Research, National Conference, Honolulu, HI, May 2008.

Funded by the Thrasher Research Fund (Salt Lake City, UT) and an unrestricted data analysis grant from Merck (Rahway, NJ). The Thrasher Research Fund and Merck did not participate in study design, data collection, analysis, interpretation, or manuscript preparation and submission.

Address for correspondence and reprints: Dorothy Damore, MD; e-mail: djt2001@med.cornell.edu.

bronchiolitis accounted for over 1.8 million U.S. emergency department (ED) visits,<sup>3</sup> and from 1980 to 2000, bronchiolitis hospitalization rates in the United States more than doubled.<sup>1</sup> The annual economic costs for bronchiolitis hospitalizations is over \$500 million in the United States.<sup>4</sup>

Admission rates for infants with bronchiolitis significantly differ between pediatric and general ED attendings<sup>5</sup> and among pediatric ED attendings.<sup>6</sup> In addition, among 10 hospitals, the thresholds for intensive care unit (ICU) admission varied widely.<sup>7</sup> Likewise, the inpatient management of children with bronchiolitis is quite variable.<sup>8</sup>

Several demographic, environmental, and medical history factors have been associated with severe bronchiolitis. Males are more likely to be hospitalized than females,<sup>1</sup> and they are also more likely to die from bronchiolitis.<sup>2</sup> In addition to gender, studies have found that children with lower socioeconomic status are hospitalized more frequently for bronchiolitis.<sup>9</sup> Increased rates of bronchiolitis and increased hospitalization have been associated with household crowding,<sup>10</sup> child care attendance,<sup>11</sup> maternal smoking during pregnancy,<sup>12</sup> passive smoke exposure,<sup>13,14</sup> family asthma and child asthma, or atopy.<sup>12,14</sup> In addition, chronic medical conditions including chronic lung disease,<sup>15</sup> congenital

heart disease,<sup>16</sup> immunocompromised conditions,<sup>17</sup> low birth weight,<sup>18</sup> and prematurity<sup>19</sup> have been associated with severe bronchiolitis.

While prior studies of children with bronchiolitis have identified many predictors of ICU admission, multivariate analysis is limited.<sup>20,21</sup> Also, prior studies have often been single-center,<sup>20,21</sup> based on small numbers,<sup>20-22</sup> enrolled only previously healthy infants,<sup>20-22</sup> had limited ED data,<sup>23</sup> or only included children with respiratory syncytial virus (RSV) bronchiolitis.<sup>15,20-23</sup> Of two studies using multivariate analysis to predict ICU admission, one determined characteristics during hospitalization (and not at ED presentation) that were associated with ICU admission,<sup>23</sup> while the other studied only infants with RSV bronchiolitis.<sup>15</sup> Another multicenter study found six predictors for hospitalization with RSV infection but did not determine predictors for ICU admission.<sup>24</sup> An exclusive focus on RSV bronchiolitis overlooks the role of many other infectious pathogens including influenza, parainfluenza, human metapneumovirus, and rhinovirus<sup>25-28</sup> and that bronchiolitis is currently a clinical, as opposed to a laboratory diagnosis.<sup>29</sup>

Therefore, we conducted a prospective, multicenter, observational study of children age <2 years who presented to the ED with bronchiolitis. From historical and clinical data, we sought to identify independent predictors of ICU admission. We hypothesized that age, gender, concomitant medical disorder, prematurity, oxygen saturation, and oral intake would be independent predictors of ICU admission.

## METHODS

### Study Design

We conducted a prospective cohort study during the 2004 through 2006 winter seasons, as part of the Multi-center Airway Research Collaboration (MARC). MARC is a division of the Emergency Medicine Network (<http://www.emnet-usa.org/>). The institutional review board at each of the 30 participating hospitals approved the study and informed consent was obtained for all participants.

### Study Setting and Population

Using a standard protocol, investigators at 30 EDs in 15 U.S. states provided 18- to 24-hour-per-day coverage for a median of 2 weeks from December to March to coincide with high numbers of bronchiolitis visits. Figure 1 shows the site locations by state. The 30 participating sites were located across the United States: Northeast (37%), Midwest (27%), South (20%), and West (17%). Forty percent were EDs in children's hospitals, 47% pediatric EDs in general hospitals, and 13% general EDs in general hospitals. The median number of annual ED visits at the participating sites was 56,813 (interquartile range [IQR] = 41,579-71,284). The number of children enrolled at each site ranged from 11 to 158 (median = 37; IQR = 29-50). All patients were managed at the discretion of the treating physician. Inclusion criteria were an attending physician diagnosis of bronchiolitis, patient age <2 years, and the ability of the parent or guardian to give informed consent. The only exclusion criterion was previous enrollment.



