CE

Guidelines and Implications for Selecting Preoperative Cardiac Stress Tests

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ABSTRACT

Nurse practitioners frequently manage patients who have cardiac risks and need further evaluation before their elective surgery. Cardiac stress testing can provide important needed data. Cardiac stress testing includes exercise treadmill testing; echocardiography, with exercise or pharmacologically; myocardial perfusion stress testing; and magnetic resonance angiography. Although a number of factors need to be considered, including prior cardiovascular history and type of surgical risk, a nurse practitioner's selection of the appropriate cardiac stress test needs to include the benefit-risk ratio and the level of evidence supporting the clinical decision-making process.

Keywords: cardiac stress testing, level of evidence, NP, preoperative testing

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Managing patients' peri- and postoperative cardiac risks begins in the preoperative setting. Common risk factors that reflect a potential increased risk of developing cardiac complications include the age of the patient, the patient's functional status, abnormal creatinine levels, and type of surgery.[1] Procedures such as endoscopy and ambulatory surgery are considered low-risk surgical procedures, and have a < 1% risk of a cardiac event. Additional cardiac testing is typically not recommended these interventions.[2] For procedures considered intermediate risk, such as abdominal, orthopedic, and prostate surgeries, the risk of a cardiac event perioperatively is < 1.5%.[3] However, the overall surgical risk increases if the patient has additional signs or symptoms of coronary artery disease (CAD), unstable angina, hypertension, a recent myocardial infarction, or a history of dysrhythmias.[3] In comparison, patients undergoing major procedures, such as peripheral vascular, aortic, or major vascular surgery, the risk of a perioperative cardiac event increases to 5%.[3] This group of patients may also require additional cardiac testing if there is a prior cardiac history.[3]

This CE learning activity is designed to augment the knowledge, skills, and attitudes of nurse practitioners and assist in their understanding of how to choose the most appropriate preoperative cardiac stress test.

At the conclusion of this activity, the participant will be able to:

A. Describe differences between exercise stress testing, pharmacological stress testing, and myocardial perfusion studies
B. Discuss significant history and physical exam data that impact the selection of each type of cardiac stress test
C. Apply the significant data provided in the case study to determine which stress test is most appropriate

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To determine whether a patient has an increased risk for a peri- or postoperative event, current guidelines recommend a preoperative assessment aimed at identifying signs and symptoms of CAD, unstable angina, a previous myocardial infarction, hypertension, history of dysrhythmias, and the patient's activity tolerance.[1] Although there are a number of tools used to estimate perioperative cardiac risk, one validated tool is the Revised Cardiac Risk Index (RCRI).[1] The RCRI predicts the rate of cardiac death or myocardial infarction based on the presence of 6 possible variables. These variables include type of surgery, preoperative serum creatinine $>$ 2.0 mg/dL, history of ischemic heart disease, heart failure, cerebrovascular disease, and diabetes requiring insulin. For example, if a patient has 1 of these 6 variables, the risk of a significant event is 1.0%. If they have 2 of these variables, the risk of a significant event is 2.4%. If a patient has $\geq$ 3 of these variables, their risk of a significant event is 5.4%.[1]

Other important assessment findings that need to be included are the presence of aortic stenosis, or a history of an aortic aneurysm, carotid disease, or chronic obstructive pulmonary disease (COPD). In addition, for individuals $>$ 55 years old, signs or symptoms of cerebrovascular disease and diabetes should be assessed, as these 2 factors alone increase the overall risk of a major adverse cardiac event to $>$ 1%.[4] Research also shows that individuals who cannot walk 2-3 mph, or who cannot expend an equivalent of at least 4 metabolic equivalents of energy, or what is referred to as METs (with 1 MET being the energy expended while at rest), are at risk for both perioperative events and long-term postoperative risks.[4] For individuals in all of these situations the issue becomes determining which stress test would provide the best data for evaluating the patient's cardiac status.

