Clinical Prediction Rule for Pulmonary Infiltrates

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Objective: To derive and validate a clinical rule for predicting pneumonic infiltrates in adult patients with acute respiratory illness.

Design: Prevalence studies in three settings.

Setting: Emergency departments of the University of Illinois Hospital at Chicago, the University of Nebraska Medical Center at Omaha, and the Medical College of Virginia at Richmond.

Patients: Symptoms, signs, comorbidity data, and chest roentgenogram results were recorded for 1134 patients from Illinois (the derivation set), 150 patients from Nebraska, and 152 patients from Virginia (the validation sets). All patients presented to the emergency department and had a chest roentgenogram to evaluate fever or respiratory complaints.

Measurements and Main Results: Within the training set, temperature greater than 37.8 °C, pulse greater than 100 beats/min, rales, decreased breath sounds, and the absence of asthma were identified as significant predictors of radiographically proved pneumonia in a stepwise logistic regression model ($P = 0.001$). The logistic rule discriminated patients with and without pneumonia in the training set with a receiver operating characteristic (ROC) area of 0.82. In the validation sets, the rule discriminated pneumonia and nonpneumonia with ROC areas of 0.82 and 0.76 after adjusting for differences in disease prevalence ($P > 0.2$ compared with the training set). The predicted probability of having pneumonia for patients with different clinical findings corresponded closely with the incidence of pneumonia among patients with such findings in the three settings.

Conclusions: Among adults presenting with acute respiratory illness, a prediction rule based on clinical findings accurately discriminated patients with and without radiographic pneumonia, and was used in two other samples of patients without significant decrement in discriminatory ability. This rule can be used by physicians to develop more effective strategies for detecting pneumonia and for helping to determine the need for radiologic study among patients with acute respiratory disease.

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Radiographic examination of the chest is done on patients with acute respiratory complaints primarily to confirm or exclude the diagnosis of pneumonia (1). However, the National Health Survey showed that the prevalence of pneumonia among adults with respiratory infection was only approximately 3% (2). Even among patients presenting to an emergency department, pneumonia was present in only 16% (3) to 28% (4) of patients with acute respiratory illness. As a consequence, patients with respiratory infection, but without pneumonia, often have unnecessary radiologic study, resulting in excess radiation exposure and additional cost. If patients could be stratified on the basis of clinical information into subgroups with differing probabilities of having pneumonia, the need for chest roentgenographic study could be determined with greater accuracy.

Other investigators have developed clinical rules that can discriminate with varying degrees of accuracy the presence and absence of pneumonia in adults with respiratory disease (3-5). However, these studies were limited by exclusion of patients with severe illness (5), use of retrospectively collected risk factor data (4), and pneumonia samples of marginal size for multivariate modeling (3, 5). In addition, none of these rules was prospectively validated in a patient sample other than that from which it was derived (6). Because prediction rules that have not been prospectively validated often do not work as accurately in new clinical settings as they did in the original one (7, 8), we studied patients with acute respiratory illness at three separate clinical sites to derive and validate a prediction rule for pneumonia.

Methods

Data Collection

Demographic information and data on symptoms, signs, comorbidity, and chest radiographic findings were collected prospectively from three sets of patients of 16 years of age or older at three sites: 1134 consecutive patients at the University of Illinois at Chicago (the derivation set); 150 patients at the University of Nebraska at Omaha (a validation set); and 152 patients at the Medical College of Virginia at Richmond (a second validation set). All patients had presented to the emergency departments of their respective institutions between July 1987 and June 1988 with complaints of fever or respiratory symptoms, and had received a chest roentgenogram to evaluate these symptoms. All patients had been examined by a medical resident or an attending physician, and the decision to order a chest roentgenogram had been made by the examining physician. Most patients received posteroanterior and lateral chest roentgenograms; however, in a few cases, because of the acuity of the medical illness, only an anteroposterior roentgenogram was obtained.

