Preoperative Cardiac Risk Assessment*

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Preoperative cardiac evaluation is aimed at evaluating the patient’s current medical status, making recommendations concerning the risk of cardiac problems in the perioperative period, and providing a clinical risk profile that the patient, primary physician, consultants, anesthesiologist, and surgeon can use in making treatment decisions. Patients can be stratified on clinical grounds into low-, medium-, and high-risk categories. Use of these categories, along with consideration of the type and urgency of noncardiac surgery, allows for a reasonable approach to preoperative testing. In general, indications for cardiac testing and treatment are similar to the nonoperative setting, but their choice and timing is dependent on factors specific to the patient, the type of surgery, and the clinical situation. Use of invasive and noninvasive testing should be limited to situations in which the results of the tests will clearly affect patient management. Further research is necessary to define the most appropriate role of such testing, both in terms of efficacy and of cost-effectiveness. Cardiac intervention is rarely necessary to lower the risk of surgery, but noncardiac surgery often represents the first opportunity for a patient to receive an appropriate assessment of short- and long-term cardiac risk, and this should be taken into consideration in planning perioperative evaluation.

The purpose of a preoperative cardiac evaluation is more appropriately the initiation of a process of communication aimed at evaluating the patient’s current medical status, making recommendations concerning the risk of cardiac problems in the perioperative period, and providing a clinical risk profile that the patient, primary physician, consultants, anesthesiologist, and surgeon can use in making treatment decisions. This is an important area, and one in which there is considerable debate. With increasing use of surgical procedures in older patients and the burgeoning development of technologies that can be used to evaluate risk, controversy in some areas is bound to intensify. Much of this controversy is attributable to the fact that different approaches function to answer different preoperative questions. If the issue is what preoperative tests have been shown definitively in clinical trials to decrease the risk of “hard” end points in the perioperative period, then a relatively circumscribed evaluation can be performed. But much of medical practice is based on physiologic principles and clinical experience, and preoperative testing can also provide information that can facilitate intraoperative and postoperative management. In addition, for many patients, the proposed surgery may be the first opportunity for a systematic cardiovascular evaluation, and may lead to further evaluation and treatments that reduce future cardiovascular risk. Both the American College of Cardiology/American Heart Association (ACC/AHA) Task Force and the American College of Physicians have developed guidelines for perioperative cardiovascular risk assessment.1 Although these guidelines differ somewhat in their general approach, there is a fair amount of general consensus. Patients can be stratified on clinical grounds into low-, medium-, and high-risk categories. These categories, along with consideration of the type and urgency of noncardiac surgery, allow for a reasonable approach to preoperative testing. In general, preoperative tests should not be performed unless they are likely to influence patient treatment. Cardiac intervention is rarely necessary to lower the risk of surgery.

**GENERAL APPROACH**

The first question to be answered concerns the urgency of the noncardiac surgery. Cardiac complications are two to five times more likely with emergent than elective operations,2 but most true surgical emergencies (perforated viscus, major trauma, symptomatic aortic aneurysms) do not permit more than a cursory cardiac evaluation. In other situations, the impending danger of the disease is greater than the anticipated perioperative risk, and only a limited cardiac evaluation is necessary; examples include

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mesenteric revascularization to prevent gangrene and arterial bypass for limb salvage.

In most other settings, the cardiac risk can be stratified according to a number of factors, including clinical predictors and the proposed surgical procedure. This can be developed into an algorithm such as the one presented within the guidelines developed by the ACC/AHA Task Force. Preoperative testing is rarely necessary in patients who have undergone coronary revascularization within 5 years and who remain asymptomatic. Similarly, in patients who have had a recent coronary evaluation within 2 years in the absence of clinical deterioration, further testing is also unnecessary.

All other patients should be stratified initially using clinical markers of perioperative cardiovascular risk, functional capacity, and surgery-specific risk. Although specific indications for further testing differ among different sets of guidelines and can be controversial, it is generally accepted that patients can be stratified into high-, medium-, and low-risk categories, and that these categories can be used to guide the cardiac evaluation.

