Evaluation of the Utility of Radiography in Acute Bronchiolitis

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Objectives **To determine the proportion of radiographs inconsistent with bronchiolitis in children with typical presentation of bronchiolitis and to compare rates of intended antibiotic therapy before radiography versus those given antibiotics after radiography.**

Study design **We conducted a prospective cohort study in a pediatric emergency department of 265 infants aged 2 to 23 months with radiographs showing either airway disease only (simple bronchiolitis), airway and airspace disease (complex bronchiolitis), and inconsistent diagnoses (eg, lobar consolidation).**

Results **The rate of inconsistent radiographs was 2 of 265 cases (0.75%; 95% CI 0-1.8). A total of 246 children (92.8%) had simple radiographs, and 17 radiographs (6.9%) were complex. To identify 1 inconsistent and 1 complex radiograph requires imaging 133 and 15 children, respectively. Of 148 infants with oxygen saturation >92% and a respiratory disease assessment score <10 of 17 points, 143 (96.6%) had a simple radiograph, compared with 102 of 117 infants (87.2%) with higher scores or lower saturation (odds ratio, 3.9; 95% CI, 1.3-14.3). Seven infants (2.6%) were identified for antibiotics pre-radiography; 39 infants (14.7%) received antibiotics post-radiography (95% CI, 8-16).**

Conclusions **Infants with typical bronchiolitis do not need imaging because it is almost always consistent with bronchiolitis. Risk of airspace disease appears particularly low in children with saturation higher than 92% and mild to moderate distress.** ***(J Pediatr 2007;150:429-33)***

Viral bronchiolitis is the most frequent cause of infant hospitalization during the winter season.[1] Well-described variations in its management reflect a lack of consensus about optimal therapy,[2-5] with propensity to persist in clinical practices that may offer little benefit.[6] The intensity of therapy and investigation bears little relationship to the severity of bronchiolitis, but is a primary determinant of resource use and costs.[6]

Chest radiography in bronchiolitis is strongly recommended[7,8] and widespread worldwide.[9-11] In North America, the rate of chest radiography is variable and performed in 20% to 89% of bronchiolitis cases.[6,12-14] Although the usual radiographic abnormalities include airway disease and atelectasis,[15] a minority of infants with bronchiolitis have both airway and airspace disease.[16] However, bacterial super-infection is uncommon in bronchiolitis,[17-19] even when airspace disease is present.[19,20] Therefore, the main potential benefit of radiography lies in the identification of diagnoses inconsistent with bronchiolitis, such as lobar consolidation. Radiography is associated with numerous disadvantages and may also be linked to an increased use of antibiotics, both in children with bronchiolitis and in older children with suspected pneumonia.[14,21-23] Because of the difficulty in obtaining accurate radiographic diagnoses, recent guidelines advise against the routine use of chest radiography in typical bronchiolitis.[24,25] Earlier studies on the usefulness of radiographs in bronchiolitis were limited by the inclusion of infants with multiple wheezing episodes[25] and by insufficient power to make specific recommendations.[25,26] A recent state-of-the-art bronchiolitis review called for further studies clarifying the usefulness of radiographs in this disease.[27]

Our study investigated the rate of radiographic alternate diagnoses in infants with acute bronchiolitis (primary objective) and examined the impact of radiography on therapy (secondary objective).

ED	Emergency department	RDAI	Respiratory Disease Assessment Instrument

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METHODS

Study Setting and Population

This study took place in the tertiary care emergency department (ED) at the Hospital for Sick Children in Toronto. We included all previously healthy infants aged 2 to 23 months who came to the ED between November and April 2001 to 2005 from 8 AM to 9 PM with a typical presentation of acute bronchiolitis while the study nurses were on duty. Typical presentation was defined as the presence of non-toxic appearance with coryza, cough, and respiratory distress with wheezing for the first time. Infants with suspected bronchiolitis without wheezing or with an associated diagnosis of otitis media are not reported in this study. We excluded infants with previous wheeze/bronchodilator therapy, children with previously diagnosed cardiopulmonary disease, aspiration, neuromuscular disease, or chronic systemic disease, infants with prematurity <35 weeks gestation, infants with a birth weight <2500 g, or infants who underwent neonatal ventilation >24 hours. Children arriving with radiographs and children whose parents had an insufficient command of the English language were also excluded. Written consent was obtained from all participating families, and the study was approved by our research ethics board.

