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AUTHORS

Harvey S. Hahn, MD, FACC, Director, Cardiovascular Fellowship Training Program and Co-Director KPN CV Quality, Kettering Medical Center, Associate Professor of Clinical Medicine, Wright State University/Boonshoft School of Medicine, Kettering, OH, and Loma Linda University, Loma Linda, CA

Erik Poldemann, MD, Cardiology Fellow, Kettering Medical Center, Kettering, OH

PEER REVIEWER

Jeffrey W. Morgan, DO, MA, FACOI, CS, Dean, School of Osteopathic Medicine in Arizona, Mesa, AZ

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RELIAS MEDIA

Appropriate Cardiac Testing in an Inappropriate World

This two-part series will look at the rationale and causes of inappropriate testing and how to select the best, most appropriate cardiac test for each patient. The first part will focus on the theory of ordering tests and strategies to minimize unnecessary testing while the second part will focus on when and how to select each individual test given the patient's clinical scenario.

Introduction

The options and frequency of advanced cardiovascular testing have been increasing over time. The accompanying increases in healthcare costs and radiation exposure have not resulted in better patient outcomes. To try to control costs and improve patient care and safety, several programs have been implemented: clinical care guidelines, appropriate use criteria, and, most recently, campaigns such as Choosing Wisely and Less Is More. It is clear that many doctors are ordering cardiovascular testing in an inappropriate manner, but we are still in the infancy of developing systems to help curb this habit.

There has been significant technological development of medical imaging that has clearly aided the physician's ability to diagnosis and treat disease.[1] Paralleling this growth has been the inevitable expansion of healthcare costs. The Medicare Payment Advisory Commission reported that imaging services have grown faster than all other medical services.[2] In fact, between 1996 and 2002, cardiac imaging studies grew at an annual 9% rate.[3] A study of medical care in Washington state demonstrated that cross-sectional imaging almost doubled from 1997 to 2006. Ultrasound increased by almost 40%, with a tripling of echocardiography orders. Computed tomography almost doubled, and magnetic resonance imaging nearly tripled.[4] This increase was associated with imaging costs more than doubling over the same time period. This explosion of medical imaging has not been clearly shown to be correlated with improved patient outcomes.[5]

Not only is there a cost in terms of dollar amount for the patient and the health system as a whole, but there also are other important costs to the patient: lost time, anxiety, and radiation exposure. Abnormal findings that were not the primary reason for imaging — so-called "incidentalomas" — are very common and have led to more testing, more time off for the patient, and typically more radiation exposure.[6]

Physicians typically practice ALARA (as low as reasonably achievable) when dealing with radioactive material or ionizing radiation, but until

EXECUTIVE SUMMARY

Primary care physicians are confronted with a dizzying array of cardiac testing options, many of which are expensive, potentially harmful, and of dubious clinical utility.

- Imaging services have grown faster than all other medical services, including ultrasound, echocardiography, computerized tomography, and magnetic resonance. This explosion in medical imaging has not clearly been correlated with reduced patient outcomes.
- The reasons physicians test so much are complex but include the desire to feel more confident and to reassure patients and families. Defensive medicine and the potentially perverse fee-for-service system are other candidates.
- Initiatives designed to reduce inappropriate testing include clinical care guidelines, the Less Is More series, the Choosing Wisely program, and the growth of appropriate use criteria. Technological strategies include point-of-care tools in electronic medical records and smartphones.
- Two populations typically at risk for inappropriate testing include the asymptomatic/stable patient and the preoperative patient.

recently, little attention has been given to the patient's overall radiation history. Now, there is considerable interest in tracking a patient's lifelong radiation exposure in the hope of not only reducing repeated exposure to ionizing radiation, but also lowering the risk of cancer.[7] An important article in the *Journal of the American Medical Association* pointed out that there really is a "zero threshold" radiation exposure level and that any and every exposure increases future cancer risk.[8] For relative radiation exposure levels for the various cardiovascular tests, see Table 1.

