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Community-acquired pneumonia in adults: Diagnostic reliability of physical examination techniques and their teaching in academia

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ABSTRACT

Background: Chest physical examination techniques are taught in academia, but their usefulness in the evaluation and diagnosis of patients in the clinical setting is controversial. **Objective:** To investigate the accuracy of physical examination techniques and their reliability in diagnosing community acquired pneumonia (CAP) and suggest a modified teaching approach to be used in academia. **Design**: Systematic Literature Review. **Methods**: Database search of PubMed and Google Scholar using the search terms "prediction of pneumonia in adults" and "prediction rule for pulmonary infiltrates." Filters were implemented to include articles that only dealt with human subjects and were full text. Articles were excluded if the patient population was not desired, if the article focused on symptoms instead of clinical findings, or if the article was a meta-analysis. **Results**: Gennis et al. found that decreased breath sounds, rales, and rhonchi are significantly associated with pneumonia. Heckerling et al. found that dullness to percussion, bronchial breath sounds, decreased breath sounds, egophony, rales, and rhonchi were all significantly associated with pneumonia. Diehr et al. found that increased fremitus, dullness to percussion, egophony, pleural friction rub, and rales were significantly associated with pneumonia. **Conclusion:** The most valuable examination technique in detecting pneumonia was rales. Wheezes were relatively not useful. Overall, performing a meticulous lung and thorax examination contributes to identifying a diagnostic hypothesis; however, the physical examination is not sufficiently accurate to rule in or rule out pneumonia on its own. If diagnostic certainty is required for the management of a patient with suspected pneumonia, chest radiographs should be obtained. In academia, teaching examination techniques with the highest diagnostic yield should be the cornerstone of a teacher's instruction.

INTRODUCTION

Background

Chest physical examination techniques are historically considered essential objective measurements when evaluating an individual with a suspected lower respiratory tract infection (LRTI). These maneuvers have been continued to be taught to students studying medicine; however, the ability to distinguish between the absence or presence of pulmonary diseases using these techniques is a skill, and one that is not easily mastered. Failure to perform and perceive the importance of such examination skills adequately may be due to poor teaching of basic clinical skills or may result from poor training during clinical rotations. With an increase in access to chest radiographs and the time constraints surrounding a patient encounter, the practicality of performing these exams and eliciting results in the clinical setting has diminished and become merely a formality. Today, students are rushed during their training and often take short cuts following in the footsteps of their predecessors.

Due to the broad range of clinical presentations and differential diagnoses, as well as the potential life threatening nature of pneumonia and its treatment course, it is important to establish the reliability of the lung and thorax examination and to safely diagnose patients using these skills. Some propose routine radiographic imaging as a reliable diagnostic test, while others believe ancillary testing is over-rated, costly, and may do more harm than good by exposing patients to unnecessary radiation. Furthermore, while imaging may provide insight as to what is occurring within the body, it cannot replace a provider's ability to recognize patterns of disease and apply them to the clinical presentation. Identifying examination techniques that are most informative in the evaluation of pulmonary disease may allow for consolidation of the thorax and lung examination, a greater focus on the proficiency of essential examination skills in education, and a decline in unnecessary testing used to assess for alternative diagnoses.

Epidemiology

Pneumonia is an infection of the lung parenchyma that although common, may potentially lead to serious illness and result in mortality if not diagnosed and treated appropriately. Community acquired pneumonia (CAP) is defined as an acute infection of the pulmonary parenchyma, acquired in the community, outside of the hospital setting. There are more than 100 microbes that can result in CAP, including bacteria, viruses, fungi, or parasites. The most common bacterial cause is *Streptococcus pneumoniae*, while rhinovirus and influenza are the leading viral etiologies.[1] Historically, CAP has been found to be mostly bacterial in nature following a brief upper respiratory tract infection (URTI). More recently, studies have shown that viral respiratory tracts infections are on the rise as another common etiology.[1] Additionally, there has been decline in the prevalence of *S. pneumoniae*, likely due to the use of pneumococcal vaccines in adults, the pneumococcal conjugate vaccines in children, and a decline in cigarette smoking.[1] The prevalence of CAP increases with age and in the winter months and is seen more frequently in males and African Americans in comparison to females and Caucasians. Today, the prevalence of CAP is approximately 5.15 to 6.11 cases per 1000 adults a year.[1] In 2013, 16.2 billion dollars was spent for pneumonia related health care expenses, and there were 56,832 deaths from pneumonia and influenza combined.[2] This accounted for the eighth leading cause of death in the U.S. at that time.[2]

Pathogenesis

The lungs are at an increased risk of infection due to exposure to microorganisms which enter the lower respiratory tract via inhalation of contaminated air or aspiration of nasopharyngeal flora.[3] The most common cause of CAP is the latter of the two. The occurrence of pneumonia is determined by multiple factors that play a role in complex interactions at the level of the lower respiratory tract. In particular, the immunity status of the host and the integrity of the innate and acquired host defenses of the lungs are of significant importance. Alteration of the following respiratory tract defense mechanisms will increase an individual's risk of infection: impaired function of the mucociliary apparatus, depressed cough and glottis reflexes, altered level of consciousness, and alveolar macrophage dysfunction.[3] Comorbidities including diabetes, alcoholism, malnutrition, and other chronic systemic disorders may also change the balance in normal oropharyngeal flora and create an environment more susceptible to colonization of gram-negative bacilli.[3] Lastly, the individual's immune response is the biggest defense mechanism against infection and those who are immunosuppressed due to disease transmission or immunosuppressive therapy are predisposed to acquiring pneumonia. Ultimately, the development of CAP indicates either a dysfunction in the natural host defenses, exposure to a virulent microorganism, or an immense inoculum.[1]

