Netter's Orthopaedic Clinical Examination

An Evidence-Based Approach

2nd Edition

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Shane Koppenhaver

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To our incredible mentors and colleagues
who have fostered our passion for
evidence-based practice and orthopaedics.

To our photography models (Jessica Palmer and
Nicole Koppenhaver) and photographers (Sara Randall,
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and retakes than we'd like to admit.

To Dr. Frank Netter and the Elsevier editorial staff
who turned our ideas into a fantastic literary guide.

And, most important, to our wonderful families,
whose sacrifices and support
made this considerable endeavor possible.

About the Artists

Frank H. Netter, MD

Frank H. Netter was born in 1906, in New York City. He studied art at the Art Student's League and the National Academy of Design before entering medical school at New York University, where he received his MD degree in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

In 2005, Elsevier, Inc., purchased the Netter Collection and all publications from Icon Learning Systems. There are now more than 50 publications featuring the art of Dr. Netter available through Elsevier, Inc. (in the U.S.: www.us.elsevierhealth.com/Netter and outside the U.S.: www.elsevierhealth.com).

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-book *Netter Collection of Medical Illustrations*, which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. *The Netter Atlas of Human Anatomy*, first published in 1989, presents the anatomical paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but, more important, for their intellectual content. As Dr. Netter wrote in 1949, ". . . clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a *medical illustration* if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what makes them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

Learn more about the physician-artist whose work has inspired the Netter Reference collection: http://www.netterimages.com/artist/netter.htm.

Carlos Machado, MD

Carlos Machado was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado's photorealistic expertise and his keen insight into the physician-patient relationship inform his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at http://www.netterimages.com/artist/machado.htm.

About the Authors

Joshua Cleland, PT, DPT, PhD, OCS, FAAOMPT

Dr. Cleland earned a Master of Physical Therapy degree from Notre Dame College in 2000 and the Doctor of Physical Therapy degree from Creighton University in 2001. In 2006, he received a PhD from Nova Southeastern University. He received board certification from the American Physical Therapy Association as an Orthopaedic Clinical Specialist in 2002 and completed a fellowship in manual therapy through Regis University in Denver, Colorado, in 2005. Josh is presently a Professor in the Physical Therapy Program at Franklin Pierce University. He practices clinically in outpatient orthopaedics at Rehabilitation Services of Concord Hospital, Concord, New Hampshire. He is actively involved in numerous clinical research studies investigating the effectiveness of manual physical therapy and exercise in the management of spine and extremities disorders. He has published more than 85 manuscripts in peer-reviewed journals. He is on the Editorial Board for *Physical Therapy* and is an Editorial Review Board Member for the *Journal of Orthopaedic and Sports Physical Therapy.* He is the recipient of the 2009 Eugene Michels New Investigator Award. He received the 2008 Jack Walker Award from the American Physical Therapy Association. In addition, Dr. Cleland was awarded the Excellence in Research Award from the American Academy of Orthopaedic Manual Physical Therapists on two separate occasions (2004 and 2006).

Shane Koppenhaver, PT, PhD, OCS, FAAOMPT

Dr. Koppenhaver received his Masters of Physical Therapy degree from the U.S. Army/Baylor University Graduate Program in 1998, and a PhD in Exercise Physiology from the University of Utah in 2009. He became board certified in Orthopedic Physical Therapy in 2001 and completed a fellowship in manual therapy through Regis University in 2009. Dr. Koppenhaver is a Major in the U.S. Army and an Assistant Professor in the U.S. Army/Baylor University Doctoral Program in Physical Therapy. He has published numerous studies on low back pain, spinal manipulation, and the use of ultrasound imaging in the measurement of trunk muscle function. His primary research interests concern mechanistic and clinical outcomes associated with manual therapy, especially as they apply to clinical reasoning and management of patients with neuromusculoskeletal conditions.

