Special Article

CME ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery: Executive Summary

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery)

Developed in Collaboration With the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery

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PREAMBLE

It is important that the medical profession play a significant role in critically evaluating the use of diagnostic procedures and therapies as they are introduced and tested in the detection, management, or prevention of disease states. Rigorous and expert analysis of the available data documenting the absolute and relative benefits and risks of those procedures and therapies can produce helpful guidelines that improve the effectiveness of care, optimize patient outcomes, and favorably affect the overall cost of care by focusing resources on the most effective strategies.

The American College of Cardiology (ACC) Foundation and the American Heart Association (AHA) have jointly engaged in the production of such guidelines in the area of cardiovascular disease since 1980. The ACC/AHA Task Force on Practice Guidelines, whose charge is to develop, update, or revise practice guidelines for important cardiovascular diseases and procedures, directs this effort. Writing committees are charged with the task of performing an assessment of the evidence and acting as an independent group of authors to develop, update, or revise written recommendations for clinical practice.

Experts in the subject under consideration have been selected from both organizations to examine subject-specific data and write guidelines. The process includes additional representatives from other medical practitioner and specialty groups when appropriate. Writing committees are specifically charged to perform a formal literature review, weigh the strength of evidence for or against a particular treatment or procedure, and include estimates of expected health outcomes where data exist. Patient-specific modifiers, comorbidities, and issues of patient preference that might influence the choice of particular tests or therapies are considered, as well as frequency of follow-up and cost-effectiveness. When available, information from studies on cost will be considered; however, review of data on efficacy and clinical outcomes will

Table 1. Applying classification of recommendations and level of evidence.

"Estimate of Certainty (Precision) of Treatment Effect"	"Size of Treatment Effect"			
	Class I *Benefit >>> Risk* **Procedure/Treatment SHOULD be performed/administered**	**Class IIa** *Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE to perform procedure/administer treatment**	**Class IIb** *Benefit ≥ Risk* *Additional studies with broad objectives needed; Additional registry data would be helpful* **Procedure/Treatment MAY BE CONSIDERED**	**Class III** *Risk ≥ Benefit* *No additional studies needed* **Procedure/Treatment should NOT be performed/administered SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL**
Level A *Multiple (3-5) population risk strata evaluated** *General consistency of direction and magnitude of effect*	• Recommendation that procedure or treatment is useful/effective • Sufficient evidence from multiple randomized trials or meta-analyses	• Recommendation in favor of treatment or procedure being useful/effective • Some conflicting evidence from multiple randomized trials or meta-analyses	• Recommendation's usefulness/efficacy less well established • Greater conflicting evidence from multiple randomized trials or meta-analyses	• Recommendation that procedure or treatment not useful/effective and may be harmful • Sufficient evidence from multiple randomized trials or meta-analyses
Level B *Limited (2-3) population risk strata evaluated**	• Recommendation that procedure or treatment is useful/effective • Limited evidence from single randomized trial or non-randomized studies	• Recommendation in favor of treatment or procedure being useful/effective • Some conflicting evidence from single randomized trial or non-randomized studies	• Recommendation's usefulness/efficacy less well established • Greater conflicting evidence from single randomized trial or non-randomized studies	• Recommendation that procedure or treatment not useful/effective and may be harmful • Limited evidence from single randomized trial or non-randomized studies
Level C *Very limited (1-2) population risk strata evaluated**	• Recommendation that procedure or treatment is useful/effective • Only expert opinion, case studies, or standard-of-care	• Recommendation in favor of treatment or procedure being useful/effective • Only diverging expert opinion, case studies, or standard-of-care	• Recommendation's usefulness/efficacy less well established • Only diverging expert opinion, case studies, or standard-of-care	• Recommendation that procedure or treatment not useful/effective and may be harmful • Only expert opinion, case studies, or standard-of-care
Suggested phrases for writing recommendations †	should is recommended is indicated is useful/effective/beneficial	is reasonable can be useful/effective/ beneficial is probably recommended or indicated	may/might be considered may/might be reasonable usefulness/effectiveness is unknown /unclear/uncertain or not well established	is not recommended is not indicated should not is not useful/effective/beneficial may be harmful

*Data available from clinical trials or registries about the usefulness/efficacy in different sub-populations, such as gender, age, history of diabetes, history of prior MI, history of heart failure, and prior aspirin use. A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Even though randomized trials are not available, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

†In 2003, the ACC/AHA Task Force on Practice Guidelines developed a list of suggested phrases to use when writing recommendations. All recommendations in this guideline have been written in full sentences that express a complete thought, such that a recommendation, even if separated and presented apart from the rest of the document (including headings above sets of recommendations), would still convey the full intent of the recommendation. It is hoped that this will increase readers' comprehension of the guidelines and will allow queries at the individual recommendation level.

constitute the primary basis for preparing recommendations in these guidelines.

The ACC/AHA Task Force on Practice Guidelines makes every effort to avoid any actual, potential, or perceived conflicts of interest that may arise as a result of an industry relationship or personal interest of the writing committee. Specifically, all members of the writing committee, as well as peer reviewers of the document, were asked to provide disclosure statements of all such relationships that may be perceived as real or potential conflicts of interest. Writing committee members are also strongly encouraged to declare a previous relationship with industry that may be perceived as relevant to guideline development. If a writing committee member develops a new relationship with industry during their tenure, they are required to notify guideline staff in writing. The continued participation of the writing committee member will be reviewed. These statements are reviewed by the parent task force, reported orally to all members of the writing committee at each meeting, and updated and reviewed by the writing committee as changes occur. Please refer to the methodology manual for ACC/AHA guideline writing committees, available on the ACC and AHA World Wide Web sites (http://www.acc.org/qualityandscience/clinical/manual/manual_I.htm and http://circ.ahajournals.org/manual/), for further description of the policy on relationships with industry. Please see Appendix I for author relationships with industry and Appendix II for peer reviewer relationships with industry that are pertinent to these guidelines.

These practice guidelines are intended to assist healthcare providers in clinical decision making by describing a range of generally acceptable approaches for the diagnosis, management, and prevention of specific diseases or conditions. These guidelines attempt to define practices that meet the needs of most patients in most circumstances. Clinical decision making should consider the quality and availability of expertise in the area where care is provided. These guideline recommendations reflect a consensus of expert opinion after a thorough review of the available, current scientific evidence and are intended to improve patient care.

Patient adherence to prescribed and agreed on medical regimens and lifestyles is an important aspect of treatment. Prescribed courses of treatment in accordance with these recommendations will only be effective if they are followed. Because lack of patient understanding and adherence may adversely affect treatment outcomes, physicians and other healthcare providers should make every effort to engage the patient in active participation with prescribed medical regimens and lifestyles.

If these guidelines are used as the basis for regulatory or payer decisions, the ultimate goal is quality of care and serving the patient's best interests. The ultimate judgment regarding care of a particular patient must be made by the healthcare provider and the patient in light of all of the circumstances presented by that patient. There are circumstances in which deviations from these guidelines are appropriate.

The guidelines will be reviewed annually by the ACC/AHA Task Force on Practice Guidelines and will be considered current unless they are updated, revised, or sunsetted and withdrawn from distribution. The executive summary and recommendations are published in the October 23, 2007, issue of the *Journal of the American College of Cardiology* and October 23, 2007, issue of *Circulation.* The full text-guidelines are e-published in the same issue of the journals noted above, as well as posted on the ACC (www.acc.org) and AHA (www.americanheart.org) Web sites. Copies of the full text and the executive summary are available from both organizations.

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I. DEFINITION OF THE PROBLEM

A. Purpose of These Guidelines

These guidelines represent an update to those published in 2002 and are intended for physicians and nonphysician caregivers 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 writing committee that prepared these guidelines strove to incorporate what is currently known about perioperative risk and how this knowledge can be used in the individual patient.

The tables and algorithms provide quick references for decision making. The overriding theme of this document is that intervention is rarely necessary to simply lower the risk of surgery unless such intervention is indicated irrespective of the preoperative context. The purpose of preoperative evaluation is not 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 and nonphysician caregivers, anesthesiologist, and surgeon can use in making treatment decisions that may influence short- and long-term cardiac outcomes. No test should be performed unless it is likely to influence patient treatment. The goal of the consultation is the optimal care of the patient.

B. Methodology and Evidence

The ACC/AHA Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery conducted a comprehensive review of the literature relevant to perioperative cardiac evaluation published since the last publication of these guidelines in 2002. Literature searches were conducted in the following databases: PubMed, MEDLINE, and the Cochrane Library (including the Cochrane Database of Systematic Reviews and the Cochrane Controlled Trials Register). Searches were limited to the English language, the years 2002 through 2007, and human subjects. Related-article searches were conducted in MEDLINE to find additional relevant articles. Finally, committee members recommended applicable articles outside the scope of the formal searches.

All of the recommendations in this guideline update were converted from the tabular format used in the 2002 guidelines to a listing of recommendations that has been written in full sentences to express a complete thought, such that a recommendation, even if separated and presented apart from the rest of the document, would still convey the full intent of the recommendation. It is hoped that this will increase the reader's comprehension of the guidelines. Also, the level of evidence, either an A, B, or C, for each recommendation is now provided (Table 1).

