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ACC/AHA Pocket Guideline Update

Perioperative Cardiovascular Evaluation for Noncardiac Surgery

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines

November 2002

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The following material was adapted from the *ACC/AHA Guideline Update for Perioperative Cardiovascular Evaluation for Noncardiac Surgery.* For a copy of the executive summary, (J Am Coll Cardiol 2002;39:542-53, Circulation 2002;105: 1257-68) and full report, visit our Web sites at *http://www.acc.org* or *http://www.americanheart.org* or call the ACC Resource Center at 1-800-253-4636, ext. 694.

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Purpose of These Guidelines

These guidelines are intended for physicians involved in the preoperative, operative, and postoperative care of patients undergoing noncardiac surgery. They provide a framework for considering cardiac risk of noncardiac surgery in a variety of patient and operative situations. They strive to incorporate what is currently known about perioperative risk and how this knowledge can be used to treat individual patients. The methods used to develop these guidelines are described in the full text of the guidelines that appear on the World Wide Web sites of the ACC *(www.acc.org)* and AHA *(www.americanheart.org)*.

General Approach

Successful perioperative evaluation and treatment of cardiac patients undergoing noncardiac surgery requires careful teamwork and communication between patient, primary care physician, anesthesiologist, surgeon, and the medical consultant. In general, indications for further cardiac testing and treatments are the same as those in the nonoperative setting, but their timing is dependent on such factors as the urgency of noncardiac surgery, the patient's risk factors, and specific surgical considerations. Coronary revascularization before noncardiac surgery to enable the patient to "get through" the noncardiac procedure is appropriate only for a small subset of patients at very high risk. Preoperative testing should be limited to circumstances in which the results will affect patient treatment and outcomes. A conservative approach to the use of expensive tests and treatments is recommended.

Preoperative Clinical Evaluation

The initial history, physical examination, and electrocardiographic (ECG) assessment should focus on the identification of potentially serious cardiac disorders, including coronary artery disease (CAD) (eg, prior myocardial infarction [MI], angina pectoris), heart failure (HF), and electrical instability (symptomatic arrhythmias).

In addition to identifying the *presence* of preexisting manifested heart disease, it is essential to define disease *severity, stability,* and prior *treatment*. Other factors that help determine cardiac risk include

- functional capacity
- age
- comorbid conditions (eg, diabetes mellitus, peripheral vascular disease, renal dysfunction, chronic pulmonary disease)
- type of surgery (vascular procedures and prolonged complicated thoracic, abdominal, and head and neck procedures are considered higher risk)

Further Preoperative Testing to Assess Coronary Risk

Coronary heart disease is the most frequent cause of perioperative cardiac mortality and morbidity after noncardiac surgery. A common question concerning noncardiac surgery is which patients are most likely to benefit from preoperative coronary assessment and treatment? The lack of adequately controlled or randomized clinical trials to define the optimal evaluation strategy has led to the proposed algorithm based on collected observational data and expert opinion. A step-wise Bayesian strategy that relies on assessment of clinical markers, prior coronary evaluation and treatment, functional capacity, and surgery-specific risk is outlined below and correlates with the information in *Tables 1-3* and *Figure 1*, which presents in algorithmic form a framework for determining which patients are candidates for cardiac testing. *Table 1* outlines clinical predictors of perioperative risk. *Table 2* presents a validated method for assessing functional capacity. *Table 3* stratifies risk of various types of noncardiac surgeries. For clarity, categories have been established as "black and white," but it is recognized that individual patient problems occur in "shades of gray." The clinician must consider several interacting variables and weigh them appropriately. Furthermore, there are no adequate controlled or randomized clinical trials to help define the process.

Table 1
Clinical Predictors of Increased Perioperative Cardiovascular Risk

(Myocardial Infarction, Heart Failure, Death)

Major

Unstable coronary syndromes
- Acute or recent myocardial infarction* with evidence of important ischemic risk by clinical symptoms or noninvasive study
- Unstable or severe† angina (Canadian Cardiovascular Society Class III or IV)‡

Decompensated heart failure

Significant arrhythmias such as
- High-grade atrioventricular block
- Symptomatic ventricular arrhythmias in the presence of underlying heart disease
- Supraventricular arrhythmias with uncontrolled ventricular rate

Severe valvular disease

Intermediate

Mild angina pectoris (Canadian Cardiovascular Society Class I or II)

Prior myocardial infarction by history or pathological Q-waves

Compensated or prior heart failure

Diabetes mellitus (particularly insulin-dependent)

Renal insufficiency

Minor

Advanced age

Abnormal electrocardiogram (left ventricular hypertrophy, left bundle branch block, ST-T abnormalities)

Rhythm other than sinus (eg, atrial fibrillation)

Low functional capacity (eg, inability to climb one flight of stairs with a bag of groceries)

History of stroke

Uncontrolled systemic hypertension

**The American College of Cardiology National Database Library defines recent myocardial infarction as greater than 7 days but less than or equal to 1 month (30 days); acute MI is within 7 days.*

†May include "stable" angina in patients who are unusually sedentary.

‡Campeau L. Grading of angina pectoris. Circulation 1976;54:522-523.

Table 2
Estimated Energy Requirements for Various Activities

1 MET	Can you take care of yourself?	4 METs	Climb a flight of stairs or walk up a hill?
	Eat, dress, or use the toilet?		Walk on level ground at 4 mph or 6.4 km/h?
	Walk indoors around the house?		Run a short distance?
	Walk a block or two on level ground at 2-3 mph or 3.2-4.8 km/h?		Do heavy work around the house like scrubbing floors or lifting or moving heavy furniture?
4 METs	Do light work around the house like dusting or washing dishes?		Participate in moderate recreational activities like golf, bowling, dancing, doubles tennis, or throwing a baseball or football?
		>10 METs	Participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?