Foreword

Diagnosis is not the end, but the beginning of practice. —Martin H. Fischer

Physical examination and the ability to differentially diagnose accurately are critical components of orthopaedic medicine. However, the decisions that providers use to select their "preferred" evaluative tools are often based on tradition or what was learned during initial professional training rather than on science. Although some questions and examination procedures may be very helpful in establishing an accurate orthopaedic diagnosis, others may be utterly useless and serve only to distract both patients and providers. With the rapidly expanding amount of recent research investigating the diagnostic utility of tests and measures, it is essential for clinicians to use selective components of the history and physical examination that are supported by current best evidence.

This textbook is unique and easy to decipher for the audience for whom it is written. The authors should be commended for compiling the evidence currently available in the literature and applying it to the regional musculoskeletal examination. First, the authors outline in detail the relevant literature and clearly describe the psychometric properties of each historical and physical examination procedure. Second, the text provides a thorough evaluation of each subarea and highlights a variety of evaluative tests for the various regions of the body. This approach helps to present the material to medical professionals in a more focused and streamlined fashion. Third, if pictures represent a thousand words, the text should be considered a million pages. The combination of hand-drawn and photographic examples of anatomy, pathoanatomy, and special tests are invaluable to the reader as they help integrate the evidence into dynamic clinical practice. Finally, the authors must be commended for organizing and presenting all the material in such a logical format that makes it highly useful in both academic environments and in those of busy orthopaedic health care professionals.

As director of an accredited clinical health care program, I appreciate that this text provides a useful resource within the library regarding our professional domains: (1) Prevention, (2) Clinical Evaluation and Diagnosis, (3) Immediate Care, (4) Treatment/Rehabilitation and Reconditioning, (5) Organization and Administration, and (6) Professional Responsibility. This text is an example of the practical information we need along with the voluminous and technical literature available to us all. I believe the authors have succeeded in their objective, and our program will be using this resource now and into the future.

Well done, and thank you.

Bradley Hayes, PhD, ATC/L
Director, Athletic Training Education
University of Utah College of Health

Preface

Over the past several years, evidence-based practice has become the standard in the medical and health care professions. As described by Sackett and colleagues (*Evidence-Based Medicine: How to Practice and Teach EBM*, 2nd ed, London, 2000, Harcourt Publishers Limited), evidence-based practice is a combination of three elements: the best available evidence, clinical experience, and patient values. Sackett has further reported that "when these three elements are integrated, clinicians and patients form a diagnostic and therapeutic alliance which optimizes clinical outcomes and quality of life." Each element contributes significantly to the clinical reasoning process by helping to identify a diagnosis or prognosis or establish an effective and efficient plan of care. Unfortunately, the evidence-based approach confronts a number of barriers that may limit the clinician's ability to utilize the best available evidence to guide decisions about patient care, most significantly a lack of time and resources. Given the increasing prevalence of new clinical tests in the orthopaedic setting and the frequent omission from textbooks of information about their diagnostic utility, the need was clear for a quick reference guide for students and busy clinicians that would enhance their ability to incorporate evidence into clinical decision making.

The purpose of *Netter's Orthopaedic Clinical Examination: An Evidence Based Approach* is twofold: to serve as a textbook for musculoskeletal evaluation courses in an academic setting and to provide a quick, user-friendly guide and reference for clinicians who want to locate the evidence related to the diagnostic utility of commonly utilized tests and measures.

The first chapter is intended to introduce the reader to the essential concepts underlying evidence-based practice, including the statistical methods it employs and the critical analysis of research articles. The remainder of the book consists of chapters devoted to individual body regions. Each chapter begins with a review of the relevant osteology, arthrology, myology, and neurology and is liberally illustrated with images by the well-known medical artist Frank H. Netter, MD. The second portion of each chapter provides information related to patient complaints and physical examination findings. Reliability and diagnostic utility estimates (sensitivity, specificity, and likelihood ratios) are presented for each patient complaint and physical examination finding and are accompanied by quick access interpretation guides. Test descriptions and definitions of positive test findings are included as reported by the original study authors, both to minimize any alteration of information and to provide readers insight into difference values reported by different studies. At the end of each chapter are tables listing information on commonly used outcome measures and quality ratings for all the studies investigating tests' diagnostic utility.

