An Evidence-Based Approach to Perioperative Care: Update for the Primary Care Physician

Kevin J. O'Leary, MD, Martin J. Arron, MD, Frank Lefevre, MD, Vinky Chadha, MD, and Steven L. Cohn, MD

Abstract

- *Objective:* To review the general principles of perioperative care for the primary care physician.
- *Methods:* Qualitative assessment of the literature.
- *Results:* A thorough history and physical examination provides the foundation of the preoperative evaluation. Laboratory testing generally should be performed when indicated rather than as routine screening prior to surgery. The American College of Cardiology and the American Heart Association have published consensus guidelines to guide the clinician on assessing cardiac risk, the potential benefit of noninvasive testing (eg, exercise electrocardiography [ECG], exercise or dobutamine stress echocardiography, and stress myocardial perfusion imaging), and the benefit of various management options. The indications for coronary artery bypass grafting and percutaneous coronary intervention prior to noncardiac surgery are identical to those for patients in which these procedures would otherwise be indicated. β-Blocker therapy has been shown to reduce the risk of perioperative cardiac death or myocardial infarction in selected patients. In patients with high or intermediate clinical risk who have known or suspected coronary artery disease and who are undergoing high or intermediate risk procedures, the most cost-effective strategy for postoperative monitoring is to obtain a 12-lead ECG immediately after surgery and on the first 2 days postoperatively.
- *Conclusion:* With knowledge of established risk factors obtained from a thorough history and physical examination and application of evidence-based guidelines, the physician can order appropriate testing and targeted interventions to maximize beneficial outcomes.

The goal of cost-effective medical care in the perioperative period is to maximize beneficial patient outcomes while avoiding the excessive use of diagnostic testing, procedures, and treatments that are unlikely to improve outcomes. This article reviews the general principles of cost-effective perioperative care for the primary care physician and discusses key recommendations from the American College of Cardiology/American Heart Association (ACC/AHA) guidelines on the perioperative cardiovascular evaluation of patients undergoing noncardiac surgery [1]. Specific areas that will be discussed include preoperative clinical evaluation, perioperative cardiac risk assessment and management, venous thromboembolism prophylaxis, and preoperative pulmonary risk assessment. Physicians should take a systematic approach to the preoperative workup. Performing a thorough history and physical examination, taking note of well-established clinical risk factors, and using evidence-based guidelines will help the physician make decisions on appropriate further testing and optimal treatment.

Preoperative Clinical Evaluation

History and Physical Examination

A thorough history and physical examination provide the foundation of the preoperative evaluation. Particular attention must be paid to cardiopulmonary disorders, which are responsible for the majority of perioperative medical complications. A past history of coronary artery disease, congestive heart failure, cardiac rhythm disturbances, cerebrovascular disease, renal insufficiency, and diabetes mellitus increases the risk of perioperative complications [1,2]. Valvular heart disease, particularly aortic stenosis, also has been shown to increase the risk of perioperative cardiac complications [1,3]. Past history of venous thromboembolism, chronic obstructive pulmonary disease (COPD), and asthma are also of particular significance. It is important to elicit active symptoms, especially chest pain, dyspnea, and difficulty with physical exertion [4]. The type of surgery, the timing of surgery (elective, urgent, or emergent), and the type of anesthesia are also important considerations. The patient's medications, including over-the-counter and herbal medications, should be reviewed and recorded. During the physical exam, special

From the Division of General Internal Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL (Drs. O'Leary, Arron, Lefevre, and Chadha), and the Division of General Internal Medicine, State University of New York, Downstate Medical Center, Brooklyn, NY (Dr. Cohn).

attention should be paid to vital signs, the cardiopulmonary examination, and assessment of volume status.

Laboratory Testing

In the past 2 decades, studies have demonstrated that 60% to 70% of preoperative laboratory tests are not indicated [5,6]. In asymptomatic patients, the rate of unexpected abnormalities is extremely low [5,7]. Even when indications for testing are present, the frequency of abnormal results that might influence perioperative management is very low [5]. Furthermore, treating physicians seldom make management changes based on abnormal test results and frequently ignore the results [7,8].

Evidence shows that forgoing preoperative laboratory testing in low-risk patients does not adversely affect outcomes. Narr et al [9] performed a retrospective chart review of 1044 patients who had undergone procedures or surgeries with no preoperative testing. The majority of patients were under the age of 50 years and had good physical status as measured by American Society of Anesthesiologists (ASA) class. No deaths or major perioperative morbidity occurred in this study. A prospective study by Schein et al [10] tested the value of preoperative testing prior to cataract surgery, a low-risk procedure. In addition to undergoing a thorough history and physical exam, patients were randomized to receive a preoperative battery of tests (electrocardiogram, complete blood count, and basic chemistry panel) versus no preoperative testing. The rate of complications was the same in the 2 groups.

Debate continues over the optimal timing of preoperative laboratory testing. MacPherson et al [11] studied preoperative laboratory values in patients who had undergone duplicate tests within the year preceding surgery. They found that 47% of tests had been duplicated, and only 0.4% of the duplicate test results were outside a range considered acceptable for surgery. In addition, most of the abnormalities could have been predicted from the patient's history. The majority of the duplicate tests had been performed within 4 months. In light of these findings, the authors concluded that results from testing performed within the previous 4 months were acceptable as long as no change in clinical status had occurred. The ASA recommends that test results obtained within 6 months of surgery are acceptable if the patient's medical history has not changed [12].

Recommendations for the use of preoperative laboratory testing are available (**Table 1**) [12–14]. While there is some degree of variability among these recommendations, they generally emphasize that testing should be performed when indicated rather than as routine screening prior to surgery.

