Admission Chest Radiograph Lacks Sensitivity in the Diagnosis of Community-Acquired Pneumonia

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Abstract: *Introduction:* The clinical and epidemiological significance of community-acquired pneumonia (CAP) with a chest radiograph demonstrating no parenchymal infiltrate has not been studied. We determined the percentage of patients with a clinical diagnosis of CAP who did not have radiographic opacifications and compared this group with patients with CAP and radiographic infiltrates. *Methods:* Patients admitted with a diagnosis of CAP were identified. Clinical history, physical examination, laboratory studies, and microbiological cultures were reviewed in a random sample of 105 patients. Admission and subsequent chest radiographs were interpreted without knowledge of the clinical data. *Results:* Twenty-one percent (22/105) of patients with a clinical diagnosis of CAP had negative chest radiographs at presentation. Demographic, clinical, and laboratory data were the same in both groups. Fifty-five percent of patients with initially negative chest radiographs who had follow-up studies developed an infiltrate within 48 hours. *Conclusions:* In patients admitted with a clinical diagnosis of CAP, the initial chest radiograph lacks sensitivity and may not demonstrate parenchymal opacifications in 21% of patients. Moreover, greater than half of patients admitted with a negative chest radiograph will develop radiographic infiltrates within 48 hours. Further studies are needed to develop evidence-based criteria for the diagnosis of CAP.

Key Indexing Terms: Pneumonia; Community acquired pneumonia; Bacterial diagnosis; Chest radiograph. **[Am J Med Sci 2009; 337(4):236–240.]**

The diagnosis of community-acquired pneumonia (CAP) is based on a constellation of signs, symptoms, laboratory, and radiographic data.[1–3] Although numerous national and international organizations have developed guidelines for the management of CAP, no group has endorsed specific criteria for its diagnosis.[4–7] The cornerstone of most diagnostic criteria used for clinical and research purposes is the presence of a new infiltrate or opacification on chest radiograph in the correct clinical setting.[8–12] Requiring an infiltrate on chest radiograph likely excludes a diagnosis of CAP in many patients.[13] The diagnostic utility of the chest radiograph has not been compared with definitive microbiological diagnostic procedures such as lung parenchymal biopsy, bronchoscopic protected brushings, or pleural fluid sampling because these studies are invasive and carry increased risk.[14,15] Most studies that have indirectly evaluated the diagnostic utility of the chest radiograph in CAP suggest that it lacks sensitivity.[16–18] Despite this lack of evidence, some authors and organizations have suggested that chest radiograph findings are a required quality marker for the management of CAP.[5,19] Indeed, the diagnosis of CAP with no significant chest radiograph findings is poorly understood and frequently omitted from CAP guidelines. The sensitivity and specificity of radiographic infiltrates in patients hospitalized with a clinical diagnosis of CAP are not known. Therefore, we determined the prevalence of CAP with a negative admission chest radiograph and compared the clinical presentation of these patients with those individuals with CAP and radiographic abnormalities.

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METHODS

Patient Selection

Patients with CAP admitted to the University Hospital at the University of Cincinnati Medical Center (an urban 450 bed academic medical center) were identified retrospectively by the ICD-9 codes (480.0–487.0) available through hospital information systems. Charts were reviewed to ensure that the final clinical diagnosis of CAP was made by the physician at discharge. The only inclusion criterion was the final clinical diagnosis as determined by the attending physician. Of 520 patients admitted between March 2003 and December 2004 with the diagnosis of CAP, every fifth chart was randomly selected and reviewed by one of the authors (JTH). A total of 105 charts were reviewed.

Data Extraction

The patient's presenting signs and symptoms and medical history were obtained from the admitting physician's history and physical examination. Laboratory data at presentation and microbiologic data throughout the hospitalization were reviewed. Disease severity was calculated by the Pneumonia Severity Index (PSI) as defined previously by Fine et al.[10] The patient's clinical course was determined by physician progress notes, physician orders, and nursing flow sheets. Death or hospital readmission within 30 days of discharge were recorded as outcome measures.

Chest Radiograph Interpretation

A senior thoracic radiologist (RTS) who was blinded to all clinical data reviewed the admission chest radiographs and classified them as positive (consistent with pneumonia) or negative (no abnormalities to suggest pneumonia). Subsequent imaging studies were interpreted in a similar manner. The classification of a CXR as positive or negative was determined by the presence of at least 1 of these findings: (1) an asymmetric increase in lung opacification; (2) the silhouette sign, loss of a normal diaphragmatic, cardiac, or mediastinal silhouette; (3) an area of increased opacity bounded by a well-defined interface against adjacent aerated lung (such as along a fissure); (4) if only an anterior-posterior view was obtained (such as a portable examination), increased attenuation of the cardiac shadow; and (5) for radiographs with widespread airspace disease, more asymmetric or multifocal distribution of opacification. The same methodology was used for both anterior–posterior, and posterior–anterior and lateral chest radiographs.