Scope of the Problem

Although some believe that these warnings are alarmist in nature, there are data to support the idea that physicians are overusing tests and testing a lower-risk population than in the past. The most egregious example is with cardiac catheterization. Patel et al demonstrated that among first-time patients taken to the catheterization laboratory, only about one-third needed an intervention.[12] The remaining two-thirds had minimal to no disease. All of these patients were seen and examined by cardiologists. Even worse is the trend in myocardial perfusion imaging (MPI). Rozanski et al tracked the number of abnormal scans performed from 1991 to 2009; they found that the percentage of abnormal scans went from 40.9% in 1991 to only 8.7% in 2009.[13]

As mentioned earlier, echocardiography utilization has increased. This test is quick, noninvasive, and carries no radiation exposure. Broad utilization of a test that has such prognostic information, such as ejection fraction and pulmonary artery pressure, should have an effect on patient care and survival, but it does not. In a large, randomized, 15-year-long study, there was no difference in survival between the group that received echocardiograms and the control group that received conservative management.[14]

Data indicate that testing and costs are up, testing occurs in a lower-risk population, and testing is resulting in no demonstrable effect on patient outcomes. This brings up the critical question: Why is this happening?

Why Do We Test Too Much?

There are many reasons why the medical community has reached this current state. Next, we will discuss and deconstruct them with the published evidence.

One of the major reasons cited for ordering advanced testing is that it is "diagnostic." Physicians often feel more confident after obtaining testing. This has been examined in an interesting vignette study.[15] Doctors were given two clinical cases — one easy, one difficult — and were asked what their confidence level was at each step of the process from history, physical, general labs and imaging, and then finally after diagnostic testing. Each doctor's accuracy was also assessed. At every point in the study, and with each case (easy and difficult), doctor confidence was much higher than accuracy. Most interestingly, accuracy dropped most after diagnostic testing in the easy case. Furthermore, diagnostic testing did not improve accuracy in the difficult case.

In another article, Kachalia et al surveyed a large group of hospitalists on how they would manage two common clinical conditions routinely seen in the hospital: syncope and preoperative risk assessment.[16] In these two scenarios, the researchers looked at appropriate use of diagnostic testing, such as carotid ultrasound, echocardiography, and stress testing.[16] In preoperative evaluation, they found that testing was appropriate in only 42% of the surveyed hospitalists, which gave an overuse rate of 58%. In syncope, it was worse, with an appropriate use rate of only 17% and an overuse rate of 83%.[16]

The authors also asked why the hospitalists ordered the tests, with three main answers available to the hospitalist on the survey: based on scientific evidence or clinical guidelines, to reassure patient/family, or to reassure themselves. There was an option to answer "other" as well. In the preoperative evaluation group, the hospitalists who used testing appropriately overwhelmingly chose "scientific evidence/clinical guidelines" as their rationale.

In the overuse group, 28% inappropriately ordered testing to reassure the patient/family, and another 23% did so to reassure themselves. The results in the syncope group were similar, and also significant.

Why do doctors need to reassure themselves? There are several reasons.

Table 1. Comparative Radiation Doses[9-11]

Radiation Source	mSv	Chest X-ray Equivalents
TSA backscatter scanner	0.001	0.05
Dental X-ray	0.0025	0.25
Chest X-ray	0.02	1
Mammogram	0.2	10
Head CT	2	100
Annual background radiation	3	150
Abdominal CT	10	500
64-slice CTA	9-15	450-750
Sestamibi perfusion scan	9	450
Thallium perfusion scan	41	2,050
Invasive diagnostic catheter	3	150
Next-generation CTA	1	50

TSA: Transportation Security Administration; CT: computed tomography; CTA: computed tomography angiography

Medical knowledge has grown at an incredible rate. Even with high rejection rates, the sheer volume of new published information in high-quality journals is difficult to keep up with. Physician confidence, while high, may not be as high as it was before. Dr. Milton Packer, an expert in congestive heart failure, summed up this conundrum in an excellent editorial about the use of B-type natriuretic peptide (BNP) in heart failure. He said, "Are physicians monitoring BNP because they really believe the assay provides unique and valuable information? Or do physicians think that heart failure has become so difficult to manage that they no longer trust their own skills and clinical judgement?"[17] People, including physicians, are uncomfortable with uncertainty. The idea of a "definitive" diagnostic test makes them feel better. Unfortunately, no test is 100% accurate, and we as physicians deal mostly with probabilities. This will be discussed in-depth later in the section about Bayes' theorem.