Clinical information was recorded on a standardized data form by the examining physician at the patient visit, before obtaining the results of the chest roentgenogram. In the approximately 15% of eligible patients for whom data forms had

Table 1. *Comparison of Demographic and Clinical Variables across Sets*

Variable	Illinois Set (Derivation)	Nebraska Set (Validation)	Virginia Set (Validation)
Mean age, *y*	45.4	45.4	41.4*
Age > 60 years	24.8	27.1	17.3
Sex, %			
Female	57.3	57.3	52.1
Male	42.7	42.7	47.9
Racial distribution, %			
White	40.4	69.8†	20.9†
Black	59.6	30.2†	79.1†
Asthma, %	21.5	28.6*	21.1
Chronic obstructive pulmonary disease, %	10.1	20.3†	9.9
Other lung disease, %	4.1	1.6	2.0
Congestive heart failure, %	11.1	8.3	5.3
Immunocompromising disease, %	13.8	4.7†	7.2*
Dementia, %	3.2	3.6	3.9
Other comorbid disease, %	19.3	5.7†	11.2*
Pneumonia, %‡	12.4	30.0†	21.5†

* Significantly different at an alpha level of 0.05 compared with the Illinois derivation set.

† Significantly different at an alpha level of 0.01 compared with the Illinois derivation set.

‡ Defined as definite or probable pneumonia according to radiographic evidence.

not been completed at the emergency department visit, clinical information was obtained from the physician within 24 hours after the visit. In these cases, the physicians were instructed to record their original findings, unaltered by their knowledge of the radiographic results. An examination of the first 50 such cases revealed good agreement between information recorded on the data forms and findings listed in the emergency department charts.

Demographic information included age, sex, and race. Symptoms included the presence or absence, within the previous 24 hours, of cough, sputum (white or colored), chills, fever, pleuritic and nonpleuritic chest pain, dyspnea, wheezing, orthopnea, and paroxysmal nocturnal dyspnea. Signs included the temperature (oral or rectal); respiratory rate; pulse; systolic and diastolic blood pressures; mental status (normal, confused, or unresponsive); and the presence or absence of splinting, cyanosis, percussion dullness, rales, rhonchi, wheezes, decreased breath sounds, bronchial breath sounds, egophony, pleural friction rub, and decreased thoracic expansion.

Coexisting medical conditions included the presence or absence of asthma, chronic obstructive pulmonary disease, other lung diseases, congestive heart failure, immunocompromising diseases (including lymphoreticular and solid neoplasms, human immunodeficiency virus [HIV] infection, collagen vascular diseases, chronic renal failure, and any other disease for which the patient was being treated with immunosuppressive medications excluding corticosteroid therapy for asthma), dementia, and other comorbid illnesses. Symptoms, signs, or coexisting medical conditions that either were not recorded on the data form or were recorded as "unknown" were considered to be absent. When the data were re-analyzed, excluding cases with missing or "unknown" symptoms, signs, or comorbidity data, the results remained essentially unchanged.

Chest roentgenogram results were obtained from the written report of an attending or resident radiologist and were classified by two independent reviewers into one of four categories: no pneumonia, if the roentgenogram was reported as normal or as showing radiographic abnormalities other than pneumonia (such as atelectasis or apical scarring); possible pneumonia, if the roentgenogram was reported as showing "possible" or "questionable" pneumonic infiltrates or if the radiologist reported being unable to exclude pneumonia in describing a radiologic finding; probable pneumonia, if the radiologist stated that an abnormality "probably" or "most likely" represented a pneumonic infiltrate; or definite pneumonia, if the roentgenogram was reported as unequivocally showing a pneumonic infiltrate. Concordance for this chest roentgenogram classification between investigators on the first 468 patients in the training cohort, measured as an unweighted kappa statistic (9), was 0.92, indicating almost perfect agreement (10). Differences in chest roentgenogram classification between investigators were resolved by consensus agreement or by the interpretation of a third investigator when agreement could not be reached.