Patient Stratification and Statistical Analysis

On the basis of the initial chest radiograph, patients were divided into 2 groups: positive (chest radiograph findings

TABLE 1. Patient characteristics

	Initial Chest x-Ray		
	Positive	**Negative**	***P***
Number of patients	83	22	
Patient age[a]	54.46 ± 3.59	55.36 ± 7.18	0.825
Male[b]	39 (47%, 36%–58%)	14 (64%, 40%–82%)	
Disease severity[b,c]			
Mean PSI	75.1	81.9	0.28
PSI class I	20 (24%, 15%–35%)	4 (18.1%, 5%–40%)	0.78
PSI class II	16 (19%, 11%–29%)	8 (36.4%, 17%–59%)	0.15
PSI class III	26 (31%, 21%–42%)	4 (18%, 5%–40%)	0.29
PSI class IV	8 (10%, 4%–18%)	5 (22.7%, 8%–45%)	0.14
PSI class V	0 (0.00%, 0%–4%)	0 (0.0%, 0%–12%)	1.00
Port score not applicable	13	1	
Length of stay (days)	4.0 ± 3.8	3.1 ± 2.1	0.24
Outcomes[b]			
Deaths	2 (2%, 0%–8%)	0 (0%, 0%–12%)	0.62
Patient made do not resuscitate during admission	4 (5%, 1%–12%)	1 (5%, 0%–22%)	0.7
Readmission within 30 d	15 (18%, 10%–28%)	3 (14%, 3%–35%)	0.75

[a] Mean with SEM.
[b] Values are number, percent of, and 95% confidence intervals.
[c] As calculated by PORT PSI.[10]

consistent with CAP) or negative (no chest radiograph findings indicating CAP). Continuous data were compared using a two-tailed Student *t* test. Categorical or dichotomous data were evaluated using χ^2 analysis or the Fisher Exact Test as appropriate. Statistical significance was set at an $\alpha \leq 0.05$. All statistical calculations were performed with SAS version 9.0 (Cary, NC).

This study was approved by the Institutional Review Board of the University of Cincinnati College of Medicine in June 2005. The requirement for informed consent was waived.

RESULTS

Twenty-one percent (22/105) of patients with a diagnosis of CAP had negative initial chest radiographs. Patients with negative chest radiographs were not different in age or gender when compared with those with positive radiographs (Table 1). Disease severity, as calculated by the PSI, was 75.1 on average for those with positive chest radiographs and 81.9 for those with negative initial studies ($P = 0.28$). The PSI was not able to be calculated due to HIV infection for 12 patients with positive chest radiographs and 1 patient with a negative initial study. Length of stay was 1 day longer for patients with positive chest radiographs (4.0 versus 3.1 d, $P = 0.24$). There were no significant differences in mortality or 30-day readmission rates between the 2 groups (Table 1).

There was no correlation between physical examination and radiographic findings. The incidence of localized chest findings such as rales and diminished breath sounds was the same for both groups. Only 5% of patients with negative chest radiographs had rhonchi versus 16% of patients with radiographic infiltrates ($P = 0.16$). Similarly, the incidence of wheezing and hypoxia was the same in both groups ($P = 0.16$ and 0.24, respectively). Also, there were no differences between the groups in reported symptoms in comorbidities (Table 2).

Only 4 patients (18%) with a negative chest radiograph had leukocytosis [white blood cell (WBC) count $>12{,}000/\mu L$] versus 40 (48%) with positive studies ($P = 0.048$) (Table 3). Patients with a negative chest radiograph also had lower WBC counts on an average (9.7 versus 13.1 $\times$ $10^3/\mu L$, $P = 0.04$). The blood urea nitrogen to creatinine ratio, a laboratory marker of volume depletion, was not different between the 2 groups (15.60 versus 14.86, $P = 0.540$). Eight patients with positive chest radiographs had bacteremia versus none with negative studies ($P = 0.059$). *Streptococcus pneumoniae*, *Pseudomonas aeruginosa*, *Streptococcus milleri*, *Staphlococcus aureus*, and *Eschericia coli* were pathogens isolated from blood cultures. Sputum microbiologic studies were similar between the 2 groups. Pathogens isolated from the sputum of patients with positive chest radiographs included *Streptococcus pneumoniae*, *Pseudomonas aeruginosa*, *Staphlococcus aureus*, and *Hemophilus influenza*. *Klebsiella pneumoniae* was isolated from the sputum of a patient with a negative chest radiograph.

