ACC/AHA Guideline Update for Perioperative Cardiovascular Evaluation for Noncardiac Surgery—Executive Summary

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1996 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery)

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1. Introduction

These guidelines represent an update of those published in 1996 and are intended for physicians who are 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 surgical situations. The overriding theme of these guidelines is that preoperative intervention is rarely necessary simply to lower the risk of surgery unless such intervention is indicated irrespective of the preoperative context. The purpose of preoperative evaluation is not simply to give medical clearance but rather to perform an evaluation of the patient's current medical status; make recommendations concerning the evaluation, management, and risk of cardiac problems over the entire perioperative period; and provide a clinical risk profile that the patient, primary physician, anesthesiologist, and surgeon can use in making treatment decisions that may influence short- and long-term cardiac outcomes. The goal of the consultation is to identify the most appropriate testing and treatment strategies to optimize care of the patient, provide assessment of both short- and

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long-term cardiac risk, and avoid unnecessary testing in this era of cost containment.

A. Development of Guidelines

These guidelines are based on an update of a Medline, EMBASE, Cochrane library, and Best Evidence search of the English literature from 1995 through 2000, a review of selected journals, and the expert opinions of 12 committee members representing various disciplines of cardiovascular care, including general cardiology, interventional cardiology, noninvasive testing, vascular medicine, vascular surgery, anesthesiology, and arrhythmia management. As a result of these searches, more than 400 relevant new articles were identified. In addition, draft guidelines were submitted for critical review and amendment to the executive officers representing the American College of Cardiology (ACC) and the American Heart Association (AHA).

A large proportion of the data used to develop these guidelines are based on observational or retrospective studies or knowledge of management of cardiovascular disorders in the nonoperative setting. Although the collective body of knowledge about the identification of high- and low-risk patients by perioperative clinical and noninvasive evaluation is substantial, the number of prospective or randomized studies that have been performed to establish the value of different treatments on perioperative outcomes is small. The ACC/AHA classifications of evidence used in this report to summarize the indication for a particular therapy or treatment are as follows:

Class I: Conditions for which there is evidence and/or general agreement that a given procedure/therapy is useful and effective.

Class II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of performing the procedure/therapy.

Class IIa: Weight of evidence/opinion is in favor of usefulness/efficacy.

Class IIb: Usefulness/efficacy is less well established by evidence/opinion.

Class III: Conditions for which there is evidence and/or general agreement that a procedure/therapy is not useful/effective and in some cases may be harmful.

Two versions of the full-text guidelines are available on the World Wide Web sites of both the American College of Cardiology (www.acc.org) and the American Heart Association (www.americanheart.org); one version highlights the updated material (deleted text in strikeout and new text in red), and the other fully incorporates the changes. This document was approved for publication by the governing bodies of the ACC and the AHA, will be reviewed annually by the Task Force, and will be considered current unless the Task Force revises or withdraws them from distribution.

B. General Approach

The preoperative cardiac evaluation must be carefully tailored to the circumstances that have prompted the consultation and to the nature of the surgical illness (e.g., acute surgical emergency) as opposed to urgent or elective cases. Successful perioperative evaluation and treatment of cardiac patients undergoing noncardiac surgery requires careful teamwork and communication between the patient, primary care physician, anesthesiologist, consultant, and surgeon. 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.

C. Preoperative Clinical Evaluation

The initial history, physical examination, and electrocardiogram (ECG) assessment should focus on identification of potentially serious cardiac disorders, including coronary artery disease (CAD) [e.g., prior myocardial infarction (MI) and angina pectoris], heart failure (HF), symptomatic arrhythmias, presence of pacemaker or implantable cardioverter defibrillator (ICD), or a history of orthostatic intolerance.[1] The presence of anemia may also place a patient at higher perioperative risk.[2–4]

In addition to identifying the presence of pre-existing 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 (e.g., diabetes mellitus, peripheral vascular disease, renal dysfunction, and chronic pulmonary disease), and type of surgery (vascular procedures and prolonged, complicated thoracic, abdominal, and head and neck procedures are considered higher risk).

Numerous risk indices have been developed over the past 25 years on the basis of multivariate analyses.[5–14] In addition to the presence of CAD and HF, a history of cerebrovascular disease, preoperative elevated creatinine greater than 2 mg per deciliter, insulin treatment for diabetes mellitus, and high-risk surgery have all been associated with increased perioperative cardiac morbidity. Despite these risk indices, there was consensus among the committee members to place clinical risk factors into 3 categories of predictors (see Section II-A).