MET indicates metabolic equivalent.

Adapted from the Duke Activity Status Index (Hlatky MA, Boineau RE, Higginbotham MB, Lee KL, Mark DB, Califf RM, Cobb FR, Pryor DB. A brief self-administered questionnaire to determine functional capacity [the Duke Activity Status Index]. Am J Cardiol. 1989;64:651-654) and AHA Exercise Standards (Fletcher GF, Balady G, Froelicher VF, Hartley LH, Haskell WL, Pollock ML. Exercise standards: a statement for healthcare professionals from the American Heart Association. Circulation 1995; 91:580-615).

Table 3
Cardiac Event Risk* Stratification for Noncardiac Surgical Procedures

High
(Reported cardiac risk often >5%)

- Emergent major operations, particularly in the elderly
- Aortic and other major vascular surgery
- Peripheral vascular surgery
- Anticipated prolonged surgical procedures associated with large fluid shifts and/or blood loss

Intermediate
(Reported cardiac risk generally <5%)

- Intraperitoneal and intrathoracic surgery
- Carotid endarterectomy surgery
- Head and neck surgery
- Orthopedic surgery
- Prostate surgery

Low†
(Reported cardiac risk generally <1%):

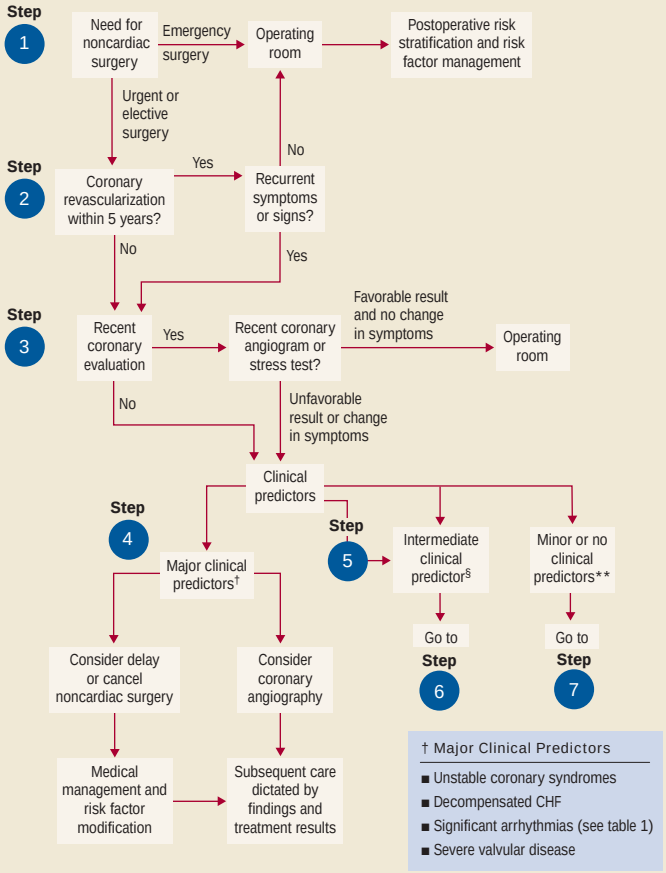
- Endoscopic procedures
- Superficial procedures
- Cataract surgery
- Breast surgery

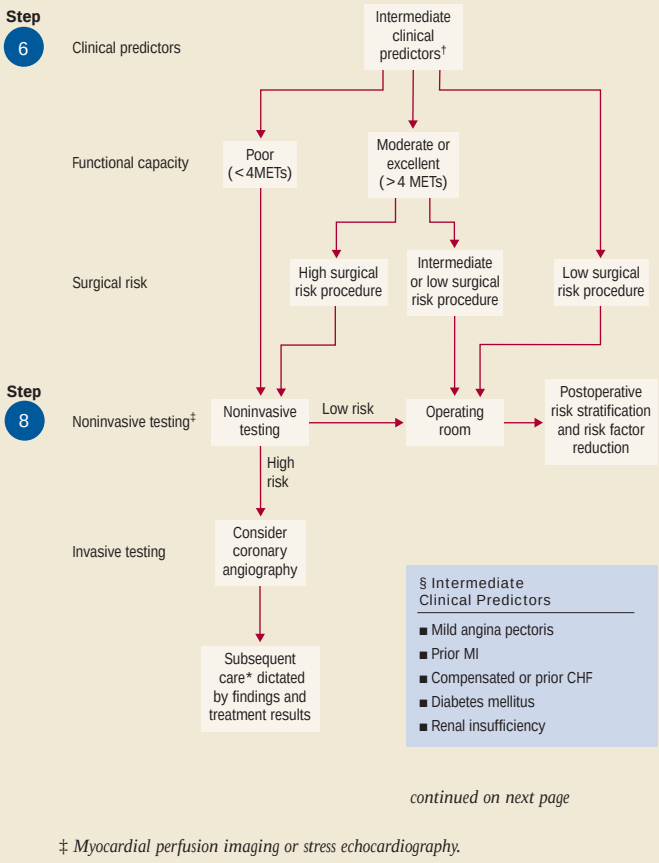
** Combined incidence of cardiac death and nonfatal myocardial infarction.*

†Further preoperative cardiac testing is not generally required.

Stepwise Approach to Preoperative Cardiac Assessment

Steps are discussed in text.





