BRIEF OBSERVATION

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Diagnostic Value of Chest Radiographs in Bedridden Patients Suspected of Having Pneumonia

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ABSTRACT

OBJECTIVES: To assess the diagnostic value of the chest radiograph for the diagnosis of pneumonia in bedridden patients, using non-contrast-enhanced high-resolution chest computed tomography (CT) as the gold standard.

METHODS: We prospectively evaluated bedridden patients hospitalized with moderate to high clinical probability of pneumonia. Chest radiographs were interpreted in a blinded fashion by 3 observers and classified as definite, normal, or uncertain for pneumonia. Chest CT was obtained within 12 hours of chest radiograph. We applied Bayesian analysis to assess the accuracy of chest radiograph in the diagnosis of pneumonia.

RESULTS: In a 5-month period, 58 patients were evaluated, 31 (53%) were female. Their chest radiographs were interpreted as negative, uncertain, or positive for pneumonia in 31 (53%), 15 (26%), and 12 (21%) patients, respectively, while CT confirmed pneumonia in 11 (35%), 10 (67%), and in 10 (83%). The sensitivity of the chest radiograph to diagnose pneumonia was 65%, the specificity was 93%, the positive and negative predictive values were, respectively, 83% and 65%, while the overall accuracy was 69% (95% confidence interval, 50%-79%).

CONCLUSIONS: In bedridden patients with suspected pneumonia, a normal chest radiograph does not rule out the diagnosis, hence, a chest CT scan might provide valuable diagnostic information.

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KEYWORDS: Bedridden; Chest computed tomography; Chest radiograph; Pneumonia; Predictive values; Sensitivity

Pneumonia is common in bedridden and elderly patients, but the diagnosis is often difficult due to its nonspecific manifestations;[1] therefore, the chest radiograph is essential to confirm the diagnosis. Some authors found that clinical criteria might predict pneumonia in 55%-84%,[2] while others found a sensitivity of 97% and a negative predictive value of 98%.[3] Furthermore, radiological confirmation of a presumed pneumonia occurred in only two thirds of hospitalized patients, according to one study.[4] In elderly and bedridden patients, kyphosis, muscular weakness, and neurological disorders often limit forced inspiration needed for accurate films. In bedridden patients, obtaining a lateral view is impossible, and the dome of the diaphragm may project over a significant portion of the anterior and basilar lung fields, obscuring findings and making the interpretation of chest radiographs difficult. There is considerable interobserver variability in the interpretation of chest radiography, even among experienced radiologists.[5] Therefore, we assessed the value of the chest radiograph in the diagnosis of pneumonia in bedridden patients, using the non-contrast-enhanced high-resolution chest computed tomography as the gold standard.

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METHODS

This study was conducted in a 550-bed university-affiliated hospital and approved by its Internal Review Board. We prospectively evaluated bedridden patients from the Emergency Department and 3 medical departments between January 1 and May 31, 2008, for whom an anteroposterior chest radiograph was ordered to diagnose or exclude pneumonia. An internist (YE), blinded to the patients' chest radiographs, assessed the clinical likelihood of pneumonia by the following criteria, First, vital signs and symptoms: tachypnea (>20 breaths per minute), temperature >38°C or <35°C and pulse >90 beats per minute. Second, respiratory indicators: cough, inspiratory rales, bronchial breathing, reduced breath sounds, use of accessory respiratory muscles and O_2 saturation <90%. Third, laboratory tests: leukocytes >10,000/mL, >85% neutrophils or >5% band forms.

The patients' chest radiographs were evaluated by the same internist, a radiology resident (IN), and an experienced radiologist (JB-Z) in a blinded fashion. In case of disagreement, the interpretation of the latter was used for final analysis. Chest radiographs were assessed for: parenchymal opacities, air bronchogram, loss of vascular markings, silhouette sign, linear opacities, and overall impression. Patients were classified into 3 groups: definite pneumonia; normal radiograph; and "uncertain," which included patients for whom no definite interpretation of the radiograph was possible because of unclear findings or technically inadequate radiographs.

CLINICAL SIGNIFICANCE

- It is difficult to diagnose pneumonia in bedridden patients.
- The accuracy of the chest radiograph in the diagnosis of pneumonia is low in these patients.
- Non-contrast-enhanced chest computed tomography might significantly contribute to diagnosing or excluding pneumonia in bedridden patients.

