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Pediatrics 2009;124;e29

DOI: 10.1542/peds.2008-2062

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American Academy of Pediatrics

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Clinical Predictors of Pneumonia Among Children With Wheezing

CONTRIBUTORS: Bonnie Mathews, MD,^a Sonal Shah, MD, MPH,^a Robert H. Cleveland, MD,^b Edward Y. Lee, MD, MPH,^b Richard G. Bachur, MD,^a and Mark I. Neuman, MD, MPH^a

^aDivision of Emergency Medicine and ^bDepartment of Radiology, Children's Hospital Boston and Harvard Medical School, Boston, Massachusetts

KEY WORDS

pneumonia, wheeze, children, asthma, bronchiolitis, radiograph

ABBREVIATIONS

CI—confidence interval

ED—emergency department

OR—odds ratio

RR—relative risk

LR—likelihood ratio

www.pediatrics.org/cgi/doi/10.1542/peds.2008-2062

doi:10.1542/peds.2008-2062

Accepted for publication Feb 27, 2009

Address correspondence to Mark I. Neuman, MD, MPH, Division of Emergency Medicine, Children's Hospital, 300 Longwood Ave, Boston, MA 02115. E-mail: mark.neuman@childrens.harvard.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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FINANCIAL DISCLOSURE: *The authors have indicated they have no financial relationships relevant to this article to disclose.*



WHAT'S KNOWN ON THIS SUBJECT: The diagnosis of pneumonia in children with wheezing can be difficult, because the clinical history and auscultatory findings may be difficult to distinguish from those for children without pneumonia. Limited data exist regarding predictors of pneumonia among children with wheezing.



WHAT THIS STUDY ADDS: The rate of radiographic pneumonia among children with wheezing is low (4.9%). Only 2% of children with wheezing but without fever had radiographic pneumonia. The routine use of chest radiography for children with wheezing but without fever should be discouraged.

abstract

OBJECTIVE: The goal was to identify factors associated with radiographically confirmed pneumonia among children with wheezing in the emergency department (ED) setting.

METHODS: A prospective cohort study was performed with children ≤ 21 years of age who were evaluated in the ED, were found to have wheezing on examination, and had chest radiography performed because of possible pneumonia. Historical features and examination findings were collected by treating physicians before knowledge of the chest radiograph results. Chest radiographs were read independently by 2 blinded radiologists.

RESULTS: A total of 526 patients met the inclusion criteria; the median age was 1.9 years (interquartile range: 0.7–4.5 years), and 36% were hospitalized. A history of wheezing was present for 247 patients (47%). Twenty-six patients (4.9% [95% confidence interval [CI]: 3.3–7.3]) had radiographic pneumonia. History of fever at home (positive likelihood ratio [LR]: 1.39 [95% CI: 1.13–1.70]), history of abdominal pain (positive LR: 2.85 [95% CI: 1.08–7.54]), triage temperature of $\geq 38^{\circ}\text{C}$ (positive LR: 2.03 [95% CI: 1.34–3.07]), maximal temperature in the ED of $\geq 38^{\circ}\text{C}$ (positive LR: 1.92 [95% CI: 1.48–2.49]), and triage oxygen saturation of $< 92\%$ (positive LR: 3.06 [95% CI: 1.15–8.16]) were associated with increased risk of pneumonia. Among afebrile children (temperature of $< 38^{\circ}\text{C}$) with wheezing, the rate of pneumonia was very low (2.2% [95% CI: 1.0–4.7]).

CONCLUSIONS: Radiographic pneumonia among children with wheezing is uncommon. Historical and clinical factors may be used to determine the need for chest radiography for wheezing children. The routine use of chest radiography for children with wheezing but without fever should be discouraged. *Pediatrics* 2009;124:e29–e36

Asthma and bronchiolitis are 2 of the most common conditions encountered in a pediatric emergency department (ED).¹ Among children with a history of wheezing or asthma, acute exacerbations can be precipitated by an underlying viral illness or pneumonia. The diagnosis of pneumonia in children with wheezing can be difficult, because the clinical history and auscultatory findings may be difficult to distinguish from those for children without pneumonia. As a result, many children who present to the ED with wheezing undergo chest radiography for evaluation of the presence of pneumonia. Many of these radiographs are read as negative for pneumonia and might have been avoided, saving time and health care dollars and avoiding exposing patients to ionizing radiation.²⁻⁴ The objectives of our study were to investigate the value of historical features and clinical examination findings in the evaluation of children with wheezing on examination for whom a chest radiograph was ordered and to develop a clinical decision rule for the use of chest radiography in this patient population.