**Figure 1.** Site locations by state.

As defined by the American Academy of Pediatrics (AAP) in its 2006 position statement, children with bronchiolitis typically have "rhinitis, tachypnea, wheezing, cough, crackles, use of accessory muscles, and/or nasal flaring."<sup>29</sup> In our data, 98% (1,423/1,456) of the children met the AAP definition of bronchiolitis and had a respiratory rate (RR) greater than normal, current wheezing, current cough, or mild/moderate/severe retractions. Among the 2% (33) of children without any one of these factors, 15% had an oxygen saturation of <96% or air entry that was not normal. In running the multivariate model in the subset of children (98%) with a RR greater than normal, current wheezing, current cough, or mild/moderate/severe retractions, the results did not change.

### Study Protocol

The standardized questionnaire consisted of an ED interview, ED chart review, and 2-week follow-up telephone interview. Physicians and researchers were trained in utilizing these forms. All forms were reviewed by site principal investigators, who are physicians, before submission to the EMNet Coordinating Center in Boston. At the Coordinating Center, the data were further reviewed by trained personnel and underwent double data entry.

### Measurements

The ED interview assessed patients' demographic characteristics, medical and environmental history, and details of their acute illness. Median household income was estimated using the patients' home zip codes.<sup>30</sup> Children were considered premature if they were born <35 weeks gestation. ED chart review provided clinical data: RR from triage, clinical assessment of degree of retractions (combined for analysis into none/mild versus moderate/severe), O<sub>2</sub> saturation, management, and disposition. Adequacy of oral hydration was determined by the ED attending. The 2-week follow-up interview discussed the illness course and any medical care occurring after the ED visit. Data are available for all patients (583) in Tables 1 and 2, except for viral testing ( $n = 401$ ; 69%) and chest x-ray ( $n = 430$ ; 74%).

The primary outcome of the current analysis was ICU admission. Children admitted to the ICU from the ED were compared to children admitted to the regular floor for >24 hours.

**Table 1**  
Demographic Characteristics and Medical History of Children Presenting to the ED with Bronchiolitis, According to Hospital Admissions  $\geq 24$  Hours vs. ICU Admissions

	Admission $\geq 24$ hours (n = 533)	ICU admission (n = 50)	OR	p-Value
<b>Demographic characteristics</b>				
Age, months (%)				
0–1.9	26	53	1.6	0.006
2–3.9	21	12	0.4	
4–5.9	14	2	0.1	
6–7.9	11	7	0.5	
8–9.9	7	5	0.5	
10–11.9	6	2	0.3	
$\geq 12$	15	19	1.0 (Reference)	
Male (%)	57	58	1.0	0.98
Race/ethnicity (%)				
White	41	54	1.0 (Reference)	0.28
African American	26	18	0.5	
Hispanic	33	28	0.6	
Estimated median household income (US\$), median (IQR)	44,240 (30,945–56,710)	43,633 (34,204–59,380)	1.0	0.82
Insurance (%)				
Private HMO/commercial	33	34	1.0 (Reference)	0.65
Medicaid	57	59	1.0	
Other public	7	2	0.3	
None	3	5	1.6	
Has PCP (%)	96	91	0.4	0.07
<b>Medical history</b>				
Concomitant medical disorder (%)	19	26	1.4	0.35
Weight when born, pounds (%)				
<3	4	2	1.0 (Reference)	0.87
3–5	7	7	1.6	
>5	89	90	1.7	
Premature (%)*	13	10	0.7	0.57
Breast-fed (%)	54	63	1.5	0.25
History of wheezing (%)	27	26	0.9	0.83
History of eczema (%)	13	5	0.3	0.10
Attends day-care (%)	20	7	0.3	0.04
Ever hospitalized (%)	23	17	0.7	0.38
Ever intubated (%)	10	5	0.4	0.24
<b>Medication use during past week</b>				
Inhaled $\beta$ -agonists (%)	35	30	0.8	0.56
Antibiotics (%)	18	12	0.6	0.30
Inhaled/nebulized corticosteroids (%)	11	9	0.9	0.80
Systemic corticosteroids (%)	11	9	0.9	0.77
No. PCP visits during past week, median (IQR)	1 (0–1)	1 (0–2)	1.1	0.44
Number ED visits during past week, median (IQR)	0 (0–0)	0 (0–1)	1.2	0.04

ED = emergency department; HMO = health maintenance organization; ICU = intensive care unit; IQR = interquartile range; OR = odds ratio; PCP = primary care provider.