Clinical Presentation

Clinical manifestations of an individual with pneumonia may include malaise, fever, chills, myalgias, sore throat, runny nose, anorexia, fatigue, cough, sputum production, chest pain, and dyspnea, all of varying intensity depending on the severity of disease.[4] The diagnosis of an individual with the above symptoms may range from a mild URTI to a severe lung parenchyma infection, such as pneumonia or tuberculosis (TB). Individuals with pneumococcal pneumonia typically present with fever, chills, and a productive cough with rusty colored sputum. Additionally, patients with pneumococcal pneumonia may have a rapid onset of chest pain, shortness of breath, and tachypnea. Those with a history of chronic obstructive pulmonary disorder (COPD), smoking, and alcohol use, as well as cystic fibrosis, pulmonary edema, and the immunosuppressed are at an increased risk of developing CAP.[1]

The initial evaluation of a patient with symptoms concerning of a URTI or LRTI involves the lung and thorax examination which typically includes the following techniques: inspection, palpation, percussion, and auscultation. The chest is first inspected, noting any increase in the anteroposterior to lateral diameter, asymmetry in chest expansion, cyanosis of the skin, and clubbing of the nails. Secondly, the chest is palpated for any tenderness and to assess the transmission of sounds through the chest wall. Next, percussion is performed to determine resonance or dullness which may indicate a particular etiology. Lastly, auscultation assesses for normal intensity breath sounds, adventitious breath sounds, egophony, whispered pectoriloquy, or bronchophony.

In CAP, infection occurs in the alveoli, in the pulmonary interstitium, or both. When assessing for CAP, some of the earliest signs to look for include crackles (previously known as rales) and diminished breath sounds, followed by dullness to percussion, increased tactile fremitus, bronchial breath sounds, and egophony over the affected area.[4] Crackles are caused by the delayed opening of the alveoli and small airways which are collapsed due to fluid or exudate as seen in pneumonia.[4] Additionally, dullness to percussion, increased tactile fremitus, and decreased breath sounds are caused by inflammation of the lung parenchyma, resulting in fluid or inflamed tissue filling previously air-filled areas.[4] Healthy lungs behave as a low pass filter, transmitting only low and filtering out high frequency sounds (such as bronchial breath sounds).[4] In CAP, therefore, consolidated areas of inflamed tissue and fluid transmit all sounds equally, so bronchial breath sounds and egophony are present over the affected area.

Diagnosis
Unfortunately, the clinical presentation and physical examination alone is not 100% reliable in predicting radiologically confirmed pneumonia. In clinical practice, the gold standard used to diagnose CAP is new infiltrates detected on chest radiography, accompanied by recently acquired respiratory symptoms and abnormal vital signs.[5] A chest radiograph is also used to provide additional information regarding the prognosis of the patient and to distinguish pneumonia from other conditions in those presenting with similar symptoms.[3] Due to the importance of prompt treatment in a patient with CAP, differentiating with certainty between pneumonia and a viral respiratory illness has important therapeutic and prognostic implications. In primary care, however, providers may not obtain a chest radiograph and rely solely on the history and physical exam in the diagnosis of the patient.

Clinical Scenario
Ms. P is a 36 year-old-woman who presents to the office in November with a one week history of a productive cough, myalgias, and a low-grade fever with chills. Three days ago, she also developed chest pain with inspiration and shortness of breath. She reports she was in great health until seven days ago when she developed these symptoms. She does not smoke, has no history of asthma, COPD, or other comorbidities. There is no recent history of hospitalization. On physical examination, oral temperature is 38.7 degrees Celsius, heart rate is 108 beats per minute, and respiratory rate is 24 breaths per minute.

Clinical Question: Among adults who present with symptoms consistent with community acquired pneumonia, are physical examination techniques reliable when making a diagnosis compared to chest radiographs?

PICO Criteria:
<u>Patient Problem:</u> Adults with suspected community acquired pneumonia
<u>Intervention:</u> Physical examination techniques
<u>Comparison:</u> Chest radiography
<u>Outcome:</u> Diagnosis of community acquired pneumonia

METHODS
Literature Search
An initial search of PubMed and Google Scholar was performed in September 2017 using the search terms “prediction of pneumonia in adults” and “prediction rule for pulmonary infiltrates” that yielded 158,051 results (Figure 1[9]). Filters were implemented to include articles that only dealt with human subjects and

were full text. About 100 articles were further screened to identify those with appropriate inclusion criteria that studied an adult patient population where pneumonia was the disease being studied and that used physical exam techniques to diagnose. This narrowed the results to 11 full-text articles which were assessed for eligibility. Articles were excluded if the patient population was not desired, the article focused on symptoms instead of clinical signs, or if the article was a meta-analysis. Prospective cohort studies were the only study types included while meta-analyses, case studies, and reviews were excluded. Ultimately, three articles were chosen because they were the only articles that focused on the physical exam findings used to detect pneumonia.