METHODS

Study Design

We performed a prospective cohort study of children ≤ 21 years of age with wheezing on examination who presented to the ED for evaluation. Children who had wheezing on examination and who underwent chest radiography for evaluation of the presence of pneumonia were eligible for the study. To avoid seasonal variations, we enrolled patients for 1 entire calendar year, starting in November 2006. We excluded patients with chronic respiratory illnesses, such as cystic fibrosis or bronchopulmonary dysplasia, and those with other illnesses that may predispose patients to pneumonia, such as complex congenital heart dis-

ease, sickle cell anemia, immunosuppression, or malignancy. In addition, patients for whom chest radiography was performed for indications other than evaluation for the presence of pneumonia, such as trauma or foreign body aspiration, were excluded.

All physicians working in the ED were asked to participate in the study. Physicians were oriented to the questionnaire before the start of the study and were continually informed of study details throughout the study period. Physicians were asked to complete a questionnaire for each patient for whom chest radiographs were obtained. The questionnaires were completed before radiography and were deposited in secure lockboxes located in the ED. Physicians participating in the study included board-certified pediatric emergency medicine physicians, pediatric emergency medicine fellows, general pediatricians, and pediatric and emergency medicine residents in residency programs affiliated with our hospital. Questionnaires completed by trainees required review by an attending physician, to ensure the accuracy of the data. The institutional review board of Children's Hospital Boston approved this study.

Data Collection

Detailed information regarding the indications for obtaining the chest radiographs, the presence of specific historical features, and examination findings at the time of the clinician's evaluation was collected. The historical features of interest included the presence or absence of cough, fever, wheezing, difficulty breathing, chest pain, and abdominal pain. Physicians were asked to rate the level of respiratory distress on a scale from 1 (no signs of respiratory distress) to 5 (severe respiratory distress). For analysis, this variable was dichotomized into 2 groups; scores of 3 to 5 were

considered positive for respiratory distress, whereas scores of 1 or 2 were considered to indicate no respiratory distress. Physicians were asked to indicate the presence or absence of specific findings associated with respiratory distress (eg, retracting or grunting), focally decreased breath sounds, crackles (either focal or diffuse), and wheezing (focal or diffuse). Physicians were also asked to indicate the reasons for obtaining the chest radiographs. Indications of interest to our study included height and duration of fever, first episode of wheezing, and lack of response to standard asthma therapy (bronchodilators, with or without corticosteroids).

Other Data Abstraction

The electronic medical records for patients for whom a study form was completed were reviewed by the study investigators for basic demographic information (eg, age and gender), vital signs (eg, temperature, oxygen saturation, and respiratory rate), and treatments administered in the ED. Records were also reviewed to determine the presence of a history of wheezing (asthma, reactive airway disease, or bronchiolitis) and the presence of conditions predisposing the patient toward pneumonia. Triage temperature, respiratory rate, and oxygen saturation were collected from the electronic records, with the maximal temperature, highest respiratory rate, and lowest oxygen saturation during the course of the ED visit. Temperature was dichotomized at various cutoff points ($\geq 38^\circ\text{C}$, $\geq 38.5^\circ\text{C}$, and $\geq 39.0^\circ\text{C}$). Age-specific tachypnea was defined as a respiratory rate of >60 breaths per minute for age of <2 years, >50 breaths per minute for age of 2 to 4.9 years, >30 breaths per minute for age of 5 to 9.9 years, and >24 breaths per minute for age of 10 to 21.9 years.⁵ Oxygen saturation was dichotomized at various cutoff points

(90%, 92%, 94%, and 96%) for analysis. Details of the discharge diagnosis, disposition, and antibiotic therapy were abstracted from the medical record.