Patients with unstable coronary syndromes require evaluation and treatment prior to elective noncardiac surgery. These syndromes are attributable to plaque rupture and render the patients extremely sensitive to any stress. In these situations, the patient's cardiac status warrants evaluation in and of itself. Patients with decompenstated congestive heart failure, symptomatic arrhythmias, and severe valvular heart disease also merit evaluation prior to surgery. In addition, patients with recent myocardial infarction (within 1 month) with postinfarction angina or residual important ischemia should be evaluated before surgery.

Patients in the low-risk category can generally proceed to surgery without further evaluation. Again, the precise determinants of this category can be debated, but the principle that further testing is neither beneficial nor cost-effective is generally accepted.

It is patients at intermediate risk who generate the most controversy. It is generally accepted that further testing has the highest yield in such patients, but the evidence regarding precisely which tests are most useful and in which patients is conflicting; few large, well-controlled studies have been performed. In the absence of definitive trials, different approaches are possible. The general approach of the American College of Physicians guidelines maintains that in the absence of convincing randomized trials demonstrating the efficacy of noninvasive testing in patients undergoing nonvascular surgery, such testing should not be undertaken. The ACC/AHA guidelines advocate an approach in which the goal of cardiac assessment is to evaluate both the risks of the impending surgery and the long-term cardiac risk, and thus recommend a somewhat more liberal attitude, based in part on the premise that many patients should have noninvasive testing sooner or later. Both are agreed that a conservative approach to the use of expensive tests and treatments is recommended, and that patient preferences and the urgency of the operation should be taken into account.

**CLINICAL ASSESSMENT**

The basic clinical evaluation obtained by history, physical examination, and ECG usually provides the consultant with sufficient data to estimate cardiac risk. Clinical predictors of increased perioperative risk of myocardial infarction (MI), congestive heart failure (CHF), and death have been established by several groups based on multivariate analysis. The original risk index established by Goldman et al assigned scores to clinical variables and assigned patients to four classes, from low (class I) to high risk; patients with angina were excluded from this study. A modification of this index put forth by Detsky et al added significant angina and remote MI as variables, simplified the scoring system into three risk classes, and demonstrated improved predictive accuracy among higher-risk patients. In the clinical practice of risk assessment, more weight is attached to active conditions, and evaluation of the degree of an abnormality is a useful supplement to assessments based on scoring systems.

As previously noted, the presence of unstable coronary syndromes such as unstable or severe angina, recent MI with evidence of residual ischemic risk, and new or poorly controlled ischemia-mediated CHF warrants consideration of cardiac catheterization to determine whether clinically important coronary artery disease is present and whether revascularization is possible. For high-risk patients who are not candidates for coronary revascularization, the operation may be delayed to improve the patient's overall status, or the operation may be cancelled if the patient's cardiac risk outweighs the risk posed by the surgical condition. Decompensated CHF, hemodynamically significant arrhythmias, and/or severe valvular heart disease also usually warrant cancellation of surgery until these problems have been clarified and treated appropriately.

Intermediate predictors of risk, which include mild angina pectoris (Canadian class I or II), compensated or prior CHF, and diabetes mellitus, have been well-validated to enhance the risk of perioperative cardiac complications, and thus justify careful
patient assessment. A prior MI (defined in the ACC/AHA guidelines as older than 1 month) is also an intermediate predictor. Current guidelines for management of MI recommend risk stratification during convalescence, and patients with evidence for residual myocardium at high risk. In the absence of such evidence, the likelihood of reinfarction is low. The ACC/AHA guidelines recommend waiting 4 to 6 weeks after MI to perform elective surgery. Scoring systems can also be used to define patients at intermediate risk for perioperative complications.