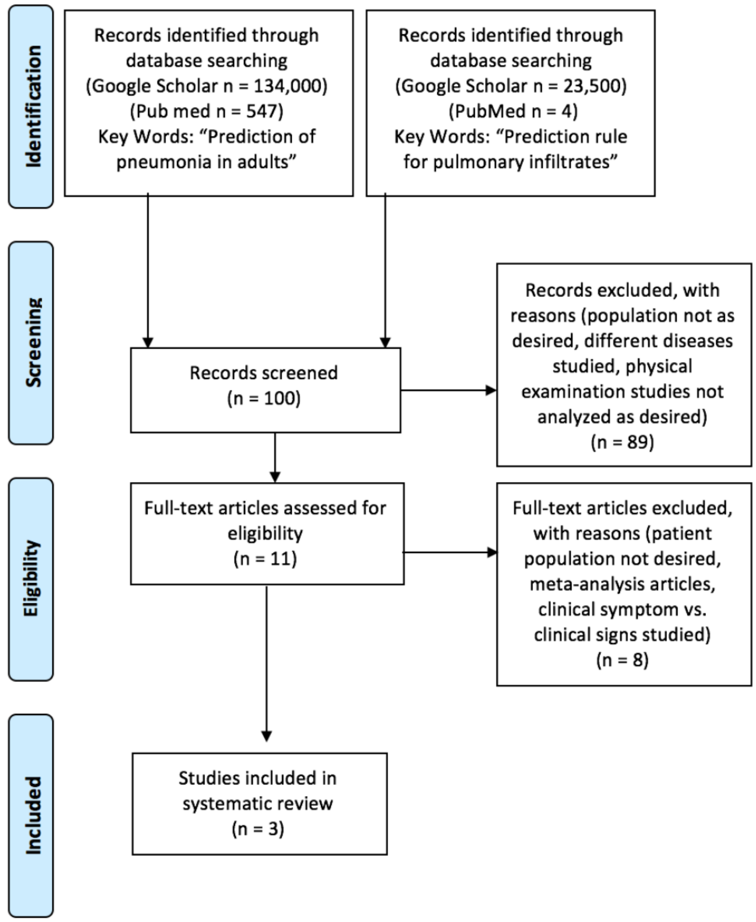

Figure 1. PRISMA Flow Diagram Summarizing the Process for Identifying Eligible Articles.

RESULTS

Statistical Analysis

When performing the physical exam, it is important to strategically choose which skills to perform by knowing the statistical evidence supporting the validity of those tests. More specifically, a medical provider should know what the statistics of each test mean and how they can be applied to diagnose the patient.

In this example, statistics will be explained using study 1 by Gennis et. al. (described in more detail below), by evaluating dullness to percussion, and the disease in question will be patients who have been diagnosed with radiographic pneumonia (Table 4). In table 1, starting with the top left corner and moving clockwise, the boxes are defined as the number of true positives (a = 15), false positives (b = 11), true negatives (c = 103) and false negatives (d = 179). These numbers are all attained using the information provided in the results section below and table 4. The number of true positives (TP) demonstrates the number of patients who were diagnosed with radiographic pneumonia who also had a positive finding (dullness to percussion) on the physical exam. The false positives (FP) represents the amount of patients who had dullness to percussion but were not found to have radiographic pneumonia. On the other hand, the true negatives (TN) describe the number of individuals who were not diagnosed radiographically with pneumonia and also a negative test result (no dullness to percussion). Lastly, the false negatives (FN) represent the number of patients who were not experiencing dullness to percussion but had evidence of pneumonia on radiographs. Adding the TP with the FP (a + b = 26), represents the total number of patients with dullness to percussion, compared to adding the FN plus the TN (c + d = 282), which demonstrates the total number of patients with

Table 1. Template for Statistical Analysis of Data

		Diagnosis of Disease of Interest	
		Disease Present	**Disease Absent**
Test Result	**Positive**	a **True Positive** (TP)	b **False Positive** (FP)
	Negative	c **False Negative** (FN)	d **True Negative** (TN)

a negative test finding (no dullness to percussion). Additionally, the TP plus the FN (a + c = 118) accounts for the total number of patients diagnosed with radiographic pneumonia compared to the FP plus the TN (b + d = 190) which shows the number of patients who had no evidence of radiographic pneumonia. Using these formulas and the data described in study 1, the following calculations given in table 2 should be performed.

Table 2. Calculations for Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, Positive Likelihood Ratio and Negative Likelihood Ratio.

Formulas	
Sensitivity %	= TP/(TP + FN) * 100 = a/(a+c) * 100
Specificity %	= TN/(FP + TN) * 100 = d/(b+d) * 100
PPV %	= TP/(TP + FP) * 100 = a/(a+b) * 100
NPV %	= TN/(FN + TN) * 100 = d/(c+d) * 100
+ LR	= sensitivity/(1-specificity)
- LR	= (1-sensitivity)/specificity

Positive Predictive Value (PPV); Negative Predictive Value (NPV); Positive Likelihood Ratio (+LR) and Negative Likelihood Ratio (-LR)

Sensitivity is the probability of those individuals who have the disease (pneumonia) who also have a positive test (dullness to percussion). In the study by Gennis, et. al. described below in table 4, the sensitivity is 13% which means 13% of patients with pneumonia will have dullness to percussion. The higher the sensitivity, the more useful a negative test is at ruling out the disease and identifying individuals with the disease. It reduces the number of false negatives and increases the number of true negatives. Sensitivity is also known as the true positive rate, whereas 1-sensitivity will give you the false negative rate. Specificity, on the other hand, is the proportion of people without the disease (pneumonia) who have a negative test (no dullness to percussion). The more specific the test, the better a positive test is to rule in favor of a disease and identify individuals without the disease. It decreases the number of false positives and increases the number of true positives. Specificity is also known as the true negative rate, whereas 1-specificity will give you the false positive rate. The specificity as demonstrated below in table 4 is 94%, which means 94% of patients who do not have pneumonia will test negative (no dullness to percussion). It is ideal for sensitivity and specificity to be as close to 100% as possible. In this case, we would rely more heavily on dullness to percussion to rule in pneumonia, as the specificity is high, but the sensitivity is very low.

Likelihood ratios (LR) help determine which tests or physical examination techniques are best at ruling in and ruling out a disease. A positive likelihood ratio is the likelihood that a patient has a disease following a positive test result and the negative likelihood ratio is the likelihood that a patient has the disease following a negative test result. Given that everything else is equal, the test with the greatest likelihood ratio of a positive test is the best test to rule in favor of a disease and the test with the smallest likelihood ratio of a negative test, is the best test to rule out a disease. A positive LR is excellent if it is greater than 10 and a negative LR is excellent if it is less than 0.1. A positive or negative likelihood ratio of 1.0 indicates the test is uninformative. Using dullness to percussion in table 4 and the formula provided in table 2, the positive LR would be 0.13/(1-0.94) = 2.2 and the negative LR would be (1-0.13)/0.94 = 0.9. Using likelihood ratios and constructing a nomogram, a connection can be made between the pretest probability of a disease to the posttest probability of the disease, also known as the positive predictive values (PPV) and negative predictive values (NPV).