\*Premature defined as gestation <35 weeks.

## Data Analysis

All analyses were performed using STATA 9.0 (Stata Corp, College Station, TX). Data are presented as proportions (with 95% confidence intervals [CI]), means (with standard deviation [SD]), or medians (with interquartile range [IQR]). The association of factors with ICU admission was examined using chi-square tests, Student's t tests, and Kruskal-Wallis rank tests, as appropriate. All p-values are two-tailed, with  $p < 0.05$  considered statistically significant.

Multivariate logistic regression was used to identify independent predictors of ICU admission compared to admission to the regular floor for  $\geq 24$  hours. Factors associated with ICU admission at  $p < 0.20$  were evaluated for inclusion in the multivariate analysis. Those that did not retain statistical significance on multivariate

analysis were removed from the model. When the final model was identified, factors that had not been retained in the model were reevaluated for inclusion. Continuous variables found not to have a linear relationship with the outcome (e.g., age) were assessed for the best cutoff point. Results are presented as ORs with 95% CI.

Several additional analyses were performed to explore the findings of the multivariate model that are not consistent with existing literature. Because an age cutoff of 6 weeks was found to be an important predictor of ICU admission in previous studies,<sup>15,20,22</sup> the final model was run replacing the age of <2 months variable with age <6 weeks. Additionally, apnea was included in the final model to determine its independent association with ICU admission. Because of the small number of children experiencing apnea ( $n = 18$ ), the resulting estimate was unstable and apnea was therefore not

**Table 2**  
ED Presentation and Clinical Course among Children with Bronchiolitis, According to Hospital Admissions  $\geq$ 24 Hours vs. ICU Admissions

	Admission $\geq$ 24 hours (n = 533)	ICU admission (n = 50)	OR	p-Value
Duration of symptoms $\geq$ 4 days (%)	55	40	0.5	0.048
RR, mean $\pm$ SD	52 $\pm$ 15	51 $\pm$ 15	1.0	0.69
Moderate/severe retractions (%)	31	48	2.0	0.03
Oxygen saturation on room air, mean $\pm$ SD	96 $\pm$ 4	94 $\pm$ 6	0.9	<0.001
Lowest room air oxygen saturation, mean $\pm$ SD	94 $\pm$ 5	88 $\pm$ 12	0.9	<0.001
Presence of cough (%)	89	84	0.6	0.29
Presence of wheeze (%)	80	67	0.5	0.05
No. inhaled $\beta$ -agonist treatments in first hour, median (IQR)	1 (0–1)	1 (0–2)	1.6	0.10
No. inhaled $\beta$ -agonist treatments over entire ED stay, median (IQR)	1 (1–2)	1 (1–3)	1.0	0.93
No. epinephrine treatments in first hour, median (IQR)	0 (0–0)	0 (0–1)	1.7	0.12
No. epinephrine treatments over entire ED stay, median (IQR)	0 (0–1)	1 (0–1)	1.3	0.07
Given corticosteroids (%)	15	21	1.6	0.25
Given antibiotics (%)	16	33	2.5	0.006
Any laboratory tests (%)	92	98	3.7	0.17
Oral intake (%)				
Adequate oral intake	64	28	1.0	<0.001
Inadequate oral intake	31	53	(Reference)	
Unknown	6	19	4.0	
7.2				
Viral test results*				
RSV positive (%)	41	53	1.7	0.11
Influenza A positive (%)	2	5	3.2	0.13
Influenza B positive (%)	0.2	2	12.7	0.02
Adenovirus positive (%)	0.4	0	—	0.69
Abnormal x-ray findings (%) †	68	76	1.5	0.37
ED LOS (minutes), median (IQR)	245 (175–353)	241 (150–398)	0.9	0.46

ED = emergency department; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay; OR = odds ratio; RR = respiratory rate; RSV = respiratory syncytial virus; SD = standard deviation.  
\*Among 401 children with viral testing performed.  
†Among 430 children with chest x-ray performed. Abnormal x-ray findings include atelectasis, infiltrate, hyperinflated, or other findings.

included in the final model. The final model was adjusted for clustering by site, but did not differ from the unadjusted model. The unadjusted model is therefore presented.