THE GOAL OF STRESS TESTING

The goal of performing a stress test is to determine whether myocardial ischemia can be identified when the oxygen demand is increased. Hence, stress testing becomes a way to evaluate the fundamental issue of oxygen supply versus oxygen demand. Myocardial ischemia may present as chest pain or angina, or it may become apparent on a 12-lead electrocardiogram (ECG) as ST segment changes. A number of stress tests can identify areas of ischemia as reversible lesions. These lesions become apparent when the myocardium is stressed, and they signal an increase in a patient's perioperative risk of having a myocardial infarction. Fixed, or nonreversible, lesions can also be identified. They are present both at rest and with stress, and fixed lesions represent areas of scarring or a previous infarction. After identification of reversible and fixed lesions, consultation with a cardiologist can help determine the potential need for cardiac interventions, such as placement of a stent, before a scheduled surgery can proceed.

LEVELS OF EVIDENCE

Guidelines from the American College of Cardiology/American Heart Association adopted a tool that facilitates applying evidence-based research findings to the actual clinical decisionmaking, and these can guide a nurse practitioner's (NP's) decision about which stress test is most appropriate. A common tool used in making these decisions is the Classification of Recommendation and Level of Evidence Guidelines.[4] This tool combines the benefit-risk ratio with levels of researchable evidence. Using this tool as a guide, a Class I recommendation indicates that the benefits strongly outweigh the risks of a procedure, and the procedure *should be done*. A Class IIa recommendation indicates that the benefits outweigh the risks, and it is *reasonable* to do the procedure. In comparison, a Class IIb recommendation indicates that the procedure may be *considered*, but the benefits are not viewed as strongly as for Class IIa. The last class is Class III, which indicates the procedure is considered either *harmful or of no benefit*. When pairing the benefit-risk classifications with the level of evidence, it is important to note that there are 3 tiers of evidence. Level of Evidence A is derived from multiple, randomized studies or meta-analyses. Level of Evidence B is derived from a single, randomized study or from a number of nonrandomized studies. Level of Evidence C is derived from consensus or case studies.[4]

TYPES OF STRESS TESTING

To determine which stress test would provide the most appropriate data, one needs to consider the different types of cardiac stress tests available and incorporate the patient's history along with the Classification of Recommendation and Level of Evidence into the decisionmaking process. Diagnostic cardiac stress testing can be divided into 3 broad classifications: exercise stress testing; pharmacologic stress testing; and radionuclide imaging studies. It is important for the NP to understand the advantages and disadvantages of each type of stress test, as well as the research that supports the use of each test, to determine which is most appropriate.

EXERCISE STRESS TESTING

Exercise Treadmill Test

The simplest stress test is an exercise treadmill in which the patient walks or runs on a treadmill, with heart rate, blood pressure, and ECG monitored before, during, and after the test. It is considered the simplest stress test because it relies on the patient's own exercise capacity to elicit signs or symptoms of ischemia. To provide the stress component, both the speed and the incline of the treadmill are increased at specific intervals as the test progresses. The Bruce protocol is an example of a protocol often used in which both the speed and the incline of the treadmill are increased every 3 minutes to increase the patient's heart rate.[3]

Because the goal of an exercise stress test is to elicit any ECG changes associated with ischemia, the patient's heart rate needs to reach 85% of a predetermined age-related heart rate.[5] The formula for age-related heart rate is 220 minus the patient's age. With an exercise stress test, the patient needs to be able to exercise to the point of achieving 85% of the calculated age-predicted target heart rate (APTHR).[6] Although physical limitations and deconditioning may prevent a patient from being a candidate for an exercise stress test, medications that restrict the heart rate may also interfere with the test. Both beta-blockers and calcium channel blockers are examples of medications that can restrict heart rate, and they should be withheld 24-48 hours prior to an exercise stress test.[5] Digitalis also interferes with exercise stress testing by producing ST segment changes that mimic ischemia, thus making the results invalid.[4]

Ideally, with an exercise stress test, the patient should be able to exercise to their APTHR and not experience any angina or have any ECG changes, and blood pressure should elevate with exercise. The test is considered abnormal if: (1) any new ST segment depression develops in any contiguous lead or leads viewing the same areas of the heart; (2) any sustained ventricular dysrhythmia develops; or (3) blood pressure fails to elevate with exercise. If a patient's heart rate fails to rise with exercise, it is called "chronotropic incompetence," which is considered an abnormal physiologic response.[6]