Defensive medicine is another reason given for increased testing, and its impact is estimated at $46 billion a year.[18] In a survey study of a large hospital system, researchers found that 28% of orders were driven by defensive medicine, which comprised 13% of the total costs.[19] The average cost per patient in this study was $1,695, with $226 being defensive. This is understandable since medical error is now the third leading cause of death in the United States[20.] In addition, being sued is rated as one of the worst experiences in a doctor's career. Of all lawsuits brought against doctors, only 3% of doctors were found guilty. The least-sued specialty is psychiatry, which arguably involves the least amount of testing, diagnostic or otherwise, of all specialties.[21]

Tort reform has been touted as a way to reduce unnecessary testing. There are many ways to achieve tort reform, but probably the most studied is damage limits. In a multivariate modeling study of 28 states with damage caps, researchers estimated that limits potentially could save states 3-4% of their healthcare expenditures.[22] A very well-done, recent cardiology study demonstrated reduced invasive testing in states that enacted damage limits. Farmer et al looked at the management of patients with ischemic symptoms among more than 70,000 cardiologists practicing in 18 states.[23] Nine states had newly enacted damage caps and the other nine states did not have caps. The authors looked for changes in test ordering practices; they found a significant drop in initial angiography (23% reduction), less referral for angiography after stress testing (21% decrease), and a 23% reduction in revascularization.[23] There was no difference in initial stress testing between the groups.

As mentioned in the hospitalist survey study discussed earlier, another reason for over-testing is to reassure the patient or families.[23] That study showed a 28% inappropriate test utilization in the hope of making the patient or family happy. This is a concern, not only from a medical-legal standpoint, but also from a patient satisfaction approach. With the linkage of hospital and individual physician payments/reimbursements to patient satisfaction scores, the use of testing to reassure patients and families could become an even greater issue. But does increased testing actually have the desired effect on patients? A systematic review/meta-analysis demonstrated that additional testing was not significantly associated with reduced patient concern about their illness.[24] The researchers found that additional testing was statistically associated with increased patient anxiety. Another strategy would be to talk with patients about the risks and benefits of testing.[25]

Another question is who should be responsible for trying to control costs. A large survey of more than 2,000 physicians revealed some important attitudes.[26] The majority of physicians surveyed believed that lawyers, insurance companies, hospitals, pharmaceutical and device companies, and patients have a "major

responsibility" for reducing health-care costs, but only 36% thought doctors had a similar responsibility.[26] The majority (51%) of surveyed physicians were "very enthusiastic" about "limiting access to expensive treatments with little net benefit," and the vast majority agreed that clinical guidelines should be followed (79%) and that doctors "need to take a more prominent role in limiting use of unnecessary tests" (89%), but only 7% were enthusiastic about "eliminating fee-for-service payment models."[26]

This leads to the final reason for over-testing that needs to be discussed openly. It is the problem of the fee-for-service medical system in which doctors are paid more as they do more, which includes testing. This is a conflict of interest (COI) and is why Stark Laws were passed years ago. It is important for non-cardiologists to know that after the passage of Stark Laws, a modification called the "in office exemption" was also passed. This allowed cardiologists to refer patients to imaging centers for stress testing and echocardiograms even if the cardiologists received financial gain from them. The rationale was that it would improve patient care, since cardiologists would be able to administer and personally interpret the test results on their own patients. COI is not just an issue with cardiovascular testing or procedures, but it cuts across all specialties. The volume of testing and certain procedures directly correlate with rates of reimbursement across the country.[27-29] Although this topic is important, it is beyond the scope of this review. For further reading, see the work of the Dartmouth Atlas Project (www.dartmouthatlas.org/).