Patients at intermediate risk can be further stratified according to their functional capacity and surgery-specific risk. Functional capacity is usually estimated in metabolic equivalents (METs), with 1 MET corresponding to oxygen consumption of 3.5 mL/kg/min, the average for a 70-kg, 40-year-old man in the resting state. Functional capacity is classified as excellent (>7 METs), moderate (4 to 7 METs), or poor (<4 METs). Functional capacity can be estimated clinically using the Duke Activity Status Index; for example, climbing a flight of stairs with a bag of groceries, jogging, or walking on level ground at 4 miles per hour corresponds to at least 4 METs; participation in strenuous sports such as basketball or swimming indicates excellent functional capacity. Functional capacity can also be measured by stress testing (4 METs corresponds roughly to achievement of a heart rate >100 beats/min). A poor functional capacity predicts substantially increased cardiac risk after noncardiac surgery. Intermediate-risk patients with poor functional capacity should probably undergo noninvasive testing to further stratify their cardiac risk. Intermediate-risk patients with moderate or excellent functional capacity undergoing high-risk surgical procedures should also have noninvasive testing; testing is probably not necessary in patients scheduled for intermediate- and low-risk surgical procedures.

Minor predictors of risk include advanced age, abnormal ECG (left ventricular hypertrophy, left bundle-branch block, or ST- and T-wave abnormalities), rhythm other than sinus (most prominently atrial fibrillation), a history of stroke, and uncontrolled systemic hypertension. Patients with minor or no clinical predictors but a low functional capacity who are being evaluated for high-risk surgery should undergo noninvasive testing; all others can proceed directly to surgery without further evaluation.

The surgery-specific risk of noncardiac surgery is related to two important factors. The type of surgery itself may identify patients with a greater likelihood of underlying heart disease. The second factor is the degree of hemodynamic stress, in that certain operations may be associated with profound alterations in heart rate, BP, intravascular volume, oxygenation, hemoglobin, and neurohumoral activation.

Patients who require vascular surgery appear to be at increased risk for cardiac complications for several reasons. Many of the risk factors contributing to peripheral vascular disease, such as smoking, diabetes, and hyperlipidemia, are also risk factors for coronary artery disease. The usual symptomatic presentation of coronary disease may be obscured by limited exercise capacity due to claudication, and the stress of surgery may be significantly greater than that encountered in daily living. Major operations can be long and associated with significant fluctuations in intravascular volume, cardiac filling pressures, systemic BP, heart rate, and thrombogenicity.

Underlying coronary artery disease is present in most patients under evaluation for vascular surgery, cardiac complications are responsible for about half of all perioperative deaths, and coronary disease may present the major cause of long-term mortality in these patients. Thus, planned vascular surgery is an indication for noninvasive testing in patients deemed to be at intermediate risk; there is strong evidence to support this approach. However, studies of the utility of noninvasive testing conducted in patients undergoing vascular surgery may not apply to the more general surgical population.

Operations with high surgery-specific cardiac risk, those with a rate of perioperative death or MI of >5%, include aortic surgery, peripheral vascular surgery, and prolonged procedures associated with large amounts of blood loss and/or fluid shifts involving the abdomen, thorax, head, and neck. Surgery with intermediate risk (death or MI rates of 1 to 5%) include urologic, orthopedic, and uncomplicated abdominal, head, neck, and thoracic procedures. Low-risk procedures include cataract resection, endoscopic procedures, breast surgery, and dermatologic operations.

Noninvasive Testing

Supplemental preoperative testing aims to provide an objective measure of functional capacity, to identify the presence of important preoperative myocardial ischemia, and to estimate perioperative cardiac risk and long-term prognosis. When conceptualized in this fashion, it is not clear that evaluating such tests against the standard of whether they have been proven in randomized trials to improve measurable perioperative is always appropriate. Nevertheless, whether such tests alter management is the measure of their efficacy. Noninvasive tests available for risk stratification include assessment of resting left ventricular function, ambulatory ECG monitoring, exer-
Exercise stress testing, and nonexercise stress testing using either myocardial perfusion imaging or dobutamine stress echocardiography.