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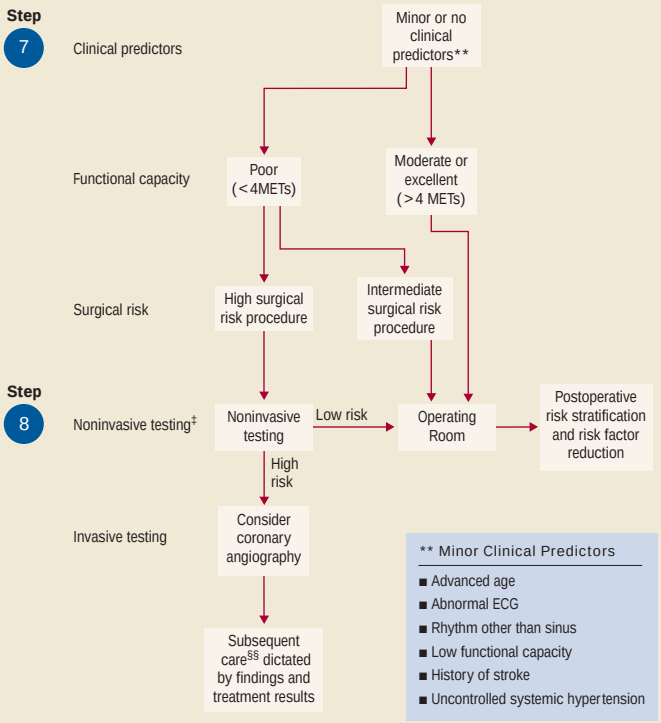
‡ *Myocardial perfusion imaging or stress echocardiography.*

Evaluation



§§ *Subsequent care may include cancellation or delay of surgery, coronary revascularization followed by noncardiac surgery, or intensified care.*

The following steps correspond to the algorithm presented in the Figure 1.

Step 1 What is the urgency of noncardiac surgery? In many instances, patient or specific surgical factors dictate an obvious strategy (ie, immediate surgery) which may not allow further cardiac evaluation. In such cases, the consultant may function best by making recommendations for perioperative medical management and surveillance. Postoperative risk stratification may be appropriate for some patients who have not had such an assessment.

Step 2 Has the patient undergone coronary revascularization in the past 5 years? If so, and if clinical status has remained stable without recurrent symptoms/signs of ischemia, further cardiac testing is generally not necessary.

Step 3 Has the patient had a coronary evaluation in the past 2 years? If coronary risk was adequately assessed and the findings were favorable, it is usually not necessary to repeat testing unless the patient has experienced a change or new symptoms of coronary ischemia since the previous evaluation.

Step 4 Does the patient have an unstable coronary syndrome or a major clinical predictor of risk *(Table 1)* ? When elective noncardiac surgery is being considered, the presence of unstable coronary disease, decompensated HF, symptomatic arrhythmias, and/or severe valvular heart disease usually leads

to cancellation or delay of surgery until the problem has been identified and treated. Examples of unstable coronary syndromes include recent MI with evidence of ischemic risk by clinical symptoms or noninvasive study, unstable or severe angina, and new or poorly controlled ischemia-mediated HF. Many patients in these circumstances are referred for coronary angiography to further assess therapeutic options.

Step 5 Does the patient have *intermediate clinical predictors of risk (Table 1)*? The presence or absence of prior MI by history or electrocardiogram, angina pectoris, compensated or prior HF, renal insufficiency, and/or diabetes mellitus helps further stratify clinical risk for perioperative coronary events. Consideration of *functional capacity* and level of *surgery specific risk* allows a rational approach to identifying patients most likely to benefit from further noninvasive testing.

Functional capacity can be expressed in metabolic equivalent (MET) levels; the oxygen consumption (VO_2) of a 70-kg, 40 year-old man in a resting state is 3.5 mL/kg per minute or 1 MET. Multiples of the baseline MET value can be used to express aerobic demands for specific activities. Perioperative cardiac and long-term risk is increased in patients who are unable to meet a 4-MET demand during most normal daily activities. The Duke Activity Status Index *(Table 2)* and other activity scales provide the clinician with a relatively easy set of questions to determine a patient's functional capacity as less than or greater than 4 METs.

Surgery-specific cardiac risk (Table 3) of noncardiac surgery is related to two important factors. First, the type of surgery itself may identify a patient with a greater likelihood of underlying heart disease, such as in vascular surgery, where underlying CAD is present in a substantial portion of patients. A second aspect is the degree of hemodynamic stress associated with surgery-specific procedures. Certain operations more predictably result in intraoperative or postoperative alterations in heart rate and blood pressure, fluid shifts, pain, bleeding, clotting tendencies, oxygenation, neurohumoral activation, and other perturbations. The duration and intensity of these coronary and myocardial stressors help estimate the likelihood of perioperative cardiac events. This likelihood is particularly evident for emergency surgery, in which the risk of cardiac complications is substantially elevated.

Examples of noncardiac surgery and their surgery-specific risks are provided in *Table 3*. Higher-risk surgery includes aortic surgery, peripheral vascular surgery, and anticipated prolonged procedures associated with major fluid shifts and/or blood loss involving the abdomen, thorax, head, and neck.

Step 6 Patients without major but with intermediate predictors of clinical risk *(Table 1)* and with moderate or excellent functional capacity can generally undergo intermediate-risk surgery with little likelihood of perioperative death or MI. Conversely, further noninvasive testing is often considered for patients with poor functional capacity or moderate functional

capacity but higher-risk surgery and especially for patients with two or more intermediate predictors (ie, prior MI, prior or compensated HF, angina, or diabetes mellitus).

Step 7 Noncardiac surgery is generally safe for patients with neither major nor intermediate predictors of clinical risk *(Table 1)* and moderate or excellent functional capacity (4 METs or greater). Further testing may be considered on an individual basis for patients without clinical markers but poor functional capacity who are facing higher-risk operations, particularly those with several minor clinical predictors of risk who are to undergo vascular surgery.