A priori, RR and oxygen saturation<sup>15,22,23</sup> were thought to be factors that would be independently associated with ICU admission. However, these factors did not retain statistical significance in multivariate analyses. As a result, two separate logistic regression analyses were performed to evaluate the association between each of these factors and ICU admission.

## RESULTS

Of 2,129 eligible children presenting to the ED with bronchiolitis, 1,459 (68%) were enrolled. Enrolled and non-enrolled children were similar with respect to demographic factors, including age, gender, and race/ethnicity (all  $p > 0.10$ ). Although enrolled children were more likely to be admitted (40% vs. 28%;  $p < 0.001$ ), they did not differ from non-enrolled children with respect to other medical history factors, ED presentation, or clinical management (data not shown). Of 1,459 enrolled patients, 583 (40%) were admitted to

the hospital. Among these 583 children, 533 (37%; 95% CI = 34% to 39%) were admitted to the regular floor and 50 (3%; 95% CI = 2% to 4%) to the ICU. ICU admissions by site ranged from 0% to 28%, but the results presented did not differ when adjusting for clustering by site (data not shown). Moreover, the time of ED presentation did not affect the admission location (i.e., regular floor vs. ICU). Fifteen percent of regular floor admissions and 16% of ICU admissions presented to the ED between midnight and 8:00 AM. The rest of the admissions, 85 and 84%, presented to the ED between 8:00 AM and midnight.

Patient demographics are shown in Table 1. ICU patients were younger than children admitted to the regular floor. More than 80% of children admitted to either the regular floor or ICU were age <12 months. The percentage of males admitted to the regular floor and ICU were similar. No differences were observed in respect to race/ethnicity, estimated median household income, or insurance status. Children admitted to the regular floor and the ICU did not differ in having a primary care provider (PCP).

Medical history is also shown in Table 1. The two groups were similar with respect to most medical

factors: being breast-fed, history of wheezing, siblings at home, parental asthma, maternal smoking during pregnancy, secondhand smoke exposure, prior hospitalization, medication use in the past week, and primary care visits during the past week. ICU patients were less likely than those admitted to the regular floor to attend daycare and more likely to have an ED visit during the past week. There were smaller numbers of patients with specific illnesses, low birth weight, premature birth, a history of eczema, or a history of intubation. Therefore, results regarding these variables should be interpreted with caution.

ED presentation and clinical course are shown in Table 2. ICU patients were more likely to have a shorter duration of symptoms. The two groups had similar RRs and presence of cough. The ICU group was more likely to have moderate/severe retractions and have lower initial and lowest oxygen saturations and less likely to have wheezing. In a separate analysis, an initial oxygen saturation of <90%, compared to initial oxygen saturation of 100%, was significantly associated with ICU admission (23% vs. 6%;  $p < 0.001$ ), while RR based on age, relative to a RR of 20–29, was not found to be associated with ICU admission (data not shown). Children admitted to the ICU were more likely to have a parent report that they stopped breathing during this illness (19% vs. 8%;  $p = 0.01$ ) and to have apnea recorded in the ED (26% vs. 1%;  $p < 0.001$ ).

Emergency department treatments were similar for the two groups except that the ICU group was more likely to receive an antibiotic. The ICU group was also more likely to have inadequate oral intake. Among the children who received viral testing while in the ED ( $n = 401$ ), rates of RSV bronchiolitis were similar in the two groups. A small number of children were positive for influenza A, influenza B, and adenovirus. Abnormal chest x-ray findings and ED length-of-stay (LOS) were similar for the two groups.

Median hospital LOS was different between the two groups. ICU patients' median hospital LOS was 4 days (range = 3–6 days) versus 2 days (range = 1–3 days) for regular floor patients ( $p < 0.001$ ). During hospitalization, ICU patients were more likely to be apneic in the hospital (12% vs. 2%;  $p < 0.001$ ) and intubated (14% vs. 0%;  $p < 0.001$ ) than floor patients.

Multivariate analysis found that initial RR, initial oxygen saturation, and lowest oxygen saturation were not independent predictors of ICU admission compared to admission to the regular floor. Further analysis showed that the test characteristics of these three factors were poor with respect to ICU admission (data not shown).