II. Further Preoperative Testing to Assess Coronary Risk

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 led to the proposed algorithm based on collected observational data and expert opinion (see Fig. 1). Since publication of the guidelines in 1996, several studies have suggested that this stepwise approach to the assessment of CAD is both efficacious and cost-effective.

A stepwise bayesian strategy that relies on assessment of clinical markers, prior coronary evaluation and treatment, functional capacity, and surgery-specific risk is outlined in Figure 1. A framework for determining which patients are candidates for cardiac testing is presented in algorithmic form. Successful use of the algorithm requires an appreciation of the different levels of risk attributable to certain clinical circumstances, levels of functional capacity, and types of surgery. These are defined below, after which the algorithm is reviewed step by step.

A. Clinical Markers

The major clinical predictors (Table 1) of increased perioperative cardiovascular risk are a recent unstable coronary syndrome such as an acute MI (documented MI less than 7 days previously), recent MI (more than 7 days but less than 1 month before surgery), unstable or severe angina, evidence of a large ischemic burden by clinical symptoms or noninvasive testing, decompensated HF, significant arrhythmias (high-grade atrioventricular block, symptomatic arrhythmias in the presence of underlying heart disease, or supraventricular arrhythmias with uncontrolled ventricular rate), and severe valvular disease.

Intermediate predictors of increased risk are mild angina pectoris, a more remote prior MI (more than 1 month before planned surgery), compensated HF, preoperative creatinine greater than or equal to 2.0 mg per deciliter, and diabetes mellitus. Minor predictors of risk are advanced age, abnormal ECG, rhythm other than sinus, low functional capacity, history of stroke, and uncontrolled systemic hypertension.

A history of MI or abnormal Q waves by ECG is listed as an intermediate predictor, whereas an acute MI (defined as at least 1 documented MI less than or equal to 7 days before the examination) or recent MI (more than 7 days but less than or equal to 1 month before the examination) with evidence of important ischemic risk by clinical symptoms or noninvasive study is a major predictor. This definition reflects the consensus of the ACC Cardiovascular Database Committee. In this way, the separation of MI into the traditional 3- and 6-month intervals has been avoided.[6,15] Current management of MI provides for risk stratification during convalescence.[16] If a recent stress test does not indicate residual myocardium at risk, the likelihood of reinfarction after noncardiac surgery is low. Although there are no adequate clinical trials on which to base firm recommendations, it appears reasonable to wait 4 to 6 weeks after MI to perform elective surgery.

B. Functional Capacity

Functional capacity can be expressed in metabolic equivalent (MET) levels (Table 2). Multiples of the baseline MET value can be used to express aerobic demands for specific activities. Perioperative cardiac and long-term risks are increased in patients unable to meet a 4-MET demand during most normal daily activities.[17–19] The Duke Activity Status Index and other activity scales provide the clinician with a set of questions to determine a patient's functional capacity.[20–22] Energy expenditures for activities such as eating, dressing, walking around the house, and dishwashing range from 1 to 4 METs. Climbing a flight of stairs, walking on level ground at 6.4 km per hour, running a short distance, scrubbing floors, or playing a game of golf represents 4 to 10 METs. Strenuous sports such as swimming, singles tennis, and football often exceed 10 METs.

C. Surgery-Specific Risk

Surgery-specific cardiac risk of noncardiac surgery is related to 2 important factors: the type of surgery itself and the degree of hemodynamic stress associated with the procedures. The duration and intensity of coronary and myocardial stressors can be helpful in estimating the likelihood of perioperative cardiac events, particularly for emergency surgery. Surgery-specific risk for noncardiac surgery can be stratified as high, intermediate, and low (Table 3).[23] High-risk surgery includes major emergency surgery, particularly in the elderly; aortic and other major vascular surgery; peripheral vascular surgery; and anticipated prolonged procedures associated with large fluid shifts and/or blood loss. Intermediate-risk procedures include intraperitoneal and intrathoracic surgery, carotid endarterectomy, head and neck surgery, orthopedic surgery, and prostate surgery. Low-risk procedures include endoscopic and superficial procedures, cataract surgery, and breast surgery.

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

Step 1 What is the urgency of noncardiac surgery? Certain emergencies do not allow time for preoperative cardiac evaluation. Postoperative risk stratification may be appropriate for some patients who have not had such an assessment before.

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.[24]

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? 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.

Step 5 Does the patient have intermediate clinical predictors of risk? The presence or absence of prior MI by history or ECG, angina pectoris, compensated or prior HF, preoperative creatinine greater than or equal to 2 mg per deciliter, and/or diabetes mellitus helps to further stratify clinical risk for perioperative coronary events. Consideration of functional capacity and level of surgery-specific risk allows a rational approach to identify patients most likely to benefit from further noninvasive testing.

