# Does This Patient Have Community-Acquired Pneumonia?

## Diagnosing Pneumonia by History and Physical Examination

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Community-acquired pneumonia is an important cause of acute respiratory symptoms (eg, cough) in the ambulatory care setting. Distinguishing pneumonia from other causes of respiratory illnesses, such as acute bronchitis and upper respiratory tract infections, has important therapeutic and prognostic implications. The reference standard for diagnosing pneumonia is chest radiography, but it is likely that many physicians rely on the patient's history and their physical examination to diagnose or exclude this disease. A review of published studies of patients suspected of having pneumonia reveals that there are no individual clinical findings, or combinations of findings, that can rule in the diagnosis of pneumonia for a patient suspected of having this illness. However, some studies have shown that the absence of any vital sign abnormalities or any abnormalities on chest auscultation substantially reduces the likelihood of pneumonia to a point where further diagnostic evaluation may be unnecessary. This article reviews the literature on the appropriate use of the history and physical examination in diagnosing community-acquired pneumonia.

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### CLINICAL SCENARIO—DOES THIS PATIENT HAVE PNEUMONIA?

A 53-year-old woman comes to your office with a cough of more than 1 week's duration. She was in excellent health until 7 days ago when she developed a nonproductive cough, mild sore throat, and myalgia. She recalls no past history of asthma or chronic obstructive pulmonary disease, and she does not smoke. Despite staying home from work for the last 2 days, she has noted increasing sputum production with her cough and worsening fatigue. She has felt warm but has not documented any fever or night sweats. On physical examination, her oral temperature is 38.3°C (101°F), her heart rate is 110 beats per minute, and auscultation of her chest reveals inspiratory crackles on the left side.

### WHY IS THIS AN IMPORTANT QUESTION TO ANSWER WITH A CLINICAL EXAMINATION?

Physicians commonly encounter patients with respiratory complaints similar to those in the clinical scenario. In 1994, there were over 10 million visits to primary care physicians by adults with a chief complaint of cough, representing over 4% of all visits to physicians that year. Pneumonia represented only 5% of all causes for these visits and was the fifth leading diagnosis, after bronchitis, upper respiratory tract infection, asthma, and sinusitis.[1] Though pneumonia may represent a small proportion of all acute respiratory illnesses, the accurate identification of this subgroup is important because of the very distinct therapeutic and prognostic features of this illness.

In the preantibiotic era, mortality from pneumococcal pneumonia was consistently higher than 20% for all cases, rising to more than 60% for bacteremic cases.[2] Since the introduction of antibiotics no one has reported results from large-scale studies comparing antibiotic therapy to nonantibiotic therapy for patients with pneumonia. As a result, such therapy is universally recommended and has become a standard of care for all patients with pneumonia. No such standard exists for alternative respiratory infections such as bronchitis[3] or the common cold.[4] Moreover, inappropriate use of antibiotics for these alternative respiratory infections may be an important determinant of the rise in antibiotic resistance among common respiratory pathogens.[5,6]

In terms of prognosis, patients with pneumonia continue to have an overall high mortality from this illness, ranging from as low 5% in studies of hospitalized and ambulatory patients to as high as 37% in studies of patients requiring admission to intensive care units.[7] This persistently high mortality underscores the

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need for physicians to choose carefully between home or hospital therapy for all patients with pneumonia.[8] For these reasons, physicians need to know how optimally to use their clinical examination to identify patients at suitable risk for pneumonia to require further, definitive diagnostic testing.

Chest radiography is the reference standard for diagnosing community-acquired pneumonia and provides additional information on the prognosis of patients with this illness,[9] as well as the presence of coexisting conditions such as bronchial obstruction or pleural effusions.[10] Moreover, chest radiography is highly reliable,[11] safe, generally available, and relatively inexpensive, so that it is a standard part of the evaluation of any patient with suspected pneumonia. It is possible that some physicians continue to diagnose and manage patients with pneumonia without the aid of chest radiography, while other physicians routinely obtain chest radiographs for all patients suspected of having pneumonia. We do not know the proportion of physicians who choose these alternative strategies. Therefore, the aims of this article are both to assess the validity of the former approach (diagnosing pneumonia without chest radiography, using history and physical examination alone) and to identify elements of the clinical examination that might improve the efficiency of the latter approach (ordering chest radiographs for all patients with suspected pneumonia).