The pretest probability is the probability of a patient having a target disorder before a diagnostic test result is obtained. This is utilized by medical providers when they are deciding if a test would be beneficial in diagnosing a patient considering an individual's circumstances. The pretest probability can be the prevalence of the disease in the patient's community, or estimated using the prevalence as well as the patient's risk factors, presenting signs and symptoms and physical exam findings. The pretest probability is plotted on a nomogram, followed by both the positive and negative LR. A straight line is then drawn between the two points to determine post-test probabilities or positive and negative predictive values. Using

Ms. P from the case study, a pretest probability will be formed and a nomogram will be shown below in the discussion section. The post-test probability values obtained from the nomogram may differ from the calculated PPV and NPV as these are estimates.

From table 4, the PPV or post-test likelihood of having the disease is 56%. This means if a patient tests positive, there is a 56% chance they will have the disease. The NPV in this case or posttest likelihood of no disease, is 63%. This means if the patient has a negative test, there is a 63% probability they do not have the disease. Clinically, having a test that has a PPV and NPV of 100% is diagnostically sound. The greater the prevalence of a disease, the higher the PPV but the lower the NPV.

Study 1

Clinical Criteria for the Detection of Pneumonia in Adults: Guidelines for Ordering Chest Roentgenograms in the Emergency Department.

Gennis, et. al.

Objective of Study:

The goal of this population study was to identify sensitive clinical criteria for the diagnosis of pneumonia.[6]

Study Design:

Table 3. Inclusion and Exclusion Criteria for Study 1: Gennis, et. al.

Inclusion Criteria	Exclusion Criteria
16 years of age or older	Pregnant
Had received a chest radiograph	Chief complaint of asthma
Pneumonia was a diagnostic consideration	

Data was collected at the emergency department of Bronx Municipal Hospital on 308 patients suspected of having pneumonia. This data collection occurred on 100 days over an eight month period by medical students trained as research assistants. Eligible patients were at least 16 years of age, not pregnant, whose provider had ordered a chest radiograph, and whose chief complaint was not asthma (Table 3). Providers included physicians, residents in internal medicine, and residents in emergency medicine who were all working under the direct supervision of attending emergency physicians.

Qualifying patients were interviewed to determine if they had any of the following symptoms: cough, fever, chest pain, sputum production, hemoptysis, dyspnea, headache, myalgias, rhinitis, ear discomfort, sore throat, chills, or altered mental status. The providers were then asked if any of the following physical signs were present: decreased breath sounds, dullness to percussion, rhonchi, rales, wheezes, egophony, tactile fremitus, pleural rub, cyanosis, respiratory distress, or toxic appearance. If there was no attempt to elicit a specific finding on physical exam, it was recorded as absent.

Radiology residents interpreted the chest radiographs and a supervising attending radiologist reviewed them. The films were read as positive, negative, or equivocal for pneumonia. This interpretation is what led to the diagnosis, disposition, and decision regarding treatment. The signs and symptoms were treated as dichotomous variables (ie; results which could only be classified into one of two variables). Chi-square analysis, with the significance established at the 0.05 level, was used to determine the association between clinical and radiographic findings. Ninety percent (276) of the films were then reviewed by a senior attending radiologist who was blinded to the previous interpretation to determine reproducibility.

Study Results:

Interpretation of the chest radiographs were as follows: 72 (23%) were interpreted as positive for pneumonia, 46 (15%) were equivocal, and 190 (62%) were negative. Patients with positive or equivocal films were considered to have pneumonia. Therefore, 118 (38%) patients were considered to have pneumonia and 190 (62%) were without pneumonia.

Decreased breath sounds (34% compared with 15%), rales (36% compared with 23%), and rhonchi (34% compared with 22%) were significantly associated with pneumonia (Table 4). Abnormal auscultatory findings in general were significantly associated with pneumonia (92% compared with 62%). Sensitivities, specificities, and positive and negative predictive values are displayed in table 4 and were provided in the original article. The positive and negative likelihood ratios were calculated by the authors of this review.

Table 4. Percentage of patients with and without radiographic evidence of pneumonia. Sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of physical examination techniques: Gennis, et. al.

	Pneumonia %	No Pneumonia %	Sensitivity %	Specificity %	PPV %	NPV %	+ LR	- LR
Altered Fremitus	1	1	1	99	50	62	1.0	1.0
Dullness to Percussion	13	6	13	94	56	63	2.2	0.9
***Decreased breath sounds	34	15	34	85	58	67	2.3	0.8
Egophony	8	4	8	96	56	63	2.0	1.0
Pleural Friction Rub	1	4	1	96	13	61	0.3	1.0
*Rales	36	23	36	77	49	66	1.6	0.8
*Rhonchi	34	22	34	78	49	65	1.5	0.8
Wheezes	22	25	22	75	36	61	0.9	1.0
**Combined Auscultatory Findings	92	62	78	38	44	74	1.3	0.6

*p values <.05; **p values <.005; ***p values <.001

- sensitivity and specificity were rounded to the nearest whole

Positive Predictive Value (PPV); Negative Predictive Value (NPV); Positive Likelihood Ratio (+LR) and Negative Likelihood Ratio (-LR)

Ninety percent (276) of the films were then reviewed by a senior attending radiologist who was blinded to the previous interpretation to determine reproducibility. The reinterpretation altered 63 results (23%). Almost half of those alterations resulted in changes of the original diagnosis of pneumonia.

Study Critique:

One strength of this study was that it included a large number of clinical symptoms and signs in the data analysis. Combined criteria, such as abnormal vital signs and auscultatory findings were also analyzed. Another strength of this study was that ninety percent of the chest radiographs were reviewed by an attending radiologist who was blinded to the previous interpretations. This allowed researchers to determine unbiased reproducibility.