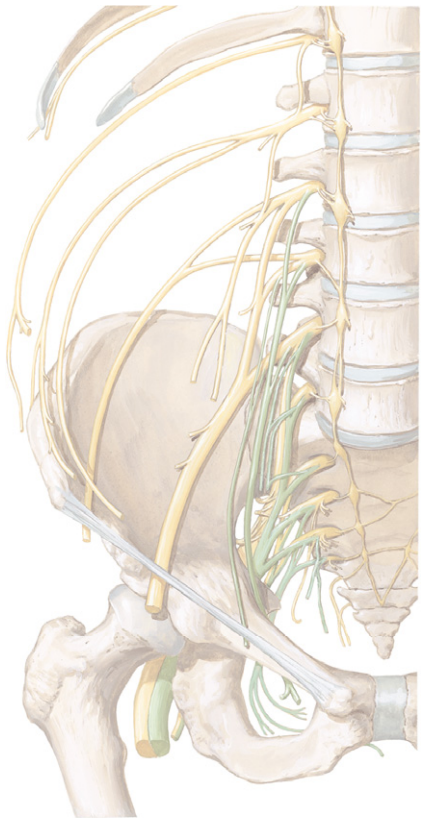
We hope that clinicians will find *Netter's Orthopaedic Clinical Examination* a user-friendly clinical resource for determining the relevance of findings from the orthopaedic examination. We also hope that students and educators will find this a valuable guide to incorporate into courses related to musculoskeletal evaluation and treatment.

Joshua A. Cleland, PT, PhD

Shane Koppenhaver, PT, PhD

The Reliability and Diagnostic Utility of the Orthopaedic Clinical Examination

1



The health sciences and medical professions are undergoing a paradigm shift toward evidence-based practice, defined as the integration of the best available research evidence and clinical expertise with the patient's values.[1,2] Evidence should be incorporated into all aspects of physical therapy patient and client management including examination, evaluation, diagnosis, prognosis, and intervention. Perhaps the most crucial component is a careful, succinct clinical examination that can lead to an accurate diagnosis, the selection of appropriate interventions, and determination of a prognosis. Thus, incorporating evidence on the ability of clinical tests and measures to distinguish between patients who do and do not present with specific musculoskeletal disorders is of utmost importance.[1,2]

The diagnostic process entails obtaining a patient history, developing a working hypothesis, and selecting specific tests and measures to confirm or refute the formulated hypothesis. The clinician must determine the pretest (before the evaluation) probability that the patient has a particular disorder. Based on this information the clinician selects appropriate tests and measures that will help determine the post-test (after the evaluation) probability of the patient having the disorder, until a degree of certainty has been reached such that patient management can begin (the *treatment threshold*). The purpose of clinical tests is not to obtain diagnostic certainty but rather to reduce the level of uncertainty until the treatment threshold is reached.[2] The concepts of pretest and post-test probability and treatment threshold are elaborated later in this chapter.

As the number of reported clinical tests and measures continues to grow, it is essential to thoroughly evaluate a test's diagnostic properties before incorporating it into clinical practice.[3] Integrating the best evidence available for the diagnostic utility of each clinical test is essential in determining an accurate diagnosis and implementing effective, efficient treatment. It seems only sensible that clinicians and students should be aware of the diagnostic properties of tests and measures and know which have clinical utility. This text assists clinicians and students in selecting tests and measures to ensure the appropriate classification of patients and to allow for quick implementation of effective management strategies.

The assessment of diagnostic tests involves examining a number of properties, including reliability and diagnostic accuracy. A test is considered *reliable* if it produces precise and reproducible information. A test is considered to have *diagnostic accuracy* if it has the ability to discriminate between patients with and without a specific disorder.[4] Scientific evaluation of the clinical utility of physical therapy tests and measures involves comparing the examination results to reference standards such as radiographic studies (which represent the closest measure of the truth). Using statistical methods from the field of epidemiology, the diagnostic accuracy of the test—its ability to determine which patients have the disorder and which do not—is then calculated. This chapter focuses on the characteristics that define the reliability and diagnostic accuracy of specific tests and measures. The chapter concludes with a discussion of quality assessment of studies investigating diagnostic utility.