Resting ventricular function can be assessed using either echocardiography or radionuclide angiography. Although patients with ejection fractions <35% are at the greatest risk of complications, and poor left ventricular function in the perioperative period is predictive of postoperative CHF, most of the available studies are retrospective and have small sample sizes and low event rates. Resting left ventricular function measured either by angiography or echocardiography has not been found to be a consistent predictor of perioperative ischemic events. Assessment of left ventricular function should be done in patients with current or poorly controlled CHF if left ventricular systolic and diastolic function is unknown, but routine assessment is not indicated.

Spontaneous ischemia as identified by ambulatory ECG monitoring for ST-segment depression may identify patients at higher risk for perioperative ischemic outcomes. A substantial proportion of patients, however, cannot be studied due to resting ECG abnormalities, and the definition of a positive test varies. The largest prospective study failed to show a benefit for screening using this technique, and it probably should not be used as the only diagnostic test to refer patients for coronary angiography.

Exercise stress testing is widely available and inexpensive. The mean sensitivity of exercise testing for the detection of coronary disease is 68%, with a mean specificity of 77%; for multivessel disease, sensitivity increases to 81%, for three-vessel disease, it increases to 86%. Exercise testing also provides an accurate assessment of functional capacity. Ischemia induced by low-level exercise (<4 METs or heart rate <100 beats/min) identifies a high-risk group, and the achievement of 7 METs or heart rate >130 beats/min without ischemia identifies a low-risk group. This was shown in the Coronary Artery Surgery Study (CASS) trial, in which patients who had ischemia and exercised <3 min on a Bruce protocol had an annual mortality exceeding 5% per year, whereas patients able to exercise at least 9 min had an annual mortality of <1% per year over a 4-year follow-up. The negative predictive value of an adequate negative exercise stress test has been reported at 93% in two studies, one in a general population of patients undergoing major surgery, the other in patients undergoing vascular surgery. Unfortunately, 30 to 70% of patients with peripheral vascular disease cannot attain target heart rates and thus have nondiagnostic exercise stress test results. Exercise stress testing is the examination of choice for initial evaluation of coronary disease, but many patients referred for preoperative cardiac risk assessment will be unable to undergo such testing due to inability to exercise or an abnormal resting ECG.

In patients who cannot exercise, artificially increasing myocardial perfusion by infusing the small vessel vasodilators dipyridamole or adenosine followed by thallium imaging provides a method for the detection of myocardial ischemia. Areas subtended by fixed coronary stenoses have small vessel vasodilation at rest to maintain normal resting flow; such areas thus have a diminished hyperemic response compared with normal myocardium, leading to a relative defect in myocardial perfusion imaging at peak flow. Fixed defects continue to show decreased uptake, whereas reversible defects reveal improved flow in later resting images; reversible defects are more likely to indicate myocardium at risk, although this is not absolute. Numerous investigations have examined the value of perioperative thallium imaging, although many are retrospective or of weak quality. Two prospective studies, one in a general surgical population and one in patients having vascular surgery, found a negative predictive value of dipyridamole-thallium imaging exceeding 95%. In the strongest study, a prospective investigation in which interpreters of test results were blinded to clinical outcome and outcome observers were blinded to test results, dipyridamole-thallium imaging added risk discrimination to that provided by clinical evidence alone. The positive predictive value in this study was only 23%, in line with the other studies in the literature, in which positive predictive values have ranged from 5 to 25%. These data need to be interpreted with some caution, because abnormal scans are used clinically to select patients for therapeutic interventions such as revascularization, which may impact perioperative risk. This would tend to lower the positive predictive value. Quantification of the extent of thallium redistribution improves risk assessment and positive predictive value significantly, since cardiac risk correlates with the size of the defect.