Recommendations

Recommendations for Preoperative Noninvasive Evaluation of Left Ventricular Function

Class IIa

1. **It is reasonable for patients with dyspnea of unknown origin to undergo preoperative evaluation of left ventricular (LV) function. (*Level of Evidence: C*)**
2. **It is reasonable for patients with current or prior heart failure with worsening dyspnea or other change in clinical status to undergo preoperative evaluation of LV function if not performed within 12 months. (*Level of Evidence: C*)**

Class IIb

1. **Reassessment of LV function in clinically stable patients with previously documented cardiomyopathy is not well established. (*Level of Evidence: C*)**

Class III

1. **Routine perioperative evaluation of LV function in patients is not recommended. (*Level of Evidence: B*)**

Recommendations for Preoperative Resting 12-Lead ECG

Class I

1. **Preoperative resting 12-lead ECG is recommended for patients with at least 1 clinical risk factor* who are undergoing vascular surgical procedures. (*Level of Evidence: B*)**
2. **Preoperative resting 12-lead ECG is recommended for patients with known coronary heart disease, peripheral arterial disease, or cerebrovascular disease who are undergoing intermediate-risk surgical procedures. (*Level of Evidence: C*)**

Class IIa

1. **Preoperative resting 12-lead ECG is reasonable in persons with no clinical risk factors who are undergoing vascular surgical procedures. (*Level of Evidence: B*)**

Class IIb

1. **Preoperative resting 12-lead ECG may be reasonable in patients with at least 1 clinical risk factor who are undergoing intermediate-risk operative procedures. (*Level of Evidence: B*)**

Class III

1. **Preoperative and postoperative resting 12-lead ECGs are not indicated in asymptomatic persons undergoing low-risk surgical procedures. (*Level of Evidence: B*)**

Recommendations for Noninvasive Stress Testing Before Noncardiac Surgery

Class I

1 **Patients with active cardiac conditions (Table 2) in whom noncardiac surgery is planned should be evaluated and treated per ACC/AHA guidelines† before noncardiac surgery. (*Level of Evidence: B*)**

Class IIa

1. **Noninvasive stress testing of patients with 3 or more clinical risk factors and poor functional capacity (less than 4 metabolic equivalents [METs]) who require vascular surgery‡** is reasonable if it will change management. (***Level of Evidence: B*)**

Class IIb

1. **Noninvasive stress testing may be considered for patients with at least 1 to 2 clinical risk factors Gand poor functional capacity (less than**

*Clinical risk factors include history of ischemic heart disease, history of compensated or prior heart failure, history of cerebrovascular disease, diabetes mellitus, and renal insufficiency.

†ACC/AHA/ESC 2006 Guidelines for the Management of Patients With Atrial Fibrillation,[1] ACC/AHA 2005 Guideline Update for the Diagnosis and Management of Chronic Heart Failure in the Adult,[2] ACC/AHA Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction,[3] ACC/AHA/ESC Guidelines for the Management of Patients With Supraventricular Arrhythmias,[4] ACC/AHA Guidelines for the Management of Patients With Unstable Angina and Non–ST-Segment Elevation Myocardial Infarction,[5] ACC/AHA 2006 Guidelines for the Management of Patients With Valvular Heart Disease,[6] and ACC/AHA/ESC 2006 Guidelines for the Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death.[7]

‡Vascular surgery is defined by aortic and other major vascular surgery and peripheral vascular surgery. See Table 4.

4 METs) who require intermediate-risk noncardiac surgery if it will change management. (*Level of Evidence: B*)
2. **Noninvasive stress testing may be considered for patients with at least 1 to 2 clinical risk factors and good functional capacity (greater than or equal to 4 METs) who are undergoing vascular surgery. (*Level of Evidence: B*)**

Class III

1. **Noninvasive testing is not useful for patients with no clinical risk factors undergoing intermediate-risk noncardiac surgery. (*Level of Evidence: C*)**
2. **Noninvasive testing is not useful for patients undergoing low-risk noncardiac surgery. (*Level of Evidence: C*)**

Recommendations for Preoperative Coronary Revascularization With Coronary Artery Bypass Grafting or Percutaneous Coronary Intervention

(All of the Class I indications below are consistent with the ACC/AHA 2004 Guideline Update for Coronary Artery Bypass Graft Surgery.)

Class I

1. **Coronary revascularization before noncardiac surgery is useful in patients with stable angina who have significant left main coronary artery stenosis. (*Level of Evidence: A*)**
2. **Coronary revascularization before noncardiac surgery is useful in patients with stable angina who have 3-vessel disease. (Survival benefit is greater when left ventricular ejection fraction is less than 0.50.) (*Level of Evidence: A*)**
3. **Coronary revascularization before noncardiac surgery is useful in patients with stable angina who have 2-vessel disease with significant proximal left anterior descending stenosis and either ejection fraction less than 0.50 or demonstrable ischemia on noninvasive testing. (*Level of Evidence: A*)**
4. **Coronary revascularization before noncardiac surgery is recommended for patients with high-risk unstable angina or non–ST-segment elevation myocardial infarction (MI).[§] (*Level of Evidence: A*)**
5. **Coronary revascularization before noncardiac surgery is recommended in patients with acute ST-elevation MI. (*Level of Evidence: A*)**

Class IIa

1. **In patients in whom coronary revascularization with percutaneous coronary intervention (PCI) is appropriate for mitigation of cardiac symptoms and who need elective noncardiac surgery in the subsequent 12 months, a strategy of balloon angioplasty or bare-metal stent placement followed by 4 to 6 weeks of dual-antiplatelet therapy is probably indicated. (*Level of Evidence: B*)**
2. **In patients who have received drug-eluting coronary stents and who must undergo urgent surgical procedures that mandate the discontinuation of thienopyridine therapy, it is reasonable to continue aspirin if at all possible and restart the thienopyridine as soon as possible. (*Level of Evidence: C*)**

Class IIb

1. **The usefulness of preoperative coronary revascularization is not well established in high-risk ischemic patients (eg, abnormal dobutamine stress echocardiogram with at least 5 segments of wall-motion abnormalities). (*Level of Evidence: C*)**
2. **The usefulness of preoperative coronary revascularization is not well established for low-risk ischemic patients with an abnormal dobutamine stress echocardiogram (segments 1 to 4). (*Level of Evidence: B*)**

Class III

1. **It is not recommended that routine prophylactic coronary revascularization be performed in patients with stable coronary artery disease (CAD) before noncardiac surgery. (*Level of Evidence: B*)**
2. **Elective noncardiac surgery is not recommended within 4 to 6 weeks of bare-metal coronary stent implantation or within 12 months of drug-eluting coronary stent implantation in patients in whom thienopyridine therapy or aspirin and thienopyridine therapy will need to be discontinued perioperatively. (*Level of Evidence: B*)**
3. **Elective noncardiac surgery is not recommended within 4 weeks of coronary revascularization with balloon angioplasty. (*Level of Evidence: B*)**

Recommendations for Beta-Blocker Medical Therapy[‖]

Class I

1. **Beta blockers should be continued in patients undergoing surgery who are receiving beta blockers to treat angina, symptomatic arrhythmias, hypertension, or other ACC/AHA Class I guideline indications. (*Level of Evidence: C*)**
2. **Beta blockers should be given to patients undergoing vascular surgery who are at high**

[§]High-risk unstable angina/non–ST-elevation MI patients were identified as those with age greater than 75 years, accelerating tempo of ischemic symptoms in the preceding 48 hours, ongoing rest pain greater than 20 minutes in duration, pulmonary edema, angina with S_3 gallop or rales, new or worsening mitral regurgitation murmur, hypotension, bradycardia, tachycardia, dynamic ST-segment change greater than or equal to 1 mm, new or presumed new bundle-branch block on ECG, or elevated cardiac biomarkers, such as troponin.

[‖]Care should be taken in applying recommendations on beta-blocker therapy to patients with decompensated heart failure, nonischemic cardiomyopathy, or severe valvular heart disease in the absence of coronary heart disease.

cardiac risk owing to the finding of ischemia on preoperative testing. (*Level of Evidence: B*)

Class IIa

1. **Beta blockers are probably recommended for patients undergoing vascular surgery in whom preoperative assessment identifies coronary heart disease. (*Level of Evidence: B*)**
2. **Beta blockers are probably recommended for patients in whom preoperative assessment for vascular surgery identifies high cardiac risk, as defined by the presence of more than 1 clinical risk factor.* (*Level of Evidence: B*)**
3. **Beta blockers are probably recommended for patients in whom preoperative assessment identifies coronary heart disease or high cardiac risk, as defined by the presence of more than 1 clinical risk factor,* who are undergoing intermediate-risk or vascular surgery. (*Level of Evidence: B*)**

Class IIb

1. **The usefulness of beta blockers is uncertain for patients who are undergoing either intermediate-risk procedures or vascular surgery, in whom preoperative assessment identifies a single clinical risk factor.* (*Level of Evidence: C*)**
2. **The usefulness of beta blockers is uncertain in patients undergoing vascular surgery with no clinical risk factors who are not currently taking beta blockers. (*Level of Evidence: B*)**

Class III

1. **Beta blockers should not be given to patients undergoing surgery who have absolute contraindications to beta blockade. (*Level of Evidence: C*)**

Recommendations for Statin Therapy

Class I

1. **For patients currently taking statins and scheduled for noncardiac surgery, statins should be continued. (*Level of Evidence: B*)**

Class IIa

1. **For patients undergoing vascular surgery with or without clinical risk factors, statin use is reasonable. (*Level of Evidence: B*)**

Class IIb

1. **For patients with at least 1 clinical risk factor who are undergoing intermediate-risk procedures, statins may be considered. (*Level of Evidence: C*)**

Recommendations for Alpha-2 Agonists

Class IIb

1. **Alpha-2 agonists for perioperative control of hypertension may be considered for patients with known CAD or at least 1 clinical risk factor who are undergoing surgery. (*Level of Evidence: B*)**

Class III

1. **Alpha-2 agonists should not be given to patients undergoing surgery who have contraindications to this medication. (*Level of Evidence: C*)**

Recommendation for Preoperative Intensive Care Monitoring

Class IIb

1. **Preoperative intensive care monitoring with a pulmonary artery catheter for optimization of hemodynamic status might be considered; however, it is rarely required and should be restricted to a very small number of highly selected patients whose presentation is unstable and who have multiple comorbid conditions. (*Level of Evidence: B*)**

