# UNDERSTANDING AND APPLYING COMMON CLINICAL REASONING STRATEGIES

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*The following article is the first in a series of tutorials on basic skills needed for evidence-based, cost-effective clinical decision making. This first article provides a background for future discussions by examining the practical value as well as limitations of clinical reasoning strategies commonly used when making a diagnosis. In addition, readers are introduced to probability analysis as a more reliable method for making clinical decisions.*

It is the end of Dr. Giardino's busy day in the office. His final patient is new to him. Ms. Ewing is a 45-year-old woman who reports 2 episodes of chest pain in the past 6 months. The most recent episode, which occurred a few days ago, lasted 20 minutes and frightened her. She wants to know if she could have had a heart attack and, if not, if she could be at risk for one.

Physicians in office-based practice routinely encounter patients like Ms. Ewing. The dilemma they face is how to make the correct diagnosis and initiate proper therapy in the most expeditious and cost-effective manner. Accurate, cost-effective diagnosis and treatment are important not only to patients but also to health plans and medical groups, who are increasingly evaluating physician performance against objective external standards. Reducing variation in clinical practice and improving patient outcomes begin with the clinical reasoning process.

In this article, we examine common clinical reasoning strategies that experienced clinicians use when making a diagnosis, with an emphasis on probability (Bayesian) analysis. Finally, we explore how these strategies are applied in a case of a 45-year-old woman with chest pain.

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## What Physicians Bring to the Clinical Encounter

Clinical problem solving requires a store of medical knowledge and a set of reasoning skills with which to apply that knowledge to a given patient. Studies of problem-solving behavior in a variety of settings suggest that medical knowledge is the crucial first requirement of the clinical reasoning process [1]. When presented with clinical problems in neurology, hematology and oncology, and gastroenterology, nonspecialty physicians perform less well than specialists, suggesting that knowledge and expertise are key components of problem solving in medicine [1,2].

Beyond the variable fund of knowledge they bring to a clinical encounter, physicians differ in their ability to collect historical and physical examination data from patients. Inconsistencies in clinical observations may occur when 2 physicians examine the same patient or when 1 physician examines the same patient twice [3]. Eddy [4] reported on a study of 4 physicians who collected data on respiratory symptoms from 993 coal miners; each physician recorded different numbers of miners reporting the occurrence of cough, dyspnea, and sputum production. In another example, Cook [5] reported interobserver variation among different physicians in assessing jugular venous distension. Similar interobserver differences have been noted in interpretation of electrocardiograms (ECGs) and mammograms [3,4]. One common reason for clinical disagreement is the tendency for physicians to report inference rather than evidence. For example, if a patient complains of chest pain on exertion, a physician may infer that the patient has angina and classify the symptoms as "cardiac," rather than stating the problem as "exertional chest pain." Replacing evidence with inference increases the risk of diagnostic errors [3].

Knowledge deficits can be reduced through reading and clinical experience. Variation in clinical examination skills can be reduced by careful repetition, reconfirmation of key findings, corroboration of key findings by witnesses (eg, family members, other clinicians), review of medical records, and recording evidence rather than inference [3]. In addition, during the medical interview, it is important to encourage good communication by setting the patient at ease, building rapport, and eliciting the history in a nonthreatening and nonjudgmental manner [3]. Observing the patient carefully during the clinical examination can add important cues that aid in diagnosis and save time.

### The Role of Uncertainty in the Clinical Reasoning Process

Nearly every physician-patient encounter has elements of uncertainty [4,6,7]. Reaching a diagnosis, then, can be conceptualized as a process of reasoning about uncertainty using imperfect information from the clinical examination [8].

Psychology literature suggests that individuals making decisions under conditions of uncertainty have certain characteristic responses. One observation is that prior information can bias interpretation of data; this bias has been demonstrated in numerous studies of test interpretation at all levels of training and experience [9]. For example, physicians will interpret ECG results differently when presented with varying clinical scenarios prior to seeing the ECG. Most individuals are unaware that simply framing a problem differently can influence the way results are interpreted [10].