## PATHOPHYSIOLOGY OF COMMUNITY-ACQUIRED PNEUMONIA

In patients with community-acquired pneumonia, the site of infection can involve the pulmonary interstitium, alveoli, or both. This provides the physiologic basis for the principle chest examination findings in pneumonia, which include dullness to percussion, changes in the intensity of tactile fremitus and breath sounds, and inspiratory crackles. Dullness to percussion and local changes in the intensity of tactile fremitus and breath sounds are the result of diffuse replacement of the pulmonary parenchyma with inflammatory tissue leading to pulmonary consolidation or the presence of pleural effusions.[12] In a patient with pneumonia, crackles (formerly called "rales") are caused by the delayed opening of alveoli in deflated regions of pathologically inflamed lung.[13] Of note, crackles refer to any discontinuous adventitious lung sounds and can therefore be heard in a variety of pulmonary diseases that cause lung stiffening, including congestive heart failure, pulmonary fibrosis, and obstructive lung disease.[12]

## HOW TO ELICIT THESE SYMPTOMS AND SIGNS

Patients with community-acquired pneumonia present with a large number of possible symptoms. In a study of more than 1800 patients with community-acquired pneumonia, these presenting symptoms ranged from typical respiratory complaints, including productive cough, dyspnea, and pleuritic chest pain, to predominately systemic complaints of fatigue, anorexia, and myalgias. Moreover, the pattern of presenting symptoms varied considerably among patients, particularly among elderly patients with pneumonia who less frequently reported a wide range of symptoms.[14] As a result, careful history taking in a patient suspected of having community-acquired pneumonia should consider a broad range of possible symptoms, including both respiratory and nonrespiratory symptoms.

In contrast, the examination of the chest in patients with suspected pneumonia is traditionally carried out in a structured manner, proceeding through the 4 steps of inspection, palpation, percussion, and auscultation. The chest is inspected for signs of asymmetric chest expansion, defined as a visible difference in excursion between the 2 sides of the chest. The chest wall is palpated while the patient speaks in order to assess the transmission of sound, or tactile fremitus. Percussion over symmetric areas of the anterior and posterior chest wall detects diminution in the resonance of the percussion note, or dullness to percussion. Finally, auscultation of the lung assesses the intensity of normal breath sounds, the transmission of spoken words, and the presence of adventitious sounds. Auscultation in the peripheral lung fields may detect the replacement of the normal vesicular breath sounds with tubular or bronchial breath sounds, which are normally heard only over the trachea. Increased transmission of speech may be detected as the increased clarity of whispered phrases, known as whispered pectoriloquy, or as the change in timbre of vowel sounds in the form of "e" to "a," known as egophony.[12] The principal abnormal sounds in community-acquired pneumonia are known as crackles, which are nonmusical, discontinuous sounds and should be detected with the patient in the upright position. It has been suggested that auscultation of each lung in the lateral dependent position is a more sensitive technique for crackles, but this has not been independently validated.[15] Auscultation should occur with the patient breathing at normal tidal volumes, since inspiration from lower lung volumes (ie, residual volume) can yield abnormal auscultatory findings in as many as 50% of normal subjects.[16] Finally, both percussion and auscultation of the chest should proceed in a systematic fashion, with an examination of symmetric areas on both the anterior and posterior chest wall.

## METHODS

### Literature Search

We searched English-language medical literature to determine the precision of the clinical examination in patients with community-acquired pneumonia and the accuracy of the examination in diagnosing patients suspected of having this illness. We searched MEDLINE from 1966 through October 1995 based on an initial search strategy similar to that used by other authors in this series. (The search strategy is available on request.) The initial retrieval of titles (n=7 for precision, n=140 for diagnostic accuracy) was reviewed by 2 of us (J.P.M., M.J.F.). Articles that focused on hospital-acquired pneumonia, pediatric pneumonia, or acquired immunodeficiency syndrome–related pneumonia were excluded. The remaining articles were retrieved, as well as any potentially eligible articles identified through review of the article reference lists (n=7 for precision, n=52 for diagnostic accuracy).