Recommendations for Use of Volatile Anesthetic Agents

Class IIa

1. **It can be beneficial to use volatile anesthetic agents during noncardiac surgery for the maintenance of general anesthesia in hemodynamically stable patients at risk for myocardial ischemia. (*Level of Evidence: B*)**

Recommendation for Prophylactic Intraoperative Nitroglycerin

Class IIb

1. **The usefulness of intraoperative nitroglycerin as a prophylactic agent to prevent myocardial ischemia and cardiac morbidity is unclear for high-risk patients undergoing noncardiac surgery, particularly 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. (*Level of Evidence: C*)**

Recommendation for Use of Transesophageal Echocardiography

Class IIa

1. **The emergency use of intraoperative or perioperative transesophageal echocardiography is reasonable to determine the cause of an acute, persistent, and life-threatening hemodynamic abnormality. (*Level of Evidence: C*)**

Recommendation for Maintenance of Body Temperature

Class I

1. **Maintenance of body temperature in a normothermic range is recommended for most procedures other than during periods in which mild**

hypothermia is intended to provide organ protection (eg, during high aortic cross-clamping). (*Level of Evidence: B*)

Recommendations for Perioperative Control of Blood Glucose Concentration

Class IIa

1. **It is reasonable that blood glucose concentration be controlled[¶] during the perioperative period in patients with diabetes mellitus or acute hyperglycemia who are at high risk for myocardial ischemia or who are undergoing vascular and major noncardiac surgical procedures with planned intensive care unit admission. (*Level of Evidence: B*)**

Class IIb

1. **The usefulness of strict control of blood glucose concentration[¶] during the perioperative period is uncertain in patients with diabetes mellitus or acute hyperglycemia who are undergoing noncardiac surgical procedures without planned intensive care unit admission. (*Level of Evidence: C*)**

Recommendations for Perioperative Use of Pulmonary Artery Catheters

Class IIb

1. **Use of a pulmonary artery catheter may be reasonable in patients at risk for major hemodynamic disturbances that are easily detected by a pulmonary artery catheter; however, the decision must be based on 3 parameters: patient disease, surgical procedure (ie, intraoperative and postoperative fluid shifts), and practice setting (experience in pulmonary artery catheter use and interpretation of results), because incorrect interpretation of the data from a pulmonary artery catheter may cause harm. (*Level of Evidence: B*)**

Class III

1. **Routine use of a pulmonary artery catheter perioperatively, especially in patients at low risk of developing hemodynamic disturbances, is not recommended. (*Level of Evidence: A*)**

Recommendations for Intraoperative and Postoperative Use of ST-Segment Monitoring

Class IIa

1. **Intraoperative and postoperative ST-segment monitoring can be useful to monitor patients with known CAD or those undergoing vascular surgery, with computerized ST-segment analysis, when available, used to detect myocardial ischemia during the perioperative period. (*Level of Evidence: B*)**

Class IIb

1. **Intraoperative and postoperative ST-segment monitoring may be considered in patients with single or multiple risk factors for CAD who are undergoing noncardiac surgery. (*Level of Evidence: B*)**

Recommendations for Surveillance for Perioperative MI

Class I

1. **Postoperative troponin measurement is recommended in patients with ECG changes or chest pain typical of acute coronary syndrome. (*Level of Evidence: C*)**

Class IIb

1. **The use of postoperative troponin measurement is not well established in patients who are clinically stable and have undergone vascular and intermediate-risk surgery. (*Level of Evidence: C*)**

Class III

1. **Postoperative troponin measurement is not recommended in asymptomatic stable patients who have undergone low-risk surgery. (*Level of Evidence: C*)**

II. GENERAL APPROACH TO THE PATIENT

This guideline focuses on the evaluation of the patient undergoing noncardiac surgery who is at risk for perioperative cardiac morbidity or mortality. In patients with known CAD or the new onset of signs or symptoms suggestive of CAD, baseline cardiac assessment should be performed. In the asymptomatic patient, a more extensive assessment of history and physical examination is warranted in those individuals 50 years of age or older, because the evidence related to the determination of cardiac risk factors and derivation of a revised cardiac risk index occurred in this population.[8] Preoperative cardiac evaluation must therefore be carefully tailored to the circumstances that have prompted the evaluation and to the nature of the surgical illness. In patients in whom coronary revascularization is not an option, it is often not necessary to perform a noninvasive stress test. Under other, less urgent circumstances, the preoperative cardiac evaluation may lead to a variety of responses, including cancellation of an elective procedure.

If a consultation is requested, then it is important to identify the key questions and ensure that all of the perioperative caregivers are considered when providing a response. Once a consultation has been obtained, the consultant should review available patient data, obtain a history, and perform a physical examination that includes a comprehensive cardiovascular examination and elements pertinent to the patient's problem and the proposed surgery. A critical role of the consultant is to determine the stability of the patient's cardiovascular status and whether the patient is in optimal medical condition within the context of the

[¶]Blood glucose levels less than 150 mg/dL appear to be beneficial.

Table 2. Active Cardiac Conditions for Which the Patient Should Undergo Evaluation and Treatment Before Noncardiac Surgery (Class I, Level of Evidence: B)

Condition	Examples
Unstable coronary syndromes	Unstable or severe angina* (CCS class III or IV)† Recent MI‡
Decompensated HF (NYHA functional class IV; worsening or new-onset HF)	
Significant arrhythmias	High-grade atrioventricular block Mobitz II atrioventricular block Third-degree atrioventricular heart block Symptomatic ventricular arrhythmias Supraventricular arrhythmias (including atrial fibrillation) with uncontrolled ventricular rate (HR greater than 100 beats per minute at rest) Symptomatic bradycardia Newly recognized ventricular tachycardia
Severe valvular disease	Severe aortic stenosis (mean pressure gradient greater than 40 mm Hg, aortic valve area less than 1.0 cm^2, or symptomatic) Symptomatic mitral stenosis (progressive dyspnea on exertion, exertional presyncope, or HF)

* According to Campeau.[9]

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

‡ The American College of Cardiology National Database Library defines recent MI as more than 7 days but less than or equal to 1 month (within 30 days).

CCS indicates Canadian Cardiovascular Society; HF, heart failure; HR, heart rate; MI, myocardial infarction; NYHA, New York Heart Association.

surgical illness. The consultant may recommend changes in medication, suggest preoperative tests or procedures, or propose higher levels of care postoperatively. In general, preoperative tests are recommended only if the information obtained will result in a change in the surgical procedure performed, a change in medical therapy or monitoring during or after surgery, or a postponement of surgery until the cardiac condition can be corrected or stabilized.

The consultant must also bear in mind that the perioperative evaluation may be the ideal opportunity to effect the long-term treatment of a patient with significant cardiac disease or risk of such disease. The referring physician and patient should be informed of the results of the evaluation and implications for the patient's prognosis. It is the cardiovascular consultant's responsibility to ensure clarity of communication so that findings and impressions will be incorporated effectively into the patient's overall plan of care. This ideally would include direct communication with the surgeon, anesthesiologist, and other physicians, as well as frank discussion directly with the patient and, if appropriate, the family. The consultant should not use phrases such as "clear for surgery."

A. History

A careful history is crucial to the discovery of cardiac and/or comorbid diseases that would place the patient in a high surgical risk category. The history should seek to identify serious cardiac conditions such as unstable coronary syndromes, prior angina, recent or past MI, decompensated heart failure, significant arrhythmias, and severe valvular disease (Table 2). It should also determine whether the patient has a prior history of a pacemaker or implantable cardioverter defibrillator (ICD) or a history of orthostatic intolerance and should identify risk factors associated with increased perioperative cardiovascular risk. In patients with established cardiac disease, any recent change in symptoms must be ascertained. Accurate recording of current medications used, including herbal and other nutritional supplements, and dosages is essential. Use of alcohol, tobacco, and over-the-counter and illicit drugs should be documented.

The history should also seek to determine the patient's functional capacity (Table 3). An assessment of an individual's capacity to perform a spectrum of common daily tasks has been shown to correlate well with maximum oxygen uptake by treadmill testing.[10] A patient classified as high risk owing to age or known CAD but who is asymptomatic and runs for 30 minutes daily may need no further evaluation. In contrast, a sedentary patient without a history of cardiovascular disease but with clinical factors that suggest increased perioperative risk may benefit from a more extensive preoperative evaluation.[12–15]

B. Physical Examination and Routine Laboratory Tests

A careful cardiovascular examination should include an assessment of vital signs (including measurement of blood pressure in both arms), carotid pulse contour and bruits, jugular venous pressure and pulsations, auscultation of the lungs, precordial palpation and auscultation, abdominal palpation, and examination of the extremities for edema and vascular integrity.

Anemia imposes a stress on the cardiovascular system that may exacerbate myocardial ischemia and aggravate heart failure.[16] Hematocrits of less than 28% are associated with an increased incidence of perioperative ischemia and postoperative complications in patients undergoing prostate and vascular surgery.[16–18]

Table 3. Estimated Energy Requirements for Various Activities

	Can you. . .		Can you. . .
1 MET	Take care of yourself? Eat, dress, or use the toilet?	4 METs	Climb a flight of stairs or walk up a hill? Walk on level ground at 4 mph (6.4 kph)?
	Walk indoors around the house?		Run a short distance?
	Walk a block or 2 on level ground at 2 to 3 mph (3.2 to 4.8 kph)?		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?

kph indicates kilometers per hour; MET, metabolic equivalent; and mph, miles per hour.