RELIABILITY

For a clinical test to provide information that can be used to guide clinical decision making, it must be reliable. Reliability is the degree of consistency to which an instrument or rater measures a particular attribute.[5] When we investigate the reliability of a measurement, we are determining the proportion of that measurement that is a true representation and the proportion that is the result of measurement error.[6]

When discussing the clinical examination process, it is important to consider two forms of reliability: intra-examiner and inter-examiner reliability. Intra-examiner reliability is the ability of a single rater to obtain the identical measurement during separate performances of the same test.

Inter-examiner reliability is a measure of the ability of two or more raters to obtain identical results with the same test.

The kappa coefficient (κ) is a measure of the proportion of potential agreement after chance is removed[1,5,7]; it is the reliability coefficient most often used for categorical data (positive or negative).[5] The correlation coefficient commonly used to determine the reliability of data that is continuous in nature (e.g., range of motion) is the intraclass correlation coefficient (ICC).[7] Although interpretations of reliability vary, coefficients are often evaluated by the criteria described by Shrout[8] with values less than 0.10 indicating no reliability, values between 0.11 and 0.40 indicating slight reliability, values between 0.61 and 0.80 indicating moderate reliability, and values greater than 0.81 indicating substantial reliability. "Acceptable reliability" must be decided by the clinician using the specific test or measure[9] and should be based on the variable being tested, why a particular test is important, and on whom the test will be used.[6] For example, 5% measurement error may be very acceptable when measuring joint range of motion, but is not nearly as acceptable when measuring pediatric core body temperature.

DIAGNOSTIC ACCURACY

Clinical tests and measures can never absolutely confirm or exclude the presence of a specific disease.[10] However, clinical tests can be used to alter the clinician's estimate of the probability that a patient has a specific musculoskeletal disorder. The accuracy of a test is determined by the measure of agreement between the clinical test and a reference standard.[11,12] A reference standard is the criterion considered the closest representation of the truth of a disorder being present.[1] The results obtained with the reference standard are compared with the results obtained with the test under investigation to determine the percentage of people correctly diagnosed, or diagnostic accuracy.[13] Because the diagnostic utility statistics are completely dependent on both the reference standard used and the population studied, we have specifically listed these within this text to provide information to consider when selecting the tests and measures reported. Diagnostic accuracy is often expressed in terms of positive and negative predictive values (PPVs and NPVs), sensitivity and specificity, and likelihood ratios (LRs).[1,14]

2×2 Contingency Table

To determine the clinical utility of a test or measure, the results of the reference standard are compared with the results of the test under investigation in a 2×2 contingency table, which provides direct comparison between the reference standard and the test under investigation.[15] It allows for the calculation of the values associated with diagnostic accuracy to assist with determining the utility of the clinical test under investigation (Table 1-1).

The 2×2 contingency table is divided into four cells (a, b, c, d) for the determination of the test's ability to correctly identify true positives (cell a) and rule out true negatives (cell d). Cell b represents the false-positive findings wherein the diagnostic test was found to be positive yet the reference standard obtained a negative result. Cell c represents the false-negative findings wherein the diagnostic test was found to be negative yet the reference standard obtained a positive result.

Once a study investigating the diagnostic utility of a clinical test has been completed and the comparison to the reference standard has been performed in the 2×2 contingency table, determination of the clinical utility in terms of overall accuracy, PPVs and NPVs, sensitivity and specificity, and LRs can be calculated. These statistics are useful in determining whether a diagnostic test is useful for either ruling in or ruling out a disorder.

Table 1-1 2×2 Contingency Table Used to Compare the Results of the Reference Standard to Those of the Test Under Investigation

	Reference Standard Positive	Reference Standard Negative
Clinical Test Positive	True-positive results a	False-positive results b
Clinical Test Negative	False-negative results c	True-negative results d

Overall Accuracy

The overall accuracy of a diagnostic test is determined by dividing the correct responses (true positives and true negatives) by the total number of patients.[16] Using the 2×2 contingency table, the overall accuracy is determined by the following equation:

$$\text{Overall accuracy} = 100\% \times (a + d)/(a + b + c + d)$$

A perfect test would exhibit an overall accuracy of 100%. This is most likely unobtainable in that no clinical test is perfect, and each will always exhibit at least a small degree of uncertainty. The accuracy of a diagnostic test should not be used to determine the clinical utility of the test because the overall accuracy can be a bit misleading. The accuracy of a test can be significantly influenced by the prevalence, or total instances of a disease in the population at a given time.[5,6]