Data Analysis

In deriving and validating the rule, to achieve maximum fidelity in the classification of pneumonia, only patients with a chest roentgenogram report of definite or probable pneumonia were included among the cases of pneumonia, and only patients with a report of no pneumonia were included among the cases without pneumonia; patients with a report of possible pneumonia were excluded. Patients with equivocal radiographic findings were then included first among the pneumonia group and then among the nonpneumonia group, and the structure and discriminatory abilities of the resulting prediction rules were compared with those of the rule derived by excluding these ambiguous cases.

Comparisons of demographic and clinical variables across study sites were made using chi-square tests for proportions and analysis of variance for means. Within each cohort, comparisons of clinical variables among patients with and without pneumonia were made using chi-square with the Yates correction for continuity. Within the derivation set, all variables with a univariate significance level of less than 0.05 were entered into a stepwise logistic regression procedure (11) to develop a subset of variables that were independent predictors of pneumonia. All variables entering the model were required to yield an improvement chi-square (the logarithm of the ratio of the likelihood function after addition of the variable to the likelihood function before addition of the variable [11]) of less than 0.01. Interaction terms were also tested as candidate variables in the logistic regression; however, none of these terms entered the model. The accuracy of the logistic model in discriminating patients with and without pneumonia in the training set was evaluated using the area under a receiver operating characteristic (ROC) curve (12), determined by the method of maximum likelihood (13). The logistic rule was then applied to both validation sets, adjusting for differences in the prevalence of pneumonia among the sets (14), and discrimination of patients with and without pneumonia was again measured by ROC analysis. Sensitivities and specificities were calculated according to standard methods (15). Confidence intervals (CIs) of 95% were used.

Results

Derivation of the Rule

The demographic and clinical characteristics of the 1134 patients in the Illinois training set are shown in

Table 2. *Multivariate Predictors of Pneumonia, with Logistic Coefficients, Odds Ratios, and 95% CIs*

Variable	Logistic Coefficient	Odds Ratio*	95% CIs
Temperature > 37.8 °C	0.494	2.69	1.73 to 4.17
Pulse > 100 beats/min	0.428	2.35	1.52 to 3.65
Rales	0.658	3.73	2.43 to 5.72
Decreased breath sounds	0.638	3.58	2.33 to 5.50
Absence of asthma	0.691	3.98	1.89 to 8.42
Intercept	−1.705	0.18	0.12 to 0.26

* Adjusted for other variables in the model.

Table 1. Chest roentgenogram results were available for 1118 of the 1134 patients (98.6%). One hundred and nineteen patients (10.6%) had definite, radiographically proved pneumonia; 20 patients (1.8%) had probable pneumonia; 142 patients (12.7%) had possible pneumonia; and 837 patients (74.9%) had no pneumonia. If patients with definite or probable, radiographically proved pneumonia were considered to have pneumonia, the prevalence of pneumonia in the training set was 12.4%.

Compared with patients without pneumonia, patients with pneumonia were more often over 60 years of age (30.9% compared with 22.8%; $P < 0.05$) and had significantly higher frequencies of immunocompromising diseases (24.5% compared with 10.9%; $P < 0.0001$) and dementia (7.9% compared with 2.4%; $P < 0.002$), but a lower frequency of asthma (7.2% compared with 24.6%; $P < 0.0001$). Symptoms of fever (62.6% compared with 36.7%; $P < 0.0001$) and chills (49.6% compared with 29.0%; $P < 0.0001$) occurred significantly more frequently among patients with pneumonia. Symptoms of cough, sputum production, and dyspnea, each of which occurred in over 50% of patients with pneumonia, were equally common among patients without pneumonia. Physical findings of a temperature greater than 37.8 °C (54.5% compared with 23.0%; $P < 0.0001$), a respiratory rate greater than 25/min (40.9% compared with 27.8%; $P < 0.003$), a pulse greater than 100 beats/min (64.5% compared with 38.4%; $P < 0.0001$), and an abnormal mental status (14.4% compared with 4.8%; $P < 0.0001$) occurred significantly more frequently among patients with pneumonia. Pulmonary findings of rales (50.4% compared with 18.8%; $P < 0.0001$), rhonchi (25.9% compared with 18.3%; $P < 0.05$), decreased breath sounds (48.9% compared with 20.3%; $P < 0.0001$), bronchial breath sounds (14.4% compared with 4.3%; $P < 0.0001$), egophony (15.8% compared with 3.2%; $P < 0.0001$), and percussion dullness (25.9% compared with 6.5%; $P < 0.0001$) were also significantly more common among patients with pneumonia. Wheezing occurred significantly less frequently among patients with pneumonia than among those without pneumonia (20.9% compared with 29.7%; $P < 0.04$).