Table 3 shows the final multivariate model of ICU admission. Statistically significant risk factors were patient age of <2 months, an ED visit during the past week, moderate/severe retractions, and inadequate oral intake. The model had good discrimination (area under the receiver operating characteristic curve, 0.80) and a good fit to the data (Hosmer-Lemeshow test, 2.46;  $p = 0.93$ ). Based on previous data,<sup>15,20,22</sup> we evaluated a 6-week age cut off in our final model and found results similar to those reported in Table 3, which is consistent with previous literature.

## DISCUSSION

When providing care for a child with bronchiolitis in the ED, one of the main decisions is whether the child requires admission and, if so, whether the regular floor is sufficient or if the child will require intensive care. When a child is in respiratory extremis, it is often clear that intensive care is needed. However, when children are seriously ill, but not in extremis, the need for intensive care may not be as straightforward. Using prospective multicenter data from 30 EDs across the country, we have identified several historical and clinical factors that are associated with ICU admission: patient age of <2 months, an ED visit during the past week, moderate/severe retractions, and inadequate oral intake.

Our multivariate model of children <2 years of age with a clinical diagnosis of bronchiolitis was somewhat different from a model created from a multicenter study performed in seven Canadian hospitals.<sup>15</sup> The Canadian study included a large Indian/Inuit population, only children with RSV bronchiolitis (prior to palivizumab), and clinical data from the inpatient ward (i.e., not ED assessments).<sup>15</sup> Based on these somewhat different data, the following variables in the Canadian study were predictors of ICU admission: native Indian or Inuit, apnea or respiratory arrest in the hospital, age of ≤6 weeks, lung disease, oxygen saturation of ≤90% on admission, and pulmonary consolidation on admission.<sup>15</sup>

The variable that seems to be a consistent predictor of ICU admission throughout the literature is young age. Our data point to age of <2 months as predictive of ICU admission, while others have found age of <6 weeks as predictive.<sup>15,22</sup> Although our data point to age of <2 months as predictive of ICU admission, age of <6 weeks performed similarly in the model, an age others have found is predictive.<sup>15,20,22</sup> A retrospective review of 62 children requiring mechanical ventilation for bronchiolitis found that the mean age of these children was 73 days.<sup>31</sup> A chart review of 185 patients younger than 12 months hospitalized with RSV infection found that recurrent apnea significantly increases the risk of mechanical ventilation and that age of

**Table 3**  
Multivariate Predictors of ICU Admission Compared to Hospital Admission to Regular Floor for ≥24 Hours

	OR	95% CI	p-Value
Age <2 months	4.14	2.05, 8.34	<0.001
ED visit during past week	2.15	1.05, 4.37	0.04
Moderate/severe retractions	2.56	1.27, 5.18	0.009
Oral intake			
Adequate	1.00	Reference	Reference
Inadequate	3.31	1.55, 7.07	0.002
Unknown	8.44	2.89, 24.69	<0.001

CI = confidence interval; ED = emergency department; OR = odds ratio.  
Area under the receiver operating characteristic curve: 0.80  
Hosmer-Lemeshow test, 2.46;  $p = 0.93$ .

<2 months is the strongest predictor of apnea.<sup>32</sup> Bronchiolitis-associated apnea is a concern for pediatricians, and it is only recently that a low-risk rule was developed. Willwerth et al.<sup>33</sup> found in a retrospective study that if a child aged >1 month or preterm and aged >48 weeks postconception has not had apnea during the illness, then the risk of subsequent apnea is low.

When considering objective respiratory parameters, our model, like others, did not include RR<sup>15,22,23</sup> or pulmonary consolidation noted on chest radiograph (CXR).<sup>22,23</sup> A recent study of CXRs in children with "typical" and mild bronchiolitis noted that the risk of airspace disease is low.<sup>34</sup> In children ill enough to be admitted to the ICU, the outcomes may be different, but our data suggest that CXR results are not a factor in the decision to admit a child to the ICU. Also unlike the previous models, our model did not include oxygen saturation. Our ICU patients not only had significantly lower initial and lowest room air oxygen saturations than the regular admission children, but they also were significantly more likely to have room air oxygen saturation of <90% in univariate analysis. However, oxygen saturation was not significant in the multivariate analysis. Three studies have found oxygen saturation of ≤90% to be predictive of ICU admission.<sup>15,22,23</sup> Moreover, perhaps it is the trend in oxygen saturation over time that is more clinically informative than specific points in time.