Definition of Pneumonia

All radiographs were reviewed independently by 2 blinded, board-certified, pediatric radiologists for the presence or absence of pneumonia. All chest radiographs were deidentified, and no clinical information was provided to the radiologists. All chest radiography was performed by using standard equipment and radiologic techniques, and all radiographs were reviewed by the radiologists in digital format. Chest radiographs were read as either normal or abnormal. For the chest radiographs read as abnormal, the radiologists indicated whether the abnormality was more likely to be atelectasis or pneumonia by using a 5-point scale, that is, 1 = definite atelectasis (<5% likelihood of pneumonia), 2 = probable atelectasis (5%–10% likelihood of pneumonia), 3 = atelectasis or pneumonia (11%–50% likelihood of pneumonia), 4 = probable pneumonia (51%–75% likelihood of pneumonia), and 5 = definite pneumonia (>75% likelihood of pneumonia). Chest radiographs that demonstrated neither atelectasis nor pneumonia were considered negative for pneumonia. Because we were interested in developing a decision rule with the goal of minimizing radiography, we decided a priori to assign a diagnosis of pneumonia to all readings with scores of ≥ 3 . The radiographic presence of pneumonia was assigned to chest radiographs for which there was consensus between the 2 radiologists with respect to the presence of pneumonia (score of ≥ 3); conversely, chest radiographs for which there was agreement with respect to the absence of pneumonia (score of < 3) were considered to be negative.

For discrepant chest radiographs, that is, those read by one radiologist as positive for pneumonia (3–5 on the 5-point scale) and by the other radiologist as negative (1 or 2 on the 5-point scale), we used the final reading of the chest radiograph, which was abstracted from the medical record, to determine the presence or absence of pneumonia. These chest radiographs were classified into 3 groups, that is, positive, negative, or equivocal for pneumonia. A chest radiograph was considered positive for pneumonia if it was read as indicating single or multiple infiltrates, opacities, or consolidations; pneumonia; or pneumonia with effusion. A chest radiograph was considered negative for pneumonia if it was read as indicating no pneumonia, normal findings, atelectasis, or peribronchial cuffing, and a radiograph was considered equivocal for pneumonia if it was read as indicating atelectasis versus pneumonia or infiltrate or atelectasis but without exclusion of pneumonia. For this study, radiographs read as equivocal were considered negative for pneumonia.

Enrollment

Daily logs of all chest radiographs obtained from the ED were reviewed to ascertain enrollment. To assess capture rate and bias attributable to sampling, we reviewed the medical records for all patients for whom a chest radiograph was obtained from the ED in the first 3 days of every month ($\sim 10\%$ of the study sample). Data abstracted from the medical records included patient age, chronic medical conditions, wheezing on examination, and radiographic presence of pneumonia, on the basis of the chest radiograph reading in the medical record.

Statistical Methods

Univariate analyses were performed to assess the relationship between history and physical examination findings

and the presence of pneumonia, by using SPSS 15.0 (SPSS, Chicago, IL). Continuous and ordinal variables were dichotomized at logical cutoff points. Categorical data for patients with versus without pneumonia were analyzed with the χ^2 statistic. Results were interpreted in a 2-tailed manner, and *P* values of $\leq .05$ were considered statistically significant. Likelihood ratios (LRs) with 95% confidence intervals (CIs) were calculated for all variables. To create a decision tree, recursive partitioning analysis was performed by using CART 5 software (Statistical Software, Stanford, CA). Variables that were significant or nearly significant ($P \leq .20$) in univariate testing were considered candidate variables for inclusion in the model. Finally, subgroup analyses of children < 2 years of age and > 2 years of age were performed.

RESULTS

Study forms were completed for 540 patients; 14 of those patients were excluded because of chronic illness (6 patients had chronic lung disease, 4 had a history of tracheostomy and/or chronic aspiration, 2 had congenital heart disease, 1 had acute lymphocytic leukemia, and 1 had an underlying immunodeficiency). Of the 526 patients included in our study, 59% were male. The median age was 1.9 years (interquartile range: 0.7–4.5 years).