The psychology literature also suggests that when individuals are forced to take risks under conditions of uncertainty, the value placed on a possible poor outcome is greater than the value placed on a good outcome [8,10]. Studies on chest pain evaluation confirm this observation. Risk avoidance dominates physicians' decision making about chest pain in emergency departments [11], leading to a large number of low-risk patients admitted to hospitals for fear of missing a possible myocardial infarction (MI)—the number 1 cause for lawsuits in emergency medicine. Although chest pain prediction rules have been shown to safely reduce hospital admissions for chest pain, they are not widely used [11]. Risk avoidance can also affect treatment decisions. In a study of physician preferences regarding hormone replacement therapy (HRT) for postmenopausal women, physicians were reluctant to prescribe HRT despite knowing that deaths from osteoporotic fractures were more common than deaths from uterine and breast cancer [8]. Doctors probably view a death from prescribing as worse than a death from not prescribing [8].

In summary, uncertainty is ever-present in the clinical decision-making process. Clinicians must be aware how their decisions can be influenced by psychological factors such as problem framing and risk avoidance.

Upon meeting Ms. Ewing and first hearing of her 2 episodes of chest pain, Dr. Giardino considers all potential causes (ie, cardiac, vascular, pulmonary, gastrointestinal, musculoskeletal). He hypothesizes that the most likely diagnoses include coronary artery disease (CAD), musculoskeletal pain, and pulmonary embolism (PE). To narrow the diagnostic possibilities, he proceeds to obtain a detailed history of Ms. Ewing's chest pain, specifically asking about the location, duration, and quality of the pain; its relation to exertion; exacerbating and relieving factors; and the occurrence of associated symptoms. He also asks whether there is any prior history of chest trauma, prolonged bed rest, immobilization, surgery, or deep venous thrombosis (DVT) and any current history of calf pain or swelling.

Ms. Ewing reports that 3 days ago she developed left-sided chest pain while walking home from shopping and carrying heavy grocery bags. She describes the pain as compressing in nature and 6/10 in severity, with some radiation to her left shoulder and upper back. She reports some shortness of breath but no other symptoms. The pain and shortness of breath lasted 20 minutes and subsided spontaneously a few minutes after she arrived home and put down the groceries. Upon further questioning she reports that when she presses on the left side of her chest she has pain similar to that which she experienced 3 days prior. She reports a similar episode about 6 months ago, which lasted approximately 2 minutes and stopped on its own. She denies any trauma, recent immobilization or surgery, prior DVT, or calf pain.

Dr. Giardino concludes that PE is unlikely based on the lack of relevant symptoms and risk factors and the presence of alternative diagnostic considerations. Thus, he now focuses his attention on CAD or a musculoskeletal disorder as the most likely cause of the chest pain. He proceeds to ask about risk factors to ascertain Ms. Ewing's baseline likelihood of having CAD. She reports no significant past medical history with the exception of bleeding hemorrhoids. Review of systems reveals no history of fever, chills, weight loss, cough, sputum production, gastrointestinal symptoms, or headache. She reports occasional postcoital burning with urination. She does not take any medications or oral contraceptives. She denies smoking and alcohol or drug abuse. Her last menstrual period was 15 days ago. Ms. Ewing is a mother of 2 healthy children. She had an uncle who died of an MI at age 65.

Based on Ms. Ewing's history, Dr. Giardino groups the problems of exertional, reproducible, left-sided chest pain and shortness of breath and puts aside the history of painful postcoital urination and hemorrhoids as not pertinent to her current diagnosis.