Step 6 Patients without major but with intermediate predictors of clinical risk and moderate or excellent

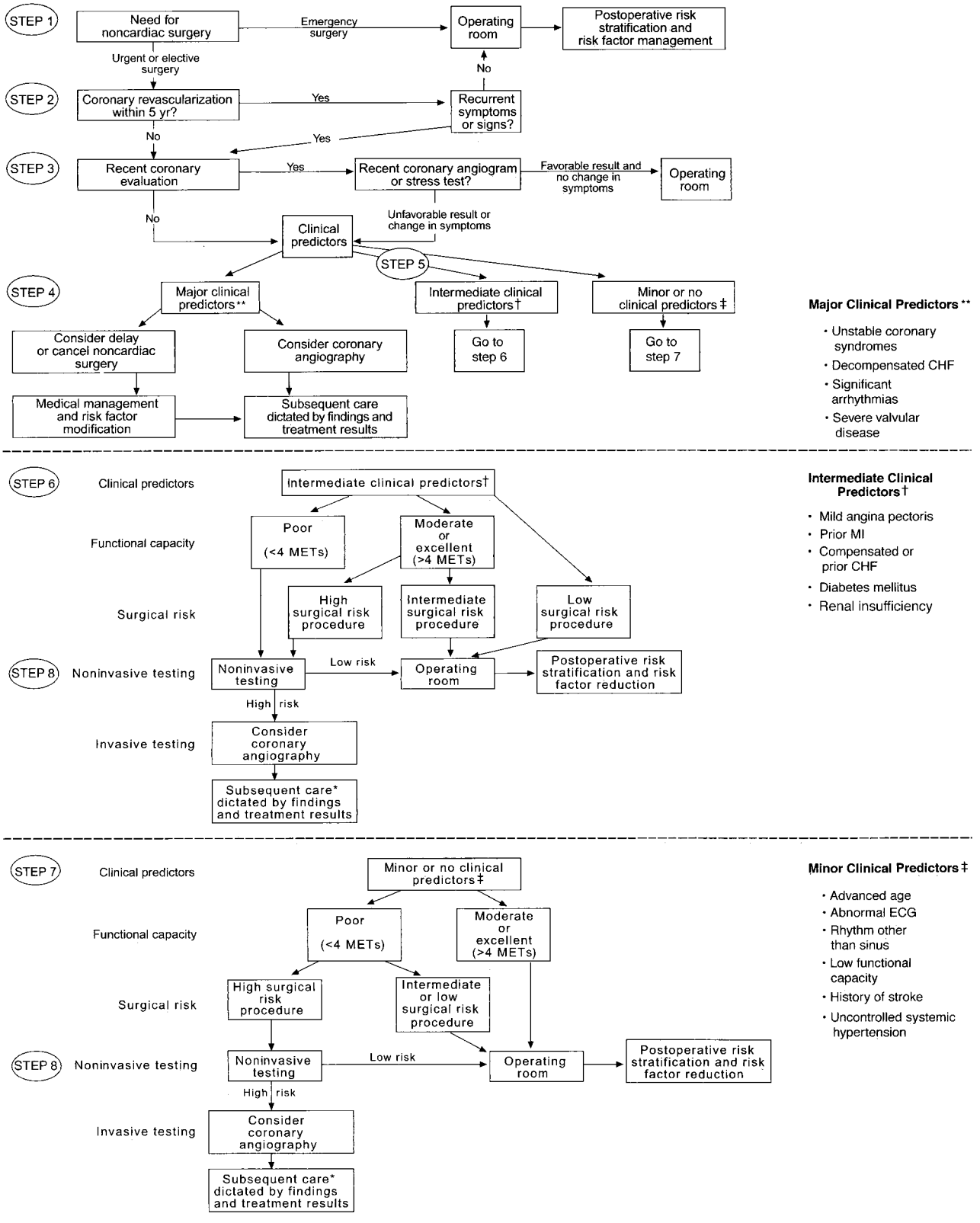

Figure 1. Stepwise approach to preoperative cardiac assessment. Steps are discussed in text. *Subsequent care may include cancellation or delay of surgery, coronary revascularization followed by noncardiac surgery, or intensified care.

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 class III or IV)
Decompensated heart failure
Significant arrhythmias
• 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 class I or II)
Previous myocardial infarction by history or pathological Q waves
Compensated or prior heart failure
Diabetes mellitus (particularly insulin-dependent)
Renal insufficiency
Minor
Advanced age
Abnormal ECG (left ventricular hypertrophy, left bundle-branch block, ST-T abnormalities)
Rhythm other than sinus (e.g., atrial fibrillation)
Low functional capacity (e.g., inability to climb one flight of stairs with a bag of groceries)
History of stroke
Uncontrolled systemic hypertension

ECG indicates electrocardiogram.