A set of explicit inclusion and exclusion criteria were applied to each retrieved article. Inclusion criteria required that the study be an original study of the accuracy or precision of the history and/or physical examination in determining the diagnosis of community-acquired pneumonia. Exclusion criteria consisted of studies of (1) patients younger than 16 years, (2) patients with known immunosuppression, or (3) patients with nosocomial infections. In addition, case series (<10 observations) or review articles without original data were excluded.

### Quality Review of Articles

The remaining eligible articles were each evaluated by one of us (J.P.M.) based on a methodologic quality filter that assigned a level of evidence from I to V based on the internal validity of the study. Level I evidence refers to a primary, prospective study of the accuracy or precision of the clinical examination in community-acquired pneumonia. For studies dealing with accuracy, this requires independent, blind comparisons of clinical findings with a criterion standard (or "gold standard") of diagnosis or etiology among a large number (>50) of consecutive patients suspected of having community-acquired pneumonia. For studies dealing with precision, this

Table 1.—Precision of Physical Examination Findings in Examination of the Chest*

| Physical Examination Finding | Agreement, %† | κ Value |
|---|---|---|
| Tachypnea | 63 | 0.25 |
| Reduced chest movement | 70 | 0.38 |
| Increased tactile fremitus | 85 | 0.01 |
| Dullness to percussion | 77 | 0.52 |
| Decreased breath sounds | . . .‡ | 0.43 |
| Wheezes | 79 | 0.51 |
| Crackles | 72 | 0.41 |
| Bronchial breath sounds | . . .‡ | 0.32 |
| Whispered pectoriloquy | . . .‡ | 0.11 |

*Adapted from Spiteri et al.[23]
†Calculated based on data provided in Table 1 of Spiteri et al.[23]
‡Mean pair agreement rates were not calculated for the signs for which 2 or more physicians in a group failed to report the presence or absence of the sign.

requires 2 or more independent blinded raters of symptoms or signs in a large number of patients suspected of having community-acquired pneumonia. Level II studies were analogous to level I studies but with smaller numbers of patients (10-50), widening the confidence limits of the resulting calculations. Level III studies were based on a retrospective design (ie, clinical findings determined by chart review). Level IV studies included nonconsecutive patients, generally selected because of their definitive results for the findings under study, or a nonblinded comparison of clinical findings with a gold standard. Level V studies included studies with an uncertain gold standard or a poorly defined study population (ie, may not even have community-acquired pneumonia). For the purposes of this study, only studies of level I quality, also called grade A evidence, were considered for the main analyses and tables. Summaries of relevant level II through V studies are provided in the text.

### Data Analysis

Likelihood ratios were calculated for the presence (positive likelihood ratio [LR+]) or absence (negative likelihood ratio [LR−]) of individual clinical findings.[17,18] Only those findings significantly associated with the presence or absence of pneumonia in at least 1 study, based on a 2-tailed $\chi^2$ or Fisher exact test with $P<.05$, were included in the results. However, the actual diagnostic value of statistically significant findings still depends on both the prior probability of pneumonia and how much the likelihood ratio moves the posterior probability from the prior probability.[19]

## RESULTS

### Precision of Symptoms and Signs of Community-Acquired Pneumonia

Interobserver variation in the recording of the presence of symptoms in patients with community-acquired pneumonia has not been directly examined. However, analogous work in assessing symptom prevalence in large-scale epidemiologic studies has revealed considerable interobserver variation in the recording of symptoms.[20,21] This has led to the adoption of standardized respiratory questionnaires in epidemiologic studies of chronic respiratory illnesses. However, no such standardized questionnaires exist for recording symptoms in patients with acute respiratory infections.[22]