* Modified from Hlatky et al,[10] copyright 1989, with permission from Elsevier, and adapted from Fletcher et al.[11]

C. Multivariable Indices to Predict Preoperative Cardiac Morbidity

The basic clinical evaluation obtained by history, physical examination, and review of the ECG usually provides the consultant with sufficient data to estimate cardiac risk. Lee et al.[8] derived and validated a "simple index" for the prediction of cardiac risk for stable patients undergoing nonurgent major noncardiac surgery. Six independent risk correlates were identified: ischemic heart disease (defined as history of MI, history of positive treadmill test, use of nitroglycerin, current complaints of chest pain thought to be secondary to coronary ischemia, or ECG with abnormal Q waves); congestive heart failure (defined as history of heart failure, pulmonary edema, paroxysmal nocturnal dyspnea, peripheral edema, bilateral rales, S_3, or chest radiograph with pulmonary vascular redistribution); cerebral vascular disease (history of transient ischemic attack or stroke); high-risk surgery (abdominal aortic aneurysm or other vascular, thoracic, abdominal, or orthopedic surgery); preoperative insulin treatment for diabetes mellitus; and preoperative creatinine greater than 2 mg per dL. Increasing numbers of risk factors correlated with increased risk, yet the risk was substantially lower than described in many of the original indices.[8] The Revised Cardiac Risk Index has become one of the most widely used risk indices.[8]

D. Clinical Assessment

In the original guidelines, the committee chose to segregate clinical risk factors into major, intermediate, and minor risk factors. There continues to be a group of active cardiac conditions that when present indicate major clinical risk. The presence of 1 or more of these conditions mandates intensive management and may result in delay or cancellation of surgery unless the surgery is emergent (Table 2). These include

- Unstable coronary syndromes,
  - Unstable or severe angina,
  - Recent MI,
- Decompensated heart failure,
- Significant arrhythmias,
- Severe valvular disease.

Given the increasing use of the Revised Cardiac Risk Index, the committee chose to replace the intermediate-risk category with the clinical risk factors from the index, with the exclusion of the type of surgery, which is incorporated elsewhere in the approach to the patient. Clinical risk factors include

- history of ischemic heart disease,
- history of compensated or prior heart failure,
- history of cerebrovascular disease,
- diabetes mellitus, and
- renal insufficiency.[8]

A history of MI or abnormal Q waves by ECG is listed as a clinical risk factor, whereas an acute MI (defined as at least 1 documented MI 7 days or less 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 an active cardiac condition. This definition reflects the consensus of the ACC Cardiovascular Database Committee. Minor predictors are recognized markers for cardiovascular disease that have not been proven to independently increase perioperative risk, For example, advanced age (greater than 70 years), abnormal ECG (LV hypertrophy, left bundle-branch block, ST-T abnormalities), rhythm other than sinus, and uncontrolled systemic hypertension. The presence of multiple minor predictors might lead to a

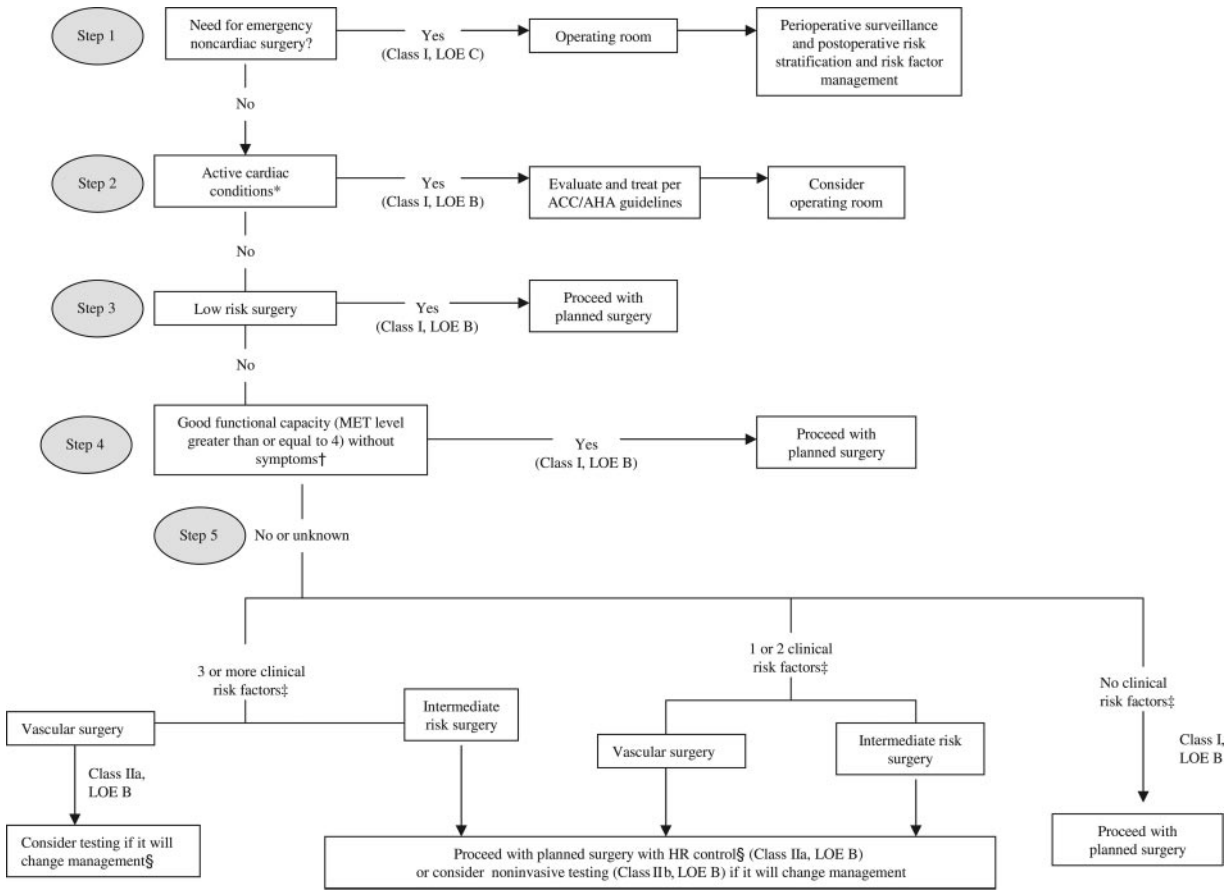

Figure 1. Cardiac evaluation and care algorithm for noncardiac surgery based on active clinical conditions, known cardiovascular disease, or cardiac risk factors for patients 50 years of age or greater. *See Table 2 for active clinical conditions. †See Table 3 for estimated MET level equivalent. ‡Clinical risk factors include ischemic heart disease, compensated or prior heart failure, diabetes mellitus, renal insufficiency, and cerebrovascular disease. §Consider perioperative beta blockade (see Table 5) for populations in which this has been shown to reduce cardiac morbidity/mortality. ACC/AHA indicates American College of Cardiology/American Heart Association; HR, heart rate; LOE, level of evidence; and MET, metabolic equivalent.

higher suspicion of CAD but is not incorporated into the recommendations for treatment.

1. Stepwise Approach to Perioperative Cardiac Assessment

Figure 1 presents in algorithmic form a framework for determining which patients are candidates for cardiac testing. Since publication of the perioperative cardiovascular evaluation guidelines in 2002,[19] several new randomized trials and cohort studies have led to modification of the original algorithm. Given the availability of this evidence, the Writing Committee chose to include the level of the recommendations and strength of evidence for many of the pathways.

Step 1: The consultant should determine the urgency of noncardiac surgery. In many instances, patient- or surgery-specific factors dictate an obvious strategy (eg, emergent surgery) that may not allow for further cardiac assessment or treatment. In such cases, the consultant may function best by providing recommendations for perioperative medical management and surveillance.

Step 2: Does the patient have 1 of the active cardiac conditions or clinical risk factors listed in Table 2? If not, proceed to Step 3. In patients being considered for elective noncardiac surgery, the presence of unstable coronary disease, decompensated heart failure, or severe arrhythmia or valvular heart disease usually leads to cancellation or delay of surgery until the cardiac problem has been clarified and treated appropriately. Examples of unstable coronary syndromes include previous MI with evidence of important ischemic risk by clinical symptoms or noninvasive study, unstable or severe angina, and new or poorly controlled ischemia-mediated heart failure. Many patients in these circumstances are referred for coronary angiography to assess further therapeutic options. Depending on the results of the test or interventions and the risk of delaying surgery, it may be appropriate to proceed to the planned surgery with maximal medical therapy.

Step 3: Is the patient undergoing low-risk surgery? In these patients, interventions based on cardiovascular testing in stable patients would rarely result in a change in management, and it would be appropriate to proceed with the planned surgical procedure.

Step 4: Does the patient have good functional capacity without symptoms? In highly functional

Table 4. Cardiac Risk* Stratification for Noncardiac Surgical Procedures

Risk Stratification	Procedure Examples
Vascular (reported cardiac risk often more than 5%)	Aortic and other major vascular surgeryPeripheral vascular surgery
Intermediate (reported cardiac risk generally 1% to 5%)	Intraperitoneal and intrathoracic surgery Carotid endarterectomy Head and neck surgery Orthopedic surgery Prostate surgery
Low† (reported cardiac risk generally less than 1%)	Endoscopic procedures Superficial procedure Cataract surgery Breast surgery Ambulatory surgery

*Combined incidence of cardiac death and nonfatal myocardial infarction.

†These procedures do not generally require further preoperative cardiac testing.

asymptomatic patients, management will rarely be changed on the basis of results of any further cardiovascular testing. It is therefore appropriate to proceed with the planned surgery. In patients with known cardiovascular disease or at least 1 clinical risk factor, perioperative heart rate control with beta blockade appears appropriate as outlined in Section VI.B.