Study Design

This was a prospective cohort study. Before the study, the research nurses were trained by the principal investigator in the measurement of the Respiratory Disease Assessment Instrument (RDAI) clinical score. The RDAI has good reported internal validity[28] and has been used frequently in measuring respiratory distress in numerous trials in bronchiolitis.[28-31] It also correlates with other measures of respiratory distress[28] and achieves excellent interobserver reliability both in our ED and elsewhere.[28,30] Before the study started, the participating radiologist provided formal instruction in the interpretation of radiographs in bronchiolitis to the ED staff physicians and fellows.

After the ED assessment and enrollment, the study nurses recorded the relevant socio-demographic and clinical information preceding pharmacotherapy and classified patients according to the predetermined criteria for typical clinical presentation aformentioned. All enrolled patients were treated with 2 to 3 consecutive nebulizations of 2.5 mg/dose of albuterol (suspended in 2 mL normal saline, via Hudson Updraft nebulizer with oxygen flow 8 l/min). Thereafter, all children underwent chest radiography. To evaluate the impact of radiography on management, immediately before the radiograph the ED staff and fellows were asked about their intended use of antibiotics and disposition if no chest x-ray were available. The radiographs were interpreted by the ED staff physicians/fellows according to predetermined criteria for simple bronchiolitis, complex bronchiolitis, or diagnoses inconsistent with bronchiolitis, according to a definition, and classified by the study nurse into these 3 categories on the basis of the physicians' responses. The study nurse then recorded the ED physicians' radiograph interpretation and subsequent disposition decision and antibiotic therapy given on the basis of this interpretation. To minimize the possibility of a significant change in the clinical status between the pre- and post-radiograph management plans, these plans were recorded immediately before and after the procedure, respectively. All radiographs were read at a later date by the primary study radiologist, who is considered to be an expert in lung disease (D.M.), according to the same criteria as used in the ED. A second senior staff radiologist (P.B.) also read the initial 242 radiographs to validate the "expert" reading. Both study radiologists knew the patients were suspected of having bronchiolitis, but were blinded to details of the presentation, the ED interpretation of the films, the readings of the other participating radiologist, and the routine interpretation by staff radiologists not participating in the study. All enrolled children received a follow-up telephone call 1 week later about subsequent diagnoses and dispositions.

Radiographic Definitions

Simple radiographs were those with prominent bronchial markings and peribronchial infiltrates (airway disease), with or without hyperinflation or atelectasis. Complex radiographs showed airway disease and adjacent airspace disease,[20] but lacked lobar consolidation. Inconsistent radiographs were those with lobar consolidation, cardiomegaly, and other features incompatible with bronchiolitis.

Outcome Measures

The primary outcome variable was the proportion of infants with a radiograph inconsistent with bronchiolitis, as per the primary study pediatric radiologist, the reference standard.

Secondary outcome variables included the proportion of children scheduled for hospitalization/antibiotics pre-radiogrpahy versus given antibiotics/admitted post-radiography, on the basis of the ED physicians' radiograph reading. Furthermore, we have examined the association between the outcome of a simple radiograph and patient characteristics such as the age, temperature, oxygen saturation, and RDAI score.

Sample Size

The sample size was calculated for a 95% CI for the primary outcome. After discussion among the investigators, we have estimated the proportion of patients with bronchiolitis and inconsistent radiographs to be $\leq 3\% \pm 2\%$, and $\alpha = 0.05$ and $\beta = 0.2$, which yields the total number of bronchiolitis patients required to be 260.[32]

Analysis

The primary analysis was the calculation of the 95% CI for the proportion of children with bronchiolitis who had a chest radiograph interpreted by the study radiologist as inconsistent with bronchiolitis.