Although both the sensitivity and specificity of dipyridamole-thallium imaging are high, the low risk of MI or death after noncardiac surgery results in low positive predictive values. Thus, broad screening of patients at low clinical risk cannot be justified and may lead to inappropriate tests or treatment. Dipyridamole should be avoided in patients with severe bronchospasm or those receiving theophylline.

Dobutamine stress echocardiography is newer than thallium imaging, and the published experience with this technique to evaluate its role in perioperative risk assessment is smaller than that with exercise testing and dipyridamole perfusion imaging. Nevertheless, two prospective studies in which the
In summary, patients at intermediate risk or those undergoing a high-risk surgical procedure should be considered for noninvasive testing for further risk stratification. Patients at high risk should be considered for angiography, and patients at low risk should not receive further testing. In most ambulatory patients, the test of choice is exercise ECG testing, which can both provide an estimate of functional capacity and detect myocardial ischemia. In patients unable to exercise, a nonexercise stress test should be performed; either perfusion imaging or stress echocardiography is appropriate. In a recent meta-analysis, dobutamine stress echocardiography and dipyridamole-thallium scanning had similar predictive values, with overlapping confidence intervals. The expertise of the local laboratory is probably more important than the particular type of test.

Attempts to document that noninvasive testing improves perioperative outcomes may be doomed to failure inasmuch as the absolute event rates are relatively low even in patients at intermediate risk, and large prospective randomized trials with blinding of both test interpreters and clinicians are extremely difficult to conduct. As previously noted, preoperative consultation can be useful for long-term management as well as assessment of the risk and prevention of perioperative events.

**Invasive Testing**

Indications for preoperative coronary angiography are similar to those in the nonoperative setting. In general, these are patients with suspected left main or triple-vessel disease in whom surgical revascularization is contemplated, or patients with unstable coronary syndromes in whom revascularization either with angioplasty or bypass surgery is likely to be appropriate. The value of angiography as a predictor of perioperative risk has not been reported.

**Preoperative Therapy**

Approximately 10% of patients will be considered to be at high surgical risk on clinical grounds. Among patients undergoing vascular surgery, another 10 to 20% will be reclassified as high risk by noninvasive testing. No good controlled trials have assessed the overall benefit of prophylactic coronary bypass surgery to lower the perioperative cardiac risk of noncardiac surgery. Nevertheless, patients who have previously undergone successful revascularization have a low perioperative mortality rate, which does not differ from that of patients without coronary artery disease.

A review of 1,600 patients in the CASS registry who underwent major noncardiac operations (7% vascular) showed a mortality of 2.4% in patients with significant coronary artery disease (CAD) and no prior bypass surgery, significantly higher that patients without CAD (0.5%) or those with prior bypass (0.9%). This did not account for mortality from the bypass itself (2.3% in the CASS registry). Since the risk of coronary artery bypass grafting itself usually exceeds the risks of noncardiac surgery, bypass is rarely justified simply to lower the risk of noncardiac surgery. However, presentation for noncardiac surgery may lead to identification of patients who would be expected to derive long-term benefit from bypass surgery. After weighing the relative urgency of the noncardiac problem and cardiac condition, preoperative bypass should be considered for patients with left main stenosis, three-vessel CAD and left ventricular dysfunction, two- vessel disease involving severe proximal left anterior descending artery obstruction, and intractable ischemia despite maximal medical therapy.

Even less data are available concerning whether prophylactic coronary revascularization with angioplasty reduces the incidence of perioperative cardiac events. Patients with previously successful percutaneous transluminal coronary angioplasty (PTCA) also have a low risk of perioperative MI or death. As with bypass surgery, it is recommended that consideration of PTCA be guided by the evidence available in the nonoperative setting. Prophylactic PTCA to lower perioperative risk is probably justifiable only when preoperative ischemia is severe and not adequately controlled with medical therapy. Although coronary stent placement is becoming much more common, prospective evaluations of this technique in the perioperative setting have not been performed.