Preoperative Risk Assessment

Risk Stratification Tools

Risk stratification tools can aid clinicians in more clearly defining the risk of elective surgery relative to its benefit in discussions with patients and surgeons. Risk indices developed over the past quarter century have identified risk factors that are most predictive of adverse cardiac outcomes [1,15,16]. Lee's revised cardiac risk index is the most recent index and was validated using the largest cohort of patients among the risk indices [2]. Lee et al studied 4315 patients undergoing major noncardiac surgery and identified 6 factors predictive of major complications: high-risk surgery, history of ischemic heart disease, history of congestive heart failure, history of cerebrovascular disease, insulin-requiring diabetes mellitus, and serum creatinine level greater than 2.0 mg/dL (**Table 2**). In the absence of any of these risk factors, major complications occurred in only 0.4% of patients. In patients with 3 or more risk factors, the rate of major complications was 11%. The revised cardiac risk index performed better than ASA class and several other previously validated indices.

Although most internists inform their patients of their perioperative cardiac risk [16], many do not use risk stratification tools [17,18]. One reason may be that risk stratification tools alone are not able to guide decisions on the need for further testing and the relative benefit of various management strategies.

Ancillary Testing to Refine Risk Assessment

Noninvasive tests available to refine perioperative cardiac risk assessment include exercise electrocardiography (ECG), exercise or dobutamine stress echocardiography, and exercise or pharmacologically induced stress myocardial perfusion imaging. If noninvasive testing is indicated, the physician should take into consideration the patient's functional capacity, certain clinical factors, availability, and performance characteristics when choosing one test over another.

The negative predictive value of exercise ECG testing is 90% to 100% [1], and the positive predictive value is 5% to 25% [1,19]. Aside from the potential to detect myocardial ischemia with exercise ECG, the workload that the patient achieves during exercise gives important prognostic information. However, the use of exercise ECG testing may be limited if the patient is unable to exercise. In patients undergoing vascular surgery or abdominal aortic aneurysm repair, only half can reach 75% of the maximum predicted heart rate during exercise [1].

The value of preoperative myocardial perfusion imaging and dobutamine stress echocardiography (DSE) has been studied extensively. These tests have very similar positive and negative predictive values. The positive predictive value for myocardial perfusion imaging is 4% to 20%, and for DSE it ranges from 7% to 25% [1]. The negative predictive value of myocardial perfusion imaging approaches 99%, while the negative predictive value of DSE ranges from 93% to 100% [1]. Dobutamine should be avoided in patients with serious arrhythmias, severe hypertension, or suspected critical aortic stenosis. Because other testing modalities have reduced sensitivity and

(continued on page 355)

(continued from page 352)

Table 1. Selected Indications for Preoperative Laboratory Testing

	Smetana 2003 [13]	ASA 2002 [12]	Fischer 1999 [14]
Hemoglobin	Anticipated major blood loss, symptoms of anemia	Consider in certain procedures, liver disease, hematologic disorders, bleeding diathesis, extremes of age	Renal disease, vascular disease, thyroid disease, hyperparathyroidism, anticoagulant use
Electrolytes	Renal disease, congestive heart failure, medications that affect electrolytes	Endocrine disorders, renal disease, liver disease, certain medications	Hypertension, renal disease, CNS disease, thyroid disease, other endocrine disorders, diuretic use
BUN/creatinine	Age > 50 yr, hypertension, cardiac disease, major surgery, medications that affect renal function	Endocrine disorders, renal disease, liver disease, certain medications	Diabetes, renal disease, malabsorption, diuretic use
Liver function	Consider albumin in major surgery or chronically ill	Endocrine disorders, renal disease, liver disease, certain medications	Liver disease
PT/PTT	Bleeding diathesis, liver disease, malabsorption, antibiotic use	Consider in coagulopathy, renal disease, liver disease, certain procedures	Liver disease, coagulopathy, anticoagulant use
Urinalysis	No indication	Certain procedures, urinary tract symptoms	Not recommended
ECG	Men > 40 yr, women > 50 yr, cardiac disease, diabetes, hypertension	Cardiac risk factors, cardiac symptoms	Cardiac disease, pulmonary disease, diabetes, CNS disease, thyroid disease, parathyroid disease, morbid obesity, malabsorption, digoxin use, age > 50 yr
Chest radiograph	Age > 50 yr, cardiac disease, pulmonary disease, active symptoms, abnormal exam	Consider in pulmonary disease, cardiac disease	Cardiac disease, pulmonary disease, morbid obesity

ASA = American Society of Anesthesiologists; BUN = blood urea nitrogen; CNS = central nervous system; ECG = electrocardiogram; PT/PTT = prothrombin time/partial thromboplastin time.

specificity in the presence of left bundle branch block, dipyridamole or adenosine stress testing is the preferred modality in this situation. Use of dipyridamole and adenosine should be avoided in patients with a significant history of asthma or COPD, especially in the presence of active symptoms.

For patients at high clinical risk, it may be appropriate to proceed directly with coronary angiography. The indications for coronary angiography prior to surgery are similar to the indications for patients who are not planned for surgery. Patients with unstable angina, recurrent angina unresponsive to medical therapy, or noninvasive testing results indicating high risk should undergo angiography. Patients scheduled for high-risk surgery who have multiple intermediate clinical predictors, moderate to large size areas of ischemia on noninvasive imaging, and equivocal noninvasive test results or who are undergoing urgent surgery while convalescing from an acute myocardial infarction (MI) are also candidates for angiography [1].

Effect of Prior Revascularization on Risk

Many patients who present for preoperative evaluation have a history of coronary artery disease and have undergone revascularization procedures in the past. Retrospective analyses suggest that patients who have undergone coronary artery bypass graft (CABG) within the past 4 to 6 years and do not have recurrent symptoms are at low risk for perioperative cardiac events [1,20]. Several retrospective case series have documented that patients who have undergone a prior successful percutaneous coronary intervention (PCI) also are at low risk for perioperative cardiac events [1,21]. In an ancillary study of the Bypass Angioplasty Revascularization Investigation (BARI), rates of MI and death after noncardiac surgery were similarly low in patients who had been treated with CABG or successful percutaneous coronary angioplasty (PTCA) [21]. The median time from PTCA to noncardiac surgery was 29 months, well past the 8- to 12-month mark in which most coronary restenosis would be expected to occur. The ACC/AHA guidelines recommend that patients who have undergone CABG in the past 5 years or PCI within the past 6 months to 5 years and remain free of signs or symptoms suggestive of recurrent ischemia can safely proceed with noncardiac surgery [1]. The relative risk and benefit of recommending CABG, PTCA, and PTCA with stent in symptomatic patients prior to surgery will be discussed later in this article.