Because a patient's exercise capacity is the strongest predictor of ischemic heart disease, an exercise treadmill test is preferred for individuals who can exercise and achieve the predicted target heart rate.[6] For patients who can exercise and have an intermediate probability of CAD (eg, those with hypertension or left ventricular hypertrophy), an exercise stress test would be a Class I recommendation (see Table).[6] However, according to Fihn et al, an individual may have 70% stenosis of a coronary artery without ischemia being detected with an exercise treadmill test.[6] This correlates with an exercise treadmill stress test of having a sensitivity of 61% and a specificity of 70% to 77% with respect to identifying areas of ischemia associated with CAD.[5] Hence, patients with mild CAD may have a normal exercise treadmill test but still have underlying areas of potential ischemia.

One further tool that can be used to evaluate the outcome of an exercise treadmill test is the Duke treadmill score (DTS). This is a derived formula that incorporates: (1) the number of minutes the patient has exercised multiplied by (2) the magnitude of any change in the ST segment in terms of millimeters (3) minus an angina score, which is recorded as "0" for no angina, "1" for nontesting limiting angina, and "2" for exercise-limiting angina.[6] A DTS of ≥ 5 is considered a low-risk outcome, with an annual mortality rate of 0.25%. A DTS between 4 and -10 is an intermediate outcome, with an annual mortality rate of 1.25%. A DTS of < -10 is a high-risk score and represents an annual mortality rate of $> 5\%$.[6]

Table. Cardiac Stress Testing and Classification of Recommendations and Level of Evidence[4,6]

Cardiac Stress Test	Probability of CAD	Class	Level of Evidence
Exercise stress test	Moderate exercise capacity (> 4 METs), no disabling comorbidities, an interpretable 12-lead ECG, and intermediate pretest probability CAD	Class I (benefit >>> risk)	A
Exercise stress with myocardial perfusion study	Intermediate to high pretest probability of CAD, uninterpretable 12-lead ECG, at least moderate physical exercise capacity (> 4 METs), and no disabling comorbidities	Class I (benefit >>> risk)	B
Pharmacologic stress test with myocardial perfusion study	Intermediate to high pretest probability of *obstructive* CAD (angina), uninterpretable 12-lead ECG, at least moderate physical exercise capacity (> 4 METs), and no disabling comorbidities	Class IIa (benefit >> risk)	B
Pharmacologic stress with either echocardiography or myocardial perfusion study	Patient cannot exercise, or has a comorbidity and intermediate to high pretest probability of CAD	Class IIa (benefit >> risk)	B
Pharmacologic stress echocardiography	Patient cannot exercise or has a comorbidity that inhibits exercise but has a low pretest probability of CAD	Class IIa (benefit >> risk)	B
Stress echocardiography	Patient is asymptomatic with low probability of CAD	Class III (no benefit)	C except for preoperative testing[5]
Pharmacological stress with myocardial imaging	Advanced cardiac assessment is needed, although patient is asymptomatic, but has diabetes or strong family history	Class IIb (benefit > risk)	C
Pharmacologic stress with myocardial imaging	Asymptomatic and with low or intermediate risk for CAD	Class III (no benefit)	C
MRA	Left main or LAD disease	Class I	A

CAD = coronary artery disease; ECG = electrocardiogram; LAD = left anterior descending; MET = metabolic equivalent; MRA = magnetic resonance angiography.

Using both actual physiologic data as well as the DTS can help determine the future risk of a cardiac event.