There were many limitations in this article. The study population was limited to the emergency department of a city hospital; there could have been differences in disease prevalence in suburban or rural environments. The difference in disease prevalence may have altered the predictive values, but sensitivity and specificity should not have been affected. This could have been avoided by including samples from a rural and a suburban setting and comparing the data. Additionally, the sample size was 308 patients with only 72 found to have definite pneumonia. This is relatively low and may have affected the statistical power. This article states measuring altered tactile fremitus; however, it did not specify if tactile fremitus was increased or decreased. Pneumonia is typically associated with increased tactile fremitus. Discrepancies found in the tables provided in the original article made interpretation of the results more challenging. For example, the sensitivity of pleural friction rub and combined auscultatory findings were miscalculated; these errors were fixed in table 4 of this review.

Data collection occurred on 100 days during an eight month period which included three different seasons. These days were not selected at random but were based on the availability of the research assistants. Therefore, there may have been selection bias of the study population, thus limiting the generalizability of the results. The reinterpretation of the films by the senior radiologist altered 63 (23%) of the initial readings. A significant number of these reinterpreted films would have changed the outcome of the diagnosis. Therefore, the data could have revealed significantly different results. This error could have been avoided by having more than one experienced radiologist review the films before a final interpretation was made.

This study took place in a teaching hospital, and the providers had varying levels of training. The results may have been different in a setting with more experienced clinicians. Also, if the providers did not perform certain physical examination techniques, the patients were considered to have a negative finding. This may have resulted in altered data if the patient did have abnormal findings that the providers failed to elicit. Chest radiographs were used in these patients. However, this may not have been the most accurate way of determining the presence or absence of pneumonia. Signs of consolidation on chest radiographs can lag behind the development of symptoms in the patient. Sputum cultures may have been a more definitive way of determining if the disease was present, but sputum cultures are not always appropriate or reliable since it may be difficult to obtain adequate sputum samples.

<u>Study 2</u>
Clinical Prediction Rule for Pulmonary Infiltrates.
Heckerling, et. al.

<u>Objective of Study</u>:
The goal of this prospective cohort study was to develop a clinical prediction rule for predicting pulmonary infiltrates present on a chest radiograph in patients with an acute respiratory illness.[7]

<u>Study Design</u>:
Data was collected over a 12 month period from three emergency departments: the University of Illinois Hospital at Chicago, the University of Nebraska Medical Center at Omaha, and the Medical College of Virginia at Richmond. Patients had to be 16 years of age or older, complained of fever or respiratory symptoms, and had received a chest radiograph (Table 5). Data was collected from 1134 patients at the University of Illinois Hospital at Chicago, 150 patients at the University of Nebraska Medical Center at Omaha, and 152 patients at the Medical College of Virginia at Richmond. All patients were seen by a medical resident or an attending physician who then decided whether or not to order a chest radiograph.

Table 5. Inclusion and Exclusion Criteria for Study 1: Heckerling, et. al.

Inclusion Criteria
16 years of age or older
Complained of fever or respiratory symptoms
Had received a chest radiograph

Data was recorded regarding the patient's signs and symptoms. Symptoms included cough, sputum (white or colored), chills, fever, pleuritic and non-pleuritic chest pain, dyspnea, wheezing, orthopnea, and paroxysmal nocturnal dyspnea. Signs included their oral or rectal temperature; respiratory rate; pulse; blood pressure; mental status (normal, confused, or unresponsive); 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.

Attending or resident radiologists classified the chest radiographs into one of four categories: no pneumonia, possible pneumonia, probable pneumonia, or definite pneumonia. Patients with chest radiographs classified as definite or probable pneumonia were considered to have pneumonia, and patients with chest radiographs classified as no pneumonia were considered to be without pneumonia. Patients with chest radiographs classified as possible pneumonia were excluded. Chest radiographs of the first 468 patients were viewed by multiple radiologists to determine the degree of interobserver variability. The unweighted kappa statistic was 0.92, indicating almost perfect agreement. Chi-square tests for proportions and analysis of variance for means were used to analyze the clinical signs and symptoms and the chest radiographic findings. All variables with a significance of less than 0.05 were then entered into a stepwise logistic regression procedure to determine which variables were independent predictors of pneumonia.

Study Results:

Chest radiographs were available for 1118 of the 1134 patients in the Illinois location. One hundred and nineteen patients (10.6%) were classified as definite pneumonia on the radiology report, 20 patients (1.8%) had probable pneumonia, 142 patients (12.7%) had possible pneumonia, and 837 patients (74.9%) had no pneumonia. The definite pneumonia and probable pneumonia based on radiographs were grouped together, and these patients were considered to have pneumonia (12.4%).

Table 6 displays the physical examination findings found to be significant. Patients with pneumonia were significantly more likely to have pulmonary findings of rales (50.4% compared with 18.8%), rhonchi (25.9% compared with 18.3%), decreased breath sounds (48.9% compared with 20.3%), bronchial breath sounds (14.4% compared with 4.3%), egophony (15.8% compared with 3.2%), and dullness to percussion (25.9% compared with 6.5%). Sensitivities, specificities, positive and negative predictive values, and positive and negative likelihood ratios are displayed in table 6 and were calculated by the authors of this review.

Table 6. Percentage of patients with and without radiographic evidence of pneumonia. Sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of physical examination techniques: Heckerling, et. al.

	Pneumonia %	No Pneumonia %	Sensitivity %	Specificity %	PPV %	NPV %	+ LR	- LR
**Dullness to Percussion	25.9	6.5	26	93	40	88	3.7	0.8
**Bronchial breath sounds	14.4	4.3	14	96	36	87	3.5	0.9
**Decreased breath sounds	48.9	20.3	49	80	29	90	2.5	0.6
**Egophony	15.8	3.2	16	97	45	87	5.3	0.9
**Rales	50.4	18.8	50	81	31	91	2.6	0.6
*Rhonchi	25.9	18.3	26	82	19	87	1.4	0.9
*p values <.05; **p values <.0001 - sensitivity and specificity were rounded to the nearest whole								

Positive Predictive Value (PPV); Negative Predictive Value (NPV); Positive Likelihood Ratio (+LR) and Negative Likelihood Ratio (-LR)

When comparing the Illinois patient population to the Nebraska and Virginia patient population, there were some significant differences including racial distribution, the prevalence of comorbid diseases, and the prevalence of pneumonia. 30% of the Nebraska population and 21.5% of the Virginia population had pneumonia compared to 12.4% in Illinois.