Current Steps to Reduce Inappropriate Testing

There have been several initiatives to try and educate and thus reduce the amount of unnecessary testing. The most universal attempt has been the development of clinical care guidelines on how to manage specific clinical conditions. Various societies, from the American College of Cardiology (ACC), American Heart Association (AHA), European Society of Cardiology, American College of Chest Physicians, American College of Physicians, and almost all subspecialty societies, have individually, or jointly published guidelines. Fanaroff et al recently re-reviewed the quality of all 26 current ACC/AHA guidelines.[30] Of the total of 2,930 separate recommendations, only 248 (8.5%) were based on grade A level of evidence.[30] Even with guidelines that had been updated, the quality of supporting evidence did not improve significantly.

Table 2. Appropriate Use Scoring and Nomenclature

Median Score	Initial Grading	Current Grading
1-3	Inappropriate	Rarely appropriate
4-6	Uncertain	May be appropriate
7-9	Appropriate	Appropriate

There are three other initiatives that bear further discussion: the Less Is More series, the Choosing Wisely program, and the growth of appropriate use criteria.

The *JAMA Internal Medicine* journal has introduced a section called "Less Is More."[31] The goal of this repeating series is to highlight better care through more appropriate care, which often means less testing and fewer procedures and treatments. The initial case report of this series recounted a case of a nurse who had non-cardiac chest pain (reproducible chest wall pain with a normal ECG and normal cardiac enzymes) who underwent a CT coronary angiogram (CCTA) of the heart "just to be sure."[32] The CCTA was abnormal and then was followed by an invasive heart catheterization, during which the patient suffered a left main dissection that required emergency bypass surgery. The patient completed her infarct of the anterior-septal wall and became a symptomatic heart failure patient and eventually needed cardiac transplantation. The worst part of this case is that she did not need any tests to begin with and that she did not have any coronary artery disease. This was completely iatrogenic and completely avoidable.

The American Board of Internal Medicine (ABIM), along with *Consumer Reports* and multiple medical societies, have joined together to form the Choosing Wisely initiative. Each society has compiled a list of typically overdone tests, procedures, and treatments by specialty. The groups are asking both doctors and patients to discuss the need to do them. It is hoped that this approach will foster more open discussion about options and form a stronger doctor-patient relationship, leveraging concepts such as the therapeutic alliance and shared decision-making.

Three questions they recommend discussing are as follows:

1. Will the results change what you will recommend for me to do?
2. What do you expect the test results to be? If the results are normal, why have the test?
3. What are the risks of the test itself and future tests/procedures it could lead to?

The major themes across the cardiovascular societies' Choosing Wisely recommendations are:

1. Do not test asymptomatic patients.
2. Do not test patients preoperatively.
3. Do not test low-risk patients.

For more information and recommendations from each specific specialty, please access the Choosing Wisely website (www.choosingwisely.org/).

The major current impetus to provide education and reduce unnecessary testing is appropriate use criteria (AUC or AU). AUC are

Table 3. Samples of Cardiac Test Appropriateness

Test	N	Appropriate	Uncertain	Inappropriate
Academic echo[53]	814	68%	18%	15%
Academic echo[54]	351	86%	2%	11%
Community echo[53]	319	71%	12%	17%
Community echo[55]	368	56%	35% (31% with important findings)	8% (20% with important findings)
CCTA[56]	243	49%	3%	48%
MPI[45]	403	66%	3%	29%
MPI[57]	284	64%	11%	14%
Stress echo[57]	298	64%	9%	18%
Stress echo[58]	477	71%	9%	20%
Cardiac cath[59]	8,986	35%	40%	25% (56% asymptomatic)

different from clinical guidelines in that they start with the end in mind. Guidelines start with the clinical scenario, such as acute myocardial infarction or congestive heart failure, and explain what should be done and why. AUC start with a specific test and ask when it should it be done.