Secondary analyses included the McNemar test for comparisons of paired proportions and Fisher exact test for comparisons of proportions involving independent samples. Because of a lack of heterogenous responses by the radiologists, kappa coefficient for agreement could not be calculated, and a percentage agreement was used instead. A univariate and multiple logistic regression analysis were also performed to identify which clinical variables were independently associated with a simple radiograph.

RESULTS

Study Population

Between November and April 2001 to 2005, 265 children with typical bronchiolitis were enrolled. All children enrolled completed the study, and 263 children received follow up. The mean (± SD) age was 7.7 ± 5.5 months; 65% were boys. The mean baseline values and their SDs were: RDAI score of 8.9 ± 3.2 points, respiratory rate of 52.6 ± 20.1 breaths per minute, heart rate of 144.2 ± 22.1 beats per minute, and oxygen saturation of 96.5% ± 2.6%.

The cases were identified from among 1375 children who came to our ED with the diagnosis of bronchiolitis. Of these, 665 were not screened—the research nurse was not available for 533 patients, 120 children were missed, and 12 patients were not screened during the severe acute respiratory syndrome epidemic. Of the 710 infants screened for the study, 46 had suspected bronchiolitis but no wheezing or co-existent otitis media, 45 were excluded because of previous wheeze, 71 had a history of prematurity/previous ventilation, 4 were critically ill, 32 families had inadequate command of the English language, 17 arrived with radiographs from other institutions, 88 refused participation, 129 had minimal respiratory distress that was regarded as not warranting treatment, and 13 had been previously enrolled. The age and sex of the enrolled children were comparable with those of children who were not enrolled.

Radiographic Outcomes

In the 265 study infants, 2 radiographs (0.75%) were read by the reference radiologist as inconsistent with bronchiolitis (1 cardiomegaly and 1 lobar consolidation; 95% CI, 0-1.8). The results suggest that 133 children with typical bronchiolitis would have to undergo radiography to identify 1 radiograph that is suggestive of an alternate diagnosis.

The first 242 radiographs were read by both study radiologists. Although the reference radiologist identified 2 of 242 radiographs (0.8%) as inconsistent, the second radiologist read 3 of 242 radiographs (1.2%) as inconsistent (95% CI, 0-1.9). Therefore, the 2 radiologists agreed in 97.9% of the cases.

Of the 265 study radiographs, 246 (92.8%) were classified as simple and 17 (6.9%) were classified as complex. Fourteen infants would therefore have to undergo radiography to identify a single radiograph that would be either complex or inconsistent with bronchiolitis. Children with simple bronchiolitis were significantly less hypoxic and had a lower bronchiolitis RDAI score than children with complex or inconsistent radiographs (Table I). Infants with both a baseline oxygen saturation >92% and a RDAI score <10 of 17 possible points were 3.9 times more likely to have a simple radiograph than their counterpars whith more more hypoxia or more distress (OR, 3.9; 95% CI, 1.3-14.3). Of the 148 children who had both of these characteristics, 143 (96.6%) had simple radiographs. In this low- risk group, 29 infants would need imaging to obtain a single complex or inconsistent radiograph.

Antibiotics were prescribed at disposition for 39 study infants (14.7%), and 31 children (11.7%) were hospitalized. Intended disposition (ie, discharge versus admission) was the same pre- and post-radiography in 258 of the 265 cases (97.4%). In contrast, on the basis of the ED physicians' radiograph interpretation, >5 times as many children received antibiotic therapy post-radiography as compared with their intended management plan pre-radiography (95% CI for the difference, 8-16; Table II).

Table I. Characteristics of infants with simple versus complex/inconsistent radiographs

	Simple (N = 246)	Complex/ Inconsistent (N = 19)	95% CI for the difference
Age* (months)	7.5 ± 5.0	9.6 ± 4.8	−4.6-0.5
Duration of respiratory distress (hours)*	41.2 ± 31.9	46.1 ± 28.5	−19.7-10.0
Temperature (°C)*	37.7 ± 0.8	37.9 ± 1.0	−0.6-0.2
Temperature ≥38°C	84 (34.1%)	8 (42.1%)	−0.31-0.15
Temperature ≥39°C	15 (6.1%)	3 (15.8%)	−0.26-0.07
Respiratory rate*	52.8 ± 20.5	50.4 ± 14.8	−7.0-11.8
Oxygen saturation rate ≤92%	16 (6.5%)	5 (26.3%)	−0.39-0.0
Positive results for respiratory syncytial virus	160 (65%)	12 (63.2%)	−0.21-0.24
Crackles	57 (23.2%)	4 (21.1%)	−0.17-0.21
RDAI score*	8.8 ± 3.2	10.4 ± 2.6	−3.2- −1.7

*Mean ± SD.