*The American College of Cardiology National Database Library defines *recent MI* 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.

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, especially for patients with 2 or more intermediate predictors of risk.

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

Step 8 The results of noninvasive testing can be used to determine the need for additional preoperative testing and treatment. In some patients with documented CAD, the risk of coronary 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 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.

III. Management of Specific Preoperative Cardiovascular Conditions

A. Hypertension

Stage 3 hypertension (systolic blood pressure greater than or equal to 180 mm Hg and diastolic blood pressure greater than or equal to 110 mm Hg) should be controlled before surgery. In many such instances, establishment of an effective regimen can be achieved over several days to weeks of preoperative outpatient treatment. If surgery is more urgent, rapid-acting agents can be administered that allow effective control in a matter of minutes or hours. Beta-blockers appear to be particularly attractive agents. Continuation of preoperative antihypertensive treatment through the perioperative period is critical.

B. Valvular Heart Disease

Indications for evaluation and treatment of valvular heart disease are identical to those in the nonpreoperative setting. Symptomatic stenotic lesions are associated with risk of perioperative HF or shock and often require percutaneous valvotomy or valve replacement before noncardiac surgery to lower cardiac risk.[6,25–27] Symptomatic regurgitant valve dis-

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 per h?
	Walk indoors around the house?		Run a short distance?
	Walk a block or two on level ground at 2 to 3 mph or 3.2 to 4.8 km per 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?
		Greater than 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[20] and AHA Exercise Standards.[96]

TABLE 3. Cardiac Risk* Stratification for Noncardiac Surgical Procedures

High (Reported cardiac risk often greater than 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 less than 5%)
• Carotid endarterectomy
• Head and neck surgery
• Intraperitoneal and intrathoracic surgery
• Orthopedic surgery
• Prostate surgery
Low (Reported cardiac risk generally less than 1%)
• Endoscopic procedures
• Superficial procedure
• Cataract surgery
• Breast surgery

*Combined incidence of cardiac death and nonfatal myocardial infarction.
†Do not generally require further preoperative cardiac testing.

ease is usually better tolerated perioperatively and may be stabilized preoperatively with intensive medical therapy and monitoring. Regurgitant valve disease can then be treated definitively with valve repair or replacement after noncardiac surgery. Medical therapy and monitoring are appropriate when a delay of several weeks or months before noncardiac surgery may have severe consequences. Exceptions may include severe valvular regurgitation with reduced left ventricular function, in which overall hemodynamic reserve is so limited that destabilization during perioperative stresses is likely.

C. Myocardial Disease

Dilated and hypertrophic cardiomyopathy are associated with an increased incidence of perioperative HF.[6,28,29] Management is aimed at maximizing preoperative hemodynamic status and providing intensive postoperative medical therapy and surveillance. An estimate of hemodynamic reserve is useful for anticipating potential complications from intraoperative or postoperative stress.

D. 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 an underlying cause and second to treat the arrhythmia. Indications for antiarrhythmic therapy and cardiac pacing are identical to those in the nonoperative setting. Frequent ventricular premature beats and/or asymptomatic nonsustained ventricular tachycardia have not been associated with an increased risk of nonfatal MI or cardiac death in the perioperative period,[30,31] and therefore, aggressive monitoring or treatment in the perioperative period generally is not necessary.

E. 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.

IV. Supplemental Preoperative Evaluation

Specific recommendations for supplemental preoperative evaluation must be individualized to each patient and circumstance. The following may be appropriate in specific situations: assessment of resting left ventricular function, exercise stress testing, pharmacological stress testing, ambulatory ECG monitoring, and coronary angiography. 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 through changes in the ECG and hemodynamic response. In patients with important abnormalities on their resting ECG (e.g., left bundle-branch block, left ventricular hypertrophy with strain pattern, or digitalis effect), other techniques such as exercise echocardiography or exercise myocardial perfusion imaging should be considered. Recommendations regarding individual testing modalities are given below.

A. Resting Left Ventricular Function

Resting left ventricular function has not been found to be a consistent predictor of perioperative ischemic events.[32–40]

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.

B. 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.[41–45]

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.