It has also been appreciated for some time that the physical examination of the chest is hampered by a high degree of interobserver error. While no study has specifically addressed the reliability of the physical examination in patients with community-acquired pneumonia, Spiteri et al[23] measured reliability among 24 physicians in the examination of 24 patients with a variety of respiratory conditions, 4 of whom had radiographic evidence of pneumonia. Table 1 presents the calculated interobserver reliability among the physicians for several chest signs. The results are presented in the form of both mean pair observer agreement rates and κ values, which account for rates of chance agreement ranging from 0, when agreement is no better than chance, to 1, when there is perfect agreement. In fact, 2 of the most reliable findings, dullness to percussion and wheezes on auscultation, had only fair to good κ values of 0.52 and 0.51, corresponding to agreement rates of 77% and 79%, respectively. Crackles had a κ value of 0.41 (agreement rate of 72%) and several findings such as whispered pectoriloquy, and increased tactile fremitus had κ values indicating poor agreement (range, 0.01-0.11), in part explained by the rarity of these findings overall.

Similarly poor interobserver reliability has been noted in the chest examination of other respiratory disease. For example, Schilling et al[24] noted an agreement rate of 76% for abnormal chest sounds in the examination of 187 men with interstitial lung disease and 88 controls; this yields a κ value of 0.25. Smyllie et al[25] measured agreement rates among 9 physicians who examined 20 patients with a variety of chronic lung diseases. Agreement rates were generally midway between chance and perfect agreement for a number of chest examination findings, including diminished breath sounds, decreased percussion note, and crackles. Though the basis for the relatively low interobserver reliability in chest examination is unknown, at least 1 group has suggested that deficiencies in the teaching of the clinical examination are to blame.[23]

### Accuracy of the Clinical History in the Diagnosis of Community-Acquired Pneumonia

For this review, 4 studies were judged to have level I evidence on the test characteristics of individual items in the clinical history in the diagnosis of community-acquired pneumonia.[26-29] In each of these studies, the reference standard for the diagnosis of pneumonia was a new infiltrate on a chest radiograph. Table 2 summarizes the value of findings from the history, including respiratory symptoms, nonrespiratory symptoms, and information on past medical history.

Though all 4 studies were based in emergency departments, variations in the patterns of the results reflect, in part, variation in the selection criteria for each study. For example, in the study by Diehr et al,[26] chest radiographs were obtained for all patients presenting with acute cough, while the other studies obtained chest radiographs only when the primary physician previously determined a need for them, often to confirm or exclude a suspected diagnosis of pneumonia. The latter approach provides a more highly selected population of patients with acute respiratory complaints that may alter the measured test characteristics of individual clinical findings. This selection bias is reflected in the fact that the prevalence of pneumonia in the study populations ranged from as low as 2.6%[26] to as high as 38.3%.[27]

Still, certain patterns emerge. For example, there are no individual items from the clinical history whose presence or absence would reduce the odds of disease sufficiently to exclude pneumonia and eliminate the need to obtain a chest radiograph. The 1 exception to this is the presence of a medical history of asthma, which reduces the odds of pneumonia by a factor of 0.1, though this has been demonstrated in only 1 study.[29]

Similarly, the presence of no single item in the clinical history raises the odds of pneumonia high enough to confirm the diagnosis without a chest radiograph. Though the presence of findings with a LR+ ranging from 2 (fever or immunosuppression) to 3 (history of dementia) may be helpful, they are not confirmatory, particularly given the typically low prevalence of pneumonia in the study populations. For example, in the study by Diehr et al, the presence of subjective fever (LR+=2.1, 95% confidence interval [CI], 1.4-2.9) had a positive predictive value of only 5.5%, reflecting the low prevalence of pneumonia in the population.[26]