## Common Clinical Reasoning Strategies Used When Making a Diagnosis

Clinical reasoning is the application of interview and clinical examination techniques to a patient to surmise the diagnosis that best fits the patient's condition. Although the clinical reasoning process is not completely understood [9], physicians tend to employ 3 core strategies when making diagnoses: *pattern recognition*, *hypothetical deductive reasoning*, and *heuristic searching* [12]. Which of these techniques were useful to Dr. Giardino in his clinical examination of Ms. Ewing?

### Pattern Recognition

Pattern recognition refers to the reflexive identification of a disorder based on a previously learned and highly specific pattern of clinical features [3]. For example, most physicians can easily recognize the classic facies of Down syndrome or Graves disease or the gait of Parkinson's disease. They can observe a patient with one of these disorders from across a room and make the correct diagnosis. Although several disorders can be recognized in a reflexive manner, this strategy is not helpful to Dr. Giardino in his clinical examination of Ms. Ewing, as her signs and symptoms are nonspecific.

### Hypothetical Deductive Reasoning and Heuristic Searching

Two clinical reasoning strategies commonly used by physicians, often simultaneously, are hypothetical deductive reasoning (ie, the generation and testing of hypotheses) and heuristic searching [3,4,8,13]. Both strategies require careful clinical examination and close attention to valuable cues drawn from observing and listening to the patient. As data are collected throughout the clinical examination process, they are categorized and aggregated.

**Hypothetical deductive reasoning.** The first step in the clinical reasoning process is the generation of hypotheses (ie, differential diagnoses). This step is observed to occur within the first 5 seconds of a clinical encounter [1–3]. Key points gleaned from the clinical examination are used as the basis for including certain diagnoses as more likely and discarding others as less likely [12]. The differential diagnosis list is then pruned, with unlikely diagnoses eliminated from consideration. This process, known as hypothetical deductive reasoning, or *iterative hypothesis testing*, allows the physician to simultaneously entertain multiple hypotheses then reject or accept them during the clinical examination process [3,14]. It is a more efficient approach to diagnosis than attempting to exhaustively gather and collect all conceivable bits of information [3]. Preliminary hypotheses are formulated based on the evidence presented and then revised and refined as more data are accumulated. Because this process begins at the outset of the clinical examination, an experienced physician can conserve time by quickly surmising the appropriate clinical data needed to establish a likely diagnosis.

Dr. Giardino clearly used hypothetical deductive reasoning in his examination of Ms. Ewing. He initially hypothesized that coronary, musculoskeletal, and pulmonary diseases were possible causes of her chest pain, and he rejected a gastrointestinal etiology on the basis of her lack of appropriate symptoms. He then designated PE as an unlikely possibility because of the absence of risk factors or predisposing conditions. This left him to focus on 2 possible diagnoses: CAD or a musculoskeletal disorder.

**Heuristic searching.** Heuristics are reasoning strategies that streamline information and allow the physician to simplify the task of generating likely diagnoses. The wealth of clinical information and experience gained in practice allows knowledge about disease patterns to be organized and stored as "prototypes" [1,9]. For example, chest pain that is brought on by exertion and relieved by rest fits a prototype [9] that could be consistent with a diagnosis of CAD. Experienced clinicians retrieve such stored disease prototypes during a clinical encounter to aid diagnosis [9,13]. Most expert physicians use heuristics in their clinical examinations, eliminating extraneous data and focusing on key pieces of evidence [12] that lead them to the most likely diagnosis. If the disease fits the prelearned prototype, other details of the clinical examination are put aside and the likely diagnosis can be identified. In contrast to an exhaustive approach that considers all possible options, heuristic searching lessens cognitive strain and saves time by reducing information to manageable proportions and converting complex clinical judgments into almost automatic, nonreflective inferences [15].

Dr. Giardino also used heuristics in his clinical examination of Ms. Ewing to help him focus on the most likely diagnoses. He had a preconceived notion of how angina presents clinically and compared Ms. Ewing's symptoms to this disease prototype. He ignored, for the time being, information he regarded as unrelated (ie, her history of hemorrhoids and occasional urinary symptoms).