If the patient has not had a recent exercise test, functional status can usually be estimated from the ability to perform activities of daily living.[20] For this purpose, functional capacity has been classified as excellent (greater than 10 METs), good (7 to 10 METs), moderate (4 to 7 METs), poor (less than 4 METs), or unknown. The Duke Activity Status Index (Table 3) contains questions that can be used to estimate the patient's functional capacity.[21]

Step 5: If the patient has poor functional capacity, is symptomatic, or has unknown functional capacity, then the presence of active clinical risk factors will determine the need for further evaluation. If the patient has no clinical risk factors, then it is appropriate to proceed with the planned surgery, and no further change in management is indicated.

If the patient has 1 or 2 clinical risk factors, then it is reasonable either to proceed with the planned surgery or, if appropriate, with heart rate control with beta blockade, or to consider testing if it will change management. In patients with 3 or more clinical risk factors, the surgery-specific cardiac risk is important.

The surgery-specific cardiac risk (Table 4) of noncardiac surgery is related to 2 important factors. First, the type of surgery itself may identify a patient with a greater likelihood of underlying heart disease and higher perioperative morbidity and mortality. Perhaps the most extensively studied example is vascular surgery, in which underlying CAD is present in a substantial portion of patients. If the patient is undergoing vascular surgery, recent studies suggest that testing should only be considered if it will change management. Other types of surgery may be associated with similar risk to vascular surgery but have not been studied extensively. In nonvascular surgery in which the perioperative morbidity related to the procedures ranges from 1% to 5% (intermediate-risk surgery), there are insufficient data to determine the best strategy (proceeding with the planned surgery with tight heart rate control with beta blockade or further cardiovascular testing if it will change management).

III. DISEASE-SPECIFIC APPROACHES

A. Coronary Artery Disease

1. Patients With Known CAD

In patients with known CAD, as well as those with previously occult coronary disease, the questions become 1) What is the amount of myocardium in jeopardy? 2) What is the ischemic threshold, that is, the amount of stress required to produce ischemia? 3) What is the patient's ventricular function? and 4) Is the patient on his or her optimal medical regimen? Clarification of these questions is an important goal of the preoperative history and physical examination, and selected noninvasive testing is used to determine the patient's prognostic gradient of ischemic response during stress testing.

B. Hypertension

For 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), the potential benefits of delaying surgery to optimize the effects of antihypertensive medications should be weighed against the risk of delaying the surgical procedure. With rapidly acting intravenous agents, blood pressure can usually be controlled within a matter of several hours. One randomized trial was unable to demonstrate a benefit to delaying surgery in chronically treated hypertensive patients who presented for noncardiac surgery with diastolic blood pressure between 110 and 130 mm Hg and who had no previous MI, unstable or severe angina pectoris, renal failure, pregnancy-induced hypertension, LV hypertrophy, previous coronary revascularization, aortic stenosis, preoperative dysrhythmias, conduction defects, or stroke.[23]

Several authors have suggested withholding angiotensin-converting enzyme inhibitors and angiotensin receptor antagonists the morning of surgery.[24–26] Consideration should be given to restarting angiotensin-converting enzyme inhibitors in the postoperative period only after the patient is euvolemic, to decrease the risk of perioperative renal dysfunction.

C. Valvular Heart Disease

In symptomatic aortic stenosis, elective noncardiac surgery should generally be postponed or canceled. Such patients require aortic valve replacement before

elective but necessary noncardiac surgery. If the aortic stenosis is severe but asymptomatic, the surgery should be postponed or canceled if the valve has not been evaluated within the year. On the other hand, in patients with severe aortic stenosis who refuse cardiac surgery or are otherwise not candidates for aortic valve replacement, noncardiac surgery can be performed with a mortality risk of approximately 10%.[27,28] If a patient is not a candidate for valve replacement, percutaneous balloon aortic valvuloplasty may be reasonable as a bridge to surgery in hemodynamically unstable adult patients with aortic stenosis who are at high risk for aortic valve replacement surgery and may be reasonable in adult patients with aortic stenosis in whom aortic valve replacement cannot be performed because of serious comorbid conditions.[6,29]

Significant mitral stenosis increases the risk of heart failure. However, preoperative surgical correction of mitral valve disease is not indicated before noncardiac surgery, unless the valvular condition should be corrected to prolong survival and prevent complications unrelated to the proposed noncardiac surgery. When the stenosis is severe, the patient may benefit from balloon mitral valvuloplasty or open surgical repair before high-risk surgery.[30]

In patients with persistent or permanent atrial fibrillation who are at high risk for thromboembolism, preoperative and postoperative therapy with intravenous heparin or subcutaneous low-molecular-weight heparin may be considered to cover periods of subtherapeutic anticoagulation.[1,31–33]

Patients with a mechanical prosthetic valve are of concern because of the need for endocarditis prophylaxis[34] when they undergo surgery that may result in bacteremia and the need for careful anticoagulation management. The Seventh American College of Chest Physicians Consensus Conference on Antithrombotic and Thrombolytic Therapy[35] recommends the following: for patients who require minimally invasive procedures (dental work, superficial biopsies), the recommendation is to briefly reduce the international normalized ratio to the low or subtherapeutic range and resume the normal dose of oral anticoagulation immediately after the procedure. Perioperative heparin therapy is recommended for patients in whom the risk of bleeding with oral anticoagulation is high and the risk of thromboembolism without anticoagulation is also high (mechanical valve in the mitral position; Bjork-Shiley valve; recent [ie, less than 1 year] thrombosis or embolus; or 3 or more of the following risk factors: atrial fibrillation, previous embolus at any time, hypercoagulable condition, mechanical prosthesis, and LV ejection fraction less than 30%).[36] For patients between these 2 extremes, physicians must assess the risk and benefit of reduced anticoagulation versus perioperative heparin therapy.

IV. SURGERY-SPECIFIC ISSUES

Although different operations are associated with different cardiac risks, these differences are most often a reflection of the context in which the patient undergoes surgery (stability or opportunity for adequate preoperative preparation), surgery-specific factors (eg, fluid shifts, stress levels, duration of procedure, or blood loss), or patient-specific factors (the incidence of CAD associated with the condition for which the patient is undergoing surgery). The surgical procedures have been classified as low risk, high risk, and vascular. Although coronary disease is the overwhelming risk factor for perioperative morbidity, procedures with different levels of stress are associated with different levels of morbidity and mortality. Superficial and ophthalmologic procedures represent the lowest risk and are rarely associated with excess morbidity and mortality. Major vascular procedures represent the highest-risk procedures and are now considered distinctly in the decision to perform further evaluation because of the large body of evidence regarding the value of perioperative interventions in this population (Figure 1). Both endovascular aortic aneurysm repair and carotid endarterectomy should be considered within the intermediate-risk category, distinct from the open vascular surgery procedures, on the basis of their preoperative morbidity and mortality rates, but clinicians should incorporate the similarly poor long-term survival rates that accompany these procedures into their decision-making processes. Within the intermediate-risk category, morbidity and mortality vary depending on the surgical location and extent of the procedure. Some procedures may be short, with minimal fluid shifts, whereas others may be associated with prolonged duration, large fluid shifts, and greater potential for postoperative myocardial ischemia and respiratory depression. Therefore, the physician must exercise judgment to correctly assess perioperative surgical risks and the need for further evaluation.

V. SUPPLEMENTAL PREOPERATIVE EVALUATION

A. Assessment of LV Function

Resting LV function has been evaluated preoperatively before noncardiac surgery by radionuclide angiography, echocardiography, and contrast ventriculography. It is noteworthy that resting LV function was not found to be a consistent predictor of perioperative ischemic events.

B. Assessment of Risk for CAD and Assessment of Functional Capacity

1. The 12-Lead ECG

Although the optimal time interval between obtaining a 12-lead ECG and elective surgery is unknown, general consensus suggests that an ECG within 30 days

of surgery is adequate for those with stable disease in whom a preoperative ECG is indicated.

2. Exercise Stress Testing for Myocardial Ischemia and Functional Capacity

The aim of supplemental preoperative testing is to provide an objective measure of functional capacity, to identify the presence of important preoperative myocardial ischemia or cardiac arrhythmias, and to estimate perioperative cardiac risk and long-term prognosis.

3. Noninvasive Stress Testing

Pharmacological stress with vasodilators or adrenergic stimulation in conjunction with radionuclide or echocardiographic cardiac imaging has been shown to predict perioperative cardiac events in patients scheduled for noncardiac surgery who are unable to exercise.[37] Importantly, perioperative cardiac risk is directly related to the extent of jeopardized viable myocardium identified by stress cardiac imaging.[37]

The expertise of the practitioner's available stress laboratory resources in identifying severe coronary disease is as important as the particular type of stress test ordered. For patients with unstable myocardial ischemia, who are at high risk for noncardiac surgery, it is usually appropriate to proceed with coronary angiography or to attempt to stabilize them with aggressive medical treatment rather than to perform a stress test.

VI. PERIOPERATIVE THERAPY

A. Preoperative Coronary Revascularization With Coronary Artery Bypass Grafting or PCI

1. Preoperative Coronary Artery Bypass Grafting

Until recently, all of the evidence regarding the value of surgical coronary revascularization was derived from cohort studies in patients who presented for noncardiac surgery after successful cardiac surgery. There are now several randomized trials that have assessed the overall benefit of prophylactic coronary bypass surgery to lower the perioperative cardiac risk of noncardiac surgery, the results of which can be applied to specific subsets of patients and will be discussed later.

The first large, randomized trial (Coronary Artery Revascularization Prophylaxis [CARP]) was published by McFalls and colleagues,[38] who randomly assigned 510 patients with significant coronary artery stenosis from among 5859 patients scheduled for vascular operations to either coronary artery revascularization before surgery or no revascularization before surgery. The authors concluded that routine coronary revascularization in patients with stable cardiac symptoms before elective vascular surgery does not significantly alter the long-term outcome or short-term risk of death or MI.