AUC are developed by presenting a group of experts with a clinical scenario that typically is much more detailed than the indications usually used in guidelines.[33,34] It is also clear that not all clinical scenarios can be addressed. Each expert votes on the appropriateness of using a specific test in each scenario and gives it a grade from 1-9, with 1 being completely inappropriate and 9 being completely appropriate. The initial AUC criteria were divided into three sections: appropriate, uncertain, and inappropriate. The updated AUC criteria have changed to a new nomenclature, dividing up the grading into appropriate, may be appropriate, and rarely appropriate. (*See Table 2.*)

There have already been a significant number of articles published on actual AUC rates[35] and their change over time, as several AUC have been updated already. See Table 3 for a sample of appropriateness across multimodality cardiac testing.

Currently there are minimal data to show that AUC criteria work. One interesting article not only tested the impact of AUC, but also monitored that metric.[36] The state of Washington started tracking AUC for percutaneous coronary interventions (PCI) from 2010.[36] Using retroactively obtained data from 2006 to 2010 as a baseline, the researchers found appropriateness increased from 2010 to 2013.[36] The total number of PCIs decreased by 6.8% in those three years, most likely driven by a 43% decrease in elective PCIs.[36] Appropriateness increased from 26% to 38%, while inappropriate PCI decreased from 16% to 13%. Although there was improvement in appropriateness, the overall level was still poor.

Why did this occur? There are probably two mechanisms in effect: the Hawthorne effect and the Dunning-Kruger effect.

The Hawthorne effect, first described in 1953, states that behavior will change if the person knows he or she is being observed.[37] In a recent meta-analysis, researchers found that this effect does occur, but that its magnitude of importance is difficult to determine.[38]

The Dunning-Kruger effect states that people generally believe that they are more competent than they truly are.[39] This was already independently demonstrated in the diagnostic accuracy vignette study described earlier.[15] In their initial studies, which tested grammar, logic, and humor, investigators showed that the people who are most competent typically underestimate their abilities while the least competent typically overestimate their skill level. In fact, the lowest quartile group, which scored at the 12th percentile, rated themselves above average at the 62nd percentile. There is also a "dual burden" in that those who were least competent not only performed poorly in the area tested, but they also did not have the self-awareness to realize this fact. Thus, they did not improve. A final, and very important, finding of the study was that once subjects were aware of their true competence level, they could improve.

Are there data to support that the Dunning-Kruger effect is true and that education about AUC could improve performance? There are. However, before we discuss those studies, a quote from Lewis Thomas, MD, sums up the attitude of most physicians toward the growth in medical knowledge: "There is within

medicine, somewhere beneath the pessimism and discouragement resulting from the disarray of the healthcare system and its stupendous cost, an undercurrent of almost outrageous optimism about what may lie ahead for the treatment of human disease if only we can keep learning."

The Mayo Clinic published the first study on AUC, and also the first study on AUC education.[40] After developing an educational program about MPI AUC, the inappropriate rate dropped from 14.4% to 7.0%. Unfortunately, the inappropriate rate rose back to 11.7% just two years later, probably pointing to the need for repeated education or additional methods of physician support.

Researchers have conducted several educational intervention studies on echocardiogram AUC. Dr. R. Sacha Bhatia has been a leader in this area. In their first study, Bhatia et al showed that an educational intervention not only decreased ordering volume from 56.5 echocardiograms to 38.3 per block,[41] but also increased the degree of appropriate studies from 84% to 93%. The degree of inappropriate studies also decreased from 13% to 5%. In their latest study, the Echo-WISELY trial, the researchers again demonstrated that an educational intervention reduced rarely appropriate studies (current nomenclature) from 10.1% in the control group to 8.8% in the intervention group.[41] In this study, unlike in their previous work, the echocardiogram ordering volume did not change. This study not only included an educational component, but also used a mobile app, and gave a monthly feedback report to each physician in the study, leveraging both the Hawthorne and Dunning-Kruger effects.