Table 2.—Likelihood Ratios for Pneumonia Given the Presence or Absence of Individual History Findings*

| | Positive Likelihood Ratio† | | | | Negative Likelihood Ratio‡ | | | |
|---|---|---|---|---|---|---|---|---|
| | Diehr et al,[26] 1984 | Gennis et al,[27] 1988 | Singal et al,[28] 1989 | Heckerling et al,[29] 1990 | Diehr et al,[26] 1984 | Gennis et al,[27] 1988 | Singal et al,[28] 1989 | Heckerling et al,[29] 1990 |
| Respiratory symptoms | | | | | | | | |
| Cough | ... | NS | 1.8 | NS | ... | NS | 0.31 | NS |
| Dyspnea | ... | 1.4 | NS | NS | ... | 0.67 | NS | NS |
| Sputum production | 1.3 | NS | ... | NS | 0.55 | NS | ... | NS |
| Nonrespiratory symptoms | | | | | | | | |
| Fever | 2.1 | NS | ... | 1.7 | 0.71 | NS | ... | 0.59 |
| Chills | 1.6 | 1.3 | ... | 1.7 | 0.85 | 0.72 | ... | 0.70 |
| Night sweats | 1.7 | ... | ... | ... | 0.83 | ... | ... | ... |
| Myalgias | 1.3 | NS | ... | ... | 0.58 | NS | ... | ... |
| Sore throat | 0.78 | NS | ... | ... | 1.6 | NS | ... | ... |
| Rhinorrhea | 0.78 | NS | ... | ... | 2.4 | NS | ... | ... |
| Past medical history | | | | | | | | |
| Asthma | ... | ... | ... | 0.10 | ... | ... | ... | 3.8 |
| Immunosuppression | ... | ... | ... | 2.2 | ... | ... | ... | 0.85 |
| Dementia | ... | ... | ... | 3.4 | ... | ... | ... | 0.94 |

*Only those findings significantly associated with the presence or absence of pneumonia in at least 1 study were included ($P<.05$ in a 2-tailed $\chi^2$ or Fisher exact test). Ellipses indicate the result is not available; NS, result not significant.
†Positive likelihood ratio for pneumonia when symptom present (sensitivity/1−specificity).
‡Negative likelihood ratio for pneumonia when symptom absent (1−sensitivity/specificity).

Table 3.—Likelihood Ratios for Pneumonia Given the Presence or Absence of Physical Examination Findings*

| | Positive Likelihood Ratio† | | | | Negative Likelihood Ratio‡ | | | |
|---|---|---|---|---|---|---|---|---|
| | Diehr et al,[26] 1984 | Gennis et al,[27] 1988 | Singal et al,[28] 1989 | Heckerling et al,[29] 1990 | Diehr et al,[26] 1984 | Gennis et al,[27] 1988 | Singal et al,[28] 1989 | Heckerling et al,[29] 1990 |
| Vital signs | | | | | | | | |
| Respiratory rate, breaths/min | | | | | | | | |
| >20 | ... | 1.2 | ... | ... | ... | 0.66 | ... | ... |
| >25 | 3.4 | ... | NS§ | 1.5 | 0.78 | ... | NS | 0.82 |
| >30 | ... | 2.6 | ... | ... | ... | 0.80 | ... | ... |
| Heart rate, beats/min | | | | | | | | |
| >100 | NS | 1.6 | NS§ | 2.3 | NS | 0.73 | NS | 0.49 |
| >120 | ... | 1.9 | ... | ... | ... | 0.89 | ... | ... |
| Temperature >37.8°C (100°F) | 4.4 | 1.4 | 2.4 | 2.4 | 0.78 | 0.63 | 0.68 | 0.58 |
| Any abnormal vital sign | ... | 1.2 | ... | ... | ... | 0.18 | ... | ... |
| Chest examination | | | | | | | | |
| Asymmetric respiration | ∞ | ... | ... | ... | 0.96 | ... | ... | ... |
| Dullness to percussion | NS | 2.2 | ... | 4.3 | NS | 0.93 | ... | 0.79 |
| Decreased breath sounds | ... | 2.3 | ... | 2.5 | ... | 0.78 | ... | 0.64 |
| Crackles | 2.7 | 1.6 | 1.7 | 2.6 | 0.87 | 0.83 | 0.78 | 0.62 |
| Bronchial breath sounds | ... | ... | ... | 3.5 | ... | ... | ... | 0.90 |
| Rhonchi | NS | 1.5 | ... | 1.4 | NS | 0.85 | ... | 0.76 |
| Egophony | 8.6 | 2.0 | ... | 5.3 | 0.96 | 0.96 | ... | 0.76 |
| Any chest finding | ... | 1.3 | ... | ... | ... | 0.57 | ... | ... |