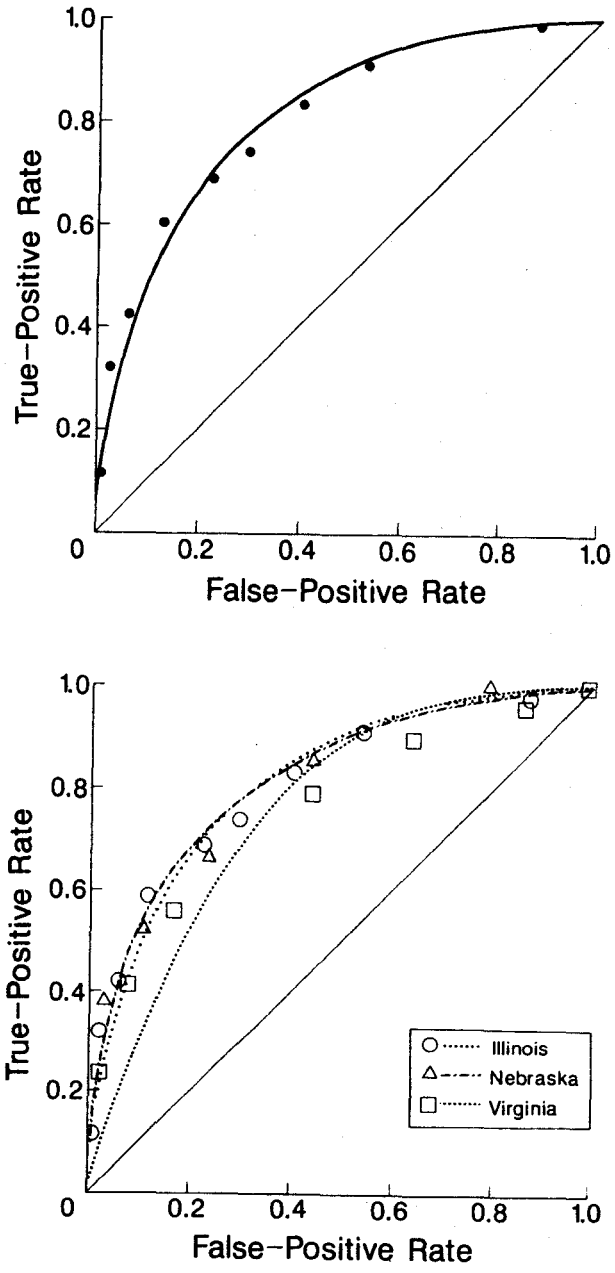

Figure 1. Top. Receiver operating characteristic (ROC) curve for the logistic rule in the derivation set. **Bottom.** Comparison of the ROC curves for the logistic rule in the derivation and validation sets.