Table 2. Lee's Revised Cardiac Risk Index

	Points Assigned*
High-risk surgery	1
Ischemic heart disease	1
History of congestive heart failure	1
History of cerebrovascular disease	1
Insulin therapy for diabetes	1
Serum creatinine level > 2.0 mg/dL	1

Adapted with permission from Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999;100:1043–9.

*Rates of major cardiac complications in patients with 0, 1, 2, and ≥ 3 of these factors were 0.4%, 0.9%, 7%, and 11%, respectively.

An Integrated Approach to Perioperative Cardiac Risk Assessment

A common clinical question that physicians performing perioperative risk evaluations will face is whether a particular patient would benefit from noninvasive testing. To guide the clinician on assessing cardiac risk, the potential benefit of noninvasive testing, and the benefit of various management options, the ACC/AHA and the American College of Physicians (ACP) have published separate guidelines on the perioperative cardiovascular evaluation [1,22]. Although other algorithms have recently been published [23], the ACC/AHA guidelines are the most authoritative consensus guidelines and provide a stepwise approach to assessing risk and the need for further testing (**Figure 1**).

The initial step in the ACC/AHA approach is to assess the urgency of the surgery. With emergency surgeries, an accurate assessment of preoperative risk cannot be made. The second step is to determine whether the patient has undergone revascularization within the past 5 years. As discussed earlier, the guidelines suggest that if a patient has undergone revascularization within the past 5 years and is without recurrent symptoms, noninvasive testing is not indicated. If the patient has not undergone a revascularization procedure within the past 5 years, the next step is to investigate whether the patient has undergone noninvasive testing within the past 2 years. If the patient has undergone adequate noninvasive testing with favorable results and does not have recurrent symptoms, the patient may proceed to surgery.

The next steps follow an algorithm that takes into account a patient's clinical risk predictors, the inherent risk of the surgical procedure, and the patient's functional capacity. Clinical risk predictors are categorized as major, intermediate, and minor (**Table 3**). Functional capacity is assessed by metabolic equivalents (METs), with less than 4 METs considered poor functional capacity (**Table 4**). Surgeries are similarly divided into high-, intermediate-, and low-risk surgical procedures (**Table 5**). By following the algorithm, the clinician can determine whether noninvasive testing is indicated to further clarify a patient's perioperative risk. Although further research is needed, the evidence-based practice of selective noninvasive testing rather than routine noninvasive testing would likely have a significant impact on the costs associated with the preoperative cardiac risk assessment.

Perioperative Management of the High-Risk Patient

Revascularization

The management of patients who have active symptoms or unfavorable results on noninvasive testing can be challenging. There are no randomized controlled trials evaluating CABG or PCI prior to noncardiac surgery. With regard to preoperative CABG, the physician must weigh the additive risk of angiography and bypass surgery against the risk of proceeding with surgery with medical therapy alone. The indications for CABG prior to noncardiac surgery are identical to those for patients in which CABG would otherwise be indicated [1].

Several retrospective studies of PCI have been reported, but the majority of these evaluated the effect of PTCA without stent placement. The time from PTCA to surgery was highly variable. The perioperative mortality rate ranged from 0% to 2.7% and the perioperative infarction rate ranged from 0% to 5.6% [1]. Only 2 studies have looked at perioperative outcomes in patients who underwent PTCA with stent prior to surgery [24,25]. Kaluza et al [24] examined the clinical course of 40 patients who underwent PTCA with stent less than 6 weeks prior to noncardiac surgery. Perioperative mortality was 20%, and the perioperative infarction rate was 16.8% overall. The major bleeding rate was 27.5%. All deaths and MI events and the majority of the episodes of major bleeding occurred in patients who had surgery within 14 days of PTCA and stent placement. Wilson et al [25] performed a retrospective analysis of 207 patients who underwent surgery in the 2 months following successful PTCA with stent. Eight patients (4%) died or had a MI or stent thrombosis. All 8 patients underwent surgery within 6 weeks of PTCA and stent placement.

In light of the available data, the ACC/AHA guidelines recommend that the indications for PCI prior to noncardiac surgery are identical to those for patients in which PCI would otherwise be indicated [1]. If PCI is pursued, the guidelines recommend that surgery be delayed at least 1 week if PTCA alone is used and 4 to 6 weeks if PTCA with stent placement is used. Expert opinion suggests that the optimal time for surgery may be between 4 and 8 weeks after PTCA with stent [1]. This allows enough time for completion of antiplatelet therapy to prevent stent thrombosis but not enough time for restenosis to begin to occur (if it is to occur)