Positive and Negative Predictive Values

Positive predictive values estimate the likelihood that a patient with a positive test actually has the disease.[5,6,17] PPVs are calculated horizontally in the 2×2 contingency table (Table 1-2) and indicate the percentage of patients accurately identified as having the disorder (true positive) divided by all the positive results of the test under investigation. A high PPV indicates that a positive result is a strong predictor that the patient has the disorder.[5,6] The formula for the PPV is:

$$\text{PPV} = 100\% \times a/(a + b)$$

NPVs estimate the likelihood that a patient with a negative test does not have the disorder.[5,6] NPVs are also calculated horizontally in the 2×2 contingency table (see Table 1-2) and indicate the percentage of patients accurately identified as not having the disorder (true negative) divided by all the negative results of the test under investigation.[11] The formula for the NPV is as follows:

$$\text{NPV} = 100\% \times d/(c + d)$$

Table 1-2 2×2 Contingency Showing the Calculation of Positive and Negative Predictive Values Horizontally and Sensitivity and Specificity Vertically

	Reference Standard Positive	Reference Standard Negative	
Clinical Test Positive	True positives a	False positives b	PPV = a/(a + b)
Clinical Test Negative	c False negatives	d True negatives	NPV = d/(c + d)
	Sensitivity = a/(a + c)	Specificity = d/(b + d)	

The predictive values are significantly influenced by the prevalence of the condition.[11] Hence, we have not specifically reported these in this text.

Sensitivity

The sensitivity of a diagnostic test indicates the test's ability to detect those patients who actually have the disorder as indicated by the reference standard. This is also referred to as the *true-positive rate.*[1] Tests with high sensitivity are good for ruling out a particular disorder. The acronym *SnNout* can be used to remember that a test with high *Sen*sitivity and a *N*egative result is good for ruling *out* the disorder.[1]

Consider, for example, a clinical test that, compared with the reference standard, exhibits a high sensitivity for detecting lumbar spinal stenosis. Considering the rule above, if the test is negative it reliably rules out lumbar spinal stenosis. If the test is positive, it is likely to accurately identify a high percentage of patients presenting with stenosis. However, it also may identify as positive many of those without the disorder (false positives). Thus, although a negative result can be relied on, a positive test result does not allow us to draw any conclusions (Figs. 1-1 and 1-2).

The sensitivity of a test also can be calculated from the 2×2 contingency tables. However, it is calculated vertically (see Table 1-2). The formula for calculating a test's sensitivity is as follows:

$$\text{Sensitivity} = 100\% \times a/(a + c)$$

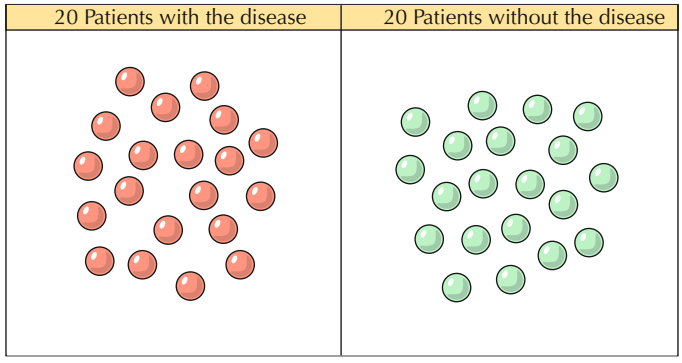


Figure 1-1 Sensitivity and specificity example. Twenty patients with and 20 patients without the disorder.