*Only those findings that were significantly associated with the presence or absence of pneumonia in at least 1 study were included ($P<.05$ in a 2-tailed $\chi^2$ or Fisher exact test). Ellipses indicate result is not available; NS, result not significant.
†Positive likelihood ratio for pneumonia when finding present (sensitivity/1−specificity).
‡Negative likelihood ratio for pneumonia when finding absent (1−sensitivity/specificity).
§Actual cut points not specified in this study.

## Accuracy of Physical Examination Findings in the Diagnosis of Community-Acquired Pneumonia

Table 3 summarizes the accuracy of 10 different potential findings (3 vital signs and 7 abnormal findings on chest examination) from the physical examination in patients with suspected pneumonia based on results from the 4 previously identified studies. Likelihood ratios for the presence of any individual vital sign abnormality (LR+), including tachypnea, tachycardia, or fever, ranged from 2 to 4. Moreover, various cut points for these abnormalities did not have a substantial impact on the calculated LRs.[27] Similarly, LRs for the absence of any individual vital sign abnormality (LR−) ranged from 0.5 to 0.8. However, Gennis et al[27] demonstrated an LR− of 0.18 (95% CI, 0.07-0.46) for the diagnosis of pneumonia based on the absence of all 3 vital sign abnormalities (ie, respiratory rate <30 breaths per minute, heart rate <100 beats per minute, and temperature <37.8°C [100°F]). Based on this finding, if the baseline prevalence of pneumonia among ambulatory patients with respiratory illnesses is assumed to be 5%, a patient without any vital sign abnormalities would have a predicted probability of pneumonia of less than 1%.

The presence of several individual findings on chest examination significantly raised the likelihood of pneumonia. For example, in 1 study the presence of asymmetric respirations essentially guaranteed the diagnosis of pneumonia (LR+=∞, 95% CI, 3.2-∞).[26] However the usefulness of this finding was limited by the fact that only 4% of patients with pneumonia were noted to have asymmetric respirations. The presence of other findings, including egophony and

Table 4.—Predictive Rules for Pneumonia Diagnosed by Chest Radiography*

| | |
|---|---|
| Diehr et al[26] | |
| Add points when present†: | |
| Rhinorrhea | −2 points |
| Sore throat | −1 point |
| Night sweats | 1 point |
| Myalgias | 1 point |
| Sputum all day | 1 point |
| Respiratory rate >25 breaths/min | 2 points |
| Temperature ≥37.8°C (100°F) | 2 points |
| Singal et al[28] | |
| Probability=$1/(1+e^{-Y})$‡ | |
| Y=−3.095+1.214 (cough) | |
| +1.007 (fever) | |
| +0.823 (crackles) | |
| Each variable=1 if present | |
| Heckerling et al[29] | |
| Determine the number of findings present§: | |
| Absence of asthma | |
| Temperature >37.8°C (100°F) | |
| Heart rate >100 beats/min | |
| Decreased breath sounds | |
| Crackles | |

*Adapted from Emerman et al.[33]

†For example, a threshold score of −1 (ie, all patients with scores ≥−1 are considered to have pneumonia), yields a positive likelihood ratio (LR+)=1.5 and negative likelihood ratio (LR−)=0.22, a threshold score of +1 yields a LR+=5.0 and LR−=0.47, and a threshold score of +3 yields a LR+=14.0 and LR−=0.82, based on the original study data.[26]

‡First calculate Y and then calculate the predicted probability of pneumonia.