Table II. Decision plan to use antibiotics pre- versus post-radiography

	Pre X-ray plan		
Post X-ray therapy	Antibiotics	No antibiotics	Total
Antibiotics	5	34	39
No antibiotics	2	224	226
Total	7	258	265

95% CI for the difference in agreement = 0.08-0.16.

Follow-up

Two of 265 children (0.8%) received additional diagnoses. One child with a blood culture positive for several strains of viridans streptococci during the initial hospitalization had received a single dose of intravenous Ceftriaxone, which was stopped because of negative results on repeat cultures taken before antibiotics were administered and excellent clinical appearance. Another child who appeared well was admitted several days after initial discharge for high fever and leukocytosis to rule out sepsis/meningitis; he had negative results on bacterial cultures and recovered well.

One of the 2 children whose radiographs were read by the primary radiologist as inconsistent with bronchiolitis had respiratory syncytial virus-positive bronchiolitis and cardiomegaly with a secundum atrial septal defect requiring follow-up. The second infant had lobar consolidation with positive results on a respiratory syncytial viral study; this infant received no antibiotics and recovered uneventfully. All the patients recovered uneventfully.

DISCUSSION

We have demonstrated that in previously healthy children with a typical presentation of bronchiolitis, the radiographic findings are usually consistent with this disease. This conclusion is strengthened by the low rates of inconsistent radiographs identified by both study radiologists. The narrow 95% CIs for the proportions of radiographs interpreted as inconsistent by both radiologists suggest that our results can be interpreted with a high degree of confidence. The agreement between the radiologists also strengthens the validity of the "expert" as a reference standard. Our results would suggest that ED physicians in a setting similar to ours should consider setting a higher threshold for radiography in this population.

In a recent large retrospective multicenter study, Christakis et al found that the use of chest radiographs in bronchiolitis is an independent predictor of antibiotic use. However, only 72% of the patients underwent radiography, and selection bias for radiography was therefore likely. Our study confirms that radiography has a significant impact on the subsequent use of antibiotics.

Several earlier studies have concluded that routine radiography may not be necessary in children wheezing for the first time.[11,25,26] However, all lacked adequate power for definitive recommendations for radiography. One study did not report rates of airspace disease and only included children whom the admitting physician thought needed radiography,[25] although another study included patients as old as 18 years, most of whom did not have bronchiolitis.[11] A smaller bronchiolitis study by Farah et al[26] found that 17% of infants had "pathologic" radiographs that included atelectasis. Because atelectasis is an integral part of bronchiolitis that rarely changes management, we have included atelectasis in the simple group. Furthermore, few children in Farah's study had fever or low oxygen saturation, and the association between these characteristics and radiographic outcomes could not be determined. Mahabee-Gittens found crackles to be the only independent predictor of pneumonia in young children with wheezing.[33] This study was retrospective, radiographs were performed in only half the study population, and many children had wheezed previously.

At some institutions, infants who had bronchiolitis with airspace disease on radiographs are treated with antibiotics for potential bacterial pathogens.[34] However, some experts feel that most airspace disease in this age group is viral[35-37] and the rate of serious bacterial infection in febrile children with bronchiolitis is low.[17,18,38] Our study suggests that almost all infants with typical bronchiolitis who do not have significant hypoxia or severe respiratory distress lack any radiographic evidence of airspace disease. This subgroup therefore appears to be at a low risk for potential bacterial pneumonia.