On the basis of review of the medical records of patients for whom radiographs were obtained during the first 3 days of each month, 61% of eligible patients were enrolled in the study. The mean age of children not enrolled did not differ from that of enrolled children during the audit period (3.2 vs 3.1 years), and neither did the rate of radiographic pneumonia (4.3% vs 4.0%).

Forty-seven percent of patients had a history of wheezing before evaluation in the ED. Eighty (15%) of 540 enrolled patients were treated with antibiotics

because of the diagnosis of pneumonia at the time of the initial ED visit. Demographic information is shown in Table 1.

The blinded radiologists agreed regarding the findings for 478 chest radiographs (91%), of which 4 (1%) were read as positive for pneumonia and 474 (99%) were read as negative for pneumonia. The radiologists did not agree regarding 48 radiographs (9%);

TABLE 1 Demographic Characteristics of the Study Population (N = 526)

Patient Characteristic	n (%)
Age	
<2 y	269 (51)
2–4.9 y	128 (24)
5–9.9 y	75 (14)
10–21.9 y	54 (10)
Male	308 (59)
History of wheezing	247 (47)
Triage temperature	
≥38.0°C	136 (26)
≥38.5°C	80 (15)
≥39.0°C	33 (6)
Maximal temperature in ED	
≥38.0°C	209 (40)
≥38.5°C	131 (25)
≥39.0°C	59 (11)
Triage tachypnea	
<2 y, >60 breaths per min	46 (17)
2–4.9 y, >50 breaths per min	21 (16)
5–9.9 y, >30 breaths per min	35 (47)
10–21.9 y, >24 breaths per min	20 (37)
Tachypnea at any time during ED course	
<2 y, >60 breaths per min	76 (28)
2–4.9 y, >50 breaths per min	34 (27)
5–9.9 y, >30 breaths per min	45 (61)
10–21.9 y, >24 breaths per min	35 (65)
Triage oxygen saturation	
<96%	159 (31)
<94%	72 (14)
<92%	26 (6)
<90%	7 (1)
Lowest oxygen saturation during ED course	
<96%	251 (48)
<94%	148 (28)
<92%	84 (16)
<90%	40 (8)
Radiographic pneumonia	26 (4.9)
Treatment administered in ED and disposition	
Antibiotic treatment with diagnosis of pneumonia	80 (15)
Albuterol treatment	445 (85)
Corticosteroid treatment	273 (52)
Admission to hospital	190 (36)

for those patients, the chest radiograph reading at the time of the patient encounter was abstracted from the medical record to determine the presence or absence of pneumonia. After medical record review for those 48 radiographs, 22 cases of pneumonia were identified. Of 26 cases (26 of 526 cases; 4.9%) in which pneumonia was identified, 12% had a single infiltrate, 6% had lobar consolidation, 5% had multiple infiltrates, 2% had lobar consolidation with effusion, and 2% had multilobar consolidation.

Comparisons of characteristics of patients with and without pneumonia and their corresponding positive LRs are shown in Table 2. Eighty-one percent of patients with pneumonia had a history of fever at home, compared with 58% of patients with no pneumonia (positive LR: 1.39 [95% CI: 1.13–1.70]; *P* = .02). Fifty percent of patients with pneumonia had a triage temperature of ≥38.0°C, compared with only 25% of patients without pneumonia (positive LR: 2.03 [95% CI: 1.34–3.07]; *P* = .01). Seventy-three percent of patients with pneumonia had a temperature of ≥38.0°C in the ED, compared with 38% of patients who did not have pneumonia (positive LR: 1.92 [95% CI: 1.48–2.49]; *P* = .001). With the use of a higher temperature threshold to define fever, 19% of patients with pneumonia had a triage temperature of ≥39.0°C, compared with 6% of patients without pneumonia (positive LR: 3.42 [95% CI: 1.44–8.16]; *P* = .02). In addition, 38% of patients with pneumonia had a temperature of ≥39.0°C during their ED course, compared with 10% of patients without pneumonia (positive LR: 3.92 [95% CI: 2.25–6.83]; *P* < .001). Children with a temperature of ≥39.0°C in the ED were 5 times more likely to have pneumonia, compared with children with lower temperatures (relative risk [RR]: 4.96 [95% CI: 2.36–10.40]).