Exercise Stress Echocardiogram

If additional data are needed related to the function of the left ventricle, as well as the presence of any ischemia, an exercise stress echocardiogram is appropriate. This combines data from the echocardiogram related to systolic and diastolic ventricular function and the ejection fraction, as well as wall motion abnormalities that reflect areas of ischemia during exercise. These changes often can be detected before a patient is symptomatic or before ischemic changes appear on a 12-lead ECG.[7] Either a treadmill or a bicycle can be used to provide the stress component, but the patient's heart rate must be at the 85% target level while the actual echocardiogram is done. Thus, the patient needs to increase their heart rate to 20-25 beats/min above the 85% of target range to account for the drop in their heart rate as they stop exercising and prepare for the echocardiogram. For some individuals, increasing their heart rate by 20-25 beats may be physiologically difficult, making this form of stress testing inappropriate. However, if the patient can exercise and achieve a heart rate of > 85% of the APTHR, an exercise stress echocardiogram can provide earlier diagnostic data about areas of ischemia when

compared with a standard exercise treadmill test. However, it is important for the NP to remember that an exercise stress echocardiogram still can have false positives and false negatives with respect to identifying CAD, as it has a sensitivity of 70% to 85% and a specificity of 77% to 89%.[5] In addition, although an exercise stress echocardiogram is considered a Class III C recommendation for patients who are asymptomatic and have a low probability of CAD, it is still a preoperative testing recommendation for patients about to undergo an intermediate- or high-risk surgical procedure.[6]

PHARMACOLOGIC STRESS TESTS

Dobutamine Stress Echocardiogram

When physical exercise is not possible, a dobutamine stress echocardiogram can be ordered. Dobutamine, a positive inotrope, pharmacologically increases both the heart rate and contractility to elicit areas of ischemia or wall motion abnormalities. Specifically, a dobutamine stress echocardiogram can document differences in wall motion when the heart rate increases versus when the myocardium is at rest. This identifies both areas of reversible ischemia as well as fixed lesions. Compared with the exercise echocardiogram, the dobutamine stress echocardiogram has a higher sensitivity and specificity (85% to 90% sensitivity, 79% to 90% specificity) in terms of identifying areas of ischemia.[5] According to the 2014 American College of Cardiology/American Heart Association guidelines, dobutamine stress echocardiography is considered an appropriate part of a preoperative evaluation for patients who have CAD risk factors, such as hypertension, an abdominal aortic aneurysm, or peripheral vascular disease, and it is considered a Class IIa B recommendation (see Table).[4,6]

Other Pharmacologic Stress Echocardiogram

Based on the physiologic principle that coronary arteries should dilate when metabolic demand is increased, a pharmacologic stress echocardiogram also may be done with dipyridamole, adenosine, or regadenoson, which are vasodilators.[7] Physiologically a vasodilator can elicit "coronary steal" by vasodilating normal coronary arteries and "stealing" blood flow away from stenotic arteries that can no longer vasodilate. This type of pharmacologic stress echocardiogram then documents the function of the heart as the vasodilator is initially injected and again 3-4 hours later. By comparing areas within the myocardium during and after injection of a vasodilator, both reversible and fixed lesions can be identified. As indicated in the Table, this is considered a Class IIa B recommendation.[4,6,7]

Because of the risk of adverse side effects associated with either dobutamine or a vasodilator, pharmacologic stress echocardiograms are contraindicated for patients with severe obstructive lung disease or high antrioventricular blocks.[4,7] Also, both echocardiogram types are inappropriate for patients with unstable angina, severe hypertension, severe aortic stenosis, poorly controlled arrhythmias, or decompensated heart failure, due to potential side effects.[7] In addition, specifically for a vasodilator stress echocardiogram, the patient needs to be instructed to abstain from caffeine for at least 12 hours prior to the study, as caffeine can inhibit the anticipated pharmacologic vasodilation.[3]

MYOCARDIAL PERFUSION STUDY

Another option with respect to stress testing is radionuclide imaging, or myocardial perfusion studies. Although there are a number of protocols that guide the specific type of perfusion study, the purpose is to identify areas of ischemia or previous infarction. The studies can be done in combination with exercise as the stressor or with a pharmacologically induced stressor. Either adenosine, dipyridamole, or regadenoson can be used as a vasodilator to pharmacologically induce stress, or dobutamine can be used if the patient cannot tolerate a vasodilator.[8] Then, a radionuclide, such as technetium-99m or rubidium-82, is used to identify areas of ischemia or infarction in conjunction with the either a pharmacologic stressor or exercise. Specifically, once either the target heart rate is reached or the vasodilator is injected, the radionuclide is injected intravenously. The difference in the uptake of the radionuclide is then detected either by single-photon emission computerized tomography (SPECT) or positron emission tomography.[8] As with the other forms of stress testing, a myocardial perfusion study can document areas of ischemia or a previous infarction.