The DECREASE (Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography) II trial[39] was designed to evaluate the utility of cardiac testing in patients undergoing major vascular surgery with intermediate cardiac risk factors and adequate beta-blocker therapy. A composite end point of death and nonfatal MI was assessed at 30 days after vascular surgery. This study confirms that extensive cardiac ischemia is a risk factor for perioperative cardiac events, but it was too small to assess the effect of revascularization.

The DECREASE-V pilot study[40] identified a high-risk cohort of patients scheduled for vascular surgery who were randomized to best medical therapy and revascularization or best medical therapy alone before vascular surgery. There was no difference in the combined outcomes of death or MI at 30 days or 1 year between the revascularization and medical therapy groups, although there was a high incidence of cardiac events in this high-risk cohort. This study was not sized to definitively answer the question as to the value of preoperative revascularization in high-risk patients; however, the findings are consistent with the previously published literature suggesting a lack of benefit of preoperative coronary revascularization in preventing death or MI. The indications for preoperative surgical coronary revascularization, therefore, are essentially identical to those recommended by the ACC/AHA 2004 Guideline Update for Coronary Artery Bypass Graft Surgery and the accumulated data on which those conclusions were based.[41]

2. Preoperative PCI

Review of the literature suggests that PCI before noncardiac surgery is of no value in preventing perioperative cardiac events, except in those patients in whom PCI is independently indicated for an acute coronary syndrome. However, unscheduled noncardiac surgery in a patient who has undergone a prior PCI presents special challenges, particularly with regard to management of dual-antiplatelet agents required in those who receive coronary stents.

3. PCI Without Stents: Coronary Balloon Angioplasty

Several retrospective series of coronary balloon angioplasty before noncardiac surgery have been reported.[42–49] On the basis of the available literature, delaying noncardiac surgery for more than 8 weeks after balloon angioplasty increases the chance that restenosis at the angioplasty site will have occurred and theoretically increases the chances of perioperative ischemia or MI. However, performing the surgical procedure too soon after the PCI procedure might also be hazardous. Delaying surgery for at least 2 to 4 weeks after balloon angioplasty to allow for healing of the vessel injury at the balloon treatment site is supported by a study by Brilakis et al.[49] Daily aspirin antiplatelet therapy should be continued perioperatively. The risk of stopping the aspirin should be

weighed against the benefit of reduction in bleeding complications from the planned surgery.

4. PCI: Bare-Metal Coronary Stents

If a coronary stent is used in the revascularization procedure, as in the majority of percutaneous revascularization procedures, further delay of noncardiac surgery may be beneficial. Bare-metal stent thrombosis is most common in the first 2 weeks after stent placement and is exceedingly rare (less than 0.1% of most case series) more than 4 weeks after stent placement.[50,51] Given that stent thrombosis will result in Q-wave MI or death in the majority of patients in whom it occurs, and given that the risk of bare-metal stent thrombosis diminishes after endothelialization of the stent has occurred (which generally takes 4 to 6 weeks), it appears reasonable to delay elective noncardiac surgery for 4 to 6 weeks to allow for at least partial endothelialization of the stent, but not for more than 12 weeks, when restenosis may begin to occur.

A thienopyridine (ticlopidine or clopidogrel) is generally administered with aspirin for 4 weeks after bare-metal stent placement. The thienopyridines and aspirin inhibit platelet aggregation and reduce stent thrombosis but increase the risk of bleeding. Rapid endothelialization of bare-metal stents makes late thrombosis rare, and thienopyridines are rarely needed for more than 4 weeks after implantation of bare-metal stents. For this reason, delaying surgery 4 to 6 weeks after bare-metal stent placement allows proper thienopyridine use to reduce the risk of coronary stent thrombosis; then, after the thienopyridine has been discontinued, the noncardiac surgery can be performed. However, once the thienopyridine is stopped, its effects do not diminish immediately. It is for this reason that some surgical teams request a 1-week delay after thienopyridines are discontinued before the patient proceeds to surgery. In patients with bare-metal stents, daily aspirin antiplatelet therapy should be continued perioperatively. The risk of stopping the aspirin should be weighed against the benefit of reduction in bleeding complications from the planned surgery. In the setting of noncardiac surgery in patients who have recently received a bare-metal stent, the risk of stopping dual-antiplatelet agents prematurely (within 4 weeks of implantation) is significant compared with the risk of major bleeding from most commonly performed surgeries.

5. PCI: Drug-Eluting Stents

Thrombosis of drug-eluting stents may occur late and has been reported up to 1.5 years after implantation, particularly in the context of discontinuation of antiplatelet agents before noncardiac surgery.[52,53] In January 2007, an AHA/ACC/Society for Cardiovascular Angiography and Interventions (SCAI)/American College of Surgeons (ACS)/American Diabetes Association (ADA) science advisory was issued regarding the prevention of premature discontinuation of dual-antiplatelet therapy in patients with coronary artery stents.[54] This advisory report[54] concluded that premature discontinuation of dual-antiplatelet therapy markedly increases the risk of catastrophic stent thrombosis and death and/or MI. To eliminate the premature discontinuation of thienopyridine therapy, the advisory group recommended the following:

- Elective procedures for which there is a significant risk of perioperative or postoperative bleeding should be deferred until patients have completed an appropriate course of thienopyridine therapy (12 months after drug-eluting stent implantation if they are not at high risk of bleeding and a minimum of 1 month for bare-metal stent implantation).
- For patients treated with drug-eluting stents who are to undergo subsequent procedures that mandate discontinuation of thienopyridine therapy, aspirin should be continued if at all possible and the thienopyridine restarted as soon as possible after the procedure because of concerns about late-stent thrombosis.

Given the above reports and recommendations, the use of drug-eluting stents for coronary revascularization before imminent or planned noncardiac surgery that will necessitate the discontinuation of dual-antiplatelet agents is not recommended.

In patients with stable CAD, the indications for PCI in the preoperative setting should be identical to those developed by the joint ACC/AHA Task Force that provided guidelines for the use of PCI in patients with stable angina and asymptomatic ischemia.[55] There is no evidence to support prophylactic preoperative percutaneous revascularization in patients with asymptomatic ischemia or stable angina, particularly with drug-eluting stents. Similarly, there is little evidence to show how long a more distant PCI (ie, months to years before noncardiac surgery) protects against perioperative MI or death. Because additional coronary restenosis is unlikely to occur more than 8 to 12 months after PCI (whether or not a stent is used), it is reasonable to expect ongoing protection against untoward perioperative ischemic complications in currently asymptomatic, active patients who had been symptomatic before complete percutaneous coronary revascularization more than 8 to 12 months previously.

6. Perioperative Management of Patients With Prior PCI Undergoing Noncardiac Surgery

For patients who have undergone successful coronary intervention with or without stent placement before planned or unplanned noncardiac surgery, there is uncertainty regarding how much time should pass before the noncardiac procedure is performed. One approach is outlined in Figure 2, which is based

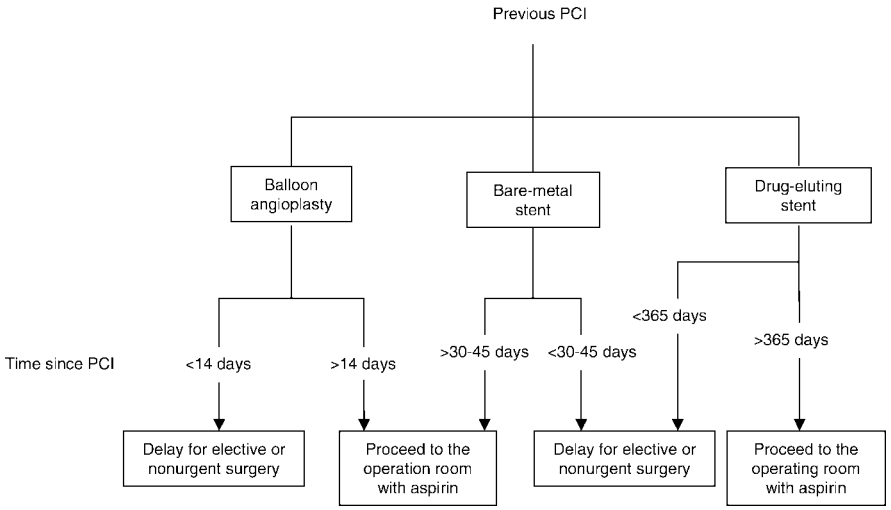

Figure 2. Proposed approach to the management of patients with previous percutaneous coronary intervention (PCI) who require noncardiac surgery, based on expert opinion.

on expert opinion. Given the reports of late drug-eluting stent thrombosis and the current recommendations discussed above, clinicians should remain vigilant even beyond 365 days after drug-eluting stent placement. The times of 14, 30 to 45, and 365 days for balloon angioplasty, bare-metal stent, and drug-eluting stent, respectively, recommended in Figure 2 are somewhat arbitrary because of a lack of high-quality evidence.