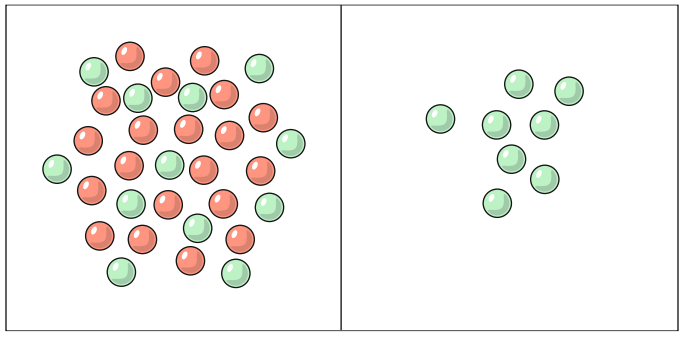


Figure 1-2 100% Sensitivity. One hundred percent sensitivity, inferring that if the test is positive, all those with the disease will be captured. However, although this test captured all those with the disease, it also captured many without. Yet if the test result is negative, we are confident that the disorder can be ruled out (SnNout).

Specificity

The specificity of a diagnostic test simply indicates the test's ability to detect those patients who actually do not have the disorder as indicated by the reference standard. This is also referred to as the *true-negative rate*.[1] Tests with high specificity are good for ruling in a disorder. The acronym *SpPin* can be used to remember that a test with high *Sp*ecificity and a *P*ositive result is good for ruling *in* the disorder.[16,18,19]

Consider a test with high specificity. It would demonstrate a strong ability to accurately identify all patients who do not have the disorder. If a highly specific clinical test is negative, it is likely to identify a high percentage of those patients who do not have the disorder. However, it is also possible that the highly specific test with a negative result will identify a number of patients who actually have the disease as being negative (false negative). Therefore, we can be fairly confident that a highly specific test with a positive finding indicates that the disorder is present (Fig. 1-3).

The formula for calculating test specificity is as follows:

$$\text{Specificity} = 100\% \times d/(b + d)$$

Sensitivity and specificity have been used for decades to determine a test's diagnostic utility; however, they possess a few clinical limitations.[11] Although sensitivity and specificity can be useful to assist clinicians in selecting tests that are good for ruling in or out a particular disorder, few clinical tests demonstrate both high sensitivity and high specificity.[11] Also the sensitivity and specificity do not provide information regarding a change in the probability of a patient having a disorder if the test results are positive or negative.[18,20] Instead, LRs have been advocated as the optimal statistics for determining a shift in pretest probability that a patient has a specific disorder.

Likelihood Ratios

A test's result is valuable only if it alters the pretest probability of a patient having a disorder.[21] LRs combine a test's sensitivity and specificity to develop an indication in the shift of probability given the specific test result and are valuable in guiding clinical decision making.[20] LRs are a powerful measure that can significantly increase or reduce the probability of a patient having a disease.[22]

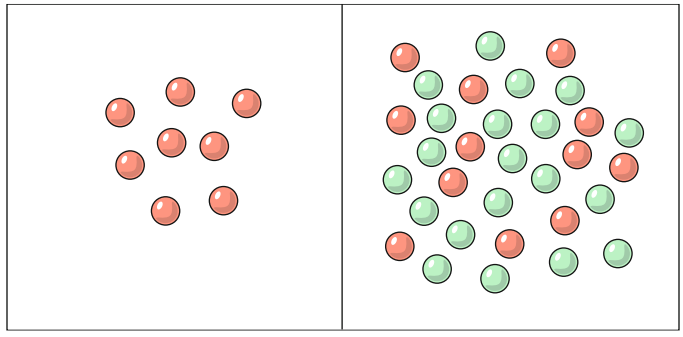


Figure 1-3 100% Specificity. One hundred percent specificity, inferring that if the test is negative all those without the disease will be captured. However, although this test captured all those without the disease, it also captured many with. Yet if the test is positive, we are confident that the patient has the disorder (SpPin).

LRs can be either positive or negative. A positive LR indicates a shift in probability favoring the existence of a disorder, whereas a negative LR indicates a shift in probability favoring the absence of a disorder. Although LRs are often not reported in studies investigating the diagnostic utility of the clinical examination, they can be calculated easily if a test's sensitivity and specificity are available. Throughout this text, for studies that did not report LRs but did document a test's sensitivity and specificity, the LRs were calculated by the authors.