The main limitation of this study is the lack of a diagnostic "gold standard" proving the absence of bacterial infection in children with complex radiographs. Ideally, the decision to do the radiography should be made after an appropriate review of the expected benefits of this procedure in each child (eg, in children with toxic appearances or those with unusual presentations or prolonged clinical courses). Also, our study had only 1 radiograph with lobar consolidation, and identification of any predictive factors for this high-risk feature was impossible. Although our recommendations are likely generalizable to non-pediatric EDs, some of our colleagues working in these settings may not feel as confident in diagnosing typical bronchiolitis and may have a lower threshold for radiography. Likewise, our colleagues in community hospitals can apply these results to their patients, provided they feel comfortable with the clinical diagnosis and adequate follow-up is provided.

In summary, our study suggests that radiographs in children with typical bronchiolitis have limited value. Subjecting this population to radiography is therefore usually not warranted, particularly in infants without severe distress and without significant hypoxia.

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REFERENCES

1. Arnold J. Acute bronchiolitis. In: Behrman R, editor. Nelson textbook of pediatrics. Philadelphia: WB Saunders; 1992. p. 1075.

2. Meissner HC. Uncertainty in the management of viral lower respiratory tract disease. Pediatrics 2001;108:1000-3.

3. Wang EEL, Law BJ, Boucher FD, Stephens D, Robinson JL, Dobson S, et al. Pediatric Investigators Collaborative Network on Infections in Canada (PICNIC) study of admission and management variation in patients hospitalized with respiratory syncytial viral lower respiratory tract infection. J Pediatr 1996;129:390-5.

4. Willson DF, Jiao JH, Donowitz L, Hendley JO. Invasive monitoring in infants with respiratory syncytial virus infection. J Pediatr 1996;128:357-62.

5. Langley JM, Wang EEL, Law BJ, Stephens D, Boucher FD, Dobson S, et al. Economic evaluation of respiratory syncytial virus infection in Canadian children: a Pediatric Investigators Collaborative Network on Infections in Canada (PICNIC) study. J Pediatr 1997;131:113-7.

6. 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.

7. Fleisher GR. Infectious disease emergencies. In: Fleisher GR, Ludwig S, editors. Textbook of pediatric emergency medicine. 4th ed. Philadelphia: Lippincott, Williams & Wilkins; 2000. p. 725-94.