In addition to young age and an ED visit in the past week, the other variables associated with ICU admission were more subjective: moderate/severe retractions and inadequate oral intake. In terms of retractions, other studies have found this clinical exam finding to be associated with hospital duration,<sup>35</sup> the need for supplemental oxygenation,<sup>36</sup> and hospital admission.<sup>36</sup> Considering oral hydration, one study found dehydration to be associated with hospitalization, but not necessarily ICU admission.<sup>37</sup>

The overall model (age <2 months, ED visit during the past week, moderate/severe retractions, and inadequate oral intake) created from this prospective multicenter cohort points to the somewhat subjective nature of ICU admissions for children with bronchiolitis. In one study by Willson et al.,<sup>7</sup> the threshold for ICU admission and intubation varied among 10 hospitals. These findings and the ones from this study point to the need for further research to attempt to better define those children with bronchiolitis who truly need critical care services.

## LIMITATIONS

Our sample size of 50 ICU patients is relatively small, and this hinders assessment of less common risk factors. In particular, there were small numbers of patients with chronic lung disease, low birth weight, and prematurity. Small numbers and nonsystematic collection of mucus samples for all patients<sup>37</sup> may also have hindered detection of possible differences between the different viral causes of bronchiolitis. Also, children were enrolled for 2 to 3 weeks during two consecutive bronchiolitis seasons, and management may vary during the season or if the ED census is higher. Given the

institutional variability in care and resource utilization for children with bronchiolitis, children with similar severity of illness may be admitted to an ICU in one hospital, but not in another.<sup>7</sup> While our study was not designed to determine the appropriateness of ICU admission, we believe that our sample—from 30 hospitals in 15 states—provides important information about bronchiolitis admissions to the ICU.

Our broad inclusion criteria, including children with any chronic medical disorder and all causes of bronchiolitis, limit comparisons with previous studies in healthy children and only RSV bronchiolitis. Yet, conclusions from our multicenter study may provide information for all children with bronchiolitis.

Enrolled patients had a greater admission rate than non-enrolled patients. We believe that this difference in enrollment was due to the admitted patients being in the ED longer and having more opportunity for enrollment. Moreover, the parents of the children ill enough to be admitted to the hospital may have been more invested in helping to understand bronchiolitis better. The two groups were similar in all other respects, including medical history, ED presentation, and clinical management. The population studied may not be generalizable outside of academic urban EDs serving medically sick populations.

The overall admission rate of 40% and ICU admission rate of 9% among admitted patients are higher than most previous studies. For example, other studies have found overall admission rates of 19% to 40%<sup>3,5,21,38</sup> and ICU admission rates of 5.4% to 6.2%.<sup>1,39</sup> Our higher admission rates may reflect our use of broad inclusion criteria and may correspond with the increasing bronchiolitis admission rates seen between 1980 and 2000.<sup>1</sup> While our inclusion criteria are broad, we note that 98% of our cohort satisfied the AAP criteria for bronchiolitis.<sup>29</sup> Higher overall and ICU admission rates may reflect increasing severity of illness, or less stringent admission criteria, which would complicate comparisons with prior data.

Finally, measuring retractions and inadequate oral intake pose challenges. Subtle differences in retractions may create variability in categorization. We minimized this variability by examining the difference between none/mild retractions and moderate/severe retractions. Certain clinical<sup>40,41</sup> and laboratory values<sup>42</sup> are better markers for dehydration than others,<sup>43</sup> but determining the adequacy of oral intake is not always straightforward.

## CONCLUSIONS

Our multicenter study examined hospital admission for clinical bronchiolitis and found four independent risk factors for ICU admission: patient age of <2 months, an ED visit during the past week, moderate/severe retractions, and inadequate oral intake. Neither oxygen saturation nor RR was an independent predictor of ICU admission. In addition, we did not confirm several putative risk factors for ICU admission, although modest associations may exist. Further studies are needed to validate these findings and to examine if the infectious etiology contributes to bronchiolitis severity.