A non-contrast-enhanced high-resolution chest CT scan was obtained within 12 hours after chest radiograph. In case of greater time lag, another chest radiograph was ordered. A radiologist, blinded to the chest radiograph results, interpreted the chest CT for the presence of pneumonia using previously described criteria.[6] Chest CT resulted in 2 groups: presence or absence of pneumonia, while according to radiograph, patients were classified into 3 groups; thus, 3 by 2 tables were constructed. For Bayesian analysis, 2 by 2 tables are required; therefore, we calculated the attributes of the chest radiograph, firstly assuming the uncertain group to be positive for pneumonia and secondly, considering it to be negative. Clinical and radiological findings were analyzed using the chi-squared test.

RESULTS

After screening 99 patients (Figure), 58 patients were included; 27 (47%) were male (mean age 83.6 years; range 18-97 years). Tables 1 and 2 summarize the clinical and radiological findings. Clinical features and leukocyte counts were not different between the groups. Difficult-to-interpret chest radiographs were common in the uncertain group (47%, P <.001). The proportion of opacities, air bronchogram, and silhouette sign was different between the groups. The proportion of pleural effusions and non-related radiological findings was significant and did not differ between the groups. CT scan boosted the rate of diagnosis of pneumonia from 21% to 53%. The correlation between

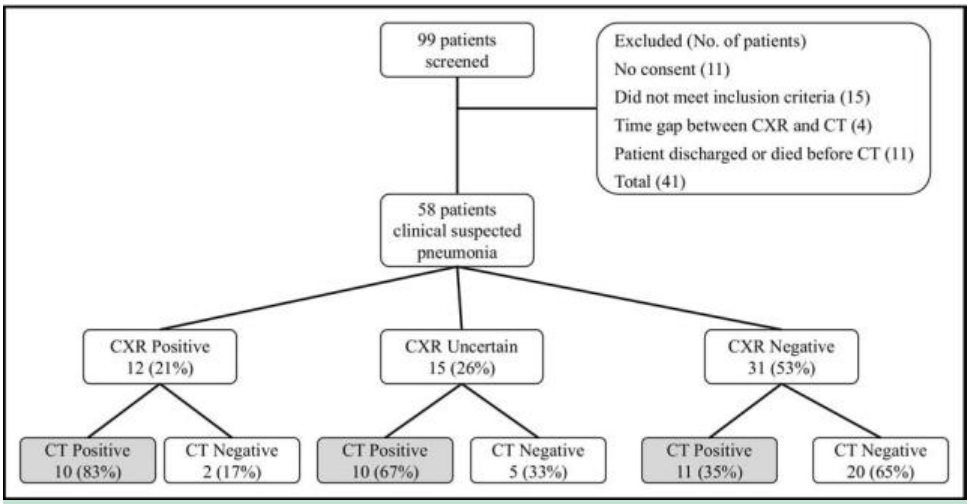

Figure Patient enrollment and classification according to CXR (chest radiograph) and CT (chest computed tomography) findings.

Table 1 Patients' Clinical Features, Stratified by Chest Radiograph Findings*

Clinical Parameter	Probability of Pneumonia According to CXR: Positive n = 12 n (%)	Uncertain n = 15 n (%)	Negative n = 31 n (%)	Total n = 58 n (%)
Historical features				
Age, years	83 ± 5	85 ± 8	83 ± 11	84 ± 9
Male	7 (58)	7 (47)	13 (42)	27 (47)
Residence				
Home	6 (50)	6 (40)	11 (35)	23 (41)
Long-term facility	6 (50)	9 (60)	17 (49)	32 (55)
Past history of:				
Chronic obstructive lung disease	2 (17)	1 (17)	2 (6)	5 (9)
Pneumonia	2 (17)	5 (33)	3 (10)	10 (17)
Smoking	1 (8)	1 (7)	0 (0)	2 (3)
Congestive heart failure	4 (33)	4 (27)	4 (13)	12 (21)
Signs and symptoms				
Dyspnea	11 (93)	13 (87)	22 (71)	46 (79)
Cough	6 (50)	13 (87)	22 (71)	41 (71)
Fever >38°C	7 (58)	10 (67)	23 (74)	40 (69)
Heart rate >90 beats per minute	4 (33)	10 (67)	22 (71)	36 (62)
O_2 saturation <90%	7 (58)	12 (80)	22 (71)	41 (71)
Inspiratory rales	9 (75)	14 (93)	28 (90)	51 (88)
Use of accessory respiratory muscles	4 (33)	10 (67)	8 (26)	22 (38)
Decreased breath sounds	4 (33)	7 (47)	8 (26)	20 (34)
Bronchial breathing	3 (25)	2 (13)	9 (29)	14 (25)
Leukocytes >10,000/mm^3	7 (58)	10 (67)	19 (61)	36 (62)
Clinical impression of pneumonia				
Positive	9 (75)	8 (53)	21 (68)	39 (67)
Uncertain	3 (25)	7 (47)	10 (32)	19 (33)

CXR = chest radiograph.
*No statistically significant difference was found between the 3 groups for all parameters.