§For example, based on a prevalence of pneumonia of 5%, the presence of 0, 1, 2, 3, 4, or 5 findings yields probabilities of pneumonia of <1%, 1%, 3%, 10%, 25%, and 50%, respectively, based on a nomogram provided by Heckerling et al.[29]

dullness to percussion, significantly increased the likelihood of pneumonia. However, given the low prevalence of pneumonia in the overall study populations, the impact of observing these findings on estimating the probability of pneumonia was only modest. For example, the presence of egophony had a positive predictive value ranging from as low as 20%[26] to no higher than 56%.[27]

Finally, all 4 studies support the conclusion that the presence or absence of crackles on examination would not be sufficient to rule in or rule out the diagnosis. For example, with a prevalence of pneumonia of 5%, the absence of crackles reduces the probability to 3%, at the lowest, and the presence of crackles raises the probability to 10%, at the highest. Moreover, the absence of any abnormality on chest examination yielded an LR− of 0.57 (95% CI, 0.39-0.83),[27] which is too close to the indeterminate LR value of 1.0 to substantially reduce the probability of pneumonia.

The low accuracy of individual findings on chest examination for detecting pneumonia has also been supported by studies that relied on retrospective data gathering[30,31] or incomplete application of chest radiography to all study patients.[32] In 1 study, the absence of crackles yielded an LR− of only 0.71 (95% CI, 0.47-0.90) and the absence of any abnormal auscultatory finding yielded an LR− of only 0.68 (95% CI, 0.44-0.89), both of which would translate into very small effects on the probability of pneumonia.[32] In contrast, another study found that the absence of any abnormality on chest auscultation resulted in an LR− of 0.13 (95% CI, 0.07-0.24),[31] which might substantially reduce the probability of pneumonia. However, this result has not been replicated in prospective studies, which would be subject to less bias in the recording of physical examination findings.

## Evaluating Algorithms to Predict Pneumonia

Because the accuracy of individual symptoms or signs for predicting pneumonia is low, several studies have attempted to build prediction rules that incorporate the presence or absence of several history or physical examination findings. Table 4 summarizes the features of 3 such rules. Though initially designed as aids in the ordering of chest radiographs for patients with suspected pneumonia, they are reasonably considered as prediction rules for the diagnosis of pneumonia in these patients and yield probabilities of pneumonia after completion of the clinical examination. For the rule of Diehr et al, points are assigned for each clinical finding and summed to yield a discriminant score. For example, a threshold score of −1 (ie, all patients with scores ≥−1 are considered to have pneumonia) yields an LR+ of 1.5 and an LR− of 0.22, a threshold score of +1 yields an LR+ of 5.0 and an LR− of 0.47, and a threshold score of +3 yields an LR+ of 14.0 and an LR− of 0.82, based on the original study data.[26] The rule of Singal et al[28] is a logistic function that can yield probabilities of pneumonia ranging from 4% (no findings present) to 49% (all 3 findings present).[28]

The final prediction rule, by Heckerling et al,[29] is based on the presence or absence of 5 clinical findings. The performance of this prediction rule depends on the pretest probability of pneumonia in the population. In most ambulatory care settings, this probability will be relatively low. For example, as noted earlier, in a national survey, only 5% of all patients visiting primary care physicians for cough were diagnosed as having pneumonia.[1] In this setting, the presence of 2, 3, or 4 predictors would result in predicted probabilities of pneumonia of 3%, 10%, or 25%, respectively, based on a nomogram provided by Heckerling et al.[29] The rule would yield a maximum probability of pneumonia of 50% if all 5 of its clinical predictors were present. These findings emphasize the inaccuracy in diagnosing pneumonia clinically, in the absence of confirmatory chest radiography.

The 3 scores summarized in Table 4, along with the decision rule suggested by Gennis et al (ie, only obtaining chest radiographs for patients suspected of having pneumonia with at least 1 vital sign abnormality),[27] were compared for their ability to predict correctly the results of chest radiography in an independent study by Emerman et al.[33] Patients presenting to an emergency department or outpatient medical clinic with a complaint of cough were enrolled prospectively, and chest radiographs were obtained for all patients regardless of the primary physician's clinical impression.