Step 8 The results of noninvasive testing can be used to determine further preoperative management. Such management may include intensified medical therapy; cardiac catheterization, which may lead to coronary revascularization; or cancellation or delay of the elective noncardiac operation. Alternatively, the results may lead to a recommendation to proceed with surgery. In some patients the risk of intervention or corrective cardiac surgery may approach or even exceed the risk of the proposed noncardiac surgery. This approach may be appropriate, however, if it also significantly improves the patient's long-term prognosis. For some patients, a careful consideration of clinical, surgery-specific, and functional status attributes leads to a decision to proceed to coronary angiography.

Shortcut to the Decision Test

The majority of patients have either intermediate or minor clinical predictors of increased perioperative cardiovascular risk. *Table 4* presents a shortcut approach to a large number of patients in whom the decision to recommend testing before surgery can be difficult. Basically, if 2 of the 3 listed factors are true, the guidelines suggest the use of noninvasive cardiac testing as part of the preoperative evaluation.

Table 4. Shortcut to Noninvasive Testing in Preoperative Patients if Any Two Factors Are Present

1. Intermediate clinical predictors are present (Canadian class 1 or 2 angina, prior MI based on history or pathologic Q-waves, compensated or prior heart failure, diabetes, or renal insufficiency)
2. Poor functional capacity (less than 4 METs)
3. High surgical risk procedure (emergency major operations*; aortic repair or peripheral vascular surgery; prolonged surgical procedures with large fluid shifts or blood loss)

MI indicates myocardial infarction; METs, metabolic equivalents.

Modified with permission from: Leppo JA, Dahlberg ST. The question: to test or not to test in preoperative cardiac risk evaluation. J Nucl Cardiol. 1998;5:332-42.

**Emergency major operations may require immediately proceeding to surgery without sufficient time for noninvasive testing or preoperative interventions.*

Methods of Assessing Cardiac Risk

Resting Left Ventricular Function

Several studies have shown that a left ventricular (LV) ejection fraction below 35% increases risk of noncardiac surgery. Patients with severe diastolic dysfunction are also at increased risk. The presence of current or poorly controlled HF is an indication for evaluation of LV function. Possible indications include prior HF or dyspnea of unknown etiology.

Recommendations for Preoperative Noninvasive Evaluation of Left Ventricular Function

Class I	Patients with current or poorly controlled HF. (If previous evaluation has documented severe left ventricular dysfunction, repeat preoperative testing may not be necessary).
Class IIa	Patients with prior HF and patients with dyspnea of unknown origin.
Class III	As a routine test of left ventricular function in patients without prior HF.

12-Lead ECG

The resting 12-lead ECG does not identify increased perioperative risk in patients undergoing low-risk surgery, but certain ECG abnormalities are clinical predictors of increased perioperative and long-term cardiovascular risk in clinically intermediate- and high-risk patients.

Recommendations for Preoperative 12-Lead Rest ECG

Class I	Recent episode of chest pain or ischemic equivalent in clinically intermediate- or high-risk patients scheduled for an intermediate- or high-risk operative procedure.
Class IIa	Asymptomatic persons with diabetes mellitus.
Class IIb	1. Patients with prior coronary revascularization. 2. Asymptomatic male more than 45 years old or female more than 55 years old with 2 or more atherosclerotic risk factors. 3. Prior hospital admission for cardiac causes.
Class III	As a routine test in asymptomatic subjects undergoing low-risk operative procedures.

Exercise Stress Testing (see *Table 5*)

Preoperative exercise testing using treadmill or bicycle stress and ECG analysis with or without nuclear myocardial perfusion imaging or echocardiography to identify ischemia provides substantial information about risk of perioperative MI and cardiac death. Poor functional capacity, particularly that associated with myocardial ischemia, identifies patients with a severalfold increased risk of untoward outcomes. A gradient of increasing ischemic risk is seen in association with degree of functional incapacity, symptoms of ischemia, severity of ischemia (eg, depth, time of onset, and duration of ST-segment depression), and evidence of hemodynamic or electrical instability during or after stress. This gradient also correlates with increasing likelihood of severe and multivessel coronary disease.

Table 5. Prognostic Gradient of Ischemic Responses During an ECG-Monitored Exercise Test

Patients with suspected or proven CAD

High risk

Ischemia induced by low-level exercise* (less than 4 METs or heart rate less than 100 bpm or less than 70% age predicted) manifested by one or more of the following:

- Horizontal or downsloping ST-depression greater than 0.1mV
- ST-segment elevation greater than 0.1mV in noninfarct lead
- Five or more abnormal leads
- Persistent ischemic response greater than 3 min. after exertion
- Typical angina

Intermediate risk

Ischemia induced by moderate-level exercise (4 to 6 METs or heart rate 100 to 130 bpm [70 to 85% age predicted) manifested by one or more of the following:

- Horizontal or downsloping ST-depression greater than 0.1mV
- Typical angina
- Persistent ischemic response greater than 1 to 3 min. after exertion
- Three to four abnormal leads

Low risk

No ischemia or ischemia induced at high-level exercise (greater than 7 METs or heart rate greater than 130 bpm [greater than 85% age predicted) manifested by:

- Horizontal or downsloping ST-depression greater than 0.1mV
- Typical angina
- One or two abnormal leads

Inadequate test

Inability to reach adequate target workload or heart rate response for age without an ischemic response. For patients undergoing noncardiac surgery, the inability to exercise to at least the intermediate-risk level without ischemia should be considered an inadequate test.

ECG indicates electrocardiographically; METs, metabolic equivalents; bpm, beats per minute.

