

Radiographic Follow-Up of Pneumonia in Children

R. Virkki, MD, T. Juven, MD, J. Mertsola, MD, and O. Ruuskanen, MD*

Summary. This study assessed the clinical value of routine follow-up chest radiographs in hospitalized children with community-acquired pneumonia. The study population consisted of 196 children hospitalized for community-acquired pneumonia diagnosed between 1993–1995. Seventeen infective agents (10 viruses and 7 bacteria) were sought. Chest radiographs were taken on admission and 3–7 weeks later. All children were treated with antibiotics. Data on the course of illness over the following 8–10 years were obtained from patient files and questionnaires sent to parents. A potential causative agent was found in 165 (84%) of 196 cases. On follow-up chest radiographs, residual or new changes were seen in 30% of cases. The residual changes tended to be more common after mixed viral-bacterial infection (43%) than after sole viral (25%) or sole bacterial (20%) infection. Interstitial infiltrates (66%), atelectasis (46%), and enlarged lymph nodes were the most common sequelae seen on follow-up. Residual findings on follow-up radiographs did not affect the treatment of the children. No further chest radiographs were taken. During the 8–10-year follow-up of 194 children, no illnesses appeared that were associated with previous pneumonia. Twenty-six children had a new episode of pneumonia, 7 of them had asthma, and 6 had different underlying illnesses. In conclusion, routine follow-up chest radiographs are not needed in childhood community-acquired pneumonia if the child has a clinically uneventful recovery. *Pediatr Pulmonol.* 2005; 40:223–227. © 2005 Wiley-Liss, Inc.

Key words: pneumonia; children; radiography; follow-up.

INTRODUCTION

Childhood community-acquired pneumonia is a common illness. Its incidence is 36–40 episodes/1,000 children/year in those <5 years of age.^{1,2} Many organisms may cause childhood community-acquired pneumonia. Recent observations suggest that 25% of patients have a viral infection alone, 25% have a bacterial infection alone, 25% have a mixed viral-bacterial infection, and 25% have an etiology that cannot be defined. *Streptococcus pneumoniae*, respiratory syncytial virus, and *Mycoplasma pneumoniae* are the most common causative agents.^{3–5} The clinical diagnosis of pneumonia is difficult, because the symptoms of illness are often nonspecific: fever, cough, rhinorrhea, dyspnea, and malaise/lethargy.^{6,7} The clinical signs (decreased breath sounds, tachypnea, and crackles) are sensitive but low in specificity.⁷ Thus the presentation of pneumonia in children can be very nonspecific, and a high index of suspicion is required. Chest radiography is suggested as a tool for the confirmation of clinical suspicion or for ruling out pneumonia.^{1,2,7,8}

Children usually recover from community-acquired pneumonia rapidly and without sequelae.⁹ The role of follow-up chest radiographs is not clear. Only a few studies with a limited number of patients addressed the value of radiologic follow-up in children with community-acquired pneumonia.

This prospective study was undertaken to investigate the resolution of chest radiographic changes in children

with viral and bacterial pneumonia, and to assess the clinical value of information obtained from follow-up radiographs taken 3–7 weeks after a diagnosis of pneumonia. For a long-term perspective, 8–10 years later, the medical records of patients were reviewed, and a questionnaire was sent to the parents to elicit the illness history after the time of follow-up chest radiograph.

PATIENTS AND METHODS

As part of a 3-year prospective study of the etiology and clinical profile of childhood community-acquired pneumonia,^{3,6,9,10} we studied follow-up chest radiographs. In addition, the illness history of the following 8–10 years was recorded. Between January 1, 1993–December 31, 1995, 296 consecutive hospitalized children with community-acquired pneumonia were enrolled in the

Departments of Diagnostic Imaging and Pediatrics, Turku University Hospital, Turku, Finland.

*Correspondence to: O. Ruuskanen, Department of Pediatrics, Turku University Hospital, PL 52, 20521 Turku, Finland.
E-mail: olli.ruuskanen@tyks.fi.