Normal or viable myocardium will have a normal uptake of radiotracer and a rapid "wash-out" time.[8] Areas of ischemia or reversible lesions will have a slow uptake of tracer, as well as a prolonged wash-out time. An infarcted region will not take up the tracer either at rest or during stress. Radionuclide imaging can also document areas that have a partially reversible lesion and predict perioperative ischemia.[4] These regions are slow to take up the tracer and also have a prolonged wash-out time, but they also have areas where no tracer is detected. These areas reflect a combination of ischemic tissue, as well as infarcted myocardium.[7] For a myocardial perfusion study to be able to identify any ischemia, there needs to be $\geq$ 50% stenosis of any given coronary artery.[7]

Myocardial perfusion studies are considered appropriate for evaluating the risk of ischemia for patients undergoing noncardiac surgery, especially if the patient has suspected CAD or an exercise capacity of $<$ 4 METs. As the Table indicates, myocardial perfusion is a Class IIa B recommendation.[3,4,6,9] However, if a patient is asymptomatic and has a low risk for CAD, it is considered a Class III C recommendation (no benefit), unless the patient has either diabetes or a strong family history of CAD—then it becomes a Class IIb C recommendation.

In comparison to other forms of stress testing, myocardial perfusion studies that combine adenosine, regadenoson, or dipyridamole with SPECT imaging have a sensitivity and specificity of between 80% and 90% for detecting myocardial ischemia.[8] Also, because of the availability of SPECT tomography, SPECT studies are more common than positron emission tomography perfusion studies. However, although a myocardial perfusion study will provide more information about areas of ischemia, it is important for NPs to consider the risk-benefit ratio associated with radioactive tracers.[3,4,9] Greenland et al recommended use of myocardial perfusion studies in older patients rather than in younger patients, in order to minimize the risk of long-term negative consequences of radiation exposure.[6] However, a myocardial perfusion study is considered appropriate for obese patients, even if they are young, because a stress echocardiogram may not be sensitive enough to detect wall motion abnormalities due to distribution of adipose tissue.[4]

MAGNETIC RESONANCE ANGIOGRAPHY

Another noninvasive imaging procedure that may be used to assess a patient's cardiac status preoperatively is magnetic resonance angiography (MRA). MRA can provide excellent anatomic details about the heart and about the viability of the myocardium, given that it is reported to have 91% sensitivity and 81% specificity for identifying areas of ischemia.[9] However, because MRA involves injection of gadolinium to identify normal myocardium from infarcted areas, it is contraindicated in patients with chronic kidney disease who have a glomerular filtration rate of $<$ 30 mL/min.[9] Other issues to consider with an MRA include whether a patient has any type of metal device or a pacemaker as well as the cost of the study. MRAs are expensive, and patients who have any metal device implanted are not candidates for this type of imaging. However, if the patient does not have chronic kidney disease or an implanted metal device, and it is suspected that they have a lesion in the left main coronary artery or the left anterior descending artery, MRA is considered a Class I A recommendation (see Table).[4,6]

APPLICATION: THE CASE SCENARIO

A common scenario encountered by NPs is as follows: A 55-year-old, insulin-dependent, diabetic man presents for a total knee arthroplasty. His history notes that he has poorly controlled hypertension, left bundle branch block (LBBB), a history of severe COPD, and a poor exercise tolerance. The patient is scheduled for an intermediate-level surgical procedure, but the RCRI indicates a risk course of 1.0% based on his need for insulin, and the history supports the need for additional cardiac testing. The NP must determine which type of stress testing is most appropriate.