Within the training set, temperature greater than 37.8 °C, pulse greater than 100 beats/min, rales, decreased breath sounds, and the absence of asthma were identified as significant independent predictors of pneumonia in the logistic regression model (Table 2). Egophony, bronchial breath sounds, and percussion dullness, although highly significant univariate correlates of pneumonia, did not enter the multivariate model, in part because they occurred less frequently than rales and decreased breath sounds. Figure 1, *top*, shows the ROC curve for the logistic rule. The area under the ROC curve was 0.82 (95% CI, 0.78 to 0.86). For two randomly selected patients with acute respiratory disease, one with and one without pneumonia, the probability that the logistic rule would correctly identify the patient with pneumonia was therefore 82%. If patients with a predicted probability of having pneumonia of less than 5% were considered as not having pneumonia, the rule would have had a sensitivity of 91% and a specificity of 47%.

Validation of the Rule

Table 1 compares the 150 patients from the Nebraska validation set and the 152 patients from the Virginia validation set with the patients from the derivation set. There were several significant differences between the sets, including racial distribution; the prevalence of several comorbid diseases (asthma, chronic obstructive pulmonary disease, congestive heart failure, and immunocompromising diseases); and the prevalence of pneu-

Table 3. *Predicted Probability and Actual Prevalence of Pneumonia, According to the Number of Abnormal Clinical Findings in the Derivation and Validation Sets*

Variable	Number of Abnormal Findings					
	0	1	2	3	4	5
Illinois (derivation)						
Predicted probability, %	1.0	3.1	9.2	24.5	51.0	76.9
Prevalence, *n/N (%)*	1/49 (2.0)	11/327 (3.4)	28/260 (10.8)	42/191 (22.0)	37/67 (55.2)	15/20 (75.0)
95% CI	1.0 to 12.2	1.8 to 6.2	7.4 to 15.4	16.5 to 28.7	42.6 to 67.2	50.9 to 90.4
Nebraska (validation)						
Predicted probability, %	3.0	9.1	24.2	50.6	76.6	91.3
Prevalence, *n/N (%)*	0/5 (0.0)	3/31 (9.7)	11/37 (29.7)	12/28 (42.9)	11/13 (84.6)	5/5 (100)
95% CI	0.0 to 52.2	2.5 to 26.9	16.4 to 47.1	25.1 to 62.6	53.6 to 97.3	47.8 to 100
Virginia (validation)						
Predicted probability, %	1.6	5.0	14.4	34.9	63.2	84.6
Prevalence, *n/N (%)*	1/8 (12.5)	2/32 (6.3)	8/52 (15.4)	6/22 (27.3)	11/19 (57.9)	1/1 (100)
95% CI	0.7 to 53.3	1.1 to 22.3	7.3 to 28.7	11.6 to 50.5	34.0 to 78.9	

monia, which was 30% in the Nebraska set and 21.5% in the Virginia set, but only 12.4% in the Illinois derivation set.

When applied to the Nebraska validation set, the logistic rule discriminated patients with and without pneumonia with an ROC area of 0.82 (CI, 0.74 to 0.90) (Figure 1, *bottom*). This area was not significantly different from the area for the derivation set ($P = 0.93$). When applied to the Virginia validation set, the logistic rule discriminated with an ROC area of 0.76 (CI, 0.66 to 0.86) (Figure 1, *bottom*). Although there was a small decrement in discrimination compared with in the derivation set, the difference was not statistically significant ($P = 0.29$). In the Nebraska set, a predicted probability of having pneumonia of less than 5% would have had a sensitivity of 93% and a specificity of 43%. In the Virginia set, a similar predicted probability would have had a sensitivity of 90% and a specificity of 35%.