At this point in the clinical examination, Dr. Giardino includes CAD as a potential hypothesis to explain Ms. Ewing's symptoms. In addition, he includes a musculoskeletal disorder as a major differential diagnosis because of the presence of some musculoskeletal symptoms. He now conducts the physical examination with a particular focus on the cardiovascular and musculoskeletal examinations.

On physical examination Ms. Ewing is a bit anxious but alert and oriented. Her temperature is 97.4° F, pulse is 88 bpm and regular, respiratory rate is 18 breaths/min, and blood pressure is 116/74 mm Hg in her right arm and 112/76 mm Hg in her left arm. She has no pallor or icterus. Her mucosa is moist. She has no bruit, jugular venous distension, or lymphadenopathy. Her trachea is central. There is mild tenderness along the left costosternal border upon deep pressure. Cardiac examination is normal, with no murmurs or rub noted. The remainder of the physical examination is normal. An ECG performed in Dr. Giardino's office shows normal sinus rhythm.

## Pitfalls of Common Clinical Reasoning Strategies

### Oversimplifying the Diagnostic Process

Although heuristics allow faster processing of information, simplifying the diagnostic process by using heuristics may lead to systematic errors in clinical judgment because not all information is considered [4,7,15]. For example, a physician might overestimate the probability that a patient has a certain disease because that disease comes to mind first or occurs frequently in the physician's practice. This is called the *availability heuristic* [7,8,10,15]. For example, a physician may assume that an adolescent girl with a fever and exudative pharyngitis has a streptococcal infection because the last few patients he saw with similar symptoms had strep throat. The availability heuristic can lead to biased judgment (ie, the physician is overrating past experiences in his evaluation of the present case). To minimize the availability bias, a physician must consistently create a complete list of differential diagnoses.

Heuristics also can lead to biased clinical judgment if a physician disregards the true prevalence of disease in the population [2,7,10,15]. If a patient's presenting signs and symptoms resemble a common disease with a representative or prototypical pattern, a physician might assume that the presence of those signs and symptoms means the patient has the disease. This is called the *representative heuristic* [7]. An example would be a physician who assumes that a 45-year-old woman who presents with exertional chest pain has a cardiac diagnosis because exertional chest pain is a common feature of CAD. If the physician minimizes or does not consider other causes of chest pain in 45-year-old women, including noncardiac pathology, she might miss the true diagnosis.

Faulty diagnostic reasoning also may result if the wrong clinical cues are used to classify a patient as belonging to a class of patients with a certain disease. The clinical signs most representative of a disease sometimes may be absent in patients with the disease or present in those without the disease. For example, dysuria is a common symptom of a urinary tract infection, but the presence of dysuria can also signify vaginitis or urethral trauma [16].

In short, to avoid oversimplification of the diagnostic process, physicians should be careful not to jump to conclusions.

### Failure to Anchor the Diagnostic Process

In establishing hypotheses, a physician must assess disease probability, so that subsequent testing can help to rule in or rule out disease. For example, if a clinician makes a diagnosis of typical angina, it is important that she accurately assess the disease probability (ie, as high, moderate, or low), such that the results of subsequent testing can be evaluated. This process is sometimes termed *anchoring the diagnosis.*

Problems with clinical reasoning occur if the diagnostic process is not anchored [6–8]. A common scenario is when a physician states the diagnosis as a problem or a plan. For example, it is common for clinicians faced with a patient similar to Ms. Ewing to make a diagnosis of "chest pain" (a problem) or "rule out MI" (a plan). In such cases, information derived from testing does not allow for adjustment of disease probability, because the diagnosis is not anchored. For example, if the diagnosis was "rule out MI" and testing revealed negative cardiac enzymes and a normal ECG, what condition does the patient have? Anchoring a diagnosis allows the clinician to use diagnostic testing to revise the likelihood of competing diagnoses.

