AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
SCIENTIFIC ASSEMBLY
1999

What Every Emergency Physician Should Know: Diagnostic Testing

Emergency physicians are diagnosticians, but when should specific diagnostic tests be ordered? This course outlines the basics of matching clinical suspicion with the sensitivity and specificity of commonly used diagnostic tests. Pretest probability, efficiency, and cost containment issues will be covered.

- Describe how to interpret a diagnostic test result based on pretest clinical suspicion.
- List two commonly used diagnostic tests that are frequently used incorrectly.
- Describe how to reduce the costs of diagnostic testing.

MO-36
Monday, October 11, 1999
3:00 PM - 3:55 PM
Room # N247
Las Vegas Convention Center

FACULTY

Douglas L McGee, DO

Assistant Professor, Temple University School of Medicine and Philadelphia College of Osteopathic Medicine; Associate Director, Emergency Medicine Residency Program, Albert Einstein Medical Center Philadelphia, Pennsylvania

What Every Emergency Physician Should Know: Diagnostic testing

Douglas McGee, D.O.

Course Description

Emergency physicians are diagnosticians, but when should specific diagnostic tests be ordered? This course outlines the basics of matching clinical suspicion with the sensitivity and specificity of commonly used diagnostic tests. Pretest probability, efficiency and cost containment issues will be covered.

Course Objectives

Upon completion of the course, participants will be able to:

1. Describe how to interpret a diagnostic test result based upon pretest clinical suspicion.

2. List two commonly used diagnostic tests that are frequently used incorrectly.

3. Describe how to reduce the costs of diagnostic testing

Course outline

A. Introduction

When the history, physical examination, medical records or previous testing are not sufficient to answer a clinical question, diagnostic testing may be warranted. Emergency Physicians order diagnostic tests based on the assumption that the information derived from the test will somehow reduce the uncertainty surrounding the clinical question at hand. Understanding how diagnostic tests are derived, utilized and interpreted are critical to the practice of Emergency Medicine.

Many discussions about diagnostic testing emphasize “cost containment”, a fuzzy term that is difficult to clearly define. The Emergency Physician’s goal is to use diagnostic testing in a “cost effective” manner. In other words, to derive maximal benefit from the test result, while incurring the lowest “cost”. “Cost effective” does not always mean “cheapest”. The most cost effective test may be the most expensive single test available. Emergency Medicine residents tend to be overly reliant on diagnostic testing; a practice that improves during the course of their training as their clinical acumen improves and confidence in clinical judgement is gained. Unrecognized improvement in understanding the use of diagnostic tests sharpens the utilization of them.

Poor utilization of diagnostic tests creates difficulties in clinical practice:

1. It unnecessarily delays patient diagnosis, treatment and disposition

2. It may subject the patient to unnecessary pain and complications

3. Consumes the EP time trying to "prove the EKG changes are old" or the "anemia is chronic"

4. May force further testing, inappropriate treatment or unnecessary admission to the hospital

Uses of diagnostic tests in the ED:

When diagnosing disease

- clinical hypotheses are tested to strengthen or weaken them
- specific tests (negative in healthy patients) are used to "rule in" disease when positive

When screening for disease

- primary purpose is to reduce mortality and morbidity through early detection
- sensitive tests (positive in diseased individuals) are used to "rule out" disease when negative
- the disease must have 3 attributes: common enough to justify detection, significant mortality and morbidity, treatment exists

When managing patients

- monitoring disease processes, identify complications, ensure therapeutic drug levels
- testing frequency is determined by the disease process and human physiology

B. Clinical suspicion and estimating the prevalence

After performing the history and physical, a list of diagnostic possibilities comes to mind. The clinician suspects that one diagnosis is more likely than another, deriving this suspicion from many factors: history, physical, age, sex, social factors and an understanding of the prevalence of the disease in the population as a whole.

Clinical suspicion can be represented by the term *pre-test probability*. In other word, how probable is this diagnosis before any testing is performed?

Since clinicians are not examining the whole population, but an individual who represents the whole population, a more useful question to ask is this:

"If I had a thousand patients exactly like this one, what would the prevalence of the disease under consideration be?"