Another strategy is to embed a point-of-care decision support tool in the electronic health record (EHR) system. Lin et al demonstrated that over an eight-month period, using a multimodality EHR tool increased the appropriate test rate in MPI, stress echocardiogram, and CCTA from 49% to 61% and decreased inappropriate testing from 22% to 6%.[42] The point-of-care decision support tool took an average of 137 seconds to go through and determine the appropriateness level.[42]

Although computers are ubiquitous in the hospital as a result of the growth of EHRs, another device is even more common and readily available — smartphones. It has been estimated by Ozdalga et al that 72% of U.S. physicians use a smartphone.[43] Franko et al noted an even higher rate of 85% usage among resident physicians.[44] The first published experience using a smartphone for AUC was reported by Mahajan et al. In evaluating appropriate use for MPI, they found that the app only took, on average, 44 seconds.[45] This is significantly shorter than the 137 seconds reported for the EMR-based decision support tool. While there are now multiple AUC smartphone apps, we recommend the multimodality AUC app, which is free.

How to Choose Wisely

Introduction: Moving From Theory to Practice

We have discussed multiple reasons to limit testing, but we also need to discuss how to decide on an appropriate test when one is needed. One of the major reasons that a test is graded as inappropriate is not that a test was unwarranted, but that the specific test ordered was not the best option for that clinical scenario. This problem stems from the multitude of options available to doctors at even the most rural hospital. Each test has specific information that it can reveal, certain benefits, and certain pitfalls or disadvantages. Selecting the best test is confusing even for experienced cardiologists, which is one of the reasons AUC were developed.

Before delving into each cardiac testing option, there are still two theoretical concepts that need to be discussed. One is the concept of the "gold standard" and the other concerns probabilities, still best described by Bayes' theorem.

Most physicians, especially cardiologists, were trained in an era when coronary angiography was considered the gold standard by which all other cardiac testing was judged. This led to a "great schism" in cardiology between those who thought anatomy was superior and those who thought physiology (function) was superior. This typically manifested itself as invasive vs. noninvasive cardiologists.

The first data to show that angiography (anatomy) was not the complete answer was the Glagov phenomena.[46] Dr. Glagov was a pathologist who looked at perfusion-fixed coronary arteries postmortem. What he described is now well-accepted and known as positive and negative remodeling. Coronary arteries that had undergone positive remodeling (dilation) typically required more than 40% diameter stenosis before angiography could detect any stenosis. This demonstrated that coronary artery disease was much more diffuse in nature and highlighted the fact that even invasive angiography could underestimate the severity of disease.

Myocardial perfusion imaging (MPI) was validated initially against the "gold standard" of invasive angiography. Because of artifacts and soft tissue attenuation, many MPI scans turned out to be false-positives after angiography demonstrated no significant blockages. There has been a resurgence of interest in functional assessment that paradoxically has been driven by invasive cardiologists. Fractional flow reserve (FFR) is a flow-mediated technique that is performed in the cardiac catheterization lab and can objectively measure the ability of an artery to increase flow. Arteries, or lesions, that cannot increase flow are deemed significant, and those patients do better with intervention.[47] Conversely, arteries that can augment flow are deemed not significant and no intervention is needed. Withholding intervention has also been shown to improve patient outcomes (less is more). The important fact for this discussion is that FFR was developed and validated against MPI. Angiography was considered superior to MPI, but now FFR is considered superior to simple angiographic grading of lesions but

Figure 1. Bayes' Theorem

- Sensitivity — Screen for disease.
- Specificity — Rule in for disease.
- Both Sensitivity/Specificity are *inherent to the test itself*.

- Positive predictive value (PPV) — % results that are a true positive.
- Negative predictive value (NPV) — % results that are a true negative.
- PPV/NPV depends on the population being tested.

- The HIV ELISA test is 95% sensitive and 90% specific, but how does it perform in low-risk populations? Example below is a population with a 10% disease prevalence.