Patients with pneumonia were more likely to have an oxygen saturation value of <92% at triage (positive LR: 3.06 [95% CI: 1.15–8.16]; *P* = .05). Fifteen percent of children with pneumonia had abdominal pain, compared with 5% of children without pneumonia (positive LR: 2.85 [95% CI: 1.08–7.54]; *P* = .06). Focally decreased breath sounds (positive LR: 0.92 [95% CI: 0.31–2.72]; *P* = 1.00) and focal crackles (positive LR: 1.96 [95% CI: 0.85–4.51]; *P* = .17) were not observed more frequently among children with pneumonia. In addition, the presence of tachypnea at triage (positive LR: 0.93 [95% CI: 0.49–1.78]; *P* = 1.00) or at any time during the ED visit (positive LR: 0.97 [95% CI: 0.59–1.60]; *P* = 1.00) was not associated with pneumonia. Patients who had chest radiographs ordered for evaluation of their first episode of wheezing had a lower risk of pneumonia than did patients who had radiographs ordered for another indication (positive LR: 0.32 [95% CI: 0.11–0.95]).

With the use of recursive partitioning, patients with a maximal temperature of <38.0°C in the ED were at low risk of pneumonia (2.2%) (Fig 1). Additional attempts to refine the multivariate model failed to decrease this risk substantially. Aside from lack of fever, we were unable to develop a clinical decision rule to guide clinicians with respect to ordering chest radiographs for children with wheezing. The presence of fever in the ED (maximal temperature of ≥38.0°C) was associated with a greater risk of pneumonia (9.1%). Twenty percent of patients with both fever and oxygen saturation values of <92% had radiographic pneumonia.

Among children <2 years of age, 8 (3.0%) of 269 had pneumonia (data not shown). In this group, triage temperature of ≥38.0°C (positive LR:

TABLE 2 Comparison of Characteristics for Patients With and Without Pneumonia

Patient Characteristic	n (%)		P	Positive LR for Pneumonia (95% CI)
	Pneumonia (N = 26)	No Pneumonia (N = 500)		
Historical features				
Fever	21 (81)	291 (58)	.02	1.39 (1.13–1.70)
Difficulty breathing	14 (54)	391 (78)	.01	0.69 (0.48–0.99)
Chest pain	2 (8)	56 (11)	.76	0.69 (0.18–2.66)
Abdominal pain	4 (15)	27 (5)	.06	2.85 (1.08–7.54)
Examination findings				
Respiratory distress ^a	10 (38)	234 (47)	.43	0.82 (0.50–1.34)
Triage temperature				
≥38.0°C	13 (50)	123 (25)	.01	2.03 (1.34–3.07)
≥38.5°C	9 (35)	71 (14)	.01	2.44 (1.38–4.31)
≥39.0°C	5 (19)	28 (6)	.02	3.42 (1.44–8.16)
Maximal temperature in ED				
≥38.0°C	19 (73)	190 (38)	<.001	1.92 (1.48–2.49)
≥38.5°C	15 (58)	116 (23)	<.001	2.49 (1.72–3.58)
≥39.0°C	10 (38)	49 (10)	<.001	3.92 (2.25–6.83)
Triage tachypnea ^b	7 (27)	144 (29)	1.00	0.93 (0.49–1.78)
Tachypnea during ED course ^b	10 (38)	198 (40)	1.00	0.97 (0.59–1.60)
Triage oxygen saturation				
<96%	10 (38)	149 (30)	.38	1.29 (0.78–2.13)
<94%	5 (19)	67 (13)	.38	1.43 (0.63–3.24)
<92%	4 (15)	25 (5)	.05	3.06 (1.15–8.16)
<90%	2 (8)	5 (1)	.04	7.66 (1.56–38)
Lowest oxygen saturation during ED course				
<96%	12 (46)	239 (48)	1.00	0.96 (0.63–1.47)
<94%	9 (35)	139 (28)	.50	1.24 (0.72–2.14)
<92%	7 (27)	77 (15)	.16	1.74 (0.89–3.39)
<90%	4 (15)	36 (7)	.13	2.13 (0.82–5.53)
Retracting	7 (27)	225 (45)	1.00	0.60 (0.32–1.14)
Grunting	0 (0)	29 (6)	.39	0.00 (0.00–5.01)
Focal decreased breath sounds	3 (12)	63 (13)	1.00	0.92 (0.31–2.72)
Diffuse crackles or rales	7 (27)	141 (28)	1.00	0.95 (0.50–1.83)
Focal crackles or rales	5 (19)	49 (10)	.17	1.96 (0.85–4.51)
Focal wheezing	4 (15)	54 (11)	.51	1.42 (0.56–3.63)
Indication for chest radiograph				
First-time wheezing	3 (12)	178 (36)	.01	0.32 (0.11–0.95)
Failure to show improvement with treatment for asthma	3 (12)	82 (16)	.78	0.70 (0.24–2.08)
Height of fever	7 (27)	88 (18)	.29	1.53 (0.79–2.96)
Duration of fever	6 (23)	64 (13)	.14	1.80 (0.86–3.77)

