SECTION 1
The Science of Diagnostic Testing and Clinical Decision Rules

Chapter 1 **Diagnostic Testing in Emergency Care**

As providers of emergency care, we spend a good deal of our time ordering and waiting for the results of diagnostic tests. When it comes to determining who needs a test to rule out potentially life-threatening conditions and subsequently interpreting test results, we are the experts. We are experts at diagnostic testing for many reasons. First and foremost, we see a lot of patients. The expectation, especially if you are working in a busy hospital, is that you see everyone in a timely way, provide quality care, and make sure patients are satisfied. If we order time-consuming tests on everyone then emergency department (ED) crowding will worsen, efficiency will decline, the costs of care will go up, and patients will experience even longer waiting times than they already do. However, differentiating which patients truly need tests in the ED is a complex process. Over the past 30 years, scientific research into diagnostic testing and clinical decision rules in emergency care has advanced considerably. Now, there is a greater understanding of the sensitivity, specificity, and overall accuracy of tests. Validated clinical decision rules provide criteria whereby many patients do not need tests at all and serious, potentially life-threatening conditions such as intracranial bleeding and C-spine fractures can be ruled out based on clinical grounds. There are also good risk stratification tools to determine the probability of disease for conditions like pulmonary embolism before any tests are even ordered.

So how do we decide who to test and who not to test? There are some people who obviously need tests, such as the head-injured patient who has altered mental status and who may have a head bleed. There are also those patients who obviously do not need tests, such as patients with a simple toothache. There is a large group of patients in the middle where testing

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decisions can sometimes be challenging. This group of patients is where you may find yourself to be 'on the fence' with regards to testing. It may not be clear whether to order a test, or even how to interpret a test once you have the results. And finally, when we receive the results of a test that is not what we suspected clinically, it may be unclear how to extrapolate from the test results to the care of that particular individual patient.

Let's give some examples of how diagnostic testing can be a challenge in the ED. You are coming onto your shift and are signed out a patient for whom your colleague has ordered a D-dimer test (a test for pulmonary embolism). She is 83 years old and developed acute shortness of breath, chest pain, and hypoxia (room air oxygen saturation = 89%). She has history of prior pulmonary embolism and physical examination is unremarkable except for mild left anterior chest wall tenderness and notably clear lung sounds. The test comes back negative. Has pulmonary embolism been satisfactorily ruled out? Should you perform a pulmonary angiogram or a computed tomography (CT) scan of the chest, or maybe even consider a ventilation/perfusion (V/Q) scan? Was D-dimer the right test for her to begin with?

Let's consider a different scenario. How about if a D-dimer was ordered on a 22-year-old male with atypical chest pain and no risk factors, and the test comes back positive; what do you do then? Should he be anticoagulated and admitted? Does he have a pulmonary embolism, or should you move forward with further confirmatory testing before initiating treatment? Or is he so low risk, that he's probably fine anyway? But you could argue, if he was so low risk, why then was the test ordered in the first place?

In another example, you are evaluating a 77-year-old female who has fallen down and has acute hip pain and is unable to ambulate. The hip radiograph is negative. Should you pursue it and possibly get a CT or magnetic resonance imaging (MRI) scan done? But the test is negative so can't she go home?

These are examples of when test results often do not confirm your clinical suspicion. What do you do in those cases? Should you believe the test result or your clinical judgment before ordering the test? Were these the optimal tests for these patients in the first place? Remember back to conversations with your teachers in emergency medicine on diagnostic testing. Didn't they always ask: "how will a test result change your management?" and "what will you do if it's positive, or negative?"

The purpose of diagnostic testing is to reach a state where we are adequately convinced of the presence or absence of a condition. Test results are interpreted in the context of the prevalence of the suspected disease state and the clinical suspicion of the presence or absence of disease in the individual patient. For example, coronary artery disease is common. However, if we look for coronary disease in 25 year olds, we are not likely to find it because

it is very uncommon in that population. There are times when your clinical suspicion is so high that you do not need objective testing. In those patients, you can proceed with treatment. Other times you do need testing to confirm what you think is the diagnosis or to rule out more severe, life-threatening diseases.

The choice over whether to test or not test in the ED also depends upon the resources of the hospital and on the patient. Some hospitals allow easy access to radiographic testing and laboratory testing. In other hospitals, obtaining a diagnostic test may not be so easy. Some places do not allow certain types of tests at night (like MRIs and ultrasounds) because staff may be unavailable to perform them. Sometimes a patient may not necessarily need a test if you believe they can be trusted to return if symptoms worsen. For others, you may believe that a patient's emergency presentation may be the only time that they will have access to diagnostic testing. For example, saying to a patient "follow-up with your doctor this week for a stress test" may be impractical if the patient does not have a primary care doctor or does not have good access to medical care. You may practice in an environment where you cannot order a lot of tests (like developing countries). You also may be in an office environment that simply does not have easy access to testing. However, regardless of the reason why we order tests in the ED, what is certain is that the use of diagnostic testing in many cases can change how you manage a patient's care.