### Errors in Estimating Probability

Although the experienced clinician uses inference and heuristics to help establish the likelihood of a given diagnosis, shortcomings of this qualitative method can lead to significant errors in estimating the true probability of a given disease [7,8,12]. Qualitative estimates of disease probability suffer because they are difficult to standardize. If Dr. Giardino believes that Ms. Ewing has a "low probability" of CAD, does this mean a 20% chance or a 1% chance? Although each estimate might be considered to be low, each would lead to markedly different diagnostic strategies. There is no universal agreement among physicians regarding the meaning of qualitative expressions of disease probability [17]. Subsequent diagnostic testing and

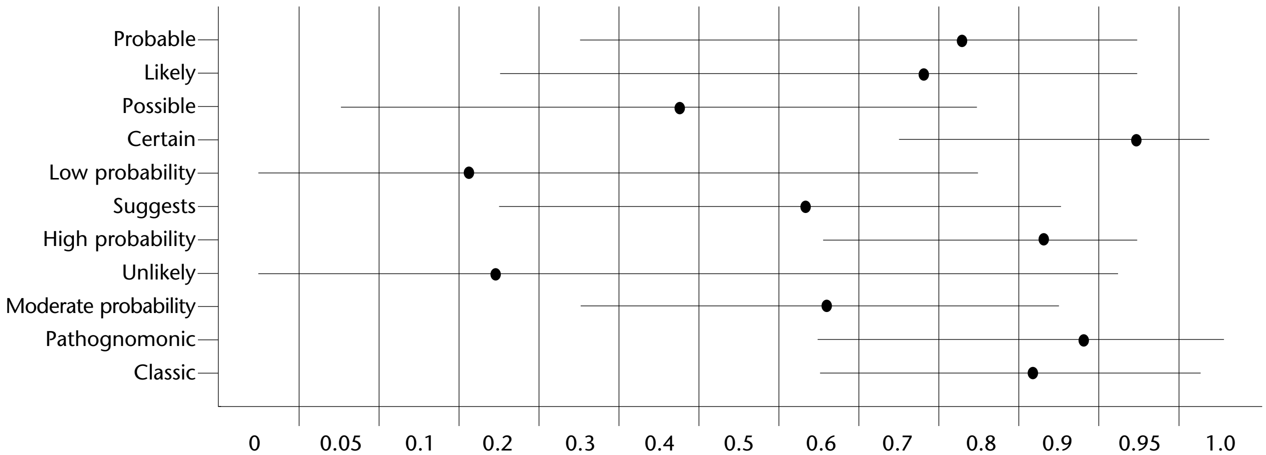


**Figure 1.** Probability estimates of disease associated with various qualitative verbal expressions. Mean values are indicated by a *dot* and ranges by a *horizontal line.* (Adapted with permission from Bryant GD, Norman GR. Expressions of probability: words and numbers [letter]. N Engl J Med 1980;302:411.)

clinical decisions depend upon the explicit likelihood of disease. **Figure 1** presents various qualitative verbal expressions of probability as reported by practicing physicians. When clinicians were asked to quantify what they meant by these verbal expressions of likelihood, the range of numerical probabilities varied widely [17]. According to Elstein [8], systematic, quantitative approaches to making inferences and decisions are preferable to qualitative approaches because they force implicit clinical reasoning decisions to become more explicit.

## Using Probability Analysis in Clinical Decision Making

The potential pitfalls of common clinical reasoning strategies lessen the likelihood of establishing a correct diagnosis. So, although Dr. Giardino has used his clinical reasoning skills to establish 2 likely diagnoses, how can he be certain that his reasoning is correct? Also, how should he decide what are the most cost-effective diagnostic and treatment strategies to pursue?