**Workload and heart rate estimates for risk severity require adjustment for patient age. Maximum target heart rates for 40- and 80-year-old subjects on no cardioactive medication are 180 and 140 bpm, respectively.*

Pharmacological Stress Testing

For patients who are unable to exercise, selected use of pharmacological stress testing allows identification of patients with heightened risk of coronary events after noncardiac surgery. Dipyridamole or adenosine with thallium (or comparable radiopharmaceutical) myocardial perfusion imaging appears to have a high sensitivity and specificity for perioperative coronary events when used in patients with preexistent clinical predictors of risk, particularly angina pectoris, diabetes mellitus, prior MI, and prior HF in patients undergoing vascular surgery.

Pharmacological stress testing involving echocardiography is another effective method for stratifying coronary risk before noncardiac surgery. While the accumulated experience is less than that associated with myocardial perfusion imaging, dobutamine echocardiography appears to provide similar information and safety. The opportunity to assess LV and valvular dysfunction simultaneously offers advantages in some patients. As with all stress testing, proper identification of patients at medium and high risk and quantification of the degree of test abnormality may enhance predictive accuracy.

Although both exercise and pharmacological stress testing provide useful information for risk prediction, no prospective study has firmly established the cost-effectiveness or efficacy of either for improving perioperative or long-term outcomes. Use of these tests to help identify patients with advanced left main or three-vessel coronary disease is justified, based upon overall knowledge of management of CAD. However, there is little or no current information to justify their use in broad populations at low risk.

Recommendations for Exercise or Pharmacological Stress Testing

Class I	1. Diagnosis of adult patients with intermediate pretest probability of CAD. 2. Prognostic assessment of patients undergoing initial evaluation for suspected or proven CAD; evaluation of subjects with significant change in clinical status. 3. Demonstration of proof of myocardial ischemia before coronary revascularization. 4. Evaluation of adequacy of medical therapy; prognostic assessment after an acute coronary syndrome (if recent evaluation unavailable).
Class IIa	Evaluation of exercise capacity when subjective assessment is unreliable.
Class IIb	1. Diagnosis of CAD patients with high or low pretest probability: those with resting ST depression less than 1 mm, those taking digitalis therapy, or those with ECG criteria for left ventricular hypertrophy. 2. Detection of restenosis in high-risk asymptomatic subjects within the initial months after percutaneous coronary intervention (PCI).

continued on next page

Assessment

Class III

1. For *exercise* stress testing, diagnosis of patients with resting ECG abnormalities that preclude adequate assessment, eg, pre-excitation syndrome, electronically paced ventricular rhythm, rest ST depression greater than 1 mm, or left bundle-branch block.

2. Severe comorbidity likely to limit life expectancy or candidacy for revascularization.

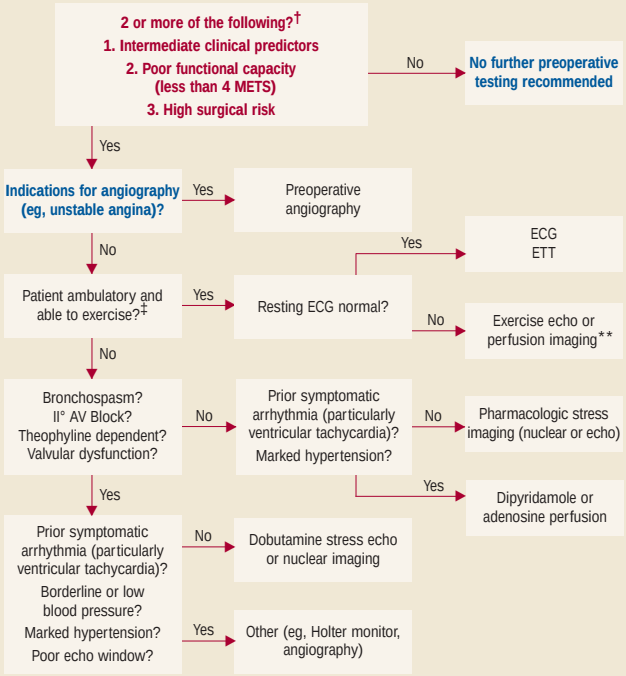
3. Routine screening of asymptomatic men or women.

4. Investigation of isolated ectopic beats in young patients.

Supplemental Preoperative Evaluation: When and Which Test?

Figure 2 illustrates an algorithm to help the clinician choose the most appropriate stress test in various situations. Testing is only indicated if the results will impact care.

Figure 2. Supplemental Preoperative Evaluation: When and Which Test*



**Testing is only indicated if the results will impact care.*

†*See* Table 1 *for the list of intermediate clinical predictors,* Table 2 *for the metabolic equivalents, and* Table 3 *for the definition of high-risk surgical procedure.*

‡*Able to achieve more than or equal to 85% MPHR.*

***In the presence of LBBB, vasodilator perfusion imaging is preferred.*

Coronary Angiography

As indicated previously, it may be appropriate to proceed directly to coronary angiography in certain patients at high risk. Indications for coronary angiography in the preoperative setting generally are similar to those in the nonoperative setting. First, it is essential to ensure that management with percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) surgery is a viable option. Otherwise, coronary angiography may add to cost and risk without measurably benefiting outcome. Second, angiography should be reserved for patients at very high risk, including those with evidence of advanced ischemic risk or symptoms, and particularly those suspected of having left main or three-vessel CAD.