Consideration should be given to continuing dual-antiplatelet therapy in the perioperative period for any patient needing noncardiac surgery that falls within the time frame that requires dual-antiplatelet therapy, particularly those who have received drug-eluting stents. In addition, consideration should be given to continuing dual-antiplatelet therapy perioperatively beyond the recommended time frame in any patient at high risk for the consequences of stent thrombosis, such as patients in whom previous stent thrombosis has occurred, after left main stenting, after multivessel stenting, and after stent placement in the only remaining coronary artery or graft conduit. Even after thienopyridines have been discontinued, serious consideration should be given to continuation of aspirin antiplatelet therapy perioperatively in any patient with previous placement of a drug-eluting stent. The risk of stopping antiplatelet therapy should be weighed against the benefit of reduction in bleeding complications from the planned surgery. If thienopyridines must be discontinued before major surgery, aspirin should be continued and the thienopyridine restarted as soon as possible. There is no evidence that warfarin, antithrombotics, or glycoprotein IIb/IIIa agents will reduce the risk of stent thrombosis after discontinuation of oral antiplatelet agents.[54]

7. Perioperative Management in Patients Who Have Received Intracoronary Brachytherapy

Intracoronary radiation with gamma or beta brachytherapy has been used in the past to treat recurrent in-stent restenosis. Antiplatelet therapy should be continued as per the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention, with a class IIa recommendation.[55]

Serious consideration should be given to continuing dual-antiplatelet therapy in the perioperative period for any patient who has received brachytherapy for restenosis or in-stent restenosis, particularly those in whom additional stents (bare-metal or drug-eluting) were placed at the time of or subsequent to the administration of brachytherapy. The risk of stopping antiplatelet therapy should be weighed against the benefit of reduction in bleeding complications from the planned surgery.

8. Strategy of Percutaneous Revascularization in Patients Needing Urgent Noncardiac Surgery

Patients who require percutaneous coronary revascularization in whom near-term noncardiac surgery is necessary require special consideration.[54,56] A potential strategy is outlined in Figure 3. Percutaneous coronary revascularization should not be routinely performed in patients who need noncardiac surgery unless clearly indicated for high-risk coronary anatomy, unstable angina, MI, or hemodynamically or rhythmically unstable active CAD amenable to percutaneous intervention. If PCI is necessary, then the urgency of the noncardiac surgery and the risk of bleeding associated with the surgery in a patient taking dual-antiplatelet agents need to be considered. If there is little risk of bleeding or if the noncardiac surgery can be delayed 12 months or more, then PCI with drug-eluting stents and prolonged aspirin and thienopyridine therapy could be considered if the patient meets the criteria outlined in the AHA/ACC/SCAI/ACS/ADA Science Advisory Group recommendations discussed above.[54] If the noncardiac surgery is likely to occur within 1 to 12 months, then a strategy of bare-metal stenting and 4 to 6 weeks of aspirin and thienopyridine therapy with continuation of aspirin perioperatively should be considered. Although the risk of restenosis with this strategy is higher than with drug-eluting stents, restenotic lesions are usually not life-threatening, even though they may present as an

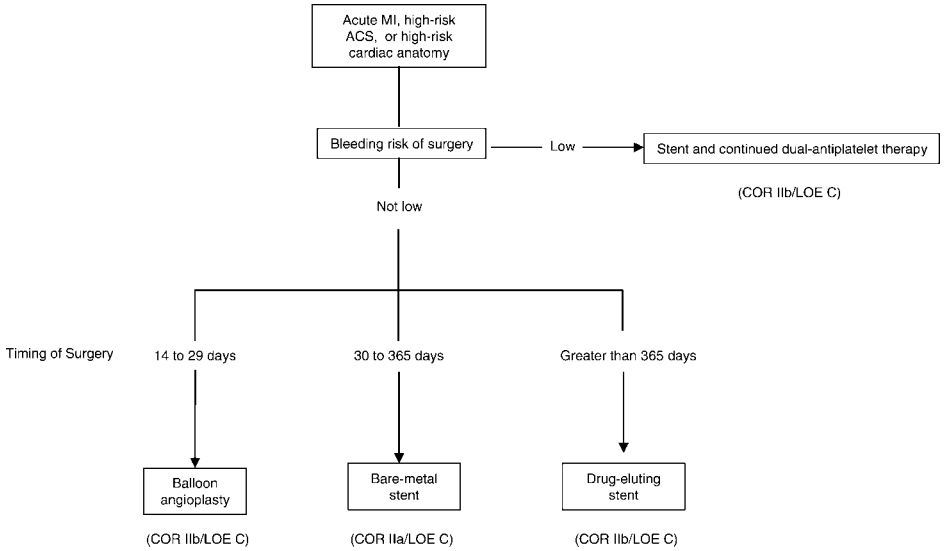

Figure 3. Treatment for patients requiring percutaneous coronary intervention who need subsequent surgery. ACS indicates acute coronary syndrome; COR, class of recommendation; LOE, level of evidence; and MI, myocardial infarction.

Table 5. Recommendations for Perioperative Beta-Blocker Therapy Based on Published Randomized Clinical Trials

Surgery	No Clinical Risk Factors	1 or More Clinical Risk Factors	CHD or High Cardiac Risk	Patients Currently Taking Beta Blockers
Vascular	Class IIb, Level of Evidence: B	Class IIa, Level of Evidence: B	Patients found to have myocardial ischemia on preoperative testing: Class I, Level of Evidence: B* Patients without ischemia or no previous test: Class IIa, Level of Evidence: B	Class I, Level of Evidence: B
Intermediate risk		Class IIb, Level of Evidence: C	Class IIa, Level of Evidence: B	Class I, Level of Evidence: C
Low risk				Class I, Level of Evidence: C

See Table 4 for definition of procedures. Ellipses () indicate that data were insufficient to determine a class of recommendation or level of evidence. See text for further discussion. CHD indicates coronary heart disease.

* Applies to patients found to have coronary ischemia on preoperative testing.

† Applies to patients found to have coronary heart disease.

acute coronary syndrome,[57] and they can usually be dealt with by repeat PCI if necessary. If the noncardiac surgery is imminent (within 2 to 6 weeks) and the risk of bleeding is high, then consideration should be given to balloon angioplasty and provisional bare-metal stenting plus continued aspirin antiplatelet monotherapy, with restenosis dealt with by repeat PCI if necessary. If the noncardiac surgery is urgent or emergent, then cardiac risks, the risk of bleeding, and the long-term benefit of coronary revascularization must be weighed, and if coronary revascularization is absolutely necessary, coronary artery bypass grafting combined with the noncardiac surgery could be considered.

B. Perioperative Medical Therapy

1. Perioperative Beta-Blocker Therapy

Since publication of the ACC/AHA focused update on perioperative beta-blocker therapy, several randomized trials have been published that have not demonstrated the efficacy of these agents, in contrast to the earlier studies that demonstrated efficacy.[58,59] Although many of the randomized controlled trials of beta blocker therapy are small, the weight of evidence—especially in aggregate—suggests a benefit to perioperative betablockade during noncardiac surgery in high-risk patients (Table 5). Current studies suggest that beta blockers reduce perioperative ischemia and may reduce the risk of MI and death in patients with known CAD. Available evidence strongly suggests but does not definitively prove that when possible, beta blockers should be started days to weeks before elective surgery. Additionally, data suggest that long-acting beta blockade may be superior to short-acting beta blockade.[60]

a. Titration of Beta Blockers

Feringa and colleagues[61] performed an observational cohort study of 272 vascular surgery patients. An absolute mean perioperative heart rate less than 70 beats per minute was associated with the best out-

come. Poldermans and colleagues[39] randomly assigned 770 intermediate-risk patients to cardiac stress testing (n = 386) or no testing (n = 384). The authors concluded that cardiac testing can safely be omitted in intermediate-risk patients, provided that beta blockers aimed at tight heart rate control are prescribed. Accumulating evidence suggests that effective heart rate control with beta blockers should be targeted at less than 65 beats per minute.

b. Withdrawal of Beta Blockers

Concerns regarding the discontinuation of beta-blocker therapy in the perioperative period have ex-isted for several decades.[62–64] As noted in the recommendations, continuation of beta-blocker therapy in the perioperative period is a Class I indication, and accumulating evidence suggests that titration to maintain tight heart rate control should be the goal.

2. Perioperative Statin Therapy

The evidence accumulated thus far suggests a protective effect of perioperative statin use on cardiac complications during noncardiac surgery. Hindler and colleagues[65] conducted a meta-analysis to evaluate the overall effect of preoperative statin therapy, and a 44% reduction in mortality was observed. Le Manach and colleagues[66] demonstrated that postoperative statin withdrawal (more than 4 days) was an independent predictor of postoperative myonecrosis. Most of these data are observational and identify patients in whom time of initiation of statin therapy and duration of statin therapy are unclear.

3. Alpha-2 Agonists

Wijeysundera and colleagues[67] performed a meta-analysis of perioperative alpha-2 agonist administration through 2002 comprising 23 trials enrolling 3395 patients. Alpha-2 agonists reduced mortality (relative risk 0.76, 95% CI 0.63 to 0.91) and MI (relative risk 0.66, 95% CI 0.46 to 0.94) during vascular surgery.

More recently, Wallace et al.[68] conducted a prospective, double-blinded, clinical trial on patients with or at risk for CAD and determined that administration of clonidine had minimal hemodynamic effects and reduced postoperative mortality for up to 2 years.

4. Perioperative Calcium Channel Blockers

A meta-analysis of perioperative calcium channel blockers in noncardiac surgery that was published in 2003 identified 11 studies involving 1007 patients.[69] Calcium channel blockers significantly reduced ischemia (relative risk 0.49, 95% confidence interval 0.30 to 0.80, $P=0.004$) and supraventricular tachycardia (relative risk 0.52, 95% confidence interval 0.37 to 0.72, P less than 0.0001) and were associated with trends toward reduced death and MI.

C. Intraoperative Electromagnetic Interference With Implanted Pacemakers and Cardioverter Defibrillators

It is important to be aware of the potential for adverse interactions between electrical/magnetic activity and pacemaker or ICD function that may occur during the operative period. A practice advisory on this topic has been published recently by the American Society of Anesthesiology.[70] Patients with permanent pacemakers, who are pacemaker dependent, should have their device evaluated within 3 to 6 months before significant surgical procedures, as well as after surgery. Significant surgical procedures include major abdominal or thoracic surgery, particularly when the surgery involves large amounts of electrocautery. If a patient is pacemaker dependent, the device should be reprogrammed to an asynchronous mode during surgery (VOO or DOO), or a magnet should be placed over the device during surgery. Implantable cardioverter defibrillator devices should have their tachyarrhythmia treatment algorithms programmed off before surgery and turned on after surgery to prevent unwanted shocks due to spurious signals that the device might interpret as ventricular tachycardia or fibrillation. If emergent cardioversion is required, the paddles should be placed as far from the implanted device as possible and in an orientation likely to be perpendicular to the orientation of the device leads (anterior-posterior paddle position is preferred). After the surgery, the function of the implanted device should be assessed and in some cases formally evaluated. In the case of an ICD, an interrogated programmer printout should be produced to verify that its antitachycardia function has been restored to its active status.