8. Fireman P. The wheezing infant. Pediatr Rev 1986;7:247-54.
9. Brand PL, Vaessen-Verberne AA. Differences in management of bronchiolitis between hospitals in The Netherlands. Eur J Pediatr 2000;159:343-7.
10. Swingler GH, Hussey GD, Zwarenstein M. Randomised controlled trial of clinical outcome after chest radiograph in ambulatory acute lower-respiratory infection in children. Lancet 1998;351:404-8.
11. Roback MG, Dreitlein DA. Chest radiograph in the evaluation of first time wheezing episodes: review of current clinical practice and efficacy. Pediatr Emerg Care 1998;14:181-4.
12. Plint AC, Johnson DW, Wiebe N, Bulloch B, Pusic M, Joubert G, et al. Practice variation among pediatric emergency departments in the treatment of bronchiolitis. Acad Emerg Med 2004;11:353-60.
13. Leader S, Kohlhase K. Recent trends in severe RSV among US infants, 1997-2000. J Pediatr 2003;143:S127-32.
14. Christakis DA, Cowan CA, Garrison MM, Molteni R, Marcuse E, Zerr DM. Variation in inpatient diagnostic testing and management of bronchiolitis. Pediatrics 2005;115:878-84.
15. Swischuk LE. Imaging of the newborn infant and young child. 4th ed. Philadelphia: Williams & Wilkins; 1997.
16. Rice RP, Loda F. A roentgenographic analysis of respiratory syncytial virus pneumonia in infants. Radiology 1966;87:1021-7.
17. Greenes DS, Harper MB. Low risk of bacteremia in febrile children with recognizable viral syndromes. Pediatr Infect Dis J 1999;18:258-61.
18. Kuppermann N, Bank DE, Walton EA, Senac MO Jr, McCaslin I. Risks for bacteremia and urinary tract infections in young febrile children with bronchiolitis. Arch Pediatr Adolesc Med 1997;151:1207-14.
19. Welliver RC. Bronchiolitis and infectious asthma. Textbook of pediatric infectious diseases. Feigin and Cherry; Philadelphia: 1997.
20. Babyn PS, Chu WC, Tsou IY, Wansaicheong GK, Allen U, Bitnun A, et al. Severe acute respiratory syndrome (SARS): chest radiographic features in children. Pediatr Radiol 2004;34:47-58.
21. Swingler GH. Observer variation in chest radiography of acute lower respiratory infections in children: a systematic review. BMC Med Imaging 2001;1:1.
22. Alario AJ, McCarthy PL, Markowitz R, Kornguth P, Rosenfield N, Leventhal JM. Usefulness of chest radiographs in children with acute lower respiratory tract disease. J Pediatr 1987;111:187-93.
23. Grossman LK, Caplan SE. Clinical, laboratory, and radiological information in the diagnosis of pneumonia in children. Ann Emerg Med 1988;17:43-6.
24. Perlstein PH, Kotagal UR, Bolling C, Steele R, Schoettker PJ, Atherton HD, et al. Evaluation of an evidence-based guideline for bronchiolitis. Pediatrics 1999; 104:1334-41.
25. Dawson KP, Long A, Kennedy J, Mogridge N. The chest radiograph in acute bronchiolitis. J Paediatr Child Health 1990;26:209-11.
26. Farah MM, Padgett LB, McLario DJ, Sullivan KM, Simon HK. First-time wheezing in infants during respiratory syncytial virus season: chest radiograph findings. Pediatr Emerg Care 2002;18:333-6.
27. Smyth RL, Openshaw JM. Bronchiolitis. Lancet 2006;368:312-22.
28. Lowell DI, Lister G, Von Koss H, McCarthy P. Wheezing in infants: the response to epinephrine. Pediatrics 1987;79:939-45.
29. Klassen TP, Rowe PC, Sutcliffe T, Ropp LJ, McDowell IW, Li MM. Randomized trial of salbutamol in acute bronchiolitis. J Pediatr 1991;118:807-11.
30. Menon K, Sutcliffe T, Klassen TP. A randomized trial comparing the efficacy of epinephrine with salbutamol in the treatment of acute bronchiolitis. J Pediatr 1995;126:1004-7.
31. Patel H, Platt RW, Pekeles GS, Ducharme FM. A randomized, controlled trial of the effectiveness of nebulized therapy with epinephrine compared with albuterol and saline in infants hospitalized for acute viral bronchiolitis. J Pediatr 2002;141:818-24.
32. McClave JT, Dietrich II FH. Statistics. Collier MacMillan Publishers; San Francisco: 1988.
33. Mahabee-Gittens EM, Bachman DT, Shapiro ED, Dowd MD. Chest radiographs in the pediatric emergency department for children $\leq$18 months of age with wheezing. Clin Pediatr (Phila) 1999;38:395-9.
34. Courtoy I, Lande AE, Turner RB. Accuracy of radiographic differentiation of bacterial from nonbacterial pneumonia. Clin Pediatr (Phila) 1989;28:261-4.
35. Turner RB, Lande AE, Chase P, Hilton N, Weinberg D. Pneumonia in pediatric outpatients: cause and clinical manifestations. J Pediatr 1987;111:194-200.
36. Claesson BA, Trollfors B, Brolin I, Granstrom M, Henrichsen J, Jodal U, et al. Etiology of community-acquired pneumonia in children based on antibody responses to bacterial and viral antigens. Pediatr Infect Dis J 1989;8:856-62.
37. McCarthy PL, Spiesel SZ, Stashwick CA, Ablow RC, Masters SJ, Dolan TF Jr. Radiographic findings and etiologic diagnosis in ambulatory childhood pneumonias. Clin Pediatr (Phila) 1981;20:686-91.
38. Purcell K, Fergie J. Concurrent serious bacterial infections in 2396 infants and children hospitalized with respiratory syncytial virus lower respiratory tract infections. Arch Pediatr Adolesc Med 2002;156:322-4.