Certain analytic methods can aid the physician to make more reliable and explicit decisions about the probability of disease and assist in the diagnostic process. The method most often applied is *probability analysis*, or *Bayesian analysis* [12,14,18]. The Bayesian approach begins with an expectation of an event (ie, a *pretest probability*, or *prior probability*) and then modifies that expectation on the basis of data collected from a test to form a new expectation of that event (ie, a *post-test probability*). In simple terms, Bayes' theorem states that the probability of an event depends on the impact of new information applied to what was previously known about the probability of that event, or:

What was thought before + New information =
What is thought now [17].

When applied to disease probability, Bayes' theorem can be summarized as follows [12]:

$$P(\text{disease/findings}) = \frac{P(\text{findings/disease}) \times P(\text{disease})}{P(\text{findings})}$$

where P(disease) refers to an underlying probability or prevalence of a disease, P(findings/disease) refers to the set of clinical findings associated with that disease, and P(findings) is the overall probability that those clinical findings are present.

### Estimating Pretest Probability

Pretest probability of disease can be derived from 3 sources: clinical experience, published studies linking symptoms and signs to disease prevalence, and clinical prediction rules [18]. Pretest probability estimates based on clinical or community experience may be reliable in some instances. However, such estimates are subject to recall biases and ignorance and are limited by the fact that they are not published and, therefore, not generalizable. Thus, it is important to use external evidence to revise estimates of pretest probabilities that are based on clinical experience [19,20]. Skilled clinicians combine the use of personal experience with published data to more accurately predict pretest probability and limit heuristic bias [19].

**Table 1.** Pretest Likelihood of Coronary Artery Disease in Symptomatic Female Patients According to Age and Type of Chest Pain

| Age (yr) | Nonanginal Chest Pain | Atypical Angina | Typical Angina |
|---|---|---|---|
| 30–39 | 0.8 ± 0.3 | 4.2 ± 1.3 | 25.8 ± 6.6 |
| 40–49 | 2.8 ± 0.7 | 13.3 ± 2.9 | 55.2 ± 6.5 |
| 50–59 | 8.4 ± 1.2 | 32.4 ± 3.0 | 79.4 ± 2.4 |
| 60–69 | 18.6 ± 1.9 | 54.4 ± 2.4 | 90.6 ± 1.0 |

NOTE. Each value represents the percent ± 1 standard error of the percent. (Adapted with permission from Diamond GA, Forrester JS. Analysis of probability as an aid in the clinical diagnosis of coronary-artery disease. N Engl J Med 1979;300:1352.)

Data to help predict prior probabilities are increasingly available from many sources [3,14,17, 19,20], although the best source of evidence about pretest probabilities is the medical literature. A physician can use probabilities derived from the medical literature as starting points for estimating the pretest probabilities in individual patients and then adjust those probabilities, taking into consideration the unique attributes of his patients and local practice [3,19]. For example, an ambulatory patient with cough, fever, and an infiltrate on chest radiograph is more likely to have community acquired pneumonia than tuberculosis if that patient lives in Chicago, yet if he lives in Calcutta he may be more likely to have tuberculosis. Another strategy is to establish the most probable disorder as the primary differential diagnosis and to list all other disorders that are serious and treatable but have lesser probabilities as *active alternatives* [19]. Once the primary diagnosis is ruled out, other disorders with lower probabilities can be considered. Resources can be conserved because one is not simultaneously testing all possible diagnoses.

Finally, a physician can estimate pretest probability using a clinical prediction rule (ie, a rule derived and validated from clinical studies to predict outcomes for patients with a specific clinical presentation). There are many examples of clinical prediction rules, including rules to predict the occurrence of PE [21] and rules to predict the occurrence of MI in patients presenting to the emergency department [22].

**Estimating Pretest Probability in Case Patient**

How would pretest probabilities be useful in determining the cause of Ms. Ewing's chest pain and dyspnea? Dr. Giardino concluded that the probability of uncomplicated PE is extremely low based on Ms. Ewing's clinical symptoms, absence of risk factors, and presence of more plausible diagnoses [21]. Thus, he now needs to determine the prevalence of significant CAD in a 45-year-old woman with the chest pain syndrome Ms. Ewing describes as well as the probability of his competing diagnosis, musculoskeletal chest pain. (Note that when considering the possibility of various diseases in a specific patient, the probabilities of all diagnoses must add up to 100%.)