Table 2 Chest Radiograph and Computed Tomography (CT) Findings

Parameters	Probability of Pneumonia According to CXR: Positive n = 12 n (%)	Uncertain n = 15 n (%)	Negative n = 31 n (%)	Total n = 58 n (%)	*P*-Value
Chest radiograph findings					
Technically difficult	0 (0)	7 (47)	1 (3)	8 (14)	.000
Opacity	12 (100)	7 (47)	5 (16)	24 (41)	.000
Air bronchogram	5 (42)	1 (7)	1 (3)	7 (12)	.002
Loss of vascular markings	8 (67)	3 (20)	4 (13)	15 (26)	.001
Silhouette sign	9 (75)	4 (27)	3 (10)	16 (28)	.000
Chest CT findings					
Alveolar infiltrates	10 (83)	10 (67)	12 (39)	32 (55)	.018
Ground glass	2 (17)	1 (7)	1 (3)	4 (7)	.296
Air bronchogram	9 (75)	7 (47)	11 (35)	27 (47)	.066
Pleural effusion	8 (67)	10 (67)	12 (39)	30 (52)	.105
Other findings	4 (33)	10 (67)	11 (35)	25 (43)	.100
Conclusion					
Pneumonia	10 (83)	10 (67)	11 (35)	31 (53)	.009
No pneumonia	2 (17)	5 (33)	20 (65)	27 (47)	

CXR = chest radiograph.

Table 3 Site of the Alveolar Opacities Visualized with Chest Computed Tomography (CT)

Imaging Modality		Site of Infiltrate by Chest CT (No. of Infiltrates)					
		Right Lobes			Left Lobes		
Chest Radiograph	Chest CT (No. of Patients)	Upper	Middle	Lower	Upper	Lingula	Lower
Negative	Unilateral (5)	0	1	3	0	0	1
	Bilateral (6)	2	2	6	2	2	6
	Total (11)	2	3	9	2	2	7
Uncertain	Unilateral (7)	0	0	4	0	0	3
	Bilateral (3)	2	2	2	1	2	1
	Total (10)	2	2	6	1	2	4
Positive	Unilateral (2)	0	0	0	0	0	2
	Bilateral (8)	5	2	8	5	3	7
	Total (10)	5	2	8	5	3	9

chest radiograph and CT findings was moderate (Phi 0.40, $P = .009$) and did not change when the uncertain group was excluded. Agreement between clinical impression and chest radiograph findings was 29%; between clinical impression and CT, 36%; and between radiograph and CT, 51%. In univariate analysis, only past history of pneumonia almost reached significance in the prediction of pneumonia by CT scan, ($P = .06$). Most infiltrates were located in the lower lobes, and 6 of 11 (54%) patients with normal radiograph had bilateral infiltrates by CT (Table 3). The sensitivity, negative predictive value, and accuracy of the chest radiograph were 32%-65% (95% confidence interval [CI], 23%-73%); 54%-65% (95% CI, 39%-74%), and 60%-69% (95% CI, 50%-79%), respectively (Table 4). The kappa coefficient was 0.21-0.51 ($P < .02$) and 0.56 ($P < .001$) for chest radiograph and CT interpretation, respectively.

Table 4 Chest Radiograph: Attributes of the Test

	Considering the Uncertain CXR Group as Negative for Pneumonia		Considering the Uncertain CXR Group as Positive for Pneumonia	
Test Attribute	%	95% CI	%	95% CI
Sensitivity	32	23-37	65	53-73
Specificity	93	82-98	74	61-85
PPV	83	58-95	74	61-85
NPV	54	39-69	65	53-74
OR	5.95	1.29-26.61	5.19	1.70-15.83
LR+	4.35	1.22-17.17	2.49	1.33-4.87
LR−	0.73	0.65-0.95	0.48	0.31-0.78
Accuracy*	60	50-65	69	56-79

CXR = chest radiograph; CI = confidence interval; PPV = positive predictive value; NPV = negative predictive value; OR = odds ratio; LR+ = likelihood ratio for positive test; LR− = likelihood ratio for negative tests.

*Accuracy calculated as true positive and true negative results divided by all tests.

DISCUSSION

The value of the chest radiograph has not been assessed in bedridden patients. Our results suggest that clinical criteria are insufficient to diagnose pneumonia in bedridden patients, and even after chest radiograph, considerable uncertainty remains (32%-47%). A hands-up maneuver optimized the radiological diagnosis of pneumonia in elderly patients by 30% and boosted interobserver reliability from 0.36 to 0.84 with only 7% suboptimal films.[7] Our rate of suboptimal radiographs was 16%; chest CT overcomes this problem, minimizing the need for patient cooperation.