C. Exercise or Pharmacological Stress Testing

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).**

Class III

1. **For *exercise* stress testing, diagnosis of patients with resting ECG abnormalities that preclude adequate assessment, e.g., 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.**

D. Coronary Angiography

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.**
4. **Noncandidate for coronary revascularization owing to concomitant medical illness, severe left ventricular dysfunction (e.g., left ventricular ejection fraction less than 0.20), or refusal to consider revascularization.**
5. **Candidate for liver, lung, or renal transplant less than 40 years old, as part of evaluation for transplantation, unless noninvasive testing reveals high risk for adverse outcome.**

V. Perioperative Therapy or Previous Coronary Revascularization

A. Coronary Artery Bypass Grafting

Indications for coronary artery bypass grafting (CABG) before noncardiac surgery are identical to those reviewed in the ACC/AHA guidelines for CABG.[46] 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.[23] Patients

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

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

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[47] should generally undergo revascularization before a noncardiac elective surgical procedure of high or intermediate risk (Table 3).

B. 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.[48–52] 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.[53] 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.[54]

VI. Perioperative Medical Therapy

Several recent trials have examined the impact of medical therapy begun just before surgery on reducing cardiac events. Two randomized, placebo-controlled trials of beta-blocker administration have been performed.[13,14,55,56] One trial demonstrated reduced perioperative cardiac events, and the other demonstrated improved 6-month survival with perioperative beta-blocker usage. Several trials have evaluated the utility of alpha-2 agonists, demonstrating reduced cardiac event rates in the subset of patients with known CAD undergoing vascular surgery.[57–60]

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

l. **Beta-blockers: preoperative assessment identifies untreated hypertension, known coronary disease, or major risk factors for coronary disease.**

Class IIb

1. **Alpha-2 agonist: 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.**

VII. Anesthetic Considerations and Intraoperative Management

A. 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.[61–65] 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.

B. 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.[66,67]

C. Intraoperative Nitroglycerin

There are insufficient data about the effects of prophylactic intraoperative intravenous nitroglycerin in patients at high risk.[68–71] Nitroglycerin should be used only when the hemodynamic effects of other agents in use have been considered.

D. 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.[72,73] Experience to date suggests that the incremental value of this technique for risk prediction is small.[72] Guidelines for appropriate use of transesophageal echocardiography have been published by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists.[74]

E. 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.[75]

VIII. Perioperative Surveillance

A. Pulmonary Artery Catheters

Although very few studies that have been reported compare patient outcomes after treatment with or without pulmonary artery catheters, 3 variables are particularly important in assessing benefit versus risk of pulmonary artery catheter use: disease severity, magnitude of anticipated surgery, and practice setting.[76] The extent of expected fluid shifts is a primary concern. Patients most likely to benefit from perioperative use of a pulmonary artery catheter appear to be those with a recent MI complicated by HF, those with significant CAD who are undergoing procedures associated with significant hemodynamic stress, and those with systolic or diastolic left ventricular dysfunction, cardiomyopathy, and/or valvular disease who are undergoing high-risk operations.

B. 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.[77–80] Similarly, postoperative ischemia is a significant predictor of long-term risk of MI and cardiac death.[81] Conversely, in patients at low risk who undergo noncardiac surgery, ST depression may occur and often is not associated with regional wall-motion abnormalities.[82–84] 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.

C. Surveillance for Perioperative MI

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.[85–90] 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.[91] 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.

IX. Postoperative and Long-Term Management

Despite even optimal perioperative management, some patients will have perioperative MI, which is associated with a 40% to 70% mortality rate.[92] For patients who experience a symptomatic perioperative ST-segment–elevation MI as a result of sudden thrombotic coronary occlusion, angioplasty should be considered after the risks versus benefits have been weighed. Pharmacological therapy with aspirin should be initiated as soon as possible, and a beta-blocker and angiotensin converting enzyme inhibitor may also be beneficial. Perioperative MI carries a high risk for future cardiac events. Patients who sustain acute MI in the perioperative period should receive careful medical evaluation for residual ischemia and overall left ventricular function.

It is also appropriate to recommend secondary risk reduction in the relatively large number of elective surgery patients in whom cardiovascular abnormalities are detected during preoperative evaluations. Although the occasion of surgery is often taken as a specific high-risk time, most of the patients who have known or newly detected CAD during their preoperative evaluations will not have any events during elective noncardiac surgery. After the preoperative cardiac risk has been determined by clinical or noninvasive testing, most patients will benefit from pharmacological agents to lower low-density lipoprotein cholesterol levels, increase high-density lipoprotein levels, or both. On the basis of expert opinion, the goal should be to lower the low-density lipoprotein level to less than 100 mg per deciliter (2.6 mmol per deciliter).[93–95]

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KEY WORDS: ACC/AHA Practice Guidelines ■ surgery ■ risk factors