Recommendations for Coronary Angiography in Perioperative Evaluation Before (or After) Noncardiac Surgery

Class I	Patients With Suspected or Known CAD 1. Evidence for high risk of adverse outcome based on noninvasive test results. 2. Angina unresponsive to adequate medical therapy. 3. Unstable angina, particularly when facing intermediate-risk* or high-risk* noncardiac surgery. 4. Equivocal noninvasive test results in patients at high clinical risk† undergoing high-risk* surgery.
Class IIa	1. Multiple markers of intermediate clinical risk† and planned vascular surgery (noninvasive testing should be considered first). 2. Moderate to large ischemia on noninvasive testing but without high-risk features and lower left ventricular ejection fraction. 3. Nondiagnostic noninvasive test results in patients at intermediate clinical risk† undergoing high-risk* noncardiac surgery. 4. Urgent noncardiac surgery while convalescing from acute MI.
Class IIb	1. Perioperative MI. 2. Medically stabilized class III or IV angina and planned low-risk or minor* surgery.
Class III	1. Low-risk* noncardiac surgery with known CAD and no high-risk results on noninvasive testing. 2. Asymptomatic after coronary revascularization with excellent exercise capacity (greater than or equal to 7 METs). 3. Mild stable angina with good left ventricular function and no high-risk noninvasive test results.

continued on next page

Assessment

4. Noncandidate for coronary revascularization owing to concomitant medical illness, severe left ventricular dysfunction (eg, left ventricular ejection fraction less than 0.20), or refusal to consider revascularization.

5. Candidate for liver, lung, or renal transplant 40 years old or more, as part of evaluation for transplantation, unless noninvasive testing reveals high risk for adverse outcome.

*Cardiac risk according to type of noncardiac surgery. High risk: emergent major operations, aortic and major vascular surgery, peripheral vascular surgery, or anticipated prolonged surgical procedure associated with large fluid shifts and blood loss; intermediate risk: carotid endarterectomy, major head and neck surgery, intraperitoneal and intrathoracic surgery, orthopedic surgery, or prostate surgery; and low risk: endoscopic procedures, superficial procedures, cataract surgery, or breast surgery.

†Cardiac risk according to clinical predictors of perioperative death, MI, or HF. High clinical risk: unstable angina, acute or recent MI with evidence of important residual ischemic risk, decompensated HF, high degree of atrioventricular block, symptomatic ventricular arrhythmias with known structural heart disease, severe symptomatic valvular heart disease, or patient with multiple intermediate-risk markers such as prior MI, HF, and diabetes; intermediate clinical risk: Canadian Cardiovascular Society class I or II angina, prior MI by history or ECG, compensated or prior HF, diabetes mellitus, or renal insufficiency.

Management of Specific Preoperative Cardiovascular Conditions

Hypertension

Severe hypertension (eg, diastolic blood pressure 110 mm Hg or greater) should be controlled before surgery when possible. The decision to delay surgery because of elevated blood pressure should take into account the urgency of surgery and the potential benefit of more intensive medical therapy. Continuation of preoperative antihypertensive treatment through the perioperative period is critical, particularly for agents such as beta blockers or clonidine, to avoid severe postoperative hypertension.

Valvular Heart Disease

Indications for evaluation and treatment of valvular heart disease are identical to those in the nonoperative setting. Symptomatic stenotic lesions such as mitral and aortic stenosis are associated with risk of perioperative severe HF or shock and often require percutaneous valvotomy or valve replacement before noncardiac surgery to lower cardiac risk. Conversely, symptomatic regurgitant valve disease (eg, aortic regurgitation and/or mitral regurgitation) is usually better tolerated perioperatively and may be stabilized before surgery with

intensive medical therapy and monitoring. It is then treated definitively with valve repair or replacement after noncardiac surgery. This is appropriate when a wait of several weeks or months before noncardiac surgery may have severe consequences, for example, in patients with surgically curable malignant neoplasms. Exceptions may include patients with both severe valvular regurgitation and reduced LV function in whom overall hemodynamic reserve is so limited that destabilization during perioperative stresses is very likely.

Myocardial Heart Disease

Dilated and hypertrophic cardiomyopathy are associated with an increased incidence of perioperative HF. Management is directed toward maximizing preoperative hemodynamic status and providing intensive postoperative medical therapy and surveillance. An estimate of hemodynamic reserve is useful for anticipating potential complications arising from intraoperative and/or postoperative stress.

Arrhythmias and Conduction Abnormalities

The presence of an arrhythmia or cardiac conduction disturbance should provoke a careful evaluation for underlying cardiopulmonary disease, drug toxicity, or metabolic abnormality. Therapy should be initiated for symptomatic or hemodynamically significant arrhythmias, first to reverse any underlying cause and second to treat the arrhythmia. Indications for antiarrhythmic therapy and cardiac pacing are identical to those in the nonoperative setting.

Implantable Pacemakers or ICDs

The type and extent of evaluation of a pacemaker or ICD depend on the urgency of the surgery, whether a pacemaker has unipolar or bipolar leads, whether electrocautery is bipolar or unipolar, the distance between electrocautery and pacemaker, and pacemaker dependency. ICD devices should be programmed off immediately before surgery and then on again postoperatively.

Venothromboembolism/Peripheral Arterial Disease

Prophylactic measures need to be planned and in some cases started preoperatively for persons with clinical circumstances associated with postoperative venous thromboembolism. *Table 6* provides published recommendations for various types of surgical procedures. Patients with chronic occlusive peripheral arterial disease may be at increased risk of perioperative cardiac complications, warranting particular attention to the preoperative evaluation and intraoperative therapy. Protection of the limbs from trauma during and after surgery is as important for those with asymptomatic arterial disease as for those with claudication.