Study Critique:

One strength of this study was that it included three different populations. This allowed for a larger sample size and more generalizability of the results. This study also used multiple radiologists to interpret films and calculated the unweighted kappa statistic to be 0.92 which indicates very limited interobserver variability.

Chest radiographs were used as the gold standard for diagnosing pneumonia in this study. This is a limitation because radiographs may not have demonstrated opacities in patients who had recently been infected. Therefore, patients with evolving pneumonia may have been considered not to have pneumonia, thus skewing the results. Cultures, bacterial and viral antigen detection tests and serological studies used to detect antibodies against pneumococcal antigens may have been more reliable detectors of pneumonia at this point in time. This should be further researched and considered in the future.

Also, not all patients being seen for respiratory complaints received a chest radiograph which is selection bias. Clinical information from each patient was provided to the radiologist. This may have led to diagnostic review bias in the interpretation of the films based on the clinical information provided to them. There was no attempt to standardize the physical exam. Therefore, interobserver variation may have altered the results. However, this variation reflects clinical practice, so it should improve the generalizability of the model.

Study 3
Prediction of Pneumonia in Outpatients with Acute Cough - A Statistical Approach.
Diehr, et. al.

Objective of Study:
A standardized history, physical exam, and chest radiograph were collected on patients presenting with an acute cough in order to discover clinical signs and symptoms to predict pneumonia.[8]

Study Design:
This population study included 1819 patients presenting with a cough of less than one month's duration to the emergency department of Brooke Army Medical Center (BAMC) at Fort Sam Houston, Texas. Those included were 13 years of age or older, not pregnant, who were seeking medical care for the first time for this acute cough (Table 7). Those excluded from the study were patients with a heart rate of 160 beats per minute or more, temperature of 104ºF or higher, systolic blood pressure of 90 mmHg or lower, and patients arriving by ambulance.

Table 7. Inclusion and Exclusion Criteria for Study 1: Diehr, et. al.

Inclusion Criteria	Exclusion Criteria
Cough for less than one month	Pregnant
13 years of age or older	Heart rate of 160 beats per minute or more
Seeking care for the first time	Temperature of 104 degrees F or higher
	Systolic blood pressure of 90 mmHg or lower
	Patients arriving by ambulance

Postero-anterior and lateral films were taken of every patient included in the study. Radiology residents interpreted each chest radiograph and only knew the patient had an acute cough. Staff radiologists were available for consultation. Research assistants obtained a standard history from every patient, and physicians reviewed and confirmed this history. The physicians then performed a standardized physical examination on each patient and had to decide whether or not they would have ordered a chest radiograph or antibiotics.

Data on all the patients with pneumonia and a 25% random subset of the patients without pneumonia was analyzed. The data from the remainder of the patients without pneumonia was used for testing of the predictive models resulting from this primary analysis. The predictive models were not the focus of this review and are not described in detail. Patients with ambiguous chest radiograph findings were not included in the initial analysis. A T, chi-square, or Fisher's exact test was used to determine the association of each symptom with radiographic pneumonia. Significance was determined at a p-value of less than 0.10 and had to have occurred in at least 20% of the pneumonia patients. Variables that could be used to predict opacities on chest radiography were selected using a stepwise discriminant analysis.

Study Results:
There was no significant difference in the pneumonia and non-pneumonia patients based on sex and age. Forty-eight (2.6%) of the 1819 patients were considered to have pneumonia based on chest radiograph. Forty-nine patients (2.7%) had ambiguous radiographic findings and were classified as having "equivocal" pneumonia. This subgroup was excluded from the analysis. The remainder of the 1722 patients (94.7%) did not have opacities on radiography and were considered to be without pneumonia.

Localized dullness to percussion (4.3% compared with 0.5%), rales (19.1% compared with 7.2%), pleural rubs (4.3% compared with 0.5%), egophony (4.3% compared with 0.5%), and increased tactile fremitus (8.3% compared with 0.9%) were found significantly more often in pneumonia patients than those without pneumonia (Table 8). Sensitivities, specificities, and positive predictive values are displayed in table 8 and were provided in the original article. The negative predictive values, positive likelihood ratios, and negative likelihood ratios were calculated by the authors of this review.

Table 8. Percentage of patients with and without radiographic evidence of pneumonia. Sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of physical examination techniques: Diehr, et. al.

	Pneumonia %	No Pneumonia %	Sensitivity %	Specificity %	PPV %	NPV %	+ LR	- LR
***Increased Fremitus	8.3	0.9	8	99	20	98	8	0.9
**Dullness to Percussion	4.3	0.5	4	100	20	97	∞	1.0
**Egophony	4.3	0.5	4	100	20	97	∞	1.0
**Pleural Friction Rub	4.3	0.5	4	100	20	97	∞	1.0
***Rales	19.1	7.2	19	93	6.8	93	2.7	0.9
Rhonchi	14.9	10.3	15	90	3.8	90	1.5	0.9
*p values <.10; **p values <.05; ***p values <.01 - sensitivity and specificity were rounded to the nearest whole								

Positive Predictive Value (PPV); Negative Predictive Value (NPV); Positive Likelihood Ratio (+LR) and Negative Likelihood Ratio (-LR)

Study Critique:

This article focused on adults in a typical primary care population presenting with an acute cough. One strength of this study was the initial history and physical examination of the patients was standardized and extensive. Physicians were blinded in that they had to make diagnostic and treatment decisions solely based on the patient history and physical exam, without knowing the interpretation of the chest radiographs. Radiologists were blinded in that they only knew the patient had a complaint of an acute cough – no other patient history of physical exam findings were known. Chest radiographs were obtained on all patients, thereby eliminating selection bias.