The formula used to determine a positive LR is as follows:

$$\text{LR} = \text{Sensitivity}/(1 - \text{Specificity})$$

The formula used to determine a negative LR is as follows:

$$\text{LR} = (1 - \text{Sensitivity})/\text{Specificity}$$

A guide to interpreting test results can be found in Table 1-3. Positive LRs > 1 increase the odds of the disorder given a positive test, and negative LRs < 1 decrease the odds of the disorder given a negative test.[22] However, it is the magnitude of the shifts in probability that determines the usefulness of a clinical test. Positive LRs > 10 and negative LRs close to zero often represent large and conclusive shifts in probability. An LR of 1 (either positive or negative) does not alter the probability that the patient does or does not have the particular disorder and is of little clinical value.[22] Once the LRs have been calculated, they can be applied to the nomogram (Fig. 1-4),[23] or a mathematical equation[24] can be used to determine more precisely the shifts in probability given a specific test result. Both methods are described in further detail later in the chapter.

If a diagnostic test exhibits a specificity of 1, the positive LR cannot be calculated because the equation will result in a zero for the denominator. In these circumstances it has been suggested to modify the 2×2 contingency table by adding 0.5 to each cell in the table to allow for the calculation of LRs.[25]

Consider, for example, the diagnostic utility of the Crank test[5,26] in detecting labral tears compared with arthroscopic examination, the reference standard. This is revealed in a 2×2 contingency table (Table 1-4). The inability to calculate a positive LR becomes obvious in the following:

$$\text{Positive LR} = \text{Sensitivity}/(1 - \text{Specificity}) = 1/(1 - 1) = 1/0.$$

Because zero cannot be the denominator in a fraction, the 2×2 contingency table is modified by adding 0.5 to each cell.

Although the addition of 0.5 to each cell is the only reported method of modifying the contingency table to prevent zero in the denominator of an LR calculation, considering the changes that occur with the diagnostic properties of sensitivity, specificity, and predictive values, this technique has not been used in this text. In circumstances in which the specificity is zero and the positive LR cannot be calculated, it is documented as "undefined" (UD). In these cases, although we are not calculating the positive LR, the test is indicative of a large shift in probability.

Table 1-3 Interpretation of Likelihood Ratios

Positive Likelihood Ratio	Negative Likelihood Ratio	Interpretation
>10	<0.1	Generate large and often conclusive shifts in probability
5 to 10	0.1 to 0.2	Generate moderate shifts in probability
2 to 5	0.2 to 0.5	Generate small but sometimes important shifts in probability
1 to 2	0.5 to 1.0	Alter probability to a small and rarely important degree

Adapted from Jaeschke R, Guyatt GH, Sackett DL III. How to use an article about a diagnostic test. B. What are the results and will they help me in caring for my patients? *JAMA*. 1994;271:703-707.

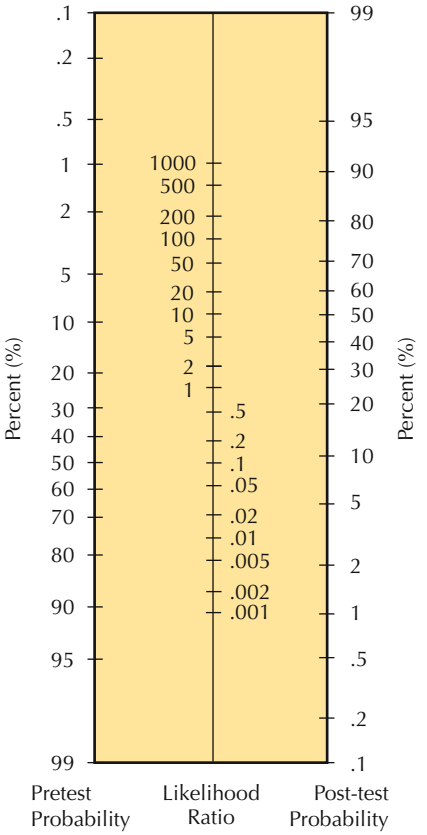


Figure 1-4 Fagan's nomogram. *(Adapted with permission from Fagan TJ. Nomogram for Baye's theorem. N Engl J Med. 1975;293:257. Copyright 2005, Massachusetts Medical Society. All rights reserved.)*