Sometimes, you may question your choice of whether to test, to not test, or whether to involve a specialist early. Should you get a CT scan first or just call a surgeon in for a young male with right lower quadrant pain, fever, nausea, and possible appendicitis? How many cases have you seen where the CT scan has changed your management? What if it is a young, non-pregnant female? Does that change your plan?

How about using clinical decision rules in practice? By determining if patients meet specific clinical criteria we can choose not to test if they are low risk. Do all patients with ankle sprains need X-rays? Can you use the Ottawa Ankle Rules in children? What are the limits of clinical decision rules? Is it possible to apply the Canadian C-spine rules to a 70-year-old female? These questions come up everyday in emergency medicine practice.

In fact, a major source of variability among physicians is whether or not they order tests. Remember back to your training when you were getting ready to present a patient to the attending physician. Weren't you trying to think to yourself: what would she do in this case? What tests would she order?

Access to test results helps us to decide whether to treat the disease, initiate even more testing, or no longer worry about a condition. As emergency physicians, we gain confidence in this process with experience. Much of the empirical science and mathematics behind the testing described in this

book becomes instinctive and intuitive the longer you practice emergency medicine. Sometimes we may think a patient does not need to be tested because the last 100 patients who had similar presentations all had negative results. Maybe you or a colleague were 'burned' once when a subtle clinical presentation of a life-threatening condition was missed (like a subarachnoid hemorrhage). The next patient who presents with those symptoms is probably more likely to get a head CT followed by a lumbar puncture. Is this evidence-based?

Step back for a moment and think about what we do when we order a test. After evaluating a patient, we come away with a differential diagnosis of both the most common and also most life-threatening possibilities. The following approach to medical decision making was derived by Pauker and Kassirer in 1980.[1] Imagine diagnostic testing as two separate thresholds, each denoted as 'I' (Fig. 1.1). The scale at the bottom of Fig. 1.1 denotes pre-test probability, which is the probability of the disease in question before any testing is employed. The threshold between 'don't test' and 'test' is known as the testing threshold; between 'test' and 'treat' is what is known as the test-treatment threshold. In this schema, treatment should be withheld if the pre-test probability of disease is smaller than the testing threshold and no testing should be performed. Treatment should be given without testing if the pre-test probability of disease is approximately equal to the test-treatment threshold. And then, when the pre-test probability lies between the testing and test-treatment thresholds, the test should be performed and the patient treated according to the test results. That is the theory; now let's make this more clinically relevant.

Sometimes disease is clinically apparent and we do not need confirmatory testing before proceeding with treatment. If you are evaluating a patient with an obvious cellulitis, you may choose to give antibiotics before initiating any testing. How about the evaluation of a 50-year-old male with chest pain who has large inferior 'tombstone' ST-segment elevations on his electrocardiogram consistent with acute myocardial infarction (AMI)? Cardiac markers are not likely to be very helpful in the acute management of this patient. This is another example where it is important to treat the patient first: give them

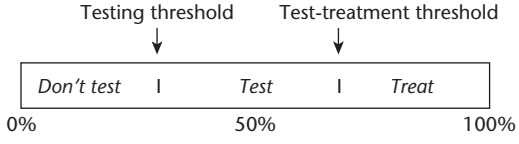

Figure 1.1 Pre-test probability of disease.

aspirin and beta-blockers, anticoagulate them, provide oxygen, and send them off to the cardiac catheterization laboratory if your hospital has one, or provide intravenous thrombolysis if cardiac catheterization is not readily available. Now imagine that the patient has a history of Marfan's syndrome and you think the patient is having an acute AMI, but you want to get a chest X-ray to make sure that they don't have an aortic dissection before you anticoagulate them. That might put you on the 'test' side of the line. If the test is positive for what may be a dissection, you won't give aspirin and anticoagulate; if it's negative, you will.

The scenario of the potential use for tissue plasminogen activator (tPA) in stroke patients frequently comes up in the ED. When a patient comes to the ED within the first 3 hours after the onset of their stroke symptoms, you rush to get a patient to the CT scanner. Why? The primary reason is to differentiate between ischemic and hemorrhagic stroke, which will make a major difference to whether or not the patient is even eligible to receive tPA.

Now imagine cases where you are below the testing threshold. You have a 32-year-old male with what appears to be musculoskeletal chest pain. Some would argue that the patient doesn't need any emergency tests at all if the patient is otherwise healthy and the physical examination is normal. Others might get a chest X-ray and an electrocardiogram to rule out occult things like pneumothorax and heart disease, while some others may even get a D-dimer to rule out pulmonary embolism. Which of these is the right way to manage the patient? Is there any evidence behind that decision or is it just physician's preference? In some patients, at the end of the ED evaluation you may still not have a definitive answer. Imagine you have a 45-year-old female with atypical chest pain and normal electrocardiogram and cardiac marker results, and your hospital does not perform stress testing from the ED. Does she need a hospital admission for rule out and a stress test?