In this study, significance was determined at a p-value of less than 0.10. Usually, significance cut-off is at a p-value of 0.05. The authors of this article did identify each variable as having a p-value value of less than 0.10, 0.05, and 0.01 so the reader was able to interpret which variables were most significant.

Forty-nine patients had ambiguous radiographic findings and were classified as having "equivocal" pneumonia, and this subgroup was excluded from the analysis. Patients in this subgroup may have had evolving pneumonia without clear consolidation apparent on the chest radiography. These patients were excluded from the study which may have skewed the results. The article stated that radiology residents reviewed the films with staff radiologists available for consultation. It failed to specify how many radiology residents reviewed the films, how often they consulted with the staff radiologists, or if there were any discrepancies among the interpretation of the films.

The article claims to be focusing on adult patients but included individuals as young as 13 years of age. Inclusion of a pediatric population may have resulted in skewed data since they can present with different clinical signs and symptoms compared to the adult population. Though the data analysis included 1722 patients, only 48 were determined to have pneumonia based on radiographic findings. This is a relatively small population size which may have led to a decreased statistical power.

DISCUSSION

Though abnormal findings on physical examination may increase the provider's suspicion of CAP, chest radiography is still the gold standard in the diagnosis of pneumonia. Clinical signs such as altered fremitus, localized dullness to percussion, decreased breath sounds, bronchial breath sounds, rhonchi, crackles/rales, pleural friction rub, and egophony may be significantly associated with pneumonia, but alone are not diagnostic (Table 9 and 10). Rales was the only physical exam finding that was determined to be significantly associated with pneumonia in all three studies. Our research presents relatively consistent statistics including high specificities and moderate sensitivities for the previously mentioned physical exam findings. Therefore, these findings may be somewhat useful at ruling in the disease, but their absence does not rule out the diagnosis of pneumonia.

Table 9. Comparison of sensitivity and specificity of significant physical examination techniques.

	Sensitivity			Specificity		
	Gennis	**Heckerling**	**Diehr**	**Gennis**	**Heckerling**	**Diehr**
°Altered Fremitus	1		8	99		99
ªBronchial breath sounds		14			96	
ª°Dullness to Percussion	13	26	4	94	93	100
*ªDecreased breath sounds	34	49		85	80	
ª°Egophony	8	16	4	96	97	100
°Pleural Friction Rub	1		4	96		100
*ª°Crackles/Rales	36	50	19	77	81	93
*ªRhonchi	34	26	15	78	82	90
*Combined Auscultatory Findings	78			38		
The following tests were significant- *Gennis; ªHeckerling; °Diehr						

Table 10. Comparison of positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of significant physical examination techniques.

	PPV %			NPV %			+ LR			- LR		
	Gennis	**Heckerling**	**Diehr**	**Gennis**	**Heckerling**	**Diehr**	**Gennis**	**Heckerling**	**Diehr**	**Gennis**	**Heckerling**	**Diehr**
°Altered Fremitus	50		20	62		98	1.0		8	1.0		0.9
ªBronchial breath sounds	56	36		63	87		2.2	3.5		0.9	0.9	
ª°Dullness to Percussion	58	40	20	67	88	97	2.3	3.7	∞	0.8	0.8	0.96
*ªDecreased breath sounds	56	29		63	90		2.0	2.5		1.0	0.6	
ª°Egophony	13	45	20	61	87	97	0.3	5.3	∞	1.0	0.9	0.96
°Pleural Friction Rub	49		20	66		97	1.6		∞	0.8		0.96
*ª°Crackles/Rales	49	31	6.8	65	91	93	1.5	2.6	2.7	0.8	0.6	0.87
*ªRhonchi	36	19	3.8	61	87	90	0.9	1.4	1.5	1.0	0.9	0.94
*Combined Auscultatory Findings	44			74			1.3			0.6		
The following tests were significant- *Gennis; ªHeckerling; °Diehr												

Positive Predictive Value (PPV); Negative Predictive Value (NPV); Positive Likelihood Ratio (+LR) and Negative Likelihood Ratio (-LR)

Limitations:

The first limitation of the studies is they were conducted in the United States which limits generalizability of the results to other countries. Another limitation was the use of chest radiography as the only diagnostic test in all three studies. This test is not 100% accurate at detecting pneumonia alone especially if the disease was recently acquired. Also, there is potential for interobserver variability among radiologists when interpreting the films. In Study 1, the films were reinterpreted by a senior attending radiologist and this altered 23% of the initial interpretations.[6] In Study 2, films were reviewed by multiple radiologists, and the unweighted kappa statistic was 0.92 which indicates almost perfect agreement.[7] However, Study 3 did not specify how many radiologists reviewed each film and if there were any discrepancies in the interpretations.[8]

Biases:
In Study 1, data collection occurred over an eight month period but was limited to 100 days. These 100 days were selected based on the availability of the research assistants rather than randomly. Therefore, selection bias may have occurred, thus limiting the generalizability of the results. In Study 2, each patient's clinical signs and symptoms were provided to the radiologist. This may have caused the radiologists to interpret the films differently which may have led to diagnostic review bias. However, this mirrors what occurs in clinical practice, allowing for greater generalizability. Studies 1 and 2 excluded patients who did not receive chest radiographs resulting in selection bias. However, Study 3 obtained chest radiographs on all patients presenting with an acute cough, thus eliminating selection bias.

Critique of Review:
The three articles used in this review were all examining the same outcome: clinical signs and symptoms most helpful in the diagnosis of pneumonia. A strength of this is that many of the same clinical signs were evaluated in each article. This created an overall larger sample size to interpret the results. However, this benefit of a larger sample size is limited by the unique inclusion and exclusion criteria each study had. This review only focused on the clinical signs elicited during physical examination of the patient. The original articles also assessed the reliability of symptoms and vital signs that are helpful in differentiating pneumonia from other respiratory illnesses. In retrospect, it would be beneficial to have more current research as the studies used in this review are fairly old. Additionally, eliciting feedback from students on their ability to adequately assess patients using these examination techniques would provide more insight into how their training could be improved upon. It should be determined if the students feel they do not have proper training in the classroom and, therefore, doubt their abilities to elicit findings using these techniques. Furthermore, if their training is dismissed by preceptors who do not appreciate the value of such testing and discourage the students from relying on these tests then newly certified clinicians may be obtaining routine radiographic testing prematurely.