^a Respiratory distress was defined as scores of 3 to 5 on a 5-point scale.

^b Age-specific tachypnea was defined as a respiratory rate of >60 breaths per minute for children <2 years of age, >50 breaths per minute for children 2 to 4.9 years of age, >30 breaths per minute for children 5 to 9.9 years of age, and >24 breaths per minute for children 10 to 21 years of age.

2.80 [95% CI: 1.79–4.37]) and triage oxygen saturation of <92% (positive LR: 11.00 [95% CI: 2.58–46.00]) were associated with radiographic pneumonia. No patient <2 years of age for whom a chest radiograph was obtained for the indication of first-time wheezing ($n = 126$) had radiographic pneumonia.

Among children 2 to 21 years of age, 18 (7.0%) of 257 had pneumonia. In this

group, triage temperature of $\geq 38.0^\circ\text{C}$ (positive LR: 1.75 [95% CI: 0.94–3.28]; RR: 2.09 [95% CI: 0.85–5.15]) and triage temperature of $\geq 39.0^\circ\text{C}$ (positive LR: 4.43 [95% CI: 1.59–12.00]; RR: 4.40 [95% CI: 1.60–11.57]) were associated with the presence of pneumonia on chest radiographs. Triage hypoxia was not associated with radiographic pneumonia among children >2 years of age (positive LR: 1.39 [95% CI: 0.35–5.49]).

DISCUSSION

To our knowledge, this is the largest prospective evaluation of clinical predictors of pneumonia in children with wheezing on examination. We found a low rate (4.9%) of radiographic pneumonia in our study population. The prevalence of pneumonia in previous investigations varied widely, ranging from 8.6% to 35%.^{6–8} Although those studies included children of varying ages, all excluded children with a known history of asthma. The prevalence of pneumonia in studies conducted among children with wheezing also varied widely, from 1% to 23%.^{9–13} However, several of those studies were limited by their exclusion of children >2 years of age, as well as children with a history of wheezing.^{10,11,13}

We were able to identify several historical and clinical findings that were associated with pneumonia in children with wheezing. The strongest predictor of radiographic pneumonia in our study was the presence and height of fever. Patients with an ED temperature of $\geq 39.0^\circ\text{C}$ were 5 times more likely to have pneumonia than were children without fever. In addition, children with a reported history of fever at home were more likely to have pneumonia than were those without a history of fever. Although fever was recognized previously as a predictor of pneumonia, this is the first study, to our knowledge, that quantifies the association between temperature and the likelihood of pneumonia in a population of wheezing patients. Children with hypoxia (oxygen saturation of <92%) were 3 times more likely to have radiographic pneumonia than were children without hypoxia. In fact, 20% of children with both fever and hypoxia had radiographic pneumonia. Other studies that sought to find clinical predictors of pneumonia among wheezing children were conducted primarily with children <3 years of age