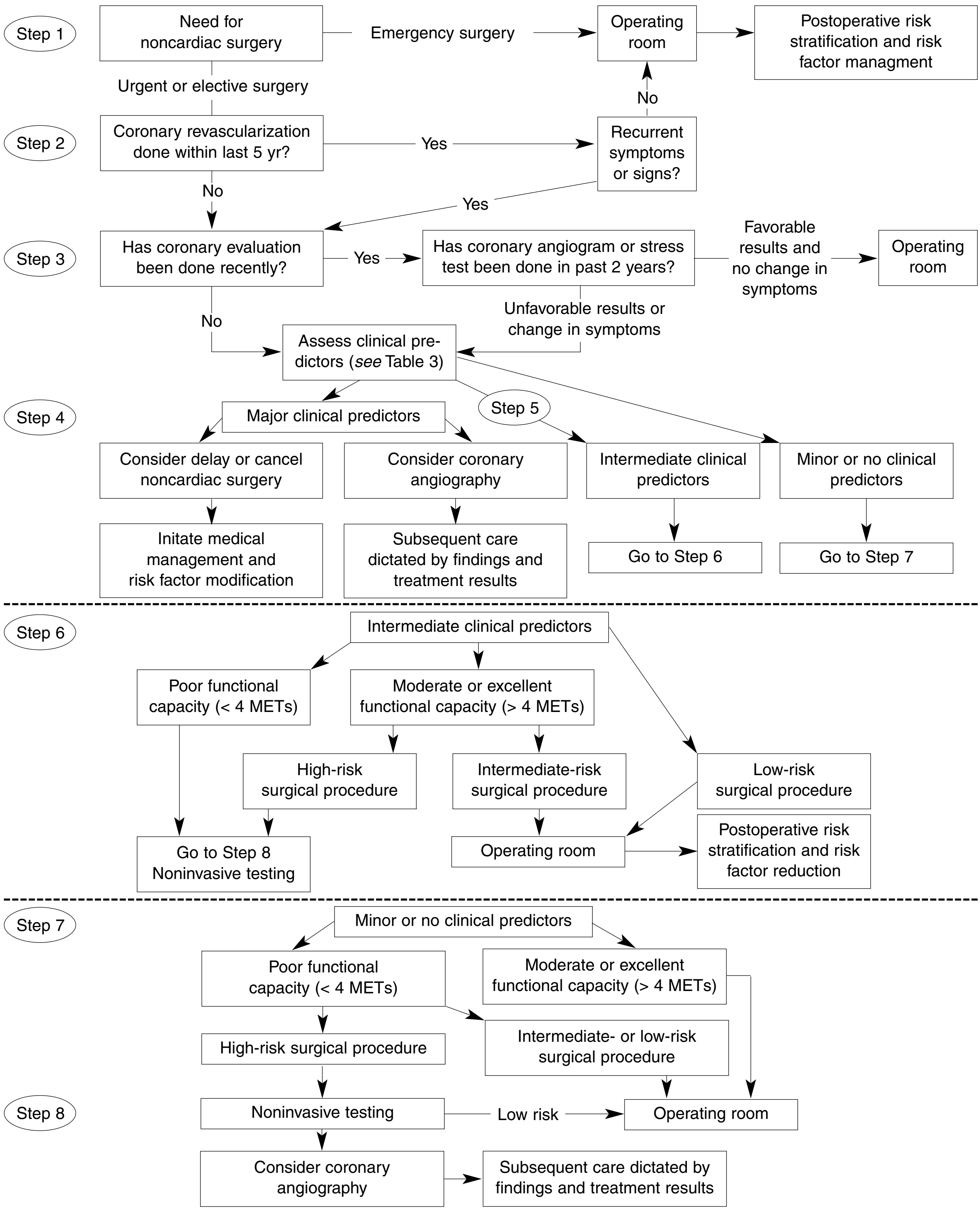

Figure 1. Stepwise approach to preoperative cardiac assessment. (Adapted with permission from Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update on perioperative cardiovascular evaluation for noncardiac surgery. Copyright © 1996, The American College of Cardiology Foundation and American Heart Association, Inc. Available at www.acc.org/clinical/guidelines/perio/update/periupdate_index.htm. Accessed 25 May 2004.)

Table 3. Clinical Predictors of Increased Perioperative Cardiovascular Risk

Major	
	Unstable coronary syndromes
	Decompensated heart failure
	Significant arrhythmia
	Severe valvular disease
Intermediate	
	Mild angina pectoris
	Previous myocardial infarction
	Compensated heart failure
	Diabetes mellitus
	Renal insufficiency
Minor	
	Advanced age
	Abnormal electrocardiogram
	Rhythm other than sinus
	Low functional capacity
	History of stroke
	Uncontrolled hypertension

Adapted with permission from Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update on perioperative cardiovascular evaluation for noncardiac surgery. Copyright © 1996, The American College of Cardiology Foundation and American Heart Association, Inc. Available at www.acc.org/clinical/guidelines/perio/update/periupdate_index.htm. Accessed 25 May 2004.

Table 4. Estimated Energy Requirements for Various Activities

1 to 4 METs	Can you take care of yourself?
	Eat, dress, or use the toilet?
	Walk indoors around the house?
	Walk a block or 2 on level ground at 2–3 miles per hour?
	Do light work around the house like dusting or washing dishes?
4 to 10 METs	Climb a flight of stairs or walk up a hill?
	Walk on level ground at 4 mph?
	Run a short distance?
	Do heavy work around the house like scrubbing floors or lifting or moving heavy furniture?
	Participate in activities such as golf, bowling, dancing, doubles tennis?
> 10 METs	Participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?

MET = metabolic equivalent. (Adapted with permission from Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update on perioperative cardiovascular evaluation for noncardiac surgery Copyright © 1996, The American College of Cardiology Foundation and American Heart Association, Inc. Available at www.acc.org/clinical/guidelines/perio/update/periupdate_index.htm. Accessed 25 May 2004.)

[1]. Further research is needed to define the perioperative role of drug-eluting stents, which generally require a longer period of antiplatelet therapy.

Medical Management

Several studies have evaluated the protective effect of β blockers on perioperative myocardial ischemia and MI. Mangano et al [26] randomized patients who had or were at risk for coronary artery disease and were undergoing noncardiac surgery to receive atenolol versus placebo. The medication was administered just prior to surgery and continued postoperatively for up to 7 days. Although there was no difference in patient mortality at the time of hospital discharge, there was a statistically significant reduction in perioperative ischemia [26,27]. A significant reduction in overall mortality in patients who received atenolol was evident 6 to 8 months after surgery and persisted for up to 2 years. Poldermans et al [28] performed a randomized placebo-controlled unblinded trial evaluating the effect of bisoprolol on perioperative mortality and MI in high-risk patients undergoing vascular surgery. Bisoprolol or placebo was begun at least 7 days prior to surgery and continued for 30 days postoperatively. There was a significant reduction in cardiac death and nonfatal MI in the bisoprolol group. It should be noted that in both the Mangano and the Poldermans studies, the β-blocker dose was adjusted in an effort to achieve effective β blockade. A recent review of 11 randomized controlled trials concluded that perioperative β-blocker therapy reduced the risk of perioperative cardiac death or MI by 75% and 80%, respectively [29].