Dr. Giardino knows that autopsy studies of individuals with death from other causes have reported the prevalence of CAD in women aged 40 to 49 years as 0.001 [23]. However, Ms. Ewing presents with a chest pain syndrome that raises her likelihood of having CAD [P(disease/findings)] to some degree. Dr. Giardino is not comfortable calling this "nonanginal chest pain," because it does have some of the features that are consistent with chest pain from CAD (ie, brought on by exertion, relieved by rest). Yet, other characteristics of the clinical picture make a classification of typical angina less likely (ie, age, sex, reproducibility, location, and absence of risk factors). He therefore classifies Ms. Ewing's chest pain syndrome as "atypical angina."

Dr. Giardino is familiar with an article that addresses probability and clinical diagnosis of CAD in various clinical situations [23]. The findings are generalizable to Ms. Ewing (**Table 1**). Ms. Ewing is a 45-year-old woman with atypical chest pain. Her pretest likelihood of having CAD given this chest pain syndrome is 13.3 ± 2.9%. This would drop to 2.8% if the pain were nonanginal and would rise to 55.2% if it were typical angina. So, Dr. Giardino realizes that his ability to discern the difference between nonanginal chest pain, typical angina, and atypical angina is crucial to his subsequent decision making. Using a clinical prediction rule that predicts which patients presenting to the emergency department with chest pain are at risk for cardiac complications [22], Dr. Giardino determines that Ms. Ewing is at low risk for cardiac complications and would not warrant hospital admission. Putting all this information together, he determines that Ms. Ewing has a 13% probability of having significant CAD. This leaves an 87% chance of having a musculoskeletal or other noncardiac cause of chest pain.

Now that Dr. Giardino has determined Ms. Ewing has a 13% probability of CAD, how does he use this information to inform his clinical decisions?

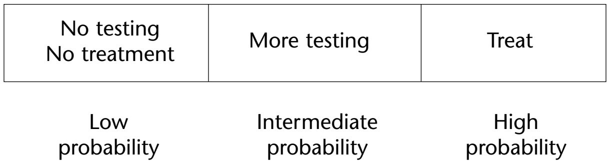


**Figure 2.** Schema illustrating decision thresholds for testing and treatment at various qualitative estimates of pretest probability of disease. Decisions about where to set decision thresholds are influenced by the potential severity and associated morbidity of the disease.

**Table 2.** Estimated Cost of Workup Strategies for a 45-Year-Old Woman with Atypical Angina

| Workup Strategy | Estimated Cost ($)* |
|---|---|
| Outpatient primary care visit | 150.00 |
| Hospital admission to "rule out myocardial infarction" | 4500.00 |
| Outpatient stress test | 1300.00 |

*Data from Mount Sinai Hospital Medical Center, Chicago (IL); January 2001.

### Using Probability and Decision Thresholds to Aid Clinical Decisions

How one decides about the use of diagnostic tests or the choice of therapy is based on the prior probability of disease and the decision threshold that is applied [24]. **Figure 2** provides a general schema of decision thresholds for testing and treatment, given various pretest probabilities of disease. Decisions about where to set diagnostic and treatment thresholds can be made intuitively or by formal decision analysis [24]. Generally speaking, thresholds vary depending on the potential severity and associated morbidity of the disorder. For example, a physician's threshold to test or treat a patient with chest pain, for whom a diagnosis of MI is being considered, would be much lower than his threshold to do a skin biopsy on a patient with a rash, for whom a diagnosis of fungal infection is possible.