We found that the sensitivity and negative predictive value of the chest radiograph are too low to rule out pneumonia when highly suspected in bedridden patients. We observed a high rate of false-negative (35%) and false-positive results (17%), the latter probably due to the presence of pleural effusions that could be interpreted as opacities. Accordingly, chest CT may change the management in 48% of bedridden patients with suspected pneumonia. Our estimates for sensitivity, specificity, likelihood rations, and accuracy of the radiograph may be generalized to similar patients, but the negative and positive predictive values depend on the sample prevalence, which reached 53% in our study. Although dehydration may theoretically account for the false negative rate, many patients were already hospitalized when their chest radiograph was ordered, making this possibility remote. Furthermore, most lung infiltrates were located in fields not well visualized by the anteroposterior view. Similar false-negative rates were previously reported in younger adults, in whom chest CT detected 31% more infiltrates.[8]

Our study has several strengths; its prospective and blinded design minimizes bias. The patients were evaluated by the same physician, obviating the interobserver variability of physical signs, which was reported as moderate.[3,9]

The low correlation between clinical and radiological findings probably would be expected in similar settings. Our study imitates everyday practice; commonly, the first work-up of patients is not based on the official report of the chest radiograph.

Our small sample prevented the detection of predictors of a positive CT scan for pneumonia. Other drawbacks are the moderate interobserver agreement in interpretation of radiographs (kappa 0.51), although comparable with previous studies,[2,7] and the inclusion of the "uncertain" category, which prevented an accurate statistical analysis. This category could be explained by the amount of technically difficult-to-interpret radiographs in addition to the large proportion of patients with pleural effusions and with past history of pneumonia, which might impact on the radiologic diagnosis of pneumonia.

Although the effective radiation dose of the spiral chest CT is 3.5 mSv, 70 times that of a posteroanterior chest radiograph, a reduced radiation dose high-resolution CT protocol approximates that of about 7-14 chest radiographs without compromising its accuracy.[10] In our hospital, chest CT is 6 times more expensive than a radiograph, but the benefits of an accurate diagnosis of pneumonia in bedridden patients might compensate for the higher cost and increased radiation exposure. Further studies are needed to formulate cost-effective recommendations.

In conclusion, when pneumonia is highly suspected in bedridden patients, the non-contrast-enhanced high-resolution chest CT might be diagnostic even in the presence of a normal radiograph.

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References

1. Marrie TJ. Pneumonia. In: Hazzard WR, Blass JP, Halter JB, Ouslander JG, Tinetti ME, eds. *Principles of Geriatric Medicine and Gerontology*, 5th edn. New York: McGraw-Hill; 2003:1083-1097.
2. Hackerling PS, Tape TG, Wingston RS, et al. Clinical prediction rule for pulmonary infiltrates. *Ann Intern Med*. 1990;113:664-670.
3. Rothrock SG, Green SM, Costanzo KA, et al. High yield criteria for obtaining non-trauma chest radiography in the adult emergency department population. *J Emerg Med*. 2002;23:117-124.
4. Basi SK, Marrie TJ, Huang JQ, Majumdar SR. Patients admitted to hospital with suspected pneumonia and normal chest radiography. Epidemiology, microbiology and outcomes. *Am J Med*. 2004;117:305-311.
5. Loeb MB, Carusone SB, Marrie TJ, et al. Interobserver reliability of radiologists' interpretations of mobile chest radiographs for nursing home-acquired pneumonia. *J Am Med Dir Assoc*. 2006;7:416-419.
6. Tanaka N, Matsumoto T, Kuramitsu T, et al. High resolution CT findings in community-acquired pneumonia. *J Comput Assist Tomogr*. 1996;20:600-608.
7. Le Blanche AF, Bazot M, Frey I, et al. Evaluation of a new hands-up ergonomics for chest radiography in geriatric patients. *Invest Radiol*. 2002;37:35-39.
8. Syrjälä H, Broas M, Suramo I, et al. High resolution computed tomography for the diagnosis of community acquired pneumonia. *Clin Infect Dis*. 1998;27:358-363.
9. Wipf JE, Lipsky BA, Hirschmann JV, et al. Diagnosing pneumonia by physical examination. Relevant or relic? *Arch Intern Med*. 1999;159:1082-1087.
10. Mayo JR, Aldrich J, Muller NL. Radiation exposure at chest CT: a statement of the Fleischner Society. *Radiology*. 2003;228:15-21.