Despite their cardioprotective effects, β blockers do not confer benefit in all surgical patients. For example, Boersma et al [30] performed an observational study of patients undergoing vascular surgery to evaluate the associations between DSE, β-blocker use, and clinical risk factors (using Lee's revised cardiac risk index). They demonstrated that patients with no cardiac risk factors were at low risk and gained little benefit from β blockade. In patients with 3 or more cardiac risk factors and large wall motion abnormalities detected on DSE (≥ 5 segments), β-blocker therapy did not provide sufficient protection, as 36% of these patients experienced postoperative cardiac death or MI. Patients with 1 or 2 risk factors were adequately protected by β-blocker therapy, even if ischemia was induced during DSE. Patients with 3 or more risk factors were also sufficiently protected by β blockers as long as ischemia was absent or involved a smaller amount of myocardium (1 to 4 segments).

Some experts advocate the use of a new algorithm (**Figure 2** and **Table 6**) that incorporates information regarding common clinical risk factors, surgery-specific risks, functional capacity, the results of prior cardiac testing, and the benefits of β-blocker therapy [31]. Low-risk patients can proceed to surgery without further testing or β-blocker therapy. High-risk patients require further noninvasive cardiac testing, aggressive pharmacologic medical management, and in some cases coronary angiography and revascularization. Intermediate-risk patients receive either empiric β-blocker therapy or undergo further noninvasive testing.

Studies have evaluated the role of other medications in reducing perioperative cardiac risk. The α_2-receptor agonists include clonidine and mivazerol. A recent review concluded that these agents reduced the likelihood of perioperative cardiac death and myocardial ischemia [29]. In the United States, clonidine is available for oral and transdermal use, but mivazerol is not available. Clonidine appears most useful in patients who cannot tolerate β-blocker therapy and for patients receiving β blockers who need additional perioperative antihypertensive therapy.

There is conflicting data regarding the efficacy of calcium channel blockers. A recent meta-analysis of 11 randomized controlled trials involving 1007 patients undergoing noncardiac surgery suggested that diltiazem reduced the likelihood of myocardial ischemia and postoperative supraventricular rhythm disturbances; in a post hoc analysis, diltiazem reduced the likelihood of the combined end point of death and MI [32]. However, a recent quantitative review focusing on the utility of calcium channel blockers in reducing death, MI, and myocardial ischemia following noncardiac surgery concluded that these agents had not been proven to be efficacious [29].

Oral and intravenous nitrates have not been shown to decrease the risk of major perioperative cardiac complications and may induce hypotension [1,29].

Postoperative Management

Cardiac Monitoring

Most cases of postoperative myocardial ischemia and infarction occur in the absence of typical symptoms [33,34]. In high-risk patients, postoperative myocardial ischemia is a strong predictor of postoperative cardiac complications and a reduced long-term survival [1,23,27,33]. The importance of detecting ischemia in patients at risk is underscored by the fact that perioperative MI is associated with a 30% to 50% mortality rate [1]. On the other hand, ST segment changes can occur in patients at low risk and are not associated with an increased risk of cardiac events in these patients [1].

Options for detecting perioperative ischemia and infarction include 12-lead ECG, computerized ST segment monitoring, and measurement of cardiac markers. Charlson et al [35] studied 232 mostly hypertensive and diabetic patients and noted a high sensitivity to detect cardiac events using a strategy of 12-lead ECG immediately after surgery and on the first and second days postoperatively. The use of cardiac markers to detect perioperative myocardial ischemia and infarction has also been evaluated. Adams et al studied [36] troponin I in 96 patients undergoing vascular surgery and 12 patients undergoing spinal surgery. Troponin I had high sensitivity and specificity to detect MI as defined by new wall motion abnormalities on postoperative echocardiogram.

Table 5. Cardiac Risk Stratification for Noncardiac Surgical Procedures

High risk (reported risk > 5%)*
Emergent major operations, particularly in the elderly
Aortic and other major vascular surgery
Peripheral vascular surgery
Anticipated prolonged surgical procedure with large fluid shifts and/or blood loss
Intermediate risk (reported risk < 5%)*
Carotid endarterectomy
Head and neck surgery
Intraperitoneal and intrathoracic surgery
Orthopedic surgery
Prostate surgery
Low risk (reported risk < 1%)*
Endoscopic procedures
Superficial procedures
Cataract surgery
Breast surgery

Adapted with permission from Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update on perioperative cardiovascular evaluation for noncardiac surgery. Copyright © 1996, The American College of Cardiology Foundation and American Heart Association, Inc. Available at www.acc.org/clinical/guidelines/perio/update/periupdate_index.htm. Accessed 25 May 2004.

*Combined incidence of cardiac death and nonfatal myocardial infarction.

The ACC/AHA guidelines acknowledge that further investigation is required to delineate the optimal strategy for perioperative surveillance. In light of the existing data, the ACC/AHA recommends that for patients with high or intermediate clinical risk who have known or suspected coronary artery disease and who are undergoing high or intermediate risk procedures, the most cost-effective strategy is to obtain a 12-lead ECG immediately after surgery and on the first 2 days postoperatively [1]. In addition, the proper use of computerized ST segment monitoring in patients with coronary artery disease or in patients undergoing vascular surgery may increase the sensitivity to detect myocardial ischemia in the perioperative period [1]. The ACC/AHA also suggest that measurement of cardiac troponin I at 24 hours and on day 4 or hospital discharge be included in the strategy to detect perioperative MI, although the clinical situations in which this testing would be useful are not clearly defined [1].