For example, a 50 year-old man presents to the ED complaining of chest pain. What is the pretest probability that he has coronary artery disease if the following is true about a thousand patients just like this man (the probabilities are theoretical)?

Chest pain	50%
Left chest pain	65%
With hypertension	70%
Who smokes	80%
With diabetes	90%
With non-specific EKG changes	95%
With ischemia on the EKG	98%

The Emergency Physician's ability to accurately estimate pretest probability is critical. In addition to clinical experience, the literature can be used to find disease prevalence in a population. In the examples below, different pretest probability estimations dramatically influence a test's utility.

C. Sensitivity, specificity and "cut off" points

Sensitivity and specificity are test attributes, not patient attributes and are generally transportable between patients

Sensitivity is the likelihood of a test to be positive in disease (PID). A highly sensitive test has a low number of false negative results.

Specificity is the likelihood of a test to be negative in health (NIH). A highly specific test has a low number of false positive results

These test characteristics can be expressed in the following 2 x 2 grid:

		Disease	
		Present	**Absent**
Test Result	**Positive**	*True positives*	*False positives*
	Negative	*False negatives*	*True negatives*

Sensitivity = TP / TP + FN   Specificity = TN / FP + TN

Sensitivity and specificity are dependent on when a test is declared "positive" or "negative". In other word, the "cut off points" between positive and negative are artificial, designed to meet a clinical goal and can be moved.

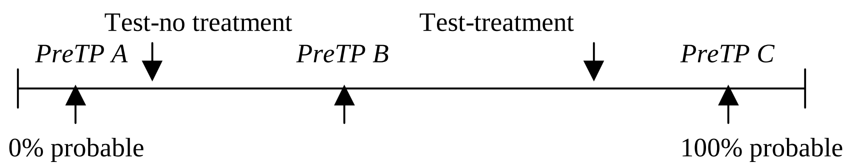
An ideal test manifests no overlap in values between diseased and disease-free patients. In other words, a test with 100% sensitivity and 100% specificity is ideal. Obviously, no such test exists. Every diagnostic test has an overlap between diseased and disease-free patients. The cut-off point can be manipulated to dramatically impact the sensitivity and specificity. Sensitivity and specificity are dependent upon each other. As the specificity goes up, the sensitivity goes down.

D. Test selection and interpretation process

The decision to obtain diagnostic tests and the process of interpreting them follows a sequential process of hypothesis testing:

1. the history and physical are performed
2. a differential diagnoses list is generated and ordered based upon the clinician's perception that a disease is probable *(pre-test probability)*
3. the estimated probability is compared with the clinician's thresholds to make the diagnosis:
   test-no treatment threshold: the probability below which there is no difference between the value of testing and the value of not treating. Below this threshold, no diagnosis is made and no treatment given
   test-treatment threshold: the probability above which there is no difference between the value of testing and treating the patient. When the pre-test probability is above this threshold, the diagnosis is made and treatment is given
   intermediate probability: the probability estimation, the pre-test probability falls between the thresholds. Further testing refines this probability estimation *(post test probability)* and moves it toward a threshold
4. Sequential or additional testing is conducted until a threshold to treat or not treat is passed

These concepts can be expressed graphically below:



When the Pre-test probability is:

A: no further testing is needed, the diagnosis is excluded

B: testing is performed; negative tests reduce the probability, positive tests increase the probability

C: no further testing is needed, the diagnosis is made

Setting thresholds

Threshold setting is important because it impacts substantially on a test's utility. The purpose of diagnostic testing is to raise or lower an estimated likelihood of disease until the diagnosis is "ruled in" or "ruled out". When a clinician places the thresholds at the extremes, they are hard to exceed. Diagnostic tests are required to satisfy them.

Thresholds are influenced by many factors. Among them: the cost of the test, the complications of treatment, and the "seriousness" of the disease. Non medical factors like prior adverse malpractice actions, patient preferences, and individual practice habits also influence a clinician's thresholds.

When the stakes are high if the disease is missed, like a myocardial infarction, the test-no treatment threshold is very low, requiring many tests to rule the disease out. When the complications of the contemplated treatment are serious, a high test-treatment threshold is set. Administering thrombolytic drugs to patient with a stroke is such an example.