Table 6. General Guidelines for Perioperative Prophylaxis for Venous Thromboembolism*

Type of Patient/Surgery	Recommendation
Minor surgery in a patient less than 40 years old with no correlates of venous thromboembolism risk†	Early ambulation
Moderate-risk surgery in a patient more than 40 to 60 years old with no correlates of thromboembolism risk	ES; LDH (2 h preoperatively and every 12 h after) or IPC (intraoperatively and postoperatively)
Major surgery in a patient less than 40 to 60 years old with clinical conditions associated with venous thromboembolism risk, or older than 60 years old without risk factors	LDH (every 8 h) or LMWH, IPC if prone to wound bleeding
Very-high-risk surgery in a patient with multiple clinical conditions associated with thromboembolism risk	LDH, LMWH, or dextran combined with IPC. In selected patients, perioperative warfarin (INR 2 to 3) may be used.
Total hip replacement	LMWH (postoperative, subcutaneous, twice daily, fixed dose unmonitored) or warfarin (INR 2 to 3, started preoperatively or immediately after surgery) or adjusted-dose unfractionated heparin (started preoperatively). ES or IPC may provide additional efficacy.
Total knee replacement	LMWH (postoperative, subcutaneous, twice daily, fixed dose unmonitored) or IPC
Hip fracture surgery	LMWH (preoperative, subcutaneous, fixed dose unmonitored) or warfarin (INR 2 to 3). IPC may provide additional benefit.
Intracranial neurosurgery	IPC with or without ES. Consider addition of LDH or LMWH in high-risk patients.
Acute spinal cord injury with lower-extremity paralysis	LMWH for prophylaxis. Warfarin may also be effective. ES and IPC may have benefit when used with LMWH.
Patients with multiple trauma	LMWH when feasible; serial surveillance with duplex ultrasonography may be useful. In selected very-high-risk patients, consider prophylactic caval filter. If LMWH not feasible, IPC may be useful.

ES indicates graded-compression elastic stockings; LDH, low-dose subcutaneous heparin; IPC, intermittent pneumatic compression; LMWH, low-molecular-weight heparin; INR, international normalized ratio.

Developed from Clagett GP, Anderson FA Jr, Geerts W, et al. Prevention of venous thromboembolism. Chest. 1998;114:531S-60S.

†*Clinical conditions associated with increased risk of venous thromboembolism: advanced age; prolonged immobility or paralysis; previous venous thromboembolism; malignancy; major surgery of abdomen, pelvis, or lower extremity; obesity; varicose veins; heart failure; myocardial infarction; stroke; fracture(s) of the pelvis, hip, or leg; hypercoagulable states; and possibly high-dose estrogen use.*

Preoperative Coronary Revascularization

Coronary Artery Bypass Graft Surgery

Indications for coronary artery bypass grafting (CABG) before noncardiac surgery are identical to those reviewed in the ACC/AHA guidelines for CABG. CABG is rarely indicated simply to "get a patient through" noncardiac surgery. In patients enrolled in the Coronary Artery Surgery Study (CASS) database, the cardiac risk associated with noncardiac operations involving the thorax, abdomen, arterial vasculature, and head and neck was reduced significantly in those patients who had undergone prior CABG. Patients undergoing elective noncardiac procedures who are found to have prognostic high-risk coronary anatomy and in whom long-term outcome would likely be improved by CABG should generally undergo revascularization before a noncardiac elective surgical procedure of high or intermediate risk *(Table 3)*.

Percutaneous Coronary Intervention

There are no controlled trials comparing perioperative cardiac outcome after noncardiac surgery for patients treated with preoperative PCI versus medical therapy. Several small observational series have suggested that cardiac death is infrequent in patients who have undergone PCI before noncardiac surgery. Several studies have also demonstrated a number of complications from angioplasty, including emergency CABG in some patients. Until further data are available, indications for PCI in the perioperative setting are similar to those in the ACC/AHA guidelines for use of PCI in general. There is uncertainty regarding how much time should pass between PCI and noncardiac procedures. Delaying surgery for at least 1 week after balloon angioplasty to allow for healing of the vessel injury has theoretical benefits. If a coronary stent is used, a delay of at least 2 weeks and ideally 4 to 6 weeks should occur before noncardiac surgery to allow 4 full weeks of dual antiplatelet therapy and re-endothelialization of the stent to be completed, or nearly so.

Medical Therapy for Coronary Artery Disease

There are still very few randomized trials of medical therapy before noncardiac surgery to prevent perioperative cardiac complications, and they do not provide enough data from which to draw firm conclusions or recommendations. Most are insufficiently powered to address the effect on outcome of MI or cardiac death, and they rely on the surrogate end point of ECG ischemia to show effect. Current studies, however, suggest that appropriately administered beta-blockers reduce perioperative ischemia and may reduce the risk of MI and death in high-risk patients. When possible, beta blockers should be started days or weeks before elective surgery, with the dose titrated to achieve a resting heart rate between 50

and 60 beats per minute. Perioperative treatment with alpha-2 agonists may have similar effects on myocardial ischemia, infarction, and cardiac death. Clearly, this is an area in which further research would be valuable.

Recommendations for Perioperative Medical Therapy

Class I	1. Beta blockers required in the recent past to control symptoms of angina or patients with symptomatic arrhythmias or hypertension. 2. Beta blockers: patients at high cardiac risk owing to the finding of ischemia on preoperative testing who are undergoing vascular surgery.
Class IIa	1. Beta blockers: preoperative assessment identifies untreated hypertension, known coronary disease, or major risk factors for coronary disease.
Class IIb	1. Alpha-2 agonists: perioperative control of hypertension, or known CAD or major risk factors for CAD.
Class III	1. Beta blockers: contraindication to beta blockade. 2. Alpha-2 agonists: contraindication to alpha-2 agonists.

Anesthetic Considerations and Intraoperative Management

Anesthetic Agent

All anesthetic techniques and drugs have known cardiac effects that should be considered in the perioperative plan. There appears to be no one best myocardium-protective anesthetic technique. Therefore, the choice of anesthesia and intraoperative monitors is best left to the discretion of the anesthesia care team, which will consider the need for postoperative ventilation, cardiovascular effects (including myocardial depression), sympathetic blockade, and dermatomal level of the procedure. Advocates of monitored anesthesia, in which local anesthesia is supplemented by intravenous sedation/analgesia, have argued that use of this technique avoids the undesirable effects of general or neuraxial techniques, but no studies have established this. Failure to produce complete local anesthesia/analgesia can lead to increased stress response and/or myocardial ischemia.