	Disease present	Disease absent
Test +	95 (tp)	90 (fp)
Test -	5 (fn)	810 (tn)
Totals	100	900

How to calculate each value

- Sens = tp/(tp+fn) = 95%
- Spec = tn/(fp+tn) = 90%
- PPV = tp/(all positives) = 51%
- NPV = tn/(all negatives) = 99%

Even a test with 95% sensitivity and 90% specificity has only a PPV of 51%. Excellent if the test is negative, but not helpful if positive.

is based on MPI leading to a circular pattern of validation. There is *no* gold standard in cardiac testing at this point.

Not only is there no gold standard, there are no guarantees. Significant cardiac lesions are those that are more than 70% of the diameter of a coronary artery on angiography or lesser lesions associated with abnormal FFR ratios or reversible MPI defects. What about normal cardiac testing followed by an acute myocardial infarction (AMI)? This may be due to a false negative test, but this also could happen due to acute plaque rupture. Acute coronary syndrome (ACS) is pathophysiologically distinct from stable coronary artery disease/stable angina. Stable angina occurs with the slowly progressive growth of a coronary lesion until it becomes significant enough to impede forward blood flow. ACS is due to plaque disruption/rupture, platelet aggregation, and rapid increase in stenosis severity, leading to acute symptoms. This was highlighted in several studies demonstrating that the infarct-related artery often was not the most diseased vessel on previous angiography.[48] In fact, about 68% of lesions accounting for ACS were less than 50% blocked on the previous angiogram. Most likely, these lesions all would have been associated with normal perfusion in that territory.

Bayes' theorem was described by the Reverend Thomas Bayes in the 1700s. Many papers explain Bayes' theorem specifically, but several describe it in relation to cardiac testing. Simply put, the likelihood of a test being correct (post-test probability) depends on the prior probability (pre-test probability). Since no test is 100% accurate, concepts such as sensitivity and specificity are used to describe how well a test works. These two measures are inherent to the test itself and correlate well with its accuracy in ruling in or out disease, but this is not how doctors think of testing clinically. Physicians think in terms of positive predictive value (PPV) or negative predictive value (NPV) or likelihood ratios. An excellent reference is the American College of Physicians Journal Club glossary page, which explains all the definitions and gives examples of how to calculate them.[49] Another excellent, and short, tutorial can be found at this reference.[50]

In Figure 1, the classic board exam example of the highly sensitive and specific HIV test is used to demonstrate the low yield of diagnostic tests in low-prevalence populations. In this example, a positive HIV test has only a 51% PPV despite 95% sensitivity and 90% specificity for detecting HIV. Similar levels of test performance hold true for testing low-risk populations with advanced cardiac testing. How accurate a test is depends not only on the test itself, but on the population being tested.

Why Order a Test?

There are many indications to order a cardiac test. Table 4 lists some potential reasons for and best options to order. Because of the numerous and complicated options in cardiac testing, the rest of this article will focus on the evaluation of chest pain and ischemic heart disease.

Two specific groups of patients bear further discussion, and they typically are the most inappropriately tested groups. The first is the asymptomatic or stable patient and the second is the preoperative patient.

Asymptomatic or stable patients do not need routine or serial studies. Since they have no symptoms, most medical therapies or procedures would not make them feel better and would offer mostly risk and little benefit. This is a major focus area of the Choosing Wisely recommendations. This applies not only to patients with no known heart disease, but also to those with known heart disease. The past practice of routine, serial testing of patients with known coronary artery disease or mild valvular disease is discouraged now.

Table 4. Common Indications for Cardiac Testing		
Indication	**Best Test Options**	**Notes**
Asymptomatic	None	Testing not indicated and inappropriate
Non-cardiac chest pain	None	Testing not indicated and inappropriate
Atypical chest pain	Exercise stress test	Try to reproduce symptoms
Detect ischemia	Exercise stress test Second option pharmacologic testing	Should be off blood pressure medications that could mask ischemia
Detect coronary artery disease	CTA	Best used in low-risk patients to rule out significant coronary artery disease and reduce further testing
Therapeutic efficacy	Exercise stress test	Patient should take all medications morning of test
Fatigue, dyspnea	Exercise stress test Echo	Check for both ischemia and chronotropic incompetence, which could be treated with a permanent pacemaker Echo to check for EF, diastolic function, PA pressures
Preoperative risk assessment	None	Testing not indicated and inappropriate
CTA: computed tomography angiography		

Testing should be ordered on these patients only if symptoms occur or if there are changes in the physical exam.