Return to the Clinical Scenario
Physical examination of Ms. P's chest reveals inspiratory crackles, increased tactile fremitus, and dullness to percussion over the right lower lobe. In lieu of radiographic evidence, the physical exam and history of present illness strongly suggests Ms. P has a right lower lobe pneumonia. Conclusively, not only is obtaining a thorough history of great significance, but performing a comprehensive physical exam contributes substantially to an appropriate diagnosis and the elimination of unnecessary testing. At this point, the provider caring for this patient should have a high clinical suspicion of CAP which would warrant further evaluation. In this case, proceeding with a chest radiograph prior to empiric treatment of CAP would be appropriate.

Given the information gathered thus far, the pre-test probability can be calculated and a nomogram can be drawn (Figure 3 and 4). We calculated Ms. P's pre-test probability to be 60%. Calculations were made starting with the prevalence of CAP in adults which was found to be 0.56%.[1] The pre-test probability was then increased from there, based on the patient's symptoms and physical examination findings. In Study 1, the positive likelihood ratio was 1.6 and the negative likelihood ratio was 0.8, resulting in a post-test probability of approximately 67% and 55%, respectively (Table 4). In Study 2, the positive likelihood ratio was 2.6 and the negative likelihood ratio was 0.6, resulting in a post-test probability of approximately 77% and 48%, respectively (Table 6). In Study 3, the positive likelihood ratio was 2.7 and the negative likelihood ratio was 0.9, resulting in a post-test probability of approximately 79% and 57%, respectively (Table 8). Therefore, with crackles found on physical examination, Ms. P would have a 67%, 77%, and 79% probability of having pneumonia, respectively (Figure 3). If crackles are not elicited on physical examination, Ms. P would have a 55%, 48%, and 57% probability of having pneumonia, respectively (Figure 4). Although these probabilities in the absence of crackles could be higher to increase the clinician's suspicion of ruling out pneumonia, these probabilities are still high enough to raise concern and a chest radiograph is still recommended.

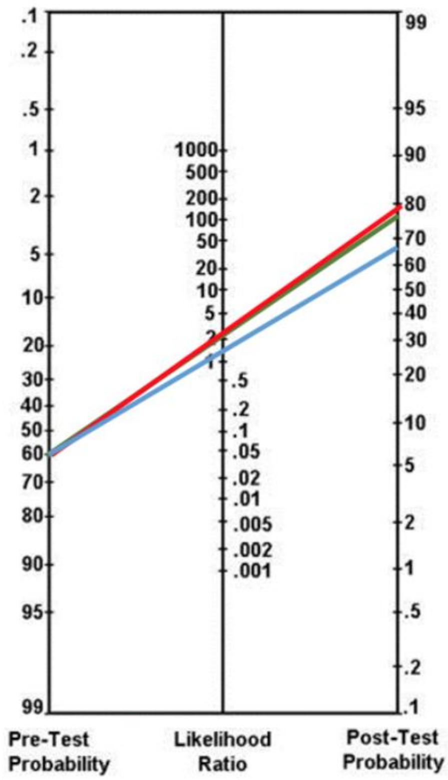

Figure 3. Nomogram using the pre-test probability and positive likelihood ratio to determine the post-test probability of the patient having pneumonia if rales are present. (Blue- Gennis, et. al.; Green- Heckerling, et. al.; Red- Diehr, et. al.)

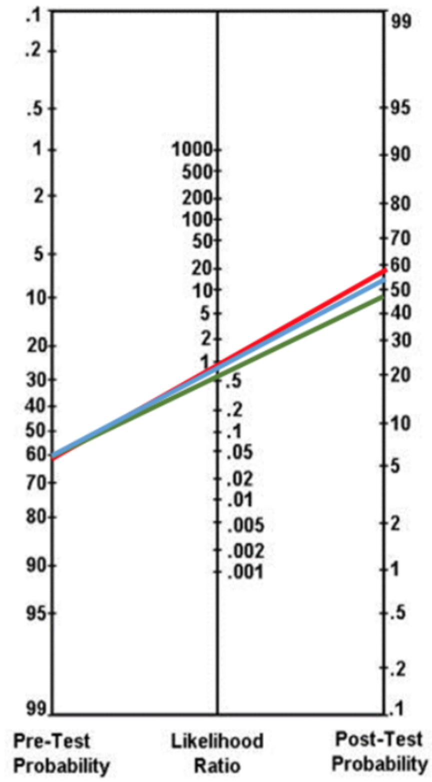

Figure 4. Nomogram using the pre-test probability and negative likelihood ratio to determine the post-test probability of the patient having pneumonia if rales are present. (Blue- Gennis, et. al.; Green- Heckerling, et. al.; Red- Diehr, et. al.)

CONCLUSION AND IMPLICATION FOR PRACTICE AND MEDICAL EDUCATION

Crackles, rhonchi, decreased breath sounds, wheezes, altered fremitus, egophony, and percussion to dullness are the physical exam findings that are traditionally associated with pneumonia. These findings, however, are only present in a small number of patients who actually have pneumonia. Through this research, the most valuable examination technique in detecting pneumonia was found to be crackles while wheezes were relatively not useful. Overall, performing a detailed lung and thorax examination contributes to identifying a diagnostic hypothesis and may increase a clinician's suspicion for the etiology of disease. Definitively, however, the physical examination is not sufficient to rule in or rule out pneumonia and the gold standard radiography may still need to be performed for diagnostic certainty. Improvements in education should be made to encourage newly practicing clinicians to perform detailed physical exams which may increase their clinical suspicion of disease. Furthermore, instruction at the academia level should be tailored to focus on teaching students the most statistically significant tests that will result in the highest diagnostic yield.

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