To simplify the model (16), the logistic equation was modified by assigning identical regression coefficients (equal to the average value of the original coefficients) to each of the five clinical variables. This modified logistic rule discriminated patients with and without pneumonia with an ROC area of 0.82 (CI, 0.78 to 0.86) in the Illinois set, 0.82 (CI, 0.74 to 0.90) in the Nebraska set, and 0.76 (CI, 0.65 to 0.87) in the Virginia cohort, results virtually equivalent to those of the original rule. Table 3 shows the predicted probability and frequency of pneumonia in the derivation and validation sets, according to the number of abnormal clinical findings and using the modified rule. Agreement between the predicted probability and actual frequency of pneumonia was generally good. For example, with two abnormal findings, the predicted probability of having pneumonia in the Illinois set was 9.2%; 28 of 260 such patients (10.8%) actually had pneumonia. Adjusting for the different prevalence of pneumonia, with two abnormal findings, the predicted probability of having pneumonia in the Nebraska set was 24.2%; 11 of 37 such patients (29.7%) had pneumonia. Similarly, with two abnormal findings, the predicted probability of having pneumonia in the Virginia set was 14.4%; 8 of 52 such patients (15.4%) had pneumonia. A nomogram for calculating the probability of having pneumonia for any patient presenting to an emergency department, adjusted for the prevalence of pneumonia in that emergency department, is given in Figure 2.

Patients with Equivocal Radiographic Findings

When patients with equivocal findings were considered as not having pneumonia, logistic regression identified the same five clinical findings as when these patients were excluded from analysis. The resulting rule discriminated cases of pneumonia from other cases in the derivation set with an ROC area of 0.83. When patients with possible pneumonia were considered as having pneumonia, six variables, including temperature greater than 37.8 °C, respiratory rate greater than 25/min, rales, percussion dullness, the absence of asthma, and the presence of an immunocompromising disease, were identified as predictors of pneumonia. However, the resulting rule discriminated cases of pneumonia from other cases with an ROC area of only 0.73.

Discussion

The results of this study show that among adults presenting with symptoms suggesting acute respiratory infection, patients with pneumonia could be discriminated from those without pneumonia on the basis of findings obtainable from a history and physical examination. Findings of a temperature greater than 37.8 °C, a pulse greater than 100 beats/min, rales, locally decreased breath sounds, and the absence of asthma each significantly and independently increased the probability of having pneumonia. A clinical prediction rule based on these five findings classified cases of pneumonia and other cases in the derivation set with an ROC curve area of 0.82, indicating good discriminatory power. When applied to two patient samples other than and different from that from which it was derived, the prediction rule maintained its discriminatory ability. In these two validation sets, the rule correctly classified cases of pneumonia and other cases with ROC areas of 0.82 and 0.76, respectively. If patients with a predicted probability of having pneumonia of less than 5% were considered as not having pneumonia, the rule would have detected between 90% and 93% of cases of pneumonia in the three sets while correctly excluding 35% to

47% of patients without pneumonia. When adjusted for differences in the prevalence of pneumonia between the sets, the rule also showed good calibration; the predicted probability of having pneumonia for patients with different clinical findings corresponded closely with the frequency of pneumonia among patients with those findings. With some knowledge of the prevalence of pneumonia in an emergency department population, the rule thus could provide information that would be useful to physicians in predicting the probability of having pneumonia in any patient and in deciding whether to order a chest roentgenogram.

Other multivariate clinical rules, derived using different study designs and statistical methods, have shown varying abilities to discriminate patients with and without pneumonia. In a study of 255 adults who presented to an emergency department for acute respiratory complaints and who had a chest roentgenogram, a logistic regression model identified cough, elevated temperature, and rales as significant predictors of pneumonia (3). The model could discriminate patients with and without pneumonia with an ROC area of only 0.73, which was inferior to the predictions of the examining physicians. In a prospective study of 1819 patients presenting to a walk-in clinic with cough, for whom chest roentgenograms were obtained whether or not the physician chose to order an x-ray film, a linear discriminant function identified temperature of greater than 37.8 °C, respiratory rate of greater than 25/min, and symptoms of sputum production, night sweats, myalgias, and the absence of sore throat and rhinorrhea as significant predictors of pneumonia (5). The discriminant rule classified cases of pneumonia and other cases with an ROC area of 0.81, which was more accurate than the roentgenogram-ordering decisions of the examining physicians. A discriminant score of greater than or equal to −1 identified pneumonia with a sensitivity of 91% and a specificity of 40%, results remarkably similar to those of our study. The discriminant rule remained valid when tested by jackknife and split-sample techniques (17, 18) in the population from which it was derived. Neither of these two clinical rules, however, was prospectively validated on a new patient population. Prediction rules that have not been prospectively validated often fail to work as accurately in new clinical settings as they did in the original one (6-8). For this reason, validation in new patient populations has been recommended as the definitive test of the misclassification rates of clinical prediction rules (6). One preliminary report of a logistic regression model based on age, smoking history, cachexia, rigors, sputum production, rhonchi, rales, and other signs of consolidation reported discrimination of pneumonia and nonpneumonia as being equally accurate in a new sample of patients (ROC area, 0.84) as in the original one (ROC area, 0.85) (19).