Venous Thromboembolism Prophylaxis

Venous thromboembolism (VTE) encompasses deep venous thrombosis (DVT) and pulmonary embolus (PE) and is a

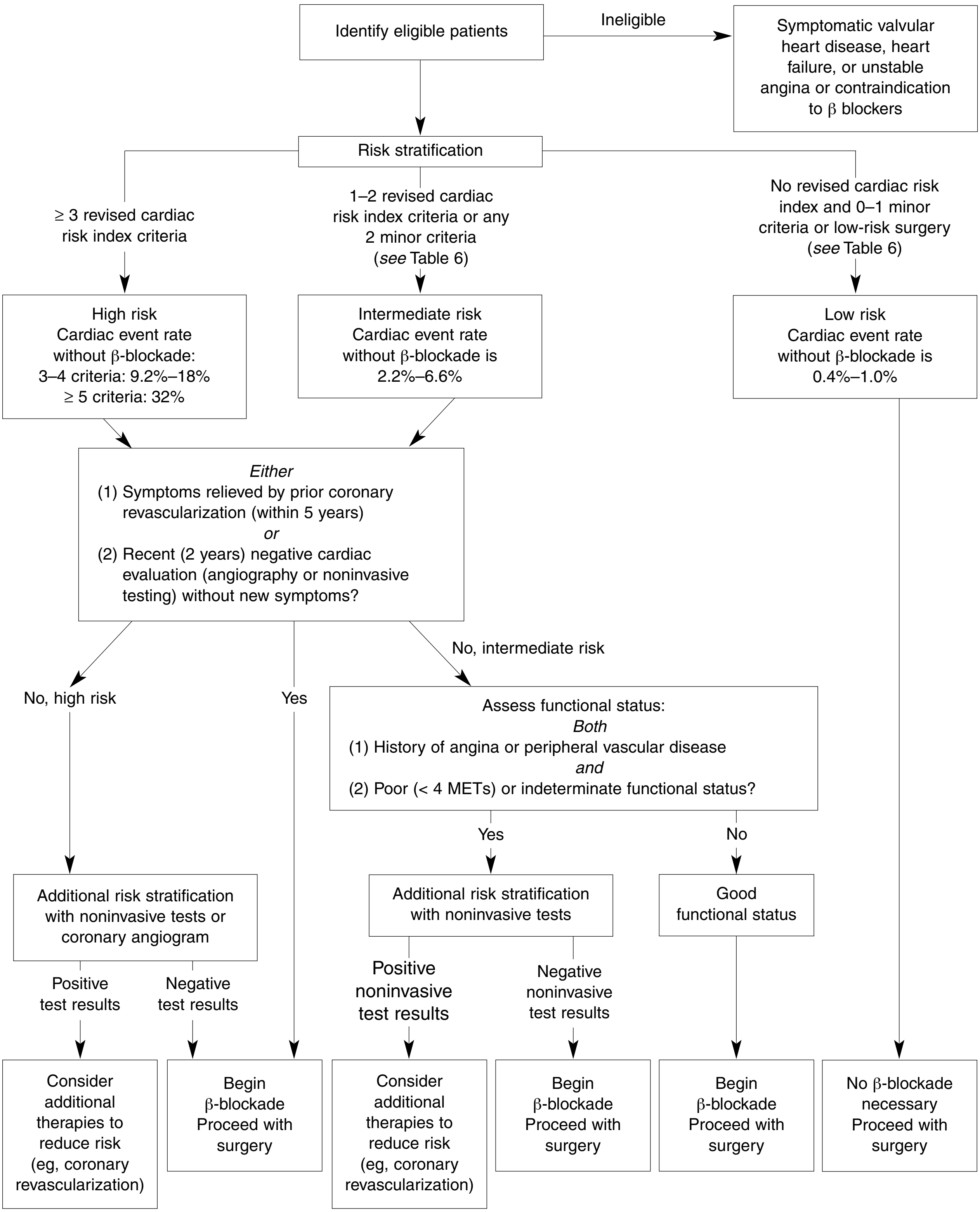

Figure 2. Perioperative β blockers for elective surgery, patient selection, and preoperative risk stratification. (Adapted with permission from Cohn SL, Goldman L. Preoperative risk evaluation and perioperative management of patients with coronary artery disease. Med Clin North Am 2003;87:111–36. Copyright © 2003, with permission from Elsevier.)

major cause of preventable death perioperatively. Kaboli et al have published a recent comprehensive review on perioperative DVT prophylaxis [37]. The risk of VTE is dependent on the type of surgery, the patient's risk factors, the duration of immobilization, and the prophylactic regimen that is used. Surgeries that carry the highest risk include invasive neurosurgery, hip and knee arthroplasty, hip fracture surgery, and major vascular surgery [38,39]. Patient-related risk factors include age, prior history of VTE, trauma, malignancy, obesity, presence of a thrombophilic disorder, history of congestive heart failure or COPD, and certain medications [37,39].

Nonpharmacologic methods that can be used to decrease the incidence of postoperative VTE, in order of increasing efficacy, include early ambulation, elastic compression stockings, and intermittent pneumatic compression devices [37]. Pharmacologic methods include low-dose unfractionated heparin (LDUH), low molecular weight heparin (LMWH), and warfarin [37,39]. Although considered comparable in efficacy and safety for most procedures, LMWH has been shown to be more effective than LDUH in many orthopedic procedures [37,39]. Warfarin is usually reserved for situations in which extended prophylaxis is required. The duration of pharmacologic prophylaxis for most procedures is not clearly defined, but there is strong evidence that extended prophylaxis (4–6 weeks) is beneficial after total hip arthroplasty [40]. Nonpharmacologic and pharmacologic methods can and should be combined in higher risk patients. In addition, inferior vena caval filters are indicated to prevent PE for high-risk patients who have an absolute contraindication for anticoagulation or have failed anticoagulation.