The way that Pauker and Kassirer[1] designed the test-treatment thresholds almost 30 years ago did not account for the proliferation of 'confirmatory' diagnostic testing in hospitals. While the lower boundary of the testing threshold is certainly lower than it has ever been, the upper boundary has also increased as there are occasions when we are loathed to treat before testing, even when the diagnosis seems apparent. The reason for this is that Occam's razor does not often hold true in emergency medicine.

So what is Occam's razor? In the 14th century William of Occam stated that "plurality must not be posited without necessity," which has been interpreted to mean 'among competing hypotheses, favor the simplest one.'[2] When applied to test-treatment thresholds, what we find is that a patient with objective findings for what might seem like pneumonia (that is hypoxia, infiltrate, and a history of cough) is likely to have pneumonia and should be

treated empirically as such, but may also have a pulmonary embolism. While finding parsimony of diagnosis is important, often the principle of test-treatment thresholds means that if you are above the test-treatment threshold then you should certainly treat, but also consider carrying out more tests, particularly in patients with objective signs of disease.

Think about how trauma surgeons practice. When the multi-injured trauma patient is seen, isn't their approach to test, test, test? If you are already injured and another part hurts, get a CT scan. Some order CT scans on patients where it doesn't even hurt; the thinking behind this approach is not illogical. When a patient has been in a major car accident and has a broken left femur and a broken left radius and mild abdominal tenderness, do they need more CT scans to rule out intra-abdominal injuries and intracranial injuries? Where Occam's razor dulls is in the situation when although the most parsimonious diagnosis (just a radius and femur fracture) is possible, patients with multiple traumatic injuries tend to have not only the obvious ones, but also tend to have occult injuries too. This necessitates the diagnostic search for the occult intra-abdominal, intra-thoracic, and intra-cranial injuries in the patient with the obviously broken arm and leg.

When deciding on care plans, we develop our own risk tolerance based on our training, clinical expertise, and experiences, and on the local standard practice, and attitudes of the patient, family, or other physicians caring for the patient. Risk tolerance guides where we draw our own individual testing and test-treatment thresholds, and how much effort we put into searching for the occult. Risk tolerance refers to the post-test probability that we are comfortable with, having excluded a disease or confirmed a disease. That is, risk tolerance is where we are comfortable setting our testing and test-treatment thresholds.

For example, let's say we are evaluating someone for a possible acute coronary syndrome. At the end of the ED stay after an electrocardiogram, chest X-ray, and evaluation of their cardiac marker levels, you calculate that they have a 2% risk of being sent home and having an unexpected event within 30 days. Is it OK to send them home with this level of risk? Isn't that the published rate for missed AMI? What if the risk is 1%, or 0.5%, or 0.1%?

How do you make the decision about when to order a test to just treat? How do you assign a pre-test probability? How do you apply test results to an individual patient? This is where research and the practice of evidence-based medicine (EBM) can influence medical practice by taking the best evidence from the literature about diagnostic testing or clinical decision rules and using that information to make an informed decision about how to care for patients. Chapters 2 and 3 provide an overview of the process of EBM and examples of its application to individual patients in the ED. Chapter 4

comprises a discussion of how we derive, validate, and study the impact of clinical decision rules in practice.

Understanding the evidence behind diagnostic testing and using clinical decision rules to decide not to test is at the core of emergency medicine practice. Think back to your last shift in the ED; how many tests did you order?

The purpose of this book is to demystify the evidence behind diagnostic testing and clinical decision rules in emergency care by going back and carefully evaluating the evidence behind our everyday decision making. This book is written to provide objective information on the evidence behind these questions and our opinion on how we manage our patients with that clinical problem given the best available evidence. Now, keep in mind that we are writing this from the perspective of academic emergency physicians. We work in an inner city ED with abundant (although not always quick) access to consultants, a state-of-the-art laboratory, and high-resolution imaging tests. Physicians in our practice also tend to have somewhat of a testing threshold, where patients often have testing done for minor symptoms. As you read this, realize that not all emergency medicine practice is the same and you should interpret the literature yourself in the context of your own clinical practice environment.

We have designed each chapter around clinical questions that come up in everyday emergency medicine practice. For each question, we present the objective data from published studies and then provide our 'expert' comment on how we use these tests in our practice. We try to provide insights into how we interpret the literature for each testing approach. Again, our comments should not necessarily be interpreted as the standard of care in emergency medicine. Standard of care is based on practice guidelines and local practice patterns. Instead, these chapters should serve as a forum or a basis for discussion for each clinical question. If you are a researcher, you can also think of this book as a roadmap to what is really 'known' or 'not known' with regard to diagnostic testing in emergency medicine, and what needs further study. Finally, rigorous and sound research often takes months to years to accomplish, and sometimes longer to publish. Therefore the discussions we present are likely to change as newer, larger, and more comprehensive studies are published, as new prediction or decision rules are validated and replicated, and as newer diagnostic technology is introduced.

References

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