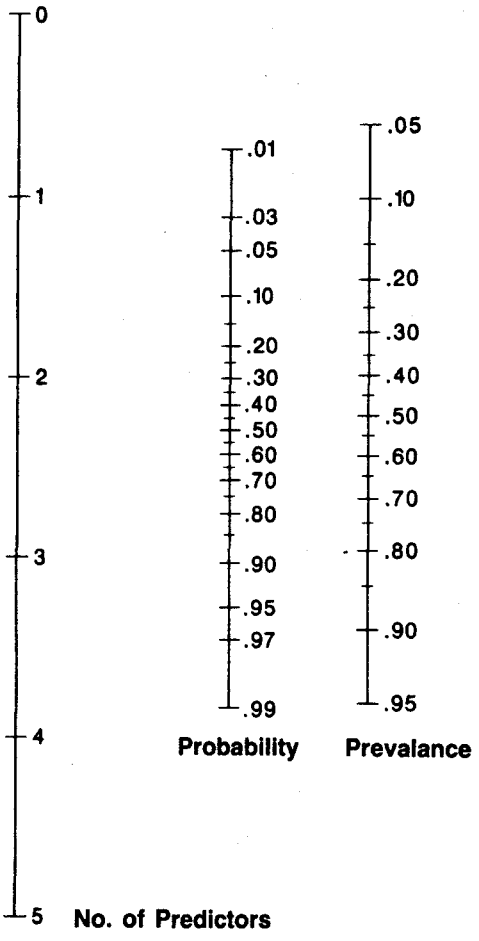

Figure 2. Nomogram for determining the probability of having pneumonia for any patient presenting to an emergency department with acute respiratory illness. **Left.** The scale represents the number of predictors of pneumonia from the logistic regression model (for example, temperature > 37.8 °C, pulse > 100 beats/min, rales, decreased breath sounds, the absence of asthma) that the patient has. **Right.** The scale represents the prevalence of pneumonia for that emergency department population. **Middle.** If a straightedge is placed on the appropriate points on the left and right scales, the point where the straightedge intersects the middle scale represents the probability that that patient has pneumonia. For example, a patient without asthma with a pulse greater than 100 beats/min and rales (thus, with three findings) from an emergency department with a 15% prevalence of pneumonia would have a predicted probability of having pneumonia of 25%.

Physical findings of pyrexia (elevated temperature), tachycardia, and consolidation (rales, decreased breath sounds) emerged as the most important predictors of pneumonia in this study. Historical findings of cough, sputum production, dyspnea, and pleuritic chest pain, often regarded as classic symptoms of pneumonia, were equally common among patients without pneumonia and therefore could not discriminate between patients with and without pneumonia. Previous studies of acute respiratory illness in adults (3, 4) and children (20, 21) have also reported that fever (3, 20) and pulmonary findings of rales, decreased breath sounds, bronchial breath sounds, and percussion dullness in various combinations (3, 4, 20, 21) were the most significant predictors of pneumonia. In these studies, as well as in ours, chest roentgenograms were done at the discretion of the examining physicians, and not all patients with respiratory symptoms had a roentgenogram. It is therefore possible that some symptoms did not emerge as significant predictors of pneumonia because they were used by physicians to select patients for radiologic study (5, 22, 23). In the only study that did not report pulmonary findings as an independent predictor of pneumonia (5), however, abnormal lung findings had been excluded