Applying both the types of stress testing available in conjunction with the benefit-risk ratios and the level of evidence, the NP needs to integrate the science and the research supporting stress testing along with the patient's history data into the decision making process. This case scenario highlights a complex patient who needs cardiac stress testing. Because of the patient's limited exercise capacity given the need for knee surgery, and because of his history of LBBB, which makes identifying ischemia

on a 12-lead ECG difficult, both an exercise treadmill test and an exercise stress echocardiogram would be inappropriate options for this patient. Combining the likelihood of having CAD with a history of severe COPD, both a dobutamine stress echocardiogram and a pharmacologic stress echocardiogram would also be poor options for this patient, because the medications used for both tests are contraindicated for patients with COPD.[4] The most appropriate diagnostic test for this patient then becomes a pharmacologic myocardial perfusion study. This would represent a Class IIb B recommendation, with the goal of appropriately identifying potential areas of ischemia as well as any previous infarctions.

CONCLUSION

There are a number of forms of stress testing available for the NP to consider in the preoperative setting to better assess a patient's cardiac status. Although there are guidelines that indicate the benefit-risk ratio, the NP first needs to obtain the appropriate baseline history to determine which stress test is most appropriate. Frequently, patients present with no confirmed cardiac history, but their signs and symptoms of shortness of breath and poor exercise tolerance become red flags, indicating the need for further cardiac testing. Although the simplest stress test is the exercise treadmill test, this form of testing requires the patient to reach 85% of their calculated target heart rate. Other variables the NP needs to consider when selecting an appropriate stress test are the presence of any dysrhythmias, any evidence of LBBB or high atrioventricular block, COPD, and the severity of the patient's hypertension. Although each type of stress test offers a different perspective, the goal is to evaluate the heart's oxygen supply capacity as the oxygen demand increases. Thus, cardiac stress testing can be a valuable tool in determining whether a patient can safely proceed with surgery or whether further consultation with a cardiologist is needed to address the patient's CAD needs before proceeding with any intermediate- or high-risk surgery. JNP

References

1. Cohn SL, Fleisher LA. Evaluation of cardiac risk prior to noncardiac surgery. *UpToDate*. 2017. https://www.uptodate.com/contents/evaluation-of-cardiac-risk-prior-to-noncardiac-surgery/. Accessed April 26, 2017.
2. Reed SJ, Pearson S. Choosing wisely recommendation analysis: prioritizing opportunities for reducing inappropriate care: preoperative stress testing. Institute for Clinical and Economic Review. 2015. http://choosingwisely.org/wp-content/uploads/2015/05/ICER_Preoperative-Stress.pdf/. Accessed July 14, 2017.
3. Foster CG, Seacord LM. The cardiac patient undergoing noncardiac surgery. In: Cuculich PS, Kates AM, eds. *The Washington Manual Cardiology Subspecialty Consult*. Philadelphia: Wolters Kluwer; 2014:79-85.
4. Fleisher LA, Fleischman KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery. *J Am Coll Cardiol*. 2014;64:1-75.
5. Sintek MA, Barger PM. Ischemic heart disease. In: Bhat P, Dretier A, Gdowski M, Ramgopal R, Williams D, eds. *Washington Manual of Medical Therapeutics*. Philadelphia: Wolters Kluwer; 2016:89-139.
6. Fihn SD, Gardin JM, Abrams S, et al. 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS guideline for the diagnosis and management of patients with stable ischemic heart disease. *J Am Coll Cardiol*. 2012;60(24):e144-e164.
7. Greenland P, Alpert JS, Beller GA, et al. 2010 ACCF/AHA guideline for assessment of cardiovascular risk in asymptomatic adults: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2010;122:e584-e636. http://dx.doi.org/10.1161/CIR.0b013e3182051b4c.
8. Brunner MP. Stress echocardiography. In: Griffin BP, Callahan TD, eds. *Manual of Cardiovascular Medicine*. Philadelphia: Wolters Kluwer; 2013:808-823.
9. Oommen SS. Nuclear cardiac imaging. In: Griffin BP, Callahan TD, eds. *Manual of Cardiovascular Medicine*. Philadelphia: Wolters Kluwer; 2013:791-808.

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