Placement of a magnet over an implanted device has variable effects depending on the type of device, its manufacturer, and its model. If a magnet will be used during surgery in a patient with a pacemaker who is pacemaker dependent, it should be applied before surgery to be certain that appropriate asynchronous pacing is triggered by the magnet. Magnet application will affect only the antitachycardia function of an ICD. With some models of ICDs, the magnet will first suspend the antitachycardia (shocking) function and then actually turn the therapy off. With other ICD models, the magnet will only temporarily disable the shock function (while the magnet is in place), and the therapy will then become active again on its removal (either intentional or unintentional). Programming the shock function off with an ICD programmer (and turning it back on after the surgery) is the preferred method of addressing these issues. Because some patients with ICDs are also pacemaker dependent, the pacing function of the ICD may need to be programmed to an asynchronous mode (eg, VOO or DOO) during surgery to prevent electromagnetic interference–induced inhibition.

VII. ANESTHETIC CONSIDERATIONS AND INTRAOPERATIVE MANAGEMENT

There are many different approaches to the details of the anesthetic care of the cardiac patient, including the use of specific anesthetic agents or anesthetic techniques (eg, general, regional, or monitored anesthesia care). Each has implications regarding anesthetic and intraoperative monitoring. In addition, no study has clearly demonstrated a change in outcome from the routine use of the following techniques: a pulmonary artery catheter, St-segment monitor, transesophageal echocardiography, or intravenous nitroglycerin. Therefore, the choice of anesthetic technique and intraoperative monitors is best left to the discretion of the anesthesia care team. Intraoperative management may be influenced by the perioperative plan, including the need for postoperative monitoring, ventilation, analgesia, and the perioperative use of anticoagulants or antiplatelet agents. Therefore, a discussion of these issues before the planned surgery will allow for a smooth transition through the perioperative period.

B. Perioperative Pain Management

From the cardiac perspective, pain management may be a crucial aspect of perioperative care. Although no randomized controlled study specifically addressing analgesic regimens has demonstrated improvement in outcome, patient-controlled analgesia techniques are associated with greater patient satisfaction and lower pain scores. An effective analgesic regimen must be included in the perioperative plan and should be based on issues unique to a given patient undergoing a specific procedure at a specific institution.

VIII. PERIOPERATIVE SURVEILLANCE

A. Intraoperative and Postoperative Use of Pulmonary Artery Catheters

Use of a pulmonary artery catheter may provide significant information critical to the care of the cardiac patient; however, the potential risk of complications and the cost associated with catheter insertion and use must be considered. Practice guidelines for pulmonary artery catheterization, as well as methods of performing perioperative optimization of the high-risk surgical patient, have been developed and reported elsewhere.[71,72] Evidence of benefit of pulmonary artery catheter use from controlled trials is equivocal, and a large-scale cohort study demonstrated potential harm.[73]

B. Surveillance for Perioperative MI

Perioperative MI can be documented by assessing clinical symptoms, serial ECGs, cardiac-specific biomarkers, comparative ventriculographic studies before and after surgery, radioisotopic or magnetic resonance studies specific for myocardial necrosis, and autopsy studies. Over the last decade, the diagnosis of myocardial damage has become more sensitive with the application of cardiac biomarkers. Measurement of troponin T or I facilitates the recognition of myocardial damage with much smaller amounts of injury. Because of the augmentation of sensitivity, the threshold to diagnosis of an MI is lower and the frequency greater.[74] On the basis of current evidence, in patients without documented CAD, surveillance should be restricted to those patients who develop perioperative signs of cardiovascular dysfunction. The diagnosis of a perioperative MI has both short- and long-term prognostic value.

On the basis of the available literature, routine measurement of troponin after surgery is more likely to identify patients without acute MI than with MI. Moreover, studies of troponin elevations neither consistently show associations with adverse cardiovascular outcomes at any time point nor provide insight into the effect of treatment on outcomes in patients with an elevated troponin level. Although it is known that elevations in troponin are more likely to occur in patients with more extensive CAD, the role of revascularization in patients with an elevated troponin level but no other manifestation of MI remains unclear. Until each of these issues has been addressed, routine troponin measurement cannot be recommended. Perioperative surveillance for acute coronary syndromes with routine ECG and cardiac serum biomarkers is unnecessary in clinically low-risk patients undergoing low-risk operative procedures.

IX. POSTOPERATIVE AND LONG-TERM MANAGEMENT

Advances in preoperative risk assessment, surgical and anesthetic techniques, and better implementation of medical therapy have served to decrease the frequency of cardiovascular complications associated with noncardiac surgery. Despite these advances, cardiovascular complications represent the most common and most treatable adverse consequences of noncardiac surgery. Those patients who have a symptomatic MI after surgery have a marked increase in the risk of death, reaching as high as 40% to 70%.[75] Because the consequences of infarction are so severe, management of patients must continue after risk assessment to the postoperative setting.

A. Myocardial Infarction: Surveillance and Treatment

In contrast to clinically silent elevations in troponin, the development of coronary artery plaque rupture that results in thrombotic coronary artery occlusion requires rapid intervention. Although fibrinolytic therapy has been administered to patients for life-threatening pulmonary embolus shortly after noncardiac surgery, the fibrinolytic dosage has generally been less and has been administered over a longer time interval than is standard for the treatment of acute MI.[76,77] Only a single small

study[74] has evaluated the role of immediate angiography and angioplasty among 48 patients who were believed able to take aspirin and intravenous heparin and to undergo immediate angiography and PCI; this study demonstrated that such a strategy is feasible and may be beneficial. These reperfusion procedures should not be performed routinely on an emergency basis in postoperative patients in whom MI is not related to an acute coronary occlusion. Moreover, because of the requirements for periprocedural anticoagulation and postrevascularization antiplatelet therapy, the benefits of revascularization must be weighed against the risk of postoperative bleeding, individualizing the decision for referral.

Therapy with aspirin, a beta blocker, and an angiotensin-converting enzyme inhibitor, particularly for patients with low ejection fractions or anterior infarctions, may be beneficial, whether or not the patients are rapidly taken to the catheterization laboratory.[79] An extensive evidence-based review of therapy for acute MI can be found in the ACC/AHA Guidelines for the Management of Patients With Acute Myocardial Infarction.[79] Similarly, the "ACC/AHA Guidelines for Unstable Angina/Non–ST-Segment Elevation Myocardial Infarction" represent an important template for management of this condition in the postoperative setting.[5]

In the approach to the long-term postoperative management of noncardiac surgery patients, one should first appreciate that the occurrence of an intraoperative nonfatal MI carries a high risk for future cardiac events that are often dominated by cardiovascular death.[80,81] Patients who sustain a perioperative MI should have evaluation of LV function performed before hospital discharge, and standard postinfarction therapeutic medical therapy should be prescribed as defined in the ACC/AHA acute MI guidelines.[3] The ACC/AHA guidelines for post-MI evaluation in these types of patients should be followed as soon as possible after surgical recovery.

B. Long-Term Management

Although the occasion of noncardiac surgery brings a period of increased cardiovascular risk, physicians should also use the opportunity to ensure appropriate cardiovascular medical therapy. In the recently released ACC/AHA 2005 Guidelines for the Management of Patients With Peripheral Arterial Disease,[82] treatment with a statin to achieve a low-density lipoprotein level of less than 100 mg/dL, control of blood pressure to less than 140/90 mm Hg, cigarette smoking cessation, and antiplatelet therapy all received Class I indications.[82]

It is important that the care team responsible for the long-term care of the patient be provided with complete information about any cardiovascular abnormalities or risk factors for CAD identified during the perioperative period.

X. CONCLUSIONS

Successful perioperative evaluation and management of high-risk cardiac patients undergoing noncardiac surgery requires careful teamwork and communication between surgeon, anesthesiologist, the patient's primary caregiver, and the consultant. In general, indications for further cardiac testing and treatments are the same as in the nonoperative setting, but their timing is dependent on several factors, including the urgency of noncardiac surgery, patient-specific risk factors, and surgery-specific considerations. The use of both noninvasive and invasive preoperative testing should be limited to those circumstances in which the results of such tests will clearly affect patient management. Finally, for many patients, noncardiac surgery represents their first opportunity to receive an appropriate assessment of both short- and long-term cardiac risk. Thus, the consultant best serves the patient by making recommendations aimed at lowering the immediate perioperative cardiac risk, as well as assessing the need for subsequent postoperative risk stratification and interventions directed at modifying coronary risk factors. Future research should be directed at determining the value of routine prophylactic medical therapy versus more extensive diagnostic testing and interventions.

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Appendix III. Abbreviations List

Abbreviation	Definition
ACC	American College of Cardiology
ACS	American College of Surgeons
ADA	American Diabetes Association
AHA	American Heart Association
CAD	coronary artery disease
CARP	Coronary Artery Revascularization Prophylaxis
DECREASE	Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography
ECG	electrocardiogram
ICD	implantable cardioverter-defibrillator
LV	left ventricle/left ventricular
MET	metabolic equivalent
MI	myocardial infarction
PCI	percutaneous coronary intervention
SCAI	Society for Cardiovascular Angiography and Interventions

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