Nine patients (41%) with an initial negative chest radiograph had a follow-up radiographic study within 48 hours. In 55% (5/9), the subsequent study showed an infiltrate that was not present on the initial chest radiograph [4 chest radiographs, 1 chest computed tomography (CT)]. Forty percent (33/83) of patients with a positive initial chest radiograph had a follow-up study within 48 hours.

Seven patients had chest CT scans—5 with initially positive chest radiographs and 2 with negative chest radiographs. All 5 patients with positive chest radiographs had infiltrates on their chest CT scans. One patient with a negative chest radiograph had an infiltrate on chest CT scan, and the other patient had a clear chest CT scan. Neither of these patients had follow-up chest radiographs during the admission.

DISCUSSION

In this study, 21% of patients admitted with a clinical diagnosis of CAP had a negative initial chest radiograph. Similarly, Basi et al[16] found 1/3 of patients admitted to Canadian hospitals and managed using a CAP pathway did not have chest radiograph findings indicative of pneumonia. Unlike most previous investigations of CAP, our study and the investigation by Basi et al[16] used the actual clinical diagnosis as inclusion

TABLE 2. Comorbidities in patients with community-acquired pneumonia

	Initial Chest x-Ray		
	Positive	**Negative**	***P***
Number of patients	83	22	
Chronic comorbidities			
COPD	12 (14%, 7%–24%)	5 (22%, 7%–45%)	0.344
Asthma	7 (8%, 3%–16%)	2 (9%, 1%–29%)	1
CHF	7 (8%, 3%–16%)	5 (22%, 7%–45%)	0.122
ESRD	4 (5%, 15–12%)	0 (0%, 0%–12%)	0.577
Alcohol abuse	6 (8%, 4%–18%)	2 (9.1%, 1–29)	0.67
Tobacco abuse	25 (30%, 20%–41%)	6 (27.3%, 10%–50%)	1
Psychiatric illness	6 (7%, 2%–15%)	1 (4.5%, 1%–22%)	1

All values are number, percent, and 95% confidence intervals.
COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; ESRD, end-stage renal disease.

criteria. Additionally, when 2 expert thoracic radiologists reviewed 282 chest radiographs of adults enrolled in the Pneumonia Patient Outcomes Research Team study with signs and symptoms of CAP and a radiographic infiltrate documented by a local study site radiologist, 12% to 14% of chest radiographs were judged definitively not to demonstrate infiltrates.[20] An additional 17.7% to 21.5% were assessed to have possible infiltrates. We believe these data show that the admission chest radiograph lacks sensitivity in the diagnosis of CAP when compared with the clinical diagnosis.

Although the sensitivity of chest radiograph findings in the diagnosis of CAP has never been studied directly, a study by Syrjala et al[17] demonstrated decreased diagnostic accuracy when compared with the chest CT. They found that nearly one third of patients with clinical presentations suggesting CAP had opacifications recognized by CT and not by chest radiograph (80% with CT versus 50% with chest radiograph).

The sensitivity and specificity of chest radiographic findings in the diagnosis of ventilator-associated pneumonia (VAP) have been studied extensively.[18] Lefcoe et al[21] compared chest radiographs with bronchial brush cultures in patients suspected of VAP and found that the chest radiograph had no better than 60% sensitivity and 24% specificity. Wunderink et al[22] compared the chest radiograph with autopsy findings in patients suspected of VAP before death and found no radiographic sign had a sensitivity greater than 68%. Thus, these data demonstrate that chest radiographs identify VAP poorly and, thus, may also lack sensitivity in the diagnosis of CAP.

Similar to the findings of Basi et al,[16] we also found that WBC counts were lower in patients with negative chest radiographs compared with patients with abnormal radiographs. Only 20% of patients with negative radiographs had WBC counts greater than 12,000. None of our patients with a negative chest radiograph were bacteremic, whereas 6% of patients in Basi's study had bacteremia.[16] As determined by the PSI, the patients in Basi's cohort (PSI, 100.7) were sicker than those in our study (PSI, 76.5), which may explain the lack of patients with bacteremia in our population.