A decision threshold analysis helps the physician to explicitly make decisions in the face of uncertainty [3,18]. In addition, making decisions based on solid evidence and thoughtful decision analysis helps to avoid unnecessary tests or treatments that waste money and may potentially cause harm. If the likelihood of disease is significantly high, the patient can be treated for that disease. If the likelihood of a competing diagnosis is sufficiently low, the diagnosis can be excluded from consideration. If the probability of a diagnosis is neither low nor high enough for clinical certainty, more diagnostic testing is needed. The major decision is to determine at what level of pretest probability of disease one feels comfortable setting the decision threshold [17].

If after clinical examination the disease probability is determined to be very low, as in the case of PE in Ms. Ewing, it is unnecessary to do a diagnostic test such as a lung scan. Conversely, if after clinical examination the likelihood of disease is believed to be quite high, as in the case of an 87% probability of musculoskeletal pain in Ms. Ewing, a diagnostic workup for CAD may be unnecessary and the patient can be reassured and sent home. On the other hand, Ms. Ewing's 13% prior probability of having CAD may not be low enough to reassure her and Dr. Giardino. As previously noted, avoiding an adverse outcome is a major motivator in psychological studies of decision making. If Dr. Giardino's threshold for making an error and missing CAD is lower than Ms. Ewing's probability of having CAD, he needs to do more testing.

What are alternative strategies to additional diagnostic testing in Ms. Ewing's case? Dr. Giardino could send her home with a nonsteroidal anti-inflammatory medication and perhaps a trial of nitroglycerine and plan to see or call her the following day. If her chest pain is truly a musculoskeletal problem brought on by lifting, it should improve. Time is a useful device that can allow both physician and patient to clarify a low-risk clinical situation. Symptoms and signs will tend to regress toward the mean on subsequent evaluation. Thus, a symptomatic patient may experience improvement in her condition, because an extreme value (outlier) is likely to be followed by a value closer to the mean. If Ms. Ewing's pain persists after a trial of time and medication, additional tests can be undertaken.

Another alternative strategy would be to admit Ms. Ewing to the hospital now to rule out an MI. This is the least cost-effective strategy. Even if Ms. Ewing does have CAD, she is at low risk for cardiac complications according to the clinical prediction rule by Goldman et al [22]. A third alternative would be to schedule an outpatient stress test as soon as possible.

**Table 2** outlines the alternative workup strategies for this case, with their estimated costs. Of these strategies, follow up in the primary care office is the least expensive and would be a reasonable choice, given the high likelihood that Ms. Ewing has a musculoskeletal disorder. Obtaining an exercise test is another acceptable strategy, although it is more costly.

Dr. Giardino orders an exercise test that day, prescribes a nonsteroidal anti-inflammatory medication, and asks Ms. Ewing to return to the office the following day. The stress test is negative. On follow up the next day, Ms. Ewing states that she has remained pain free. Dr. Giardino's final diagnosis is musculoskeletal chest pain, and he reassures Ms. Ewing that she did not experience an MI or angina. Ms. Ewing continues to do well 6 months later.

## Conclusion

Physicians must continuously refine their clinical reasoning skills to ensure that they are practicing cost-effective medicine. Effective clinical reasoning requires knowledge of the medical literature, expertise in conducting a clinical examination, and application of strategies that can aid in making a diagnosis. When appropriately applied, the reasoning strategies presented here (ie, hypothetical deductive reasoning, heuristic searching, and probability analysis) can improve the speed, accuracy, and effectiveness with which one forms a list of probable diagnoses and applies diagnostic testing. Implicit in making a differential diagnosis list is the assignment of prior probabilities (using evidence from the medical literature) to the disease estimates and anchoring the diagnosis. The accurate assignment of prior probabilities to the differential diagnoses and the rational application of diagnostic tests based on predetermined decision thresholds are the final important steps in the clinical reasoning process. Future articles in this series will explore how these techniques may be applied in various settings to decrease the cost and improve the effectiveness of clinical decision making.

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