E. Predictive value and calculating post test probabilities

Understanding a test's sensitivity and specificity is important, but several real questions face the clinician. How useful is this test result? Is this positive result really positive or is it a false positive? Is this negative result a false negative?

Stated another way, how probable is the disease when the test is positive (or negative)? This new probability, calculated after the test result is known, is called the *post test probability*.

Bayes theorem is the algebraic model that describes the post test probability and although it is complicated, it can be simply described by revisiting the 2x2 grid:

		Disease	
		Present	**Absent**
Test Result	**Positive**	*True positives*	*False positives*
	Negative	*False negatives*	*True negatives*

Instead of focusing on the vertical rows, focus on the horizontal rows. The post test probabilities (Post TP) are calculated as follows:

Post TP of disease when the test is positive: TP / TP + FP

Post TP of disease when the test is negative: FN / FN + TN

Calculating the post test probability estimation requires knowledge of the operating characteristics of the test and an estimation of the prevalence of disease. Again in the case of an individual patient, the prevalence is represented by the pretest probability of the disease in question. Consider the following example:

Two patients present to the ED complaining of chest pain and are admitted to the Chest Pain Observation Unit in the ED. Part of the protocol for such patients is to undergo exercise stress testing (ETT) before discharge from the unit. The ETT has a sensitivity of 86% and a specificity of 77%.

Patient 1
The first patient is 65 years old and is a smoker, with diabetes and hypertension who also has a strong family history of coronary artery disease. The Emergency Physician estimates that the probability of coronary artery disease in this patient to be 90% before the ETT is performed. Let's calculate the post test probabilities.

		Coronary artery disease Present N=900	Coronary artery disease Absent N=100
ETT Result	Positive	*TP=774*	*FP=23*
	Negative	*FN=126*	*TN=77*

Remember, the sensitivity represents the TP, 86% of our 900 theoretic patients. The specificity represents the TN, 77% of 100 patients without the CAD.

Post TP when the ETT is positive = 774 / 774 + 23 = 774/797 = 97%
Post TP when the ETT is negative = 126 / 126 + 77 = 126/203 = 62%

The EP estimated the probability to be 90% before the ETT, a positive test made this only more probable, confirming the original clinical suspicion. A negative ETT reduced the probability to 62%. Six patients out of 10 will still have CAD, even with a negative ETT. Since 62% is still well above the test-no treatment threshold, this patient will probably require more testing until a threshold is passed.

Patient 2
The second patient is 38 years old and smokes cigarettes. His chest pain was atypical and his EKG was normal. The Emergency Physician estimates that the probability of coronary artery disease in this patient to be 10% before the ETT is performed. Let's calculate the post TPs.

		Coronary artery disease Present N=100	Coronary artery disease Absent N=900
ETT Result	Positive	*TP=86*	*FP=207*

Negative	*FN=14*	*TN=693*

Post TP when the ETT is positive = 86 / 86 + 207 = 86/293 = 29%
Post TP when the ETT is negative = 14 / 14 + 693 = 14/707 = 2%

The EP thought the probability was low in this patient, estimating it to be about 10%. A positive ETT raises the probability to 29%, but among those with a positive ETT, 71% will be disease free. Since 29% is probably not high enough to pass the test-treatment threshold, this patient is probably in for more testing.

A negative ETT in this patient reduces the probability to 2%, probably below the test-no treatment threshold. If the 10% estimation was below the EP's test-no treatment threshold initially, the test should not have been performed.

In these two cases, the ETT was not as helpful as expected because the pre TP estimations were near the extremes. Diagnostic testing is most useful when the pre TP is intermediate. Consider the following example:

		Coronary artery disease	
		Present N=500	**Absent N=500**
ETT Result	**Positive**	*TP=430*	*FP=115*
	Negative	*FN=70*	*TN=385*

Post TP when the ETT is positive = 430 / 430 + 115 = 430/545 = 79%
Post TP when the ETT is negative = 70 / 70 + 385 = 70/455 = 15%

The probabilities have been moved substantially toward the thresholds. Whether these Post TPs exceed those thresholds depends on where the clinician sets them.