A more complicated situation is the preoperative patient. Many believe stress testing can help assess risk in the preoperative patient. The majority of the risk assessment is done by the history. If the patient is asymptomatic and can do more than 4 metabolic equivalent of task (METs) of work (climb one flight of stairs, walk fast on level ground, climb a hill, do heavy house work), then he or she is low risk. The current AHA/ACC preoperative guidelines state that stress testing low-risk patients is a class III indication, meaning that it is of no benefit.[51]

The test itself involves a small but finite risk, as described in the initial Less Is More case report cited earlier. Delaying surgery also involves risk. If the patient has an abnormal stress test and then undergoes a heart catheterization that demonstrates a significant stenosis, a stent may be placed to treat that lesion. Many would view this as a good outcome, but it is not. If the patient was asymptomatic, then he or she still would not be made to feel better. Depending on the surgical procedure, the operation now may be delayed for 3-12 months until the patient can safely stop dual antiplatelet therapy with agents such as clopidogrel, which could be especially disastrous if it allows cancer to spread.

Finally, preoperative revascularization with stents and bypass surgery has not been shown to affect perioperative complication risk. The CARP trial demonstrated this well in vascular surgery patients.[52] In this study, patients were randomized to medical therapy or preoperative revascularization for vascular surgery. All patients in the study had significant CAD. Revascularization only delayed surgery. At the end, there was no difference in cardiovascular outcomes between the groups.

Summary

With the development of more cardiovascular tests, clinicians are constantly faced with more and more options to choose from. As a result, there has been enormous growth in the number of tests that are ordered in an inappropriate manner. Recently, there have been a number of attempts to provide education and reduce the amount of unnecessary testing, including the Choosing Wisely initiative. When considering whether to order a cardiovascular test, clinicians should ask themselves three straightforward questions. First, will the results of the study change the management? Second, if the test is positive, what is the next step/test? Third, what are the risks of the test I am ordering and future tests/procedures that it could lead to?

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1. Which of the following statements regarding radiation exposure and chest X-ray equivalents is true?
   a. A thallium perfusion scan exposes the patient to about 1 mSv or 50 chest X-ray equivalents.
   b. An invasive diagnostic cardiac catheterization exposes the patient to about 3 mSv or 150 chest X-ray equivalents.
   c. An abdominal CT scan exposes the patient to about 41 mSv or 2,050 chest X-ray equivalents.
   d. Annual background radiation exposure is about 1 mSv or 50 chest X-ray equivalents.

2. Which of the following statements best describes the Hawthorne effect?
   a. People believe that they are more competent than they truly are.
   b. People who have lower expectations placed upon them have poorer performance.
   c. People will change their behavior if they know that they are being observed.
   d. People tend to make judgments/decisions based on how easily an example of a previous case comes to mind.

3. Which of the following conclusions can be drawn from the results of the CARP trial?
   a. Coronary-artery revascularization before elective vascular surgery does not significantly alter the long-term outcome.
   b. Coronary-artery revascularization before elective vascular surgery improves outcomes of the elective surgeries.
   c. Screening for myocardial ischemia with preoperative stress testing reduces the risk of major adverse cardiac events during elective surgery.
   d. Preoperative cardiac interventions reduce the risk of major adverse cardiac events during elective surgery.

4. Which of following initiatives to reduce the amount of unnecessary testing states 1) do not test asymptomatic patients; 2) do not test patients preoperatively; and 3) do not test low-risk patients?
   a. Less Is More series
   b. Choosing Wisely initiative
   c. The THINK initiative
   d. Appropriate use criteria

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