We used the initial chest radiograph to define our cohorts. Of the 22 patients with initially negative chest radiographs, only 9 (41%) had follow-up studies within 48 hours. In 5 of these 9 patients, the subsequent radiologic study showed an infiltrate. The remaining 13 patients did not have a follow up study. The reasons for progression from negative to positive chest radiograph are unknown. Clinical experience suggests that initial volume depletion and subsequent fluid administration cause occult pulmonary processes to "fluff out" and become radiographically apparent. The data supporting such a relationship are scarce.[23,24] In our entire cohort, patients with

TABLE 3. Laboratory data for patients with community-acquired pneumonia

	Initial Chest x-ray		
	Positive	**Negative**	***P***
Number of patients	83	22	
WBC count (1000/μL)[b]	13.1 ± 7.6	9.7 ± 7.5	0.048
Number with leukocytosis (WBC >12,000/μL)[a]	40 (48%, 37%–59%)	4 (18%, 5%–40%)	0.014
Hemoglobin (g/dL)[b]	12.2 ± 6.5	12.1 ± 6.5	0.852
Blood urea nitrogen (mg/dL)[b]	19.6 ± 15.3	17.8 ± 13.7	0.612
BUN/creatinine ratio[b]	15.6	14.9	0.540
Microbiologic results			
Positive blood cultures[a]	8/62 (12.9%, 6%–22%)	0/18 (0.0%, 0%–21%)	0.12
Sputum culture with normal respiratory flora[a]	13/17 (76%, 52%–91%)	5/6 (83%, 42%–91%)	0.61
Sputum culture with apparent pathogen[a]	4/17 (24%, 9%–48%)	1/6 (17%, 1%–59%)	0.61

[a] Values reported with percent of whole and 95% confidence intervals.
[b] Value is mean with SEM.

negative chest radiographs had no evidence of dehydration, as suggested by hemoconcentration, higher incidence of tachycardia or elevated BUN/Cr ratios. When the analysis was confined to those 9 patients who had follow-up radiographic studies, patients who developed infiltrates had a trend towards a higher BUN/Cr than those who remained negative although the difference was not significant (25 versus 10.5, $P = 0.24$).

The lower WBC counts for patients with negative chest radiographs in our cohort and in Basi et al's study[16] suggest that a reduced or absent inflammatory response may be a possible explanation for the lack of alveolar opacification on initial chest radiographs in many patients presenting with clinically apparent CAP. It is possible that this subset of patients with lower WBC counts and no radiographic infiltrate had tracheobronchitis rather than CAP but the presence or absence of leukocytosis cannot differentiate CAP from tracheobronchitis.[25–27] Additionally, our data show that between one quarter and one-half of patients with suspected CAP whose admission chest radiograph does not demonstrate infiltrates will develop radiographic findings indicative of CAP on subsequent chest radiographs.

As one of the more common illnesses precipitating hospitalization, CAP is a frequently identified diagnosis for the employment of quality assessment measures to document the delivery of effective healthcare. Markers designed to test the accuracy of the diagnosis of CAP (such as requiring a new infiltrate on chest radiograph) are very attractive measures of quality. The study by Basi et al[16] and our data suggest that the admission chest radiograph is an insensitive test for the diagnosis of CAP. Furthermore, subsequent radiographic studies demonstrate abnormalities in many of these patients. Therefore, quality measures requiring the presence of an infiltrate on admission chest radiographs for the diagnosis of CAP should be avoided. A broader definition of pneumonia that includes patients with negative chest radiographs should be considered. Unfortunately, currently available diagnostic criteria are vague and unhelpful. Future studies are needed to establish firm evidence-based criteria for the diagnosis of CAP.

Our results are limited by the retrospective nature of the study design and small cohort size. We were unable to control systematically the performance of subsequent chest radiographs, and only 40% of patients with negative initial chest radiographs had studies repeated. Our reliance on the treating physician's diagnosis of CAP to establish our study group also limits our results. No microbiological diagnostic criteria were applied, so we may have included patients erroneously diagnosed with CAP. Additionally, all physicians in this study were from the same academic center making them prone to regional bias. Our study did not include any class V disease severity patients (the most severe class as calculated by the PSI), even though 5% to 10% of patients with CAP are generally within this group. We speculate that the physicians treating this sickest group of patients may have utilized diagnostic coding to reflect diagnoses such as respiratory failure or sepsis rather than CAP, but the precise reason remains unknown.

We have demonstrated that 21% of patients hospitalized with the clinical diagnosis of CAP initially have negative chest radiographs. Over one-half of the 9 patients who had subsequent radiographic studies within 48 hours of hospitalization developed infiltrates. Therefore, we feel that diagnostic criteria requiring new radiographic opacifications on admission may not be valid for the diagnosis of CAP and exclude a significant percentage of patients with CAP. Future studies are needed to develop evidence-based diagnostic criteria for CAP and determine the effect of CAP with a negative admission chest radiograph on quality assurance measures.

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