from analysis because they occurred so infrequently in this clinic sample in which the prevalence of pneumonia was only 2.6%. When a composite variable consisting of all abnormal pulmonary findings was included, this variable was the first selected by the discriminant model (5), suggesting that abnormal lung findings are the most important predictor of pneumonia in a sample of ambulatory patients as well as in patients presenting to emergency departments, such as ours.

The absence of asthma also emerged as an important independent predictor of pneumonia in our patients. Only 4.6% of our patients with acute asthma had radiographic infiltrates compatible with pneumonia, similar to the 1.9% frequency of pneumonic infiltrates previously reported among adults presenting with asthma (4). These results suggest that patients with acute asthma may not routinely require chest roentgenograms, because they rarely have pneumonia or other radiographic abnormalities (24). However, 12.5% of our patients with asthma who had an elevated temperature and pulse plus rales, locally decreased breath sounds, or both had radiographic evidence of pneumonia. Patients with asthma with these additional clinical findings therefore are at increased risk for having pneumonia and should probably receive a chest roentgenogram. Although other comorbid illnesses, such as dementia and several immunocompromising diseases, were significant univariate correlates of pneumonia, after adjusting for the presence of elevated temperature, tachycardia, and abnormal pulmonary findings, they did not remain independent predictors of pneumonia.

Our study had some methodologic limitations. First, pneumonia was defined as an infiltrate on chest roentgenogram, which may represent an imperfect gold standard. Some patients with evolving pneumonia may not have radiographic infiltrates at presentation, and some patients with infiltrates suggesting pneumonia will ultimately prove to have noninfectious illnesses. Nevertheless, physicians' management decisions, such as those about hospitalization and antimicrobial therapy, often depend on the initial radiographic evidence for pneumonia, making it a clinically relevant gold standard. Second, as previously noted, because not all patients with respiratory symptoms received a chest roentgenogram, the bias of the selection process may have obscured some of the significant correlates of pneumonia.

In addition, the cases in which data were collected after the emergency department visit may contain a test-review bias (25) if the examining physicians' knowledge of the chest roentgenogram results influenced the recording of symptoms and signs of pneumonia. Because recorded data in such cases were quite consistent with information in the emergency department charts, it is unlikely that such bias significantly influenced our results. Diagnostic-review bias may have affected the roentgenographic classifications of pneumonia if dissemination of clinical information to the radiologists influenced their readings of the films.

Because no attempt was made to standardize the pulmonary examinations, interobserver variation in detecting pulmonary signs may have led to an underestimation of the predictive power of some lung findings. However, such variability reflects usual clinical practice, and its incorporation into the model should therefore increase the model's robustness and generalizability when applied to other clinical settings. Finally, because microbiologic and serologic studies were not available for all patients, distinction among cases of bacterial, atypical bacterial (for example, mycoplasma, legionella), and viral pneumonia was not possible. The optimal clinical predictors of pneumonia may conceivably differ, depending on microbiologic etiology.

In conclusion, among adults presenting with acute respiratory illness, a prediction rule based on clinical findings accurately discriminated patients with and without pneumonia and was used in two other patient populations without significant decrement in discriminatory ability. Findings of a temperature greater than 37.8 °C, a pulse greater than 100 beats/min, rales, locally decreased breath sounds, and the absence of asthma emerged as significant predictors of the presence of pneumonia. Clinical prediction rules, when properly validated, can be used by physicians to develop more effective strategies for detecting pneumonia and for helping to determine the need for radiologic study among patients with acute respiratory disease.

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