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study. The diagnosis was based on a simultaneous finding of an infiltrate (opacity in the lung) on chest radiograph and fever ($>37.5^{\circ}\text{C}$), and/or respiratory symptoms. The radiologic diagnosis was made by either a pediatric radiologist (during office hours) or a resident on call. One hundred children were excluded. The exclusion criteria were unavailability of a convalescent serum for viral and bacterial studies (33 cases), unavailability of initial chest radiographs for review or absence of infiltrate found on the radiograph on review (9 cases), or unavailability of follow-up chest radiographs taken within 21–48 days after the initial radiographs or their unavailability for review (58 cases). The remaining 196 cases were the material of this study.

Posteroanterior and lateral chest radiographs were obtained on admission. They were reviewed retrospectively and separately by three pediatric radiologists. The radiographic findings at time of diagnosis in the original 254 cases were reported earlier.¹⁰ Findings were classified according to alveolar (dense fluffy opacity/consolidation) and/or interstitial (ill-defined diffuse opacity of interstitium) pneumonic changes, hyperaeration, hilar enlargement, atelectasis (a dense streak or a triangular shape opacity), pleural fluid, and location in one lung or both lungs. The 196 follow-up posteroanterior and lateral chest radiographs were reviewed in the same manner by one (R.V.) of the original three pediatric radiologists.

The role of 17 microbes (10 viruses and 7 bacteria) as causative agent was studied. Details of the methods were reported earlier.³ In brief, antibody tests in acute and convalescent serum samples were used for bacterial diagnosis. For viral diagnosis, we used virus culture, sensitive immunoassay for seven viruses, a polymerase chain reaction assay for rhinovirus from nasopharyngeal aspirates, and serologic tests from acute and convalescent sera. The antibiotic treatment was chosen by the attending physician.

Total white blood cell count (WBC), erythrocyte sedimentation rate (ESR), and serum C-reactive protein (CRP) were determined on admission, using routine laboratory methods.

The follow-up examination was made 3–7 weeks after discharge, when in addition to a history of the time after discharge and clinical examination, blood samples for viral and bacterial serology and a chest radiograph were taken.

Between June 1–August 31, 2003, 8–10 years after the initial pneumonia episode, we studied the medical records of these 196 children. One child had died of myocarditis, and 13 families had relocated from our hospital district. Thus, the medical records of 182 of 196 (93%) children were studied for illness history during the 8–10-year follow-up. In addition, a questionnaire was sent to the parents of 195 patients, asking the illness history of the child after the occurrence of pneumonia. The questions

were: 1) Has the child had bouts of pneumonia? 2) If so, where was the diagnosis made and was it based on a chest radiograph? 3) Was the child treated after the occurrence of pneumonia in a hospital for a respiratory illness? 4) Has the child had asthma diagnosed by a physician? 5) Has the child received any asthma treatment for difficulty in breathing during the past 12 months? 6) Has the child coughed for longer than 4 weeks at any time?

Statistical Analyses

Pearson's standard chi-square test was used to compare proportions between groups (or Fisher's exact test when the expected count was less than 5).

RESULTS

Patient Characteristics

The median age of 196 children with pneumonia was 2.4 years (range, 0.1–15.6 years; 27 aged <1 year, 59 aged 1–2 years, 60 aged 2–5 years, and 50 >5 years of age). Of the patients, 53% were boys. A probable etiology was found in 84% of cases. Evidence of a bacterial infection was documented in 40 (20%) cases, viral infection in 65 (33%) cases, and mixed viral-bacterial infection in 60 (31%) cases, whereas no etiologic agent was found in 31 (16%) cases. The causative agents were *S. pneumoniae* (37%), respiratory syncytial virus (RSV) (31%), rhinovirus (18%), adenovirus (9%), parainfluenza type 1, 2, or 3 viruses (8%), nontypable *Haemophilus influenzae* (8%), *M. pneumoniae* (5%), coronavirus (3%), *Chlamydia pneumoniae* (2%), influenza A or B viruses (2%), human herpesvirus 6 (1%), and Epstein-Barr virus (1%). Table 1 shows the laboratory findings. In 75% of patients, fever $\geq 39.0^{\circ}\text{C}$ was recorded. Of the patients, 51% had WBC $>15 \times 10^9/\text{l}$, 73% had ESR >30 mm/hr, and 44% had serum CRP >80 mg/l. All patients were treated with antibiotics, usually with penicillin G (78%), cefuroxime (9%), or erythromycin (7%).