Perioperative Pain Management

Patient-controlled intravenous and/or epidural analgesia is a popular method for reducing postoperative pain. Several studies suggest that effective pain management leads to a reduction in postoperative catecholamine surges and hypercoagulability.

Transesophageal Echocardiography

There are few data on the value of transesophageal echocardiography to detect transient wall motion abnormalities in predicting cardiac morbidity in noncardiac surgical patients. Experience to date suggests that the incremental value of this technique for risk prediction is small. Guidelines for appropriate use of transesophageal echocardiography have been published by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists.

Perioperative Maintenance of Body Temperature

One randomized trial demonstrated a reduced incidence of perioperative cardiac events in patients who were maintained in a state of normothermia via forced-air warming compared with routine care.

Intraoperative Nitroglycerin

There are insufficient data about the effects of prophylactic intraoperative intravenous nitroglycerin in patients at high risk. Nitroglycerin should be used only when the hemodynamic effects of other agents in use have been considered.

Recommendations for Intraoperative Nitroglycerin

Class I	High-risk patients previously taking nitroglycerin who have active signs of myocardial ischemia without hypotension.
Class IIb	As a prophylactic agent for high-risk patients to prevent myocardial ischemia and cardiac morbidity, particularly in those who have required nitrate therapy to control angina. The recommendation for prophylactic use of nitroglycerin must take into account the anesthetic plan and patient hemodynamics and must recognize that vasodilation and hypovolemia can readily occur during anesthesia and surgery.
Class III	Patients with signs of hypovolemia or hypotension.

Perioperative Surveillance

Pulmonary Artery Catheters

Although a great deal of literature has evaluated the usefulness of pulmonary artery catheters in treating perioperative patients, very few studies have compared outcomes in patients treated with or without such monitoring. The American Society of Anesthesiologists recommends that the following three variables are particularly important in assessing benefit versus risk of pulmonary artery catheter use: disease severity, magnitude of anticipated surgical procedure, and practice setting. The extent of expected fluid shifts is a primary concern with regard to surgery. Current evidence indicates that patients most likely to benefit from use of pulmonary artery catheters in the perioperative period are those with a recent MI complicated by CHF, those with significant CAD who are undergoing procedures associated with significant hemodynamic stress, and those with systolic or diastolic LV dysfunction, cardiomyopathy, and valvular disease undergoing high-risk operations.

Recommendations for Intraoperative Use of Pulmonary Artery Catheters

Class IIa	Patients at risk for major hemodynamic disturbances that are most easily detected by a pulmonary artery catheter who are undergoing a procedure that is likely to cause these hemodynamic changes in a setting with experience in interpreting the results (eg, suprarenal aortic aneurysm repair in a patient with angina).
Class IIb	Either the patient's condition or the surgical procedure (but not both) places the patient at risk for hemodynamic disturbances (eg, supraceliac aortic aneurysm repair in a patient with a negative stress test).
Class III	No risk of hemodynamic disturbances.

Intraoperative and Postoperative ST-Segment Monitoring

Intraoperative and postoperative ST changes indicating myocardial ischemia are strong predictors of perioperative MI in patients at high risk who undergo noncardiac surgery. Similarly, postoperative ischemia is a significant predictor of long-term risk of MI and cardiac death. Conversely, in

patients at low risk who undergo noncardiac surgery, ST depression may occur and often is not associated with regional wall-motion abnormalities. Accumulating evidence suggests that proper use of computerized ST-segment analysis in appropriately selected patients at high risk may improve sensitivity for myocardial ischemia detection.

Recommendations for Perioperative ST-Segment Monitoring

Class IIa	When available, proper use of computerized ST-segment analysis in patients with known CAD or undergoing vascular surgery may provide increased sensitivity to detect myocardial ischemia during the perioperative period and may identify patients who would benefit from further postoperative and long-term interventions.
Class IIb	Patients with single or multiple risk factors for CAD.
Class III	Patients at low risk for CAD.

Surveillance for Perioperative Myocardial Infarction

Few studies have examined the optimal method for diagnosing a perioperative MI. Clinical symptoms, postoperative ECG changes, and elevation of the MB fraction of creatine kinase (CK-MB) have been studied most extensively. Recently, elevations of myocardium-specific enzymes such as troponin-I, troponin-T, or CK-MB isoforms have also been shown to be of value. In patients with known or suspected CAD who are undergoing high-risk procedures, ECGs obtained at baseline, immediately after surgery, and on the first 2 days after surgery appear to be cost-effective. A risk gradient can be based on the magnitude of biomarker elevation, the presence or absence of concomitant new ECG abnormalities, hemodynamic instability, and quality and intensity of chest pain syndrome, if present. Use of cardiac biomarkers is best reserved for patients at high risk and those with clinical, ECG, or hemodynamic evidence of cardiovascular dysfunction.

Postoperative Therapy and Long-Term Management

When possible, postoperative management should include assessment and management of modifiable risk factors for CAD, heart failure, hypertension, stroke, and other cardiovascular diseases. For many patients, the need for non-cardiac surgery may be their first opportunity for a systematic cardiovascular evaluation. Assessment for hypercholesterolemia, smoking, hypertension, diabetes, physical inactivity, peripheral vascular disease, cardiac murmur(s), arrhythmias, conduction abnormalities, perioperative ischemia, and postoperative MI may lead to evaluation and treatments that reduce future cardiovascular risk. In particular, patients who experience repetitive postoperative myocardial ischemia and/or sustain a perioperative MI are at substantially elevated risk for MI or cardiac death during long-term follow-up. These patients should be a particular focus for risk factor interventions and future risk stratification and therapy.