## References

- Shay DK, Holman RC, Newman RD, Liu LL, Stout JW, Anderson LJ. Bronchiolitis-associated hospitalizations among US children, 1980–1996. *JAMA*. 1999; 282:1440–6.
- Shay DK, Holman RC, Roosevelt GE, Clarke MJ, Anderson LJ. Bronchiolitis-associated mortality and estimates of respiratory syncytial virus-associated deaths among US children, 1979–1997. *J Infect Dis*. 2001; 183:16–22.
- Mansbach JM, Emond JA, Camargo CA Jr. Bronchiolitis in US emergency departments 1992 to 2000: epidemiology and practice variation. *Pediatr Emerg Care*. 2005; 21:242–7.
- Pelletier AJ, Mansbach JM, Camargo CA Jr. Direct medical costs of bronchiolitis hospitalizations in the United States. *Pediatrics*. 2006; 118:2418–23.
- Johnson DW, Adair C, Brant R, Holmwood J, Mitchell I. Differences in admission rates of children with bronchiolitis by pediatric and general emergency departments. *Pediatrics*. 2002; 110:e49.
- Mallory MD, Shay DK, Garrett J, Bordley WC. Bronchiolitis management preferences and the influence of pulse oximetry and respiratory rate on the decision to admit. *Pediatrics*. 2003; 111:e45–51.
- Willson DF, Horn SD, Hendley JO, Smout R, Gassaway J. Effect of practice variation on resource utilization in infants hospitalized for viral lower respiratory illness. *Pediatrics*. 2001; 108:851–5.
- Law BJ, Carvalho VD. Respiratory syncytial virus infections in hospitalized Canadian children: regional differences in patient populations and management practices. *Ped Infect Dis J*. 1993; 12:659–63.
- Jansson L, Nilsson P, Olsson M. Socioeconomic environmental factors and hospitalization for acute bronchiolitis during infancy. *Acta Paediatr*. 2002; 91:335–8.
- Figueras-Aloy J, Carbonell-Estrany X, Quero J. Case-control study of the risk factors linked to respiratory syncytial virus infection requiring hospitalization in premature infants born at a gestational age of 33–35 weeks in Spain. *Pediatr Infect Dis J*. 2004; 23:815–20.
- Simoes EA. Environmental and demographic risk factors for respiratory syncytial virus lower respiratory tract disease. *J Pediatr*. 2003; 143(5 Suppl): S118–26.
- Carroll K, Gebretsadik T, Griffin MR, et al. Maternal asthma and maternal smoking are associated with increased risk of bronchiolitis during infancy. *Pediatrics*. 2007; 119:1104–12.
- McConnochie KM, Roghmann KJ. Parental smoking, presence of older siblings, and family history of asthma increase risk of bronchiolitis. *Am J Dis Child*. 1986; 140:806–12.
- Stensballe LG, Kristensen K, Simoes EA, et al. Atopic disposition, wheezing, and subsequent respiratory syncytial virus hospitalization in Danish children younger than 18 months: a nested case-control study. *Pediatrics*. 2006; 118:e1360–8.
- Wang EE, Law BJ, Stephens D. Pediatric Investigators Collaborative Network on Infections in Canada (PICNIC) prospective study of risk factors and outcomes in patients hospitalized with respiratory syncytial viral lower respiratory tract infection. *J Pediatr*. 1995; 126:212–9.
- MacDonald NE, Hall CB, Suffin SC, Alexson C, Harris PJ, Manning JA. Respiratory syncytial viral infection in infants with congenital heart disease. *N Engl J Med*. 1982; 307:397–400.
- Meissner HC. Selected populations at increased risk from respiratory syncytial virus infection. *Pediatr Infect Dis J*. 2003; 22(2 Suppl):S40–4.
- Holman RC, Shay DK, Curns AT, Lingappa JR, Anderson LJ. Risk factors for bronchiolitis-associated deaths among infants in the United States. *Pediatr Infect Dis J*. 2003; 22:483–90.
- Navas L, Wang E, de Carvalho V, Robinson J. Improved outcome of respiratory syncytial virus infection in a high-risk hospitalized population of Canadian children. *Pediatric Investigators Collaborative Network on Infections in Canada*. *J Pediatr*. 1992; 121:348–54.
- Green M, Brayer AF, Schenkman KA, Wald ER. Duration of hospitalization in previously well infants with respiratory syncytial virus infection. *Pediatr Infect Dis J*. 1989; 8:601–5.
- Voets S, van Berlaer G, Hachimi-Idrissi S. Clinical predictors of the severity of bronchiolitis. *Eur J Emerg Med*. 2006; 13:134–8.
- Opavsky MA, Stephens D, Wang EE. Testing models predicting severity of respiratory syncytial virus infection on the PICNIC RSV database. *Pediatric Investigators Collaborative Network on Infections in Canada*. *Arch Pediatr Adolesc Med*. 1995; 149:1217–20.
- McConnochie KM, Hall CB, Walsh EE, Roghmann KJ. Variation in severity of respiratory syncytial virus infections with subtype. *J Pediatr*. 1990; 117(1 Pt 1):52–62.
- Rietveld E, Vergouwe Y, Steyerberg EW, Huysman MW, de Groot R, Moll HA. Hospitalization for respiratory syncytial virus infection in young children: development of a clinical prediction rule. *Pediatr Infect Dis J*. 2006; 25:201–7.
- Iwane MK, Edwards KM, Szilagyi PG, et al. Population-based surveillance for hospitalizations associated with respiratory syncytial virus, influenza virus, and parainfluenza viruses among young children. *Pediatrics*. 2004; 113:1758–64.
- Wolf DG, Greenberg D, Kalkstein D, et al. Comparison of human metapneumovirus, respiratory syncytial virus and influenza A virus lower respiratory tract infections in hospitalized young children. *Pediatr Infect Dis J*. 2006; 25:320–4.
- Kusel MM, de Klerk NH, Holt PG, Keadze T, Johnston SL, Sly PD. Role of respiratory viruses in acute upper and lower respiratory tract illness in the first year of life: a birth cohort study. *Pediatr Infect Dis J*. 2006; 25:680–6.
- Mansbach JM, McAdam A, Clark S, et al. Prospective multicenter study of the viral etiology of bronchiolitis