Overall, the prevalence of pneumonia among the study patients was 7%. In the absence of an explicit guideline, physician judgment that the patient did not need chest radiography reduced the probability of pneumonia to just less than 2% (LR−=0.25, 95% CI, 0.09-0.61), which exceeded all 4 prediction rules. In contrast, physician judgment that the patient needed chest radiography to diagnose pneumonia only increased the probability of pneumonia to 13% (LR+=2.0, 95% CI, 1.5-2.4), which meant that reliance on implicit physician judgment alone would have led to many unnecessary chest radiographs.

In comparison, the simple decision rule of Gennis et al—ordering chest radiographs only for patients with abnormal vital signs—yielded the highest overall LR+ for predicting pneumonia, but the LR+ was a modest 2.6 (95% CI, 1.6-3.7). Using this rule, 40% fewer radiographs would have been ordered compared with unaided physician judgment. However, excluding pneumonia on the basis of the absence of any vital sign abnormalities would have missed 38% of patients subsequently shown to have pneumonia on chest radiography (LR−=0.50 [95% CI, 0.27-0.78], compared with LR−=0.18 in the original study of Gennis et al[27]). The clinical significance of this finding remains unknown.

It should be emphasized that an algorithm that is less than perfect, ie, not all ordered chest radiographs demonstrate a new infiltrate, will still be acceptable given the relatively low cost and risk associated with this test. Ultimately, optimum yields for chest radiography in the evaluation of patients with suspected pneumonia will need to be determined, balancing the costs of the test with the costs of missed diagnoses. Additional factors, such as illness severity and patient preferences, will also play a role in determining the appropriate threshold for ordering chest radiographs in patients with acute respiratory illnesses. For example, thresholds may be lower for patients who appear severely ill or

who express strong desires to have a definitive diagnosis. We suggest that an algorithm that yields less than a 100% negative predictive value may still be acceptable assuming that the missed cases of pneumonia continue to have good clinical outcomes. However, this hypothesis will need to be tested.

## RETURN TO THE CLINICAL SCENARIO

The patient presents with typical symptoms of community-acquired pneumonia, including a productive cough and fever. Physical examination reveals fever and crackles on chest auscultation. In particular, the patient has 4 of 5 of the clinical pneumonia predictors identified by Heckerling et al (absence of asthma, presence of fever, tachycardia, and crackles). Using the nomogram of Heckerling et al, a 5% prevalence of pneumonia among outpatients yields a 25% probability of pneumonia.[29] Similarly, the patient is at the threshold score of +3 points on the prediction rule of Diehr et al[26] (presence of sore throat, sputum, myalgias, and fever), yielding an LR for pneumonia of 14.0 (based on the original study data) and a calculated probability of pneumonia of 42%. Finally, the patient has 3 of 3 of the criteria of Singal et al, yielding a probability of pneumonia of 49%, based on their logistic formula.[28] We conclude that none of these combinations of findings can be said to "rule in" the diagnosis, yet the possibility of pneumonia remains high enough that further diagnostic testing, in particular chest radiography, is warranted.

## THE BOTTOM LINE

1. Physicians frequently disagree about the presence or absence of individual findings on chest examinations of patients with respiratory illnesses, including community-acquired pneumonia.

2. Individual symptoms and signs have inadequate test characteristics to rule in or rule out the diagnosis of pneumonia. Decision rules that use the presence or absence of several symptoms and signs to modify the probability of pneumonia are available, the simplest of which requires the absence of any vital sign abnormalities to exclude the diagnosis. There are no combinations of history and physical examination findings that confirm the diagnosis of pneumonia. If diagnostic certainty is required in the management of a patient with suspected pneumonia, then chest radiography should be performed.

3. Future research should examine ways to improve the precision of the clinical examination in patients with suspected pneumonia, as well as to determine the accuracy of the clinical examination in these patients in settings outside the emergency department. In addition, studies should address appropriate thresholds for obtaining chest radiographs and treating accordingly vs empirical antimicrobial therapy vs clinical observation in the management of patients with suspected community-acquired pneumonia.

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