Surgical stress can lead to release of large amounts of catecholamines, and this increases the risk of adverse cardiac outcomes; catecholamine surges can mediate arrhythmias and may predispose to coronary plaque rupture. Accordingly, use of β-adrenergic...
blocks has been proposed in the perioperative period. Previous observational studies and small randomized trials showed that β-blockade reduced surrogate end points such as perioperative ischemia and suggested that the incidence of MI may have been reduced as well.

Recently, a randomized controlled trial documented that perioperative β-blockade can reduce perioperative clinical events. These findings are consistent with pre-analyses of the effect inasmuch as most of the benefits were late. Interestingly, there was no difference in cardiac events in-hospital, raising questions as to the mechanisms of the effect inasmuch as most of the benefits were late. These findings are consistent with previous studies and support the initiation of atenolol therapy in the perioperative period for high-risk patients, particularly those with CAD.

**Specific Perioperative Conditions**

CHF is associated with substantially increased risk during noncardiac surgery. A careful history and physical examination can detect unsuspected heart failure. When CHF is identified, echocardiography should be performed, as systolic and diastolic dysfunction have different prognostic import. Results of such echocardiograms can suggest strategies for pre-operative optimization of cardiovascular status and also for perioperative management.

Moderate hypertension is not an independent risk factor for perioperative complications, but effective perioperative BP control is important to minimize cardiovascular stress. Severe hypertension (diastolic BP > 110 mm Hg) should be controlled prior to elective surgery, with the choice of regimen (oral or IV) dependent on the urgency of the surgery. Patients with preoperative hypertension appear to be more likely to develop intraoperative hypotension, possibly due to a subset with decreased intravascular volume.

Few studies have examined the implications of valvular heart disease on surgical risk. Severe aortic stenosis poses the greatest risk for noncardiac surgery and is included in the risk indexes. Elective noncardiac surgery should generally be postponed in the presence of severe and symptomatic aortic stenosis and valve replacement should be performed. In rare instances, when the patient is not a candidate for valve replacement and there is a pressing need for surgery, percutaneous aortic valvuloplasty may be justified. Significant aortic regurgitation needs to be identified, not only for appropriate antibiotic prophylaxis, but also to ensure appropriate volume control and afterload reduction. Such patients may not tolerate bradycardia, since this increases diastolic time and regurgitant volume. Similar considerations pertain for significant mitral regurgitation. Patients with severe mitral regurgitation may benefit from afterload reduction and diuresis, and pulmonary artery catheterization may sometimes be useful to guide therapy.

**Conclusions**

Intraoperative and postoperative monitoring and management are beyond the scope of this section, but it is clear that information obtained from preoperative cardiac assessment can be invaluable in many cases. Successful perioperative evaluation and management require careful teamwork and communication. In general, indications for cardiac testing and treatment are similar to the nonoperative setting, but their choice and timing are dependent on factors specific to the patient, the type of surgery, and the clinical situation. Use of invasive and noninvasive testing should be limited to those settings in which the results of the tests will clearly affect patient management. Further research is necessary to define the most appropriate role of such testing, both in terms of efficacy and of cost-effectiveness. Finally, noncardiac surgery often represents the first opportunity for a patient to receive an appropriate assessment of short- and long-term cardiac risk, and this should be taken into consideration in planning perioperative evaluation.

The following references have been annotated into levels of scientific support according to the guidelines of evidence-based medicine as follows:

- Level I: Large, randomized trials with clear-cut results; low risk of false-positive (α) error or false-negative (β) error
- Level II: Small, randomized trials with uncertain results; moderate-to-high risk of false-positive (α) error and/or false-negative (β) error
- Level III: Nonrandomized, contemporaneous controls
- Level IV: Nonrandomized, historical controls and expert opinion
- Level V: Case series, uncontrolled studies, and expert opinion

**References**

1. American College of Physicians. Guidelines for assessing and managing the perioperative risk from coronary artery disease
2 Mangano DT. Perioperative cardiac morbidity. Anesthesiology 1990; 72:153–184 (level V)