- in the Emergency Department. *Acad Emerg Med*. 2008; 15:111–8.
29. American Academy of Pediatrics Subcommittee on Diagnosis and Management of Bronchiolitis. *Diagnosis and Management of Bronchiolitis*. Pediatrics. 2006; 118:1774–93.
  30. 2005 Community Sourcebook of ZIP Code Demographics. 19th ed. Omaha, NE: ESRI, 2005.
  31. Lebel MH, Gauthier M, Lacroix J, Rousseau E, Buithieu M. Respiratory failure and mechanical ventilation in severe bronchiolitis. *Arch Dis Child*. 1989; 64:1431–7.
  32. Kneyber MC, Brandenburg AH, de Groot R, et al. Risk factors for respiratory syncytial virus associated apnoea. *Eur J Pediatr*. 1998; 157:331–5.
  33. Willwerth BM, Harper MB, Greenes DS. Identifying hospitalized infants who have bronchiolitis and are at risk for apnea. *Ann Emerg Med*. 2006; 48:441–7.
  34. Schuh S, Lalani A, Allen U, et al. Evaluation of the utility of radiography in acute bronchiolitis. *J Pediatr*. 2007; 150:429–33.
  35. Weigl JA, Puppe W, Schmitt HJ. Variables explaining the duration of hospitalization in children under two years of age admitted with acute airway infections: does respiratory syncytial virus have a direct impact? *Klin Padiatr*. 2004; 216:7–15.
  36. Mai TV, Selby AM, Simpson JM, Isacs D. Use of simple clinical parameters to assess severity of bronchiolitis. *J Paediatr Child Health*. 1995; 31:465–8.
  37. Walsh P, Rothenberg SJ, O'Doherty S, Hoey H, Healy R. A validated clinical model to predict the need for admission and length of stay in children with acute bronchiolitis. *Eur J Emerg Med*. 2004; 11:265–72.
  38. Corneli HM, Zorc JJ, Majahan P, et al. A multicenter, randomized, controlled trial of dexamethasone for bronchiolitis. *New Eng J Med*. 2007; 357:331–9.
  39. Wahab AA, Dawod ST, Raman HM. Clinical characteristics of respiratory syncytial virus infection in hospitalized healthy infants and young children in Qatar. *J Trop Pediatr*. 2001; 47:363–6.
  40. Steiner MJ, DeWalt DA, Byerley JS. Is this child dehydrated? *JAMA*. 2004; 291:2746–54.
  41. Mackenzie A, Barnes G, Shann F. Clinical signs of dehydration in children. *Lancet*. 1989; 2(8663):605–7.
  42. Wathen JE, MacKenzie T, Bothner JP. Usefulness of the serum electrolyte panel in the management of pediatric dehydration treated with intravenously administered fluids. *Pediatrics*. 2004; 114:1227–34.
  43. Steiner MJ, Nager AL, Wang VJ. Urine specific gravity and other urinary indices: inaccurate tests for dehydration. *Pediatr Emerg Care*. 2007; 23:298–303.