Table 7 provides a summary of the recommendations provided by Kaboli et al [37]. These recommendations are adapted from recent literature as well as an extensive review of the evidence published by the American College of Chest Physicians [39].

Preoperative Pulmonary Risk Assessment and Perioperative Management

Postoperative pulmonary complications occur frequently and cause significant morbidity and mortality. The definition of what constitutes a postoperative pulmonary complication varies from study to study. The definition may include atelectasis, pneumonia, respiratory failure, adult respiratory distress syndrome, and pleural effusion. Risk factors for postoperative pulmonary complications can be classified as patient-related, surgery-related, or anesthesia-related. Patient-related risk factors include advanced age, history of COPD, obstructive sleep apnea, poor functional status, current smoking, alcohol use, prior stroke, altered sensorium, and chronic steroid use [41]. Surgeries that carry the highest risk of postoperative pulmonary complications include thoracic surgery (particularly lung resection), abdominal aortic aneurysm repair, and upper abdominal surgery [41,42]. Laparoscopic techniques seem to carry less risk for postoperative pulmonary complications compared to open procedures [43,44]. Longer duration of anesthesia (greater than 2–6 hours) increases the risk for postoperative pulmonary complications [45]. Although this issue is still under debate, studies suggest that regional anesthesia may confer less risk for postoperative pulmonary complications than general anesthesia [45].

Table 6. Eligibility Criteria for Perioperative β-Blocker Therapy

Minor criteria (Mangano) [25]
Age ≥ 65 years
Hypertension
Current smoker
Serum cholesterol > 240 mg/dL
Diabetes mellitus not requiring insulin
Revised cardiac risk index criteria (Lee) [2]
High-risk surgical procedure: intraperitoneal, intrathoracic, suprainguinal vascular
Ischemic heart disease: prior myocardial infarction or Q waves, previous orcurrent angina, use of nitroglycerin, positive exercise test, ischemic chest pain despite prior coronary artery bypass grafting or percutaneous coronary intervention
Cerebrovascular disease: history of transient ischemic attack or cerebrovascular accident
Diabetes mellitus requiring insulin
Chronic renal insufficiency (creatinine > 2.0 mg/dL)

As stated previously, current smoking is a risk factor for postoperative pulmonary complications. Whether the clinician should recommend smoking cessation to patients preoperatively depends on the timing of their surgery. Paradoxically, the risk of postoperative pulmonary complications is increased in patients who quit smoking shortly before surgery [42,45]. Patients who quit smoking 8 or more weeks prior to surgery may decrease their risk for postoperative pulmonary complications [45]. Because of the tremendous long-term benefits, patients should be encouraged to quit smoking 8 or more weeks prior to surgery if time permits.

Lung expansion maneuvers are often used in the postoperative period in an attempt to decrease the risk of postoperative pulmonary complications. Lung expansion maneuvers include deep breathing exercises, incentive spirometry, intermittent positive pressure breathing, chest physical therapy, and nasal continuous positive airway pressure. Deep breathing exercises and incentive spirometry have been shown to decrease the risk of postoperative pulmonary complications in high-risk patients [45]. Most studies comparing these techniques have found similar efficacy [45].

Table 7. Venous Thromboembolism Prophylaxis Options in Surgical Patients

	Nonpharmacologic Methods			Pharmacologic Methods		
	Early Ambulation	Elastic Stockings	IPC	LDUH	Warfarin	LMWH
General surgery						
Low risk	A	A	A			
Moderate risk	X	A	A	A		A
High risk	X	X	A	A		A
Very high risk	X	X	X	A+		A+
Gynecologic surgery						
Low risk	A					
Moderate risk	X	X	A	A		B
High risk	X	X	A	A or +		A
Urologic surgery						
Low risk	A					
Moderate risk	X	A	A	A		A
High risk	X	X	X	A+		A+
Orthopedic surgery						
Hip fracture	X	X	X	B	A	A
THA	X	X	X	X	A	A
TKA	X	X	B		A	A
Neurosurgery	X	X	A or +	B or +		B or +
Trauma	X	B or +	B or +			A

Note: Risk definitions are as follows:

General surgery: low risk—minor procedure, age < 40 years, no VTE risk factors; moderate risk—minor procedure but with VTE risk factors, or minor procedure between ages of 40 and 60 years and no other risk factors, or major surgery, but age < 40 years; high risk—minor procedure but age over 60 or additional VTE risk factors, or major surgery over age 40 with additional risk factors; very high risk—major surgery with multiple VTE risk factors.

Gynecologic surgery: low risk—brief procedure for benign disease; moderate risk—major surgery for benign disease with no additional VTE risk factors; high risk—extensive surgery for malignancy.

Urologic surgery; low risk—transurethral resection of the prostate or other low risk procedure; moderate risk—major open urologic procedure; high risk—major procedure with additional risk factors.

+ = combine with nonpharmacologic method; A = acceptable for solo prophylaxis; B = acceptable as an alternative; IPC = intermittent pneumatic compression device; LDUH = low dose unfractionated heparin; LMWH = low molecular weight heparin; THA = total hip arthroplasty; TKA = total knee arthroplasty; X = beneficial, but inadequate prophylaxis alone. (Based on data from Kaboli P, Henderson MC, White RH. DVT prophylaxis and anticoagulation in the surgical patient. Med Clin North Am 2003;87:77–110.)

Conclusion

A wide array of tests is available to the physician to help assess a patient's risk for perioperative complications. However, testing can be costly, have limited predictive value, and may not lead to interventions that reduce perioperative risk. As a result, some testing may be unnecessary. Physicians should take a systematic approach to the preoperative assessment, beginning with a thorough history and physical examination, which provides the foundation for risk stratification. With knowledge of established risk factors and evidence-based guidelines, the physician can then order appropriate testing and targeted interventions to maximize beneficial outcomes.

Corresponding author: Kevin J. O'Leary, MD, 675 North St. Clair, Ste. 18-200, Chicago, IL 60611, koleary@nmff.org.

Financial disclosures: None.