Findings on Initial and Follow-Up Chest Radiographs

Table 2 shows the radiographic findings at time of diagnosis and at follow-up. At time of diagnosis, sole alveolar changes were seen in 22%, sole interstitial changes in 39%, and mixed alveolar-interstitial changes in 39% of patients. One patient had empyema, and in her case, several chest radiographs were taken during recovery. On follow-up, 30% of 196 patients had radiographic abnormalities. Sole interstitial infiltrates (67%), atelectasis (47%), and enlarged lymph nodes (28%) were the most frequent findings. In 10% of patients with original sole alveolar changes and in 37% of patients with original sole interstitial changes, the infiltrates were still detectable at follow-up (chi-square $P=0.001$; Fisher's

TABLE 1—Characteristics of 196 Children With Community-Acquired Childhood Pneumonia¹

	All patients	Viral infection	Bacterial infection	Mixed viral and bacterial infection	No etiology found
Number of patients	196	65	40	60	31
High fever ≥39°C	147 (75%)	43 (66%)	32 (80%)	48 (80%)	24 (77%)
WBC × 10 ⁹ /l ²	16.0 (3.0–57.5)	14.5 (4.6–34.3)	18.7 (5.2–57.5)	13.6 (3.0–50.1)	18.8 (5.5–35.5)
WBC >15 × 10 ⁹ /l	100 (51%)	29 (45%)	26 (65%)	24 (40%)	21 (68%)
ESR mm/hr ²	50 (5–125)	44 (8–122)	68 (16–125)	44 (5–98)	52 (8–120)
ESR >30 mm/hr	116 (73%)	37 (69%)	27 (93%)	36 (72%)	16 (64%)
CRP mg/l ²	57 (9–388)	40 (9–290)	118 (9–350)	90 (9–388)	53 (9–250)
CRP >80 mg/l	87 (44%)	18 (28%)	25 (63%)	32 (54%)	12 (39%)

¹WBC, total white blood cell count; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.

²Median (range).

exact *P* = 0.001). Hyperaeration disappeared in all cases, while enlarged lymph nodes remained in 3 of 42 and atelectasis in 3 of 20 original cases. In 20% of patients, new radiographic changes developed after the original chest radiograph: most commonly, small atelectasis (in 24 cases), enlarged lymph nodes, and interstitial infiltrates (Table 2).

No single etiologic agent predicted the persistence of radiographic changes (data not shown), and the numbers of viral and bacterial infections showed no significant differences between the original patient population and those with residual findings on follow-up radiograph (Table 3). The age of the patient, increased WBC (>15.0 × 10⁹/l), increased serum CRP (>80 mg/l), or increased ESR (>30 mm/hr) did not predict the persistence of inflammatory changes on chest radiograph (data not shown).

The radiographic findings at the follow-up visit did not change the treatment in any patient, and further follow-up radiographs were not taken in spite of residual changes.

Medical History After Follow-Up Chest Radiograph

Information about medical events during the following 8–10 years was obtained from medical records of 182 of 196 (93%) children and from 165 (answer rate, 85%) questionnaires. The parents of two families who relocated could not be reached, and follow-up information was thus available on 194 children. In the questionnaire, the parents of 19 children reported new episodes of pneumonia during the follow-up. Eight of these diagnoses had been made in a hospital. In addition, from the hospital records, we found 7 patients with pneumonia that the parents had not reported. Of these 26 patients with recurrent pneumonia, 6 had an underlying illness predisposing to pneumonia, including Down syndrome (2 cases), large brain cysts with tetraplegia (1 case), postoperative status after resection of astrocytoma of pons (1 case), complement system deficiency (1 case), and left upper lobe bronchiectasis (1 case; after lobectomy, this patient has been well). Thus, 20 (13%) of 159 children without any known predisposing illness had recurrent pneumonia during follow-up. One