Table 1-4 Results of the Crank Test in Detecting Labral Tears When Compared with the Reference Standard of Arthroscopic Examination

	Arthroscopic Examination Positive (n = 12)	**Arthroscopic Examination Negative (n = 3)**	
Crank Test Positive	10 a	0 b	PPV = 100 × 10/10 = 100%
Crank Test Negative	c 2	d 3	NPV = 100 × 3/5 = 60%
	Sensitivity = 100% × 10/12 = 83%	Specificity = 100% × 3/3 = 100%	

CONFIDENCE INTERVALS

Calculations of sensitivity, specificity, and LRs are known as *point estimates.* That is, they are the single best estimates of the population values.[5] However, because point estimates are based on small subsets of people (samples), it is unlikely that they are a perfect representation of the larger population. It is more accurate, therefore, to include a range of values (interval estimate) in which the population value is likely to fall. A confidence interval (CI) is a range of scores around the point estimate that likely contains the population value.[27] Commonly, the 95% CI is calculated for studies investigating the diagnostic utility of the clinical examination. A 95% CI indicates the spread of scores that we can be 95% confident in to contain the population value.[5] In this text, 95% CI is reported for all studies that provided this information.

PRETEST AND POST-TEST PROBABILITY

Pretest probability is the likelihood that a patient exhibits a specific disorder before the clinical examination. Often prevalence rates are used as an indication of pretest probability, but when prevalence rates are unknown, the pretest probability is based on a combination of the patient's medical history, results of previous tests, and the clinician's experience.[16] Determining the pretest probability is the first step in the decision-making process for clinicians. Pretest probability is an estimate by the clinician and can be expressed as a percentage (e.g., 75%, 80%) or as a qualitative measure (e.g., somewhat likely, very likely).[11,16] Once the pretest probability of a patient having a particular disorder is identified, tests and measures that have the potential to alter the probability should be selected for the physical examination. Post-test probability is the likelihood that a patient has a specific disorder after the clinical examination procedures have been performed.

CALCULATING POST-TEST PROBABILITY

As previously mentioned, LRs can assist with determining the shifts in probability that would occur following a given test result and depend on the respective LR ratios of that given test. The quickest method of determining the shifts in probability once an LR is known for a specific test can be determined using the nomogram (Fig. 1-5).[23] The nomogram is a diagram that illustrates the pretest probability on the right and the post-test probability on the left, and the LRs are in the middle. To determine the shift in probability, a mark is placed on the nomogram representing the pretest probability. Then a mark is made on the nomogram at the level of the LR (either negative

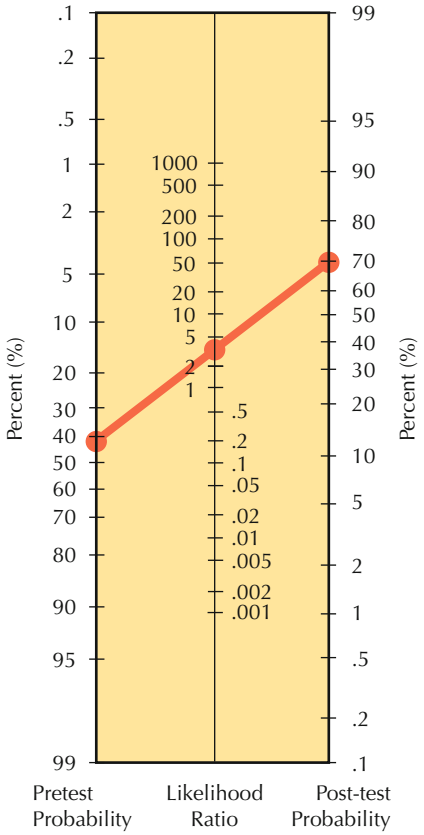


Figure 1-5 Nomogram representing the change in pretest probability from 42% if the test was positive (positive likelihood ratio = 4.2) to a post-test probability of 71%. *(Adapted with permission from Fagan TJ. Nomogram for Baye's theorem.* N Engl J Med. *1975;293:257. Copyright 2005, Massachusetts Medical Society. All rights reserved.)*