Author contributions: conception and design, KJO, FL, SLC; analysis and interpretation of data, KJO, FL; drafting of the article, KJO, SLC; critical revision of the article for important intellectual content, KJO, MJA, FL, VC, SLC.

References

1. Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update on perioperative cardiovascular evaluation for noncardiac surgery. Available at www.acc.org/clinical/guidelines/

(continued on page 365)

(continued from page 362)

perio/update/periupdate_index.htm. Accessed 25 May 2004.
2. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999; 100:1043–9.
3. Kertai MD, Bountioukos M, Boersma E, et al. Aortic stenosis: an underestimated risk factor for perioperative complications in patients undergoing noncardiac surgery. Am J Med 2004;116:8–13.
4. Reilly DF, McNeely MJ, Doerner D, et al. Self-reported exercise tolerance and the risk of serious perioperative complications. Arch Intern Med 1999;159:2185–92.
5. Kaplan EB, Sheiner LB, Boeckmann AJ, et al. The usefulness of preoperative laboratory screening. JAMA 1985;253: 3576–81.
6. Macario A, Roizen MF, Thisted RA, et al. Reassessment of preoperative laboratory testing has changed the test-ordering patterns of physicians. Surg Gynecol Obstet 1992;175:539–47.
7. Narr BJ, Hansen TR, Warner MA. Preoperative laboratory screening in healthy Mayo patients: cost-effective elimination of tests and unchanged outcomes. Mayo Clin Proc 1991;66: 155–9.
8. Roizen MF. More preoperative assessment by physicians and less by laboratory tests. N Engl J Med 2000;342:204–5.
9. Narr BJ, Warner ME, Schroeder MS, Warner MA. Outcomes of patients with no laboratory assessment before anesthesia and a surgical procedure. Mayo Clin Proc 1997;72:505–9.
10. Schein OD, Katz J, Bass EB, et al. The value of routine preoperative medical testing before cataract surgery. Study of the Medical Testing for Cataract Surgery. N Engl J Med 2000;342: 168–75.
11. MacPherson DS, Snow R, Lofgren RP. Preoperative screening: value of previous tests. Ann Intern Med 1990;113:969–73.
12. American Society of Anesthesiologists Task Force on Preanesthesia Evaluation. Practice advisory for preanesthesia evaluation: a report by the American Society of Anesthesiologists Task Force on Preanesthesia Evaluation. Anesthesiology 2002;96:485–96.
13. Smetana GW, MacPherson DS. The case against routing preoperative laboratory testing. Med Clin North Am 2003;87:7–40.
14. Fischer SP. Cost-effective preoperative evaluation and testing. Chest 1999;115(5 Suppl):96S–100S.
15. Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. N Engl J Med 1977;297:845–50.
16. Taher T, Khan NA, Devereax PJ, et al. Assessment and reporting of perioperative cardiac risk by Canadian general internists: art or science? J Gen Intern Med 2002;17:933–6.
17. Detsky AS, Abrams HB, McLaughlin JR, et al. Predicting cardiac complications in patients undergoing non-cardiac surgery. J Gen Intern Med 1986;1:211–9.
18. Devereaux PJ, Ghali WA, Gibson NE, et al. Physician estimates of perioperative cardiac risk in patients undergoing noncardiac surgery. Arch Intern Med 1999;159:713–7.
19. Gauss A, Rohm HJ, Schauffelen A, et al. Electrocardiographic exercise stress testing for cardiac risk assessment in patients undergoing noncardiac surgery. Anesthesiology 2001;94:38–46.
20. Rihal CS. The role of myocardial revascularization preceding noncardiac surgery. Prog Cardiovasc Dis 1998;40:383–404.
21. Hassan SA, Hlatky MA, Boothroyd DB, et al. Outcomes of noncardiac surgery after coronary bypass surgery or coronary angioplasty in the Bypass Angioplasty Revascularization Investigation (BARI). Am J Med 2001;110:260–6.
22. Guidelines for assessing and managing the perioperative risk from coronary artery disease associated with major noncardiac surgery. American College of Physicians. Ann Intern Med 1997;127:309–12.
23. Auerbach AD, Goldman L. Beta-blockers and reduction of cardiac events in noncardiac surgery: scientific review. JAMA 2002;287:1435–44.
24. Kaluza GL, Joseph J, Lee JR, et al. Catastrophic outcomes of noncardiac surgery after coronary stenting. J Am Coll Cardiol 2000;35:1288–94.
25. Wilson SH, Fasseas P, Orford JL, et al. Clinical outcome of patients undergoing non-cardiac surgery in the two months following coronary stenting. J Am Coll Cardiol 2003;42:234–40.
26. Mangano DT, Layug EL, Wallace A, Tateo I. Effect of atenolol on mortality and cardiovascular morbidity after noncardiac surgery. Multicenter Study of Perioperative Ischemia Research Group [published erratum in N Engl J Med 1997;336:1039]. N Engl J Medicine 1996;335:1713–20.
27. Wallace A, Layug B, Tateo I, et al. Prophylactic atenolol reduces postoperative myocardial ischemia. McSPI Research Group. Anesthesiology 1998;88:7–17.
28. Poldermans D, Boersma E, Bax, JJ, et al. The effect of bisoprolol on perioperative mortality and myocardial infarction in high-risk patients undergoing vascular surgery. Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography Study Group. N Engl J Med 1999;341: 1789–94.
29. Stevens RD, Burri H, Tramer MR. Pharmacologic myocardial protection in patients undergoing noncardiac surgery: a quantitative systematic review. Anesth Analg 2003;97:623–33.
30. Boersma E, Poldermans D, Bax JJ, et al. Predictors of cardiac events after major vascular surgery. Role of clinical characteristics, dobutamine echocardiography, and beta-blocker therapy. JAMA 2001;285:1865–73.
31. Cohn SL, Goldman L. Preoperative risk evaluation and perioperative management of patients with coronary artery disease. Med Clin North Am 2003;87:111–36.