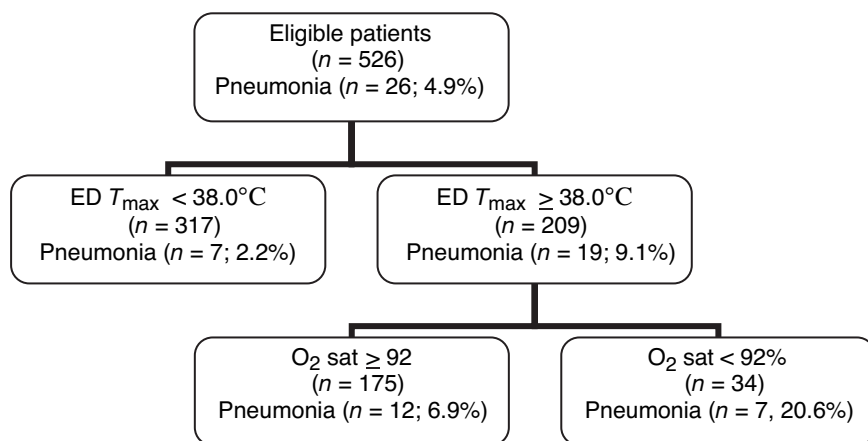


FIGURE 1
Recursive partitioning. Tmax indicates maximal temperature; O2 sat, oxygen saturation.

with bronchiolitis. A prospective study of children up to 23 months of age with clinically diagnosed bronchiolitis observed the rate of lobar consolidation to be <1%; furthermore, the risk of airspace disease was even lower in the absence of hypoxia and respiratory distress.¹³ A retrospective study of wheezing children <18 months of age found the following characteristics to be associated with radiographic pneumonia: history of fever (odds ratio [OR]: 2.1 [95% CI: 1.0–4.4]), temperature of $\geq 38.4^{\circ}\text{C}$ (OR: 2.5 [95% CI: 1.1–5.8]), and crackles on examination (OR: 3.9 [95% CI: 1.7–9.0]).¹⁰ A prospective study conducted by the same authors found that, among infants <18 months of age, grunting on examination (OR: 4.1 [95% CI: 2.0–8.6]) and oxygen saturation of $\leq 93\%$ (OR: 2.2 [95% CI: 1.1–4.8]) were predictors of radiographic pneumonia, whereas fever and tachypnea were not associated with pneumonia risk.¹¹

A study of children >1 year of age with a first episode of wheezing found that the combination of tachypnea, tachycardia, fever, and localized findings (rales or wheezing) both before and after bronchodilator therapy could identify 95% of patients with pneumonia.⁹ Another retrospective study of children with asthma found that 24%

of children with rales on examination demonstrated abnormalities on chest radiographs.¹² Similar to our study, those studies found the presence of fever and hypoxia to be associated with the radiographic presence of pneumonia among wheezing children, although tachypnea and focal auscultatory findings were not associated with pneumonia in our study. Unlike our study, several of those studies did not include children with known asthma or a history of wheezing and did not perform blinded radiologist review of chest radiographs.^{10,11,13} Consistent with previous evaluations, we observed that children for whom radiographs were obtained for the indication of a first episode of wheezing were less likely to have radiographic pneumonia than were those for whom chest radiographs were obtained for another indication.^{9,11,14}

We also observed that many of the physical examination findings classically associated with pneumonia were not associated with radiographic pneumonia in our study population of children with wheezing. This differs from other studies, which found various clinical findings, such as tachypnea, focal rales, decreased breath sounds, and crackles, to be associated with pneumonia.^{6,15,16} Again, all of those

studies were conducted among children without wheezing, and all excluded children with a history of asthma.