TABLE 2—Radiographic Findings on 196 Follow-Up Chest Radiographs

Findings	Number of patients with changes on initial chest radiograph (I) (n)	Number of patients with residual changes on follow-up chest radiograph (II) (n)	Viral etiology (n)		Bacterial etiology (n)		Mixed viral/bacterial etiology (n)		No etiology found (n)	
			I	II	I	II	I	II	I	II
			Sole alveolar changes	43	7 ¹	8	2	14	1	10
Sole interstitial changes	76	39 ²	38	10	12	9	17	14	9	6
Alveolar + interstitial changes	77	10 ³	19	1	14	1	33	8	11	0
Hyperaeration	74	0	30	0	9	0	27	0	8	0
Enlarged lymph nodes	18	16 ⁴	8	4	4	1	4	10	2	1
Atelectasis	20	27 ⁵	9	9	4	6	4	11	3	1
Pleural fluid	8	2 ⁶	4	0	2	2	0	0	2	0

¹Including 2 patients with alveolar changes on follow-up but not on initial radiograph.

²Including 11 patients with interstitial changes on follow-up but not on initial radiograph.

³Including one patient who had interstitial and alveolar changes on follow-up but only interstitial changes on initial radiograph.

⁴Including 13 patients with enlarged lymph nodes on follow-up but not on initial radiograph.

⁵Including 24 patients with atelectasis on follow-up but not on initial radiograph.

⁶Including 1 patient with pleural fluid on follow-up but not on initial radiograph.

TABLE 3—Occurrence of Inflammatory Changes on Follow-Up Chest Radiographs According to Etiology

Etiology	Patients with follow-up chest radiograph (n)	Patients with residual changes on follow-up chest radiograph (n, %)
Sole bacterial	40	12 (33)
Sole pneumococcal	29	9 (31)
Sole viral	65	15 (23)
Sole RSV	23	5 (22)
Mixed viral/bacterial	60	25 (42)
No etiology found	31	7 (23)
Total	196	59 (30)

patient had three pneumonia episodes. Of these 20 patients, only one had changes on follow-up chest radiograph 3–7 weeks after the initial pneumonia. Eleven of these 20 recurrent pneumonias had been diagnosed at our hospital, and 9 at a health center or a private practice. In 17 (85%) cases, the diagnosis of pneumonia had been based on chest radiograph, and 5 children were hospitalized due to pneumonia. A further 15 children had been hospitalized for a respiratory illness during the 8–10-year follow-up: 9 for asthma, 5 for wheezy bronchitis, and 1 for laryngitis. Twenty-six of 139 (18%) patients without pneumonia and 7 (35%) of 20 patients with pneumonia during follow-up had asthma ($P=0.093$). Twenty-five (16%) of 159 patients had received asthma medication during the past 12 months. Cough had occurred in 37 patients ≥ 4 weeks, and 10 of them were among patients with changes on the follow-up radiograph.

DISCUSSION

Our results confirm that a routine repeat chest radiograph is not necessary in children with community-acquired pneumonia. In uncomplicated cases, 90% of patients become afebrile within 48 hr after onset of antibiotic treatment, and only a short hospital stay may be needed.⁹ It is well-known that infiltrates seen on chest radiograph lag behind clinical recovery. In this study, one third of the fully recovered patients still had changes on chest radiograph, mainly interstitial infiltrates and atelectasis. Interestingly, in 20% of patients, new changes had developed, showing that the diagnostic chest radiograph is only one illustration of the dynamic inflammatory process. The radiographic findings at follow-up resulted in no changes in the treatment of the children. Most important, during the following 8–10 years, no illnesses appeared that were associated with previous pneumonia and that had gone undetected at time of diagnosis.