To maximize a positive result's utility, test populations in which the prevalence of the disease in question is higher. To maximize a negative test's utility, test populations with low prevalence of disease. Eight-year-old children are not routinely tested for HIV because the prevalence in the population (and any single individual's pre TP) is low. A positive result in this group would be discarded as a false positive. The converse is true for intravenous drug users.

Tests subject to misuse in the ED: example

Plain radiographs for uncomplicated low back pain.

The sensitivity and specificity of plain radiographs for vertebral fractures is 99% and about 31%. The incidence of acute compression fracture in mechanical back pain seen in a primary care practice is 4%. Based on this information, calculate the post test probability of a positive and negative radiograph.

		Spine abnormalities Present N=40	Spine abnormalities Absent N=960
L-S Radiograph Result	**Positive**	*TP=39*	*FP=662*
	Negative	*FN=1*	*TN=298*

Post TP when the film is positive = 39 / 39 + 662 = 39/701 = 5.5%
Post TP when the film is negative = 1 / 1 + 298 = 1/299 = 0.3%

The incidence of spinal abnormality seen on x-ray that requires any treatment is about 1% in all populations. Calculate the post test-probability after x-rays searching for fracture.

		Spine abnormalities requiring treatment Present N=10	Spine abnormalities requiring treatment Absent N=990
L-S Radiograph Result	**Positive**	*TP=9.99*	*FP=690*

Negative	*FN=0.01*	*TN=310*

Post TP when the film is positive = 9.99/9.99 + 690 = 9.99/699.99 = 1.4%
Post TP when the film is negative = 0.01/0.01 + 310 = 0.01/310.01 = 0.003%

"Rapid strep screen" for sore throat
Among patients with sore throat, a combination of fever, tonsillar exudate and anterior cervical adenopathy stratify patients with suspected streptococcal pharyngitis. When only one of these finding is present with sore throat, the probability of strep throat was 3%. The sensitivity and specificity of a "rapid strep screen" is 50% and 90%.

		Streptococcal infection	
		Present N=30	**Absent N=970**
"Rapid strep" Result	**Positive**	*TP=15*	*FP=97*
	Negative	*FN=15*	*TN=873*

Post TP when the screen is positive = 15 / 15 + 97 = 15/112 = 13%
Post TP when the screen is negative = 15/ 15 + 873 = 15/888 = 1.6%

F. Using diagnostic tests in the ED; cost effectiveness

The principles of diagnostic testing theory must be understood to derive the most benefit from tests conducted in the ED. When maximum benefit is derived at the least cost, cost effective medicine is practiced.

Diagnostic tests ordered in the ED can be very powerful or completely useless. In practical terms, the sensitivity and specificity for many tests is not available in the ED. Estimating the pretest probability can be very difficult, even with the best history and physical. Many consequential and inconsequential bits of data remain undiscovered in the ED encounter.

In order to maximize benefit from diagnostic tests, the Emergency Physician should:

Perform a thorough history and physical, relative to the complaint, to assist in pretest probability estimation. When prevalence rates among patients similar to the ED patient are described in the literature they should be used when formulating a pretest probability.

Understand sensitivity and sensitivity of tests ordered. Select tests designed to move the pretest probability estimation toward a threshold to "rule in" or "rule out" the disease.

Do not test patients when they have exceed the threshold to "rule in" or "rule out" the disease. This type of testing is wasteful and contributes little to the encounter. Testing like this either confirms a strong suspicion or confuses the clinical picture. This confusion often leads to additional testing or unnecessary treatment.

Know where his or her thresholds are set. Whenever possible, compare thresholds with other seasoned clinicians. Reset threshold when appropriate.

Additional readings

Some excellent references were used in part to prepare this presentation and provide additional reading on the subject of "Diagnostic Testing".

Black ER, Bordley DR, Tape TG, Panzer RJ. **Diagnostic Strategies for Common Medical Problems.** American College of Physicians, Philadelphia 1999.

Gross R. **Making Medical Decisions.** American College of Physicians, Philadelphia 1999.

Wolfson AB, Paris PM. **Diagnostic Testing in Emergency Medicine**. WB Saunders Company, Philadelphia 1996.