The presence of fever was associated with pneumonia among both younger (<2-year-old) and older (2–21-year-old) children, and lack of fever made the diagnosis of radiographic pneumonia unlikely. Among older children (2–21 years of age), those with a triage temperature of $\geq 38.0^{\circ}\text{C}$ were twice as likely to have pneumonia, and those with a higher temperature ($\geq 39.0^{\circ}\text{C}$) were 4 times as likely to have pneumonia, compared with those without fever. Hypoxia was associated with the radiographic presence of pneumonia only among children <2 years of age. Other studies conducted with children with wheezing used the chest radiograph reading at the time of the ED encounter to determine the presence or absence of pneumonia.^{10,11,13} This reading may be influenced by the clinical history provided to the radiologist by the referring physician, which introduces bias, especially in the case of equivocal chest radiographs.^{17–20} We reduced this bias by having all chest radiographs read by 2 pediatric radiologists who were blinded to all historical and clinical information. The use of blinded radiologists as the standard for the diagnosis of pneumonia has been described.^{6,8,13,21,22} However, there is variability among radiologists in evaluations of chest radiographs for the presence of pneumonia.^{17,23} Although we were unable to develop a clinical decision rule to define a group of wheezing children at low risk of pneumonia, we did determine that children with fever of $<38.0^{\circ}\text{C}$ in the ED were at very low risk for pneumonia (2.2%).

There are several limitations to our study. We relied on the participation of physicians working in a busy ED; therefore, not all eligible patients were en-

rolled. In addition, chest radiographs were ordered at the discretion of the physicians caring for the patients, rather than on the basis of predefined criteria, which potentially introduced selection bias. We enrolled ~61% of all patients seen in our ED who underwent chest radiography for evaluation of the presence of pneumonia. Although 39% of eligible patients were not enrolled, the patients we failed to enroll did not differ from our study population with respect to age or the presence of radiographic pneumonia. We sought to include children of all ages; therefore, extrapolation of our results to decisions on whether to order chest radiographs for patients of specific ages may be difficult. The lack of specificity is balanced by increased generalizability of our results. We studied all children for whom chest radiographs were obtained and did not include children with wheezing on examination for whom chest radiographs were not obtained. Therefore, our results are not generalizable to all children with wheezing and, because of this, it is likely that we overestimated the rate of

pneumonia. To optimize our standard for diagnosis of radiographic pneumonia, we relied on blinded radiologist review, which may limit the generalizability of our results. Lastly, even in the best of circumstances, it is difficult to distinguish a viral process from bacterial pneumonia on chest radiographs, and radiographic pneumonia does not necessarily indicate a bacterial infection. However, *Streptococcus pneumoniae* remains a common pathogen among patients with pneumonia,^{24–26} and most experts agree that antimicrobial agents are indicated for children with radiographic pneumonia.^{27,28}

In an attempt to standardize the interpretation of chest radiographs for consistency among epidemiological studies, the World Health Organization developed criteria for the radiographic diagnosis of pneumonia. These criteria include the presence of an opacity, consolidation, infiltrate, or effusion. This classification was found to improve agreement among radiologists in their interpretations of chest radiographs in epidemiological studies.²⁹ Although all chest radiographs in

our study were interpreted by 2 blinded pediatric radiologists, we did not use the World Health Organization classification specifically or have predefined criteria for determination of the presence or absence of radiographic pneumonia. The World Health Organization classification scheme may not apply well to our population of children with wheezing, because many of the radiographs in this population demonstrated atelectasis, which can be difficult to distinguish from an infiltrate.

CONCLUSIONS

We found that the presence of radiographic pneumonia in children with wheezing was low. Children with fever of $\geq 38.0^{\circ}\text{C}$ had a greater likelihood of pneumonia, particularly in the setting of hypoxia. The routine use of chest radiography for children with wheezing but without fever should be discouraged.

ACKNOWLEDGMENT

We thank Daniel Kim for his significant contributions to this study.

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Bonnie Mathews, Sonal Shah, Robert H. Cleveland, Edward Y. Lee, Richard G. Bachur and Mark I. Neuman

Pediatrics 2009;124:e29

DOI: 10.1542/peds.2008-2062

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