Three earlier studies addressed the value of a follow-up chest radiograph in community-acquired childhood pneumonia. In their prospective investigation, Grossman et al.¹¹ studied 129 children with radiologically confirmed pneumonia, and 70 of them had a repeat chest radiograph 3–

4 weeks after the initial diagnosis. Only two of the obtained blood cultures showed significant pathogens. No further etiologic investigations were carried out. Of the patients, 14 (20%) did not have complete radiologic resolution. Nine of these patients had a second follow-up between 6 weeks and 3 months later, all of them showing complete radiologic resolution. Gibson et al.¹² studied 77 consecutive pneumonias. Nine of them showed microbiological evidence of etiology, but no detailed information was given. The investigators reported residual pulmonary infiltrates in 16 (22%) of the repeat chest radiographs of 72 children returning for a follow-up visit 3–4 weeks after discharge. Of these 16 patients, 8 had complete clinical resolution, and they had only minor resolving radiologic changes. Seven of the 8 children with symptoms or signs at follow-up showed an improved appearance, and only one remained unchanged. In the study by Heaton and Arthur¹³ of 65 children with pneumonia, a nasopharyngeal aspirate was positive for respiratory syncytial virus in 10 children. No other information on the etiology of pneumonia was given. Of 41 patients with follow-up chest radiographs, 31 had a follow-up visit between 4–6 weeks, 5 at less than 4 weeks, and 5 more than 6 weeks after discharge. The follow-up chest radiograph was normal in 36 (88%) children, 4 showed residual shadowing, and 1 had an unchanged appearance. The conclusion of these three studies on 182 patients with community-acquired pneumonia was that a follow-up chest radiography is not necessary if symptoms and signs are absent. If a follow-up chest radiograph is indicated, it should be put off till at least 4 weeks after discharge.^{11–13}

Our study differs from previous studies in several important respects. We included patients during 3 years to be able to have a higher number of patients and all major causative agents. The etiology of pneumonia was detected in 84% of cases. This permitted a comparison between bacterial and viral infections. Patients were followed for 8–10 years after follow-up chest radiographs to find out long-term outcomes of the illness.

Radiological resolution of pneumonia was seen equally after sole viral (most often RSV) and sole bacterial (most often *S. pneumoniae*) pneumonia. However, after mixed viral-bacterial infection, the children tended to have more residual changes on follow-up chest radiograph than after viral and bacterial pneumonia. The duration of fever after onset of antibiotic treatment was reported to be longer in mixed viral-bacterial pneumonia than in viral and bacterial pneumonia.⁹ Mixed viral-bacterial infections are probably more common than previously recognized, and may induce a more severe inflammatory process in pneumonia than sole viral or sole bacterial infection.^{14,15}

Several studies suggest that the relative frequency of empyema as a complication of pneumonia in children is increasing.^{16–18} In the first study of Tan et al.¹⁹ during 1993–1996, 13.8% of hospitalized children had

empyema, and in their second study¹⁷ during 1993–2000, 36% of patients had a complicated pneumonia. Empyema may not be seen on the first chest radiograph. Slow response to antibiotic treatment is an indication for a repeat radiograph. Children with empyema are usually >3 years of age, with a history of ≥ 7 days of fever. They often have antibiotic treatment before diagnosis, and have immature polymorphonuclear leukocytes in peripheral blood and high CRP levels.^{15–17} Only one of our patients developed empyema. However, during the following 8 years, 25 cases of empyema were diagnosed at our center (R. Virkki, unpublished findings).

It is of interest that every tenth child without a chronic underlying illness had a second episode of community-acquired pneumonia. Only one child had at least two recurrent episodes of pneumonia. Children with recurrent pneumonia tended to have asthma more often than children without recurrent pneumonia. This finding is in agreement with the study of Lodha et al.,²⁰ showing that 14% of children with recurrent pneumonia had asthma.

In adults, the radiographic resolution of community-acquired pneumonia is comparable to that in children. Mittl et al.²¹ prospectively assessed resolution in 81 patients. Complete resolution occurred in 51% of patients after 2 weeks, and in 73% after 6 weeks. Faster clearance occurred in younger patients and in patients with only one lobe involved. A follow-up chest radiography is necessary in adults to exclude noninfectious diseases such as partially obstructing tumors or pulmonary embolism, which may become diagnosed only after pneumonic changes have resolved.^{22,23} In children, pulmonary tumors are very rare, and repeat chest radiographs are thus not needed to exclude them.

In conclusion, routine follow-up chest radiographs are not needed in childhood community-acquired pneumonia if the child has an uneventful recovery. However, the frequency of complicated pneumonia is increasing, and a repeat chest radiograph should be taken in case of a poor response to treatment.

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