J of Nuclear Medicine Technology, first published online April 10, 2020 as doi:10.2967/jnmt.120.244525

The Importance of Measurement for Quality Improvement:

Submaximal Cardiac Stress Testing

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Disclosure: Ms. Farrell received no funding for this research. Ms. Farrell is an employee of the Intersocietal Accreditation Commission.

Brief Title: Submaximal Stress Testing QI Measurement

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Abstract

One of the most effective techniques to improve quality is to measure quality. The aim of this article is to defend the importance of quality measurement in nuclear medicine utilizing the long-standing problem of submaximal exercise stress testing. Numerous evidence-based guidelines and research studies establish the importance of maximal stress testing for myocardial perfusion imaging. The three cutoff thresholds that indicate adequate cardiac stress that must all be met include expenditure of five metabolic equivalents (METs) of energy, production of symptoms (e.g., fatigue or shortness of breath), and attainment of 85 percent of the maximum predicted heart rate. Measurement and evaluation of these three criteria along with several other metrics can help to validate one aspect of laboratory quality related to myocardial perfusion imaging accuracy.

Key Words: exercise stress testing, submaximal stress, quality improvement, measurement, guideline adherence

The Institute of Medicine defines quality as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge".*(1)* Key to this definition is a comprehensive understanding of two phrases: 'health outcomes' and 'consistent with professional knowledge.' Health outcomes, otherwise referred to as patient outcomes, as defined by the World Health Organization (WHO) is "a change in the health of an individual, group of people, or population that is attributable to an intervention or series of interventions".*(2)* Professional knowledge, otherwise referred to as evidence-based medicine is the careful, precise, judicious, and sensible use of current knowledge and evidence when making decisions regarding the care of a patient.*(3)* It is important to note that evidence-based medicine skillfully combines a physician's clinical experience and expertise with a patient's desires and value using the soundest information available.

One of the most effective ways to improve health outcomes is through the application of professional, evidence-based guidelines.*(4)* Evidenced-based imaging guidelines provide concise instructions on how to perform a procedure; consequently, ensuring standardization and improving quality.*(5)* However, the question arises, "How do you know you are improving quality?" One way to assess quality and safeguard improvement is through measurement. Laboratories must select appropriate metrics and apply the correct knowledge base to improve quality.

The aim of this article is to defend the importance of measurement in improving quality. This article will describe a long-standing quality issue in nuclear cardiology that is recently getting renewed attention: submaximal stress testing. The paper will describe that problem, explain the evidence-based guidelines related to the problem, and suggest metrics to quantify and correct the problem.

Importance of Measuring Quality

There is a plethora of axioms and reasons to support the importance of measurement in improving quality. Peter Drucker, a pioneer in quality, stated, "you can't manage what you can't measure".*(6)* By this Drucker meant you cannot determine if you are successful unless you first define success and track it. When success is bound by a metric, progress can be quantified, and actions can be adjusted to produce the desired outcome. A quote by H. James Harrington, another quality guru is more prescriptive than Drucker. Harrington stated, "Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it".*(7)*

One practical reason for measuring is that it increases confidence in decision-making.*(8)* For example, baseball coaches use players batting averages to determine where to put them in the line-up. Measurement helps an individual to know what is going on or the status of things. Teachers use the results of tests to assess how well a student comprehends the material. Measurement monitors or keeps tabs and is an indicator of change – whether change is an improvement or deterioration. If decline is noted, measurements highlight the need for improvement. Metrics provide a framework to keep people focused on what is most important. It allows them to set goals and then evaluate progress.

Through measurement, a view of the entire system can be obtained, providing a more comprehensive understanding of system function as opposed to anecdotal occurrences. Systematic assessments as opposed to haphazard, random efforts to evaluate and enhance quality produce better long-term results.*(9)* Deliberate data collection and analyses produce more consequential system transformation than does knee-jerk reactions and policing actions. By evaluating systems, long-term "cures" are obtainable as opposed to just treating the system's "symptoms."

Perhaps the most definitive reason for measuring quality in healthcare is provided by the Agency for Healthcare Research and Quality (AHRQ). In its 2012 National Health Care Quality Report, the AHRQ noted, "patients receive the proper diagnosis and care only about 55 percent of the time".*(10)* Although this figure represents the continuum of patients and diagnoses, it is apposite for diagnostic medicine because clinicians derive most diagnoses based on the results of an imaging procedure or clinical laboratory test.

Quality in Advanced Diagnostic Imaging

Hendee et al. estimate that between 20 to 50 percent of advanced diagnostic imaging tests (i.e., nuclear medicine, computed tomography, and magnetic resonance imaging) do not provide results improving patient outcomes.*(11)* There are many reasons why a diagnostic imaging test may fail to provide meaningful information. For example, the referring physician may not have ordered the correct scan to answer the clinical question. Referring physicians must order the most appropriate test from the profusion of available imaging options with new tests and clinical indications continually emerging. Suboptimal imaging findings can occur if the patient was not adequately prepared for the test or the test is performed incorrectly. For example, if a patient does not fast before a cardiac positron emission tomography scan, the heart will fail to accumulate the radiotracer and the images will be poor quality.*(12)*

One diagnostic accuracy problem in nuclear cardiology has received recent public attention. A study published in *JACC: Cardiovascular Imaging* and picked up by the media in

April 2019 found considerable variation in the performance of stress testing at Veteran's Administration hospitals.*(13)* At issue, was the diagnostic accuracy of myocardial perfusion imaging due to submaximal cardiac stress testing.

Submaximal Stress Testing Problem and Evidence-Based Guidelines

The goal of stress myocardial perfusion imaging is to provoke myocardial ischemia (decreased blood flow) to a region of the heart at risk of infarction. In essence, the objective is to diagnose coronary artery disease by comparing the blood flow to the heart muscle during stress and resting conditions using radioactive tracers and nuclear medicine scanners.*(14)* For the test to be accurate, the patient must adequately exert themselves during an exercise treadmill test to produce ischemia. If the patient is unable to exercise to sufficient levels, the test can be performed using pharmacologic agents to simulate exercise. The problem at hand is that in many nuclear cardiology stress laboratories, the radioactive tracer is being injected too soon or before the patient has reached their ischemic threshold. Bluntly stated, many facilities inject the moment the patient reaches 85 percent of the maximum predicted heart rate. The result is a false negative test – meaning the imaging results do not show ischemia incorrectly indicating the patient's coronary arteries are healthy when in fact they may contain a blockage. Without an adequate cardiac stress test, there is no way to determine if the patient is or is not at risk of infarction.

A substantial number of clinical research studies have evaluated and determined an adequate level of exercise in most adults to produce ischemia. There are three cutoff thresholds that the patient must meet that indicate adequate cardiac stress: the patient must exercise to expend five metabolic equivalents (METs) of energy (a workload of about 6 minutes on the standard treadmill Bruce protocol indicating moderate exercise suffient to provoke ischemia); the patient must reach higher than 85 percent of the maximum predicted heart rate (MPHR) based on age (MPHR = 220 – age); and the patient must have symptoms such as fatigue, shortness of breath, chest pain, or electrocardiogram changes indicative of ischemia.*(15,16)* Basically, the patient must be markedly fatigued. The published evidence-based, clinical guidelines from various imaging professional societies mandate these three exercise requirements or the patient should undergo a pharmacological stress test.

Submaximal Stress Quality Improvement Activity

To assess current laboratory adherence to the evidence-based guidelines for stress myocardial perfusion imaging and set baseline levels, the following metrics are suggested: patient identification number, gender, age, maximum predicted heart rate, exercise protocol, METs achieved, total exercise time, peak heart rate, peak systolic blood pressure, rate pressure product, patient symptoms, whether the patient performed maximal stress exertion, whether the study was abandoned and a pharmacologic stress test performed, electrocardiogram findings, and myocardial perfusion imaging findings (FIGURE 1).

Metrics Rationale

The most critical metrics from the list above are the peak heart rate achieved, METs achieved, whether the patient had symptoms, whether the patient was markedly fatigued (maximal stress), and exercise time. These five metrics are essential. The other metrics provide a quality check. The reason these metrics are needed is that a patient could exercise less than 2 minutes and because of severe deconditioning or obesity achieve greater than 85 percent of the maximum predicted heart rate. The imaging would result in a false negative test in this situation because less than two minutes of exercise is not sufficient time to provoke maximal coronary artery dilation. METs achieved and heart rate are also important metrics considered together because an athlete could exercise for 6 minutes and achieve 5 METs, but because of conditioning, the patient's heart rate may be significantly less than 85 percent of the maximum predicted heart rate, and thus the coronary arteries may not be maximally dilated. Similarly, a patient could walk less than two minutes, exert less than 5 METs and have crushing chest pain but still not have maximal coronary artery dilation. The concern with this scenario is that if the patient had chest pain, it could be indicative of coronary artery disease, but because the patient did not exercise long enough, the images are may not be abnormal.

Several of the other metrics are germane to improving quality, the first whether the patient was converted to a pharmacologic stress test if the three conditions were not met. Remember, if the three conditions are not met, there is an increased likelihood of false-negative results. Meaning the patient is told they are disease-free when in fact, they may have blockages in their coronary arteries increasing the likelihood of future myocardial infarction. Relatedly another important quality metric is the results of the imaging test; whether the scan results were normal or abnormal. If the laboratory truly wants to improve quality, they should also compare the imaging results to a gold standard such as cardiac catheterization.*(17)* Comparison to a gold standard or correlation is a measure of the number of false positives, false, negatives, true positives, and true negatives, or in other words, the accuracy of the test.

Metric Goals

There are two goals associated with the collection of data from these metrics. First, a laboratory can determine the level of accuracy associated with myocardial perfusion imaging. As mentioned previously, 20-50 percent of patients undergoing advanced diagnostic imaging do not receive results or information improving outcomes. Only through accurate results can patient outcomes hope to be improved. One of the ways to improve the accuracy of a test is through proper performance. Thus, adherence to evidence-based procedure guidelines is a method for enhancing performance. The second goal of these metrics is to establish the degree of laboratory adherence to the clinical guidelines.

Conclusion

The Institute of Medicine's definition of quality emphasizes patient outcomes through the application of evidence-based knowledge. There are several evidence-based imaging guidelines for the performance of stress myocardial perfusion imaging. These guidelines provide concise instructions on how to perform the test to obtain the highest level of accuracy. However, a laboratory cannot just assume tests are being performed correctly, nor can they assume tests comply with the guidelines. The only way to ensure these things, and thereby improve quality, is through measurement.

This paper provided a rationale for measuring the quality of cardiac exercise stress testing associated with myocardial perfusion imaging. At issue is the performance of maximal exercise to achieve accurate imaging results. Three conditions must be met to substantiate a maximal exercise test. The patient must exercise to a level of five METs or approximately six minutes on the treadmill. The patient must reach higher than 85 percent of the maximum predicted heart rate, and the patient must be symptomatic. These three conditions were suggested along with several other exercise attributes as practical metrics to ascertain quality. From the measurement of these metrics, adherence to evidence-based guidelines and accuracy of the cardiac stress test for myocardial perfusion imaging can be demonstrated. Affirming the words of H. James Harrington, measurement of exercise stress testing adequacy furthers understanding. Understanding the current performance of stress testing can assist a laboratory in controlling performance, and by controlling performance, a laboratory can facilitate improvement.

Financial Disclosure: The author received no funding for this continuing education article. The author is an employee of the Intersocietal Accreditation Commission.

Disclaimer: None

Acknowledgement: None

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Figure 1. Sample Submaximal Stress Testing Data Collection Form.

Submaximal Stress Test Data Collection

Patient	Sex M/F	Age (Yrs)	MPHR (220 - Age)	Exercise Protocol	METs Achieved	Total Exercise Time (XX:XX)	Peak HR (bpm)	Peak Systolic BP (mm Hg)	Rate Pressure Product (>25,000)	% MPHR	Patient Symptoms	Patient Performed Maximal Stress Y/N	Study Converted to Pharm Stress	ECG Findings (Horizontal or downsloping ST-segment depression ≥ 1 mm)	MPI Findings (Normal/ Abnormal)
1	F	50	170	Bruce	12.0	10:30	150	186	27900	88%	Fatigue	Y	N	Normal	Normal
2	M	70	150	Modified Na	11.0	10:00	120	110	13200	80%	Fatigue	Y	Y	Normal	Abnormal
3	F	55	165	Bruce	5.0	4:30	160	166	26560	97%	None	N	N	Normal	Normal
4	M	40	180	Bruce	7.0	5:55	153	158	24174	85%	Chest Pain	Y	N	Abnormal	Abnormal
5	F	67	153	Bruce	4.5	3:45	130	198	25740	85%	None	N	N	Normal	Normal
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Results

% of Patients Not Reaching 85% -	20%	% of Submaximal	40%

Figure 1. A sample data collection form with the critical metrics to ascertain the adequacy of cardiac stress testing prior to myocardial perfusion imaging. The most critical variables are percentage of the maximum predicted heart rate, metabolic equivalents (METs) achieved, and patient symptoms.