

False-Negative Chest Radiographs in Emergency Department Diagnosis of Pneumonia

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ABSTRACT

BACKGROUND: Emergency department (ED) patients frequently undergo chest x-ray (CXR) to evaluate for pneumonia. The rate of false-negative CXR in patients with pneumonia is unclear.

OBJECTIVES: Identify patients admitted with pneumonia who were diagnosed by CT despite nondiagnostic CXR.

METHODS: Retrospective analysis of quality improvement data on adult ED patients admitted with pneumonia over 21 months. Primary outcome was percent of patients diagnosed by CT despite normal CXR. Patients were classified as CXR-diagnosed if they had CXR and no CT, or if antibiotics were ordered after CXR and before CT. CT-based diagnosis was indicated by administration of antibiotics only after CT was completed.

RESULTS: 49 patients (11.4%) were diagnosed by CT ($p < 0.001$). These patients were younger ($p < 0.001$) and more often complained of chest pain ($p < 0.001$).

CONCLUSIONS: Patients with pneumonia may present with normal or nondiagnostic CXR, although false negatives may be less common than previously reported.

KEYWORDS: pneumonia, chest radiograph, computed tomography, false negative

INTRODUCTION

Pneumonia is a common illness in the United States, particularly among elderly and immunocompromised populations. It is associated with significant morbidity, mortality, and costs. In 2011, there were 1.1 million inpatient hospital discharges with a principal diagnosis of pneumonia.¹ Associated inpatient mortality was 3.3% and total charges exceeded \$35.3 billion.

There are no formal consensus guidelines for the diagnosis of pneumonia. Rather, the diagnosis is based on symptoms, physical exam, laboratory studies and radiographic imaging. Since no exam findings can definitively confirm its presence, chest x-rays (CXR) have been used to confirm pneumonia in the right clinical context.² However, research has suggested that CXR may lack sensitivity for diagnosing pneumonia at initial presentation.³

It has been documented that computed tomography (CT) can identify pneumonias not seen on CXR, particularly

those in upper lobes or the lingula, or in patients with nosocomial or atypical pathogens.^{4,5} Literature suggests CT may be diagnostically superior for pneumonia in ICU and ED patients.⁶ However, there is no evidence that CT imaging for pneumonia improves clinical outcomes. In this study we report on our experience with both CXR- and CT-based diagnosis of pneumonia in the ED, as well as the comparative clinical outcomes.

METHODS

Purpose

The primary aim was to determine how frequently CT scans diagnosed pneumonia when standard CXR was nondiagnostic. Second, we sought to investigate the clinical outcomes of these patients on the basis of whether pneumonia was visualized on CXR or CT.

Study design and population

This study is a retrospective analysis of quality improvement data collected on all adult ED patients admitted with diagnosis of pneumonia from February 2005 to October 2006. The study was performed in a large, urban academic hospital in Providence, Rhode Island, with an annual ED volume of 78,000 patients during the study period. Patients under age 18 and those discharged from the ED were excluded. This project received IRB approval with waiver of informed consent.

Data collection

All ED physician orders were entered electronically using the MedHost™ Information System (Medhost Corporation, Addison, TX), which performed patient tracking and physician documentation. All staff members were educated regarding the department's quality improvement program, which included recommendations for pneumonia management from the Joint Commission and the Centers for Medicare and Medicaid Services. Specific focal elements included antibiotic selection and timeliness of administration.

Chief complaint data and emergency severity index (ESI, version 3) were prospectively determined by ED triage nurses. ED quality-assurance nurses who were blinded to study aims reviewed ED admitting records on a daily basis for patients admitted with pneumonia. For each patient, pertinent clinical data were abstracted onto data sheets, including

demographics, medical history, vital signs, and clinical outcomes. This information was entered into an Access™ database (Microsoft Corporation, Redmond, WA). A 5% sample of charts was abstracted by two staff members to measure inter-rater reliability.

Outcome measures

The primary outcome was the percent of pneumonia diagnoses made by chest radiograph or CT scan. Patients were classified as diagnosed by CXR if they were admitted with a diagnosis of pneumonia, and (a) no chest CT was performed or (b) antibiotics were started after CXR but before CT was performed. Patients were classified as diagnosed by CT if antibiotics were not administered after CXR but were given after chest CT, or if physician documentation noted that antibiotics were held after CXR until additional imaging could clarify the diagnosis. Patients were also included in this group if antibiotics were administered after abdominal CT and before a normal CXR, as pneumonia may be visualized in lung bases by abdominal CT. Secondary and clinical outcomes included intubation, ICU admission, length-of-stay (LOS), and in-hospital mortality.

Data analysis

Statistical analysis was performed using independent samples t-test (with adjustment for unequal variance where appropriate) and chi-square test. Given the multiple comparisons between groups, the likelihood of a statistically significant result due to random chance was high, so an alpha probability of 0.01 was selected a priori.

For a dependent variable of imaging by CXR vs. CT, explainer variables resulting in p-values <0.1 were entered into a multiple logistic regression model. Covariates included patient demographics and medical comorbidities. We employed Wald and likelihood ratio testing to iteratively remove non-contributory variables from the model. Continuous data are presented as medians with interquartile range. Means are presented with standard deviations. Statistical analysis was performed using Stata v.10 (Stata Corp., College Station, TX).

RESULTS

A total of 428 patients were admitted with a diagnosis of pneumonia. While 379 patients were diagnosed using CXR, 49 patients (11.4%) were diagnosed by CT. This fraction was significantly lower than the 27% value reported in prior retrospective literature ($X^2=15.2$, $p<0.001$).⁶

Table 1 summarizes demographics, clinical characteristics, and outcomes among patients in both groups. Patients in the CT-diagnosed group were significantly younger than the CXR-diagnosed

group (60 years vs. 77 years, $p<0.001$). There were no significant differences in gender composition or insurance status.

Patients in the CT-diagnosed group were more likely to present with chest pain (24% vs. 7%, $p<0.001$) than patients in the CXR-diagnosed group. There was also a trend toward tachycardia in the CT-diagnosed group (105 vs. 96 beats per minute, $p<0.02$). Presenting complaints and triage vital signs were similar between groups. There were no differences regarding triage ESI, the proportion of patients triaged to a resuscitation/trauma room, or clinical outcomes. Inter-rater agreement was moderate with a Cohen's kappa coefficient of 0.71.

DISCUSSION

For many years, chest x-rays were considered the gold standard for diagnosis of pneumonia. In recent years, literature has documented that CXR may miss a significant number of pneumonias visible on CT. In a prospective study of 47 patients with suspected pneumonia who underwent both CT and CXR, 31% of pneumonias diagnosed by CT were not visualized on CXR.⁴ In a large retrospective study of 1057 adult ED patients with pneumonia, 97 patients underwent both CXR and chest CT. Twenty six (27%) of these patients

Table 1. Patient Characteristics and Outcomes

	CT-diagnosed	CXR-diagnosed	P-value
Demographics			
Number of patients	49	379	
Age	60 (49, 77)	77 (62, 86)	<0.001
Female gender % (n)	51 (25)	47 (178)	0.59
Insured % (n)	86 (42)	92 (349)	0.12
Comorbidities			
Congestive heart failure % (n)	10 (5)	21 (80)	0.07
Coronary artery disease % (n)	8 (4)	15 (56)	0.21
COPD % (n)	4 (2)	15 (55)	0.04
Diabetes % (n)	22 (11)	27 (101)	0.53
Chief complaint			
Fever % (n)	47 (23)	48 (181)	0.91
Cough % (n)	61 (30)	64 (241)	0.75
Shortness of breath % (n)	61 (30)	59 (222)	0.72
Chest pain % (n)	24 (12)	7 (28)	<0.001
Other % (n)	25 (12)	26 (98)	0.84
Vital signs			
Systolic blood pressure	133 (115, 153)	131 (114, 151)	0.66
Heart rate	105 (86, 124)	96 (80, 111)	0.02
Respiratory rate	21 (18, 26)	20 (18, 24)	0.35
Temperature (F)	99 (97.8, 100)	98.5 (97.7, 99.7)	0.21
Pulse oximetry at arrival	97 (93, 99)	96 (93, 98)	0.4
ED Triage			
ESI at triage	2 (2, 3)	2 (2, 3)	0.71
Triaged to critical care room % (n)	37 (18)	33 (125)	0.6
Outcomes			
Intubated % (n)	6 (3)	5 (20)	0.81
ICU admission % (n)	31 (15)	22 (80)	0.14
Complications % (n) ^b	35 (17)	26 (97)	0.18
In-hospital mortality % (n)	10 (5)	6 (24)	0.32
Hospital LOS (days)	4.5 (3, 10)	4 (3, 7)	0.3

^a Continuous variables presented as median $\pm$ IQR. ^b Intubation, ICU admission, or death.

had CT-visualized pneumonias despite nondiagnostic CXR.⁶

Our study examined ED patients who were provisionally diagnosed by CT scan rather than CXR. In our population, 11% of patients were diagnosed by findings on CT. While this rate is lower than prior studies, it does not eliminate the need for consideration of further evaluation or treatment. Although our data were several years old, pneumonia remains a common condition and CXR remains the standard of care for diagnosing pneumonia. As such, our results remain relevant to contemporary emergency medicine practice.

Several reasons may contribute to diagnostic inaccuracy of early CXR. Early pneumonia may not produce significant findings on CXR. Basi reviewed 92 patients admitted with diagnosis of pneumonia who had normal initial radiographs and repeat radiographs within 72 hours.⁷ Of this group, 7% developed infiltrates on follow-up radiographs within 72 hours. Hagaman studied 22 patients admitted for pneumonia with negative initial radiographs.³ Of the nine patients in that study who had follow-up imaging within 48 hours, a majority (55%) had radiographic infiltrates, although the significance of this finding is limited by sample size, selection bias, and use of CT for repeat imaging in one patient. It is important to note that CT may reveal infiltrates that represent causes other than bacterial pneumonia (e.g., viral lower respiratory infections) for which CXR may also be insensitive. Dehydration has been linked with absence of CXR infiltrates in patients with pneumonia, although this assertion has limited supporting literature.⁸⁻⁹ Prior literature suggested CXR may be less sensitive for infiltrates in certain anatomic regions such as the lingula. Unfortunately, our data lacked these details on radiologic interpretations and thus these hypotheses could not be tested.

In our study, there were several differences between CXR-diagnosed and CT-diagnosed groups. First, patients with chest pain and tachycardia were more likely to be diagnosed by CT. This difference may reflect high CT use among patients who had a higher apparent risk of pulmonary embolism. Banker and colleagues examined ED patients diagnosed with pneumonia by CT and compared them to age- and sex-matched controls diagnosed by CXR.¹⁰ Their data noted more patients in the CT-diagnosed group presented with chest pain, but the results did not reach statistical significance. Second, our CT-diagnosed patients were younger than those diagnosed by CXR, but this subgroup nonetheless had similar morbidities and mortality as the older patients. Since age at diagnosis is a strong predictor of mortality, it is possible that unmeasured comorbidities exerted a clinically relevant impact upon outcome in this subgroup.

LIMITATIONS

This study is limited as a retrospective analysis. The study was not designed to measure sensitivity and specificity of CXR as not all patients underwent CT scan. Conclusions regarding diagnosis were based on timing of diagnostic tests

and orders for antibiotics. We did not include patients who were diagnosed with pneumonia and discharged from the ED, or patients admitted with an alternative diagnosis and later diagnosed with pneumonia. CT findings consistent with pneumonia may have been noted incidentally during clinical investigation for other diagnoses. Inpatient and discharge data were not included in our data set and thus we could not correlate admission diagnosis with inpatient treatments, laboratory tests, or discharge diagnosis. However, we sought to mimic real-world practice by examining information available to emergency physicians at time of treatment.

CONCLUSIONS

More than 11% of ED patients admitted to the hospital with provisional diagnosis of pneumonia were diagnosed by CT imaging rather than chest radiograph. Infiltrates consistent with pneumonia may be missed by CXR alone in a significant minority of ED patients. In the appropriate clinical context, clinicians should consider advanced imaging in patients with negative CXR. Our results suggest a smaller proportion of infiltrates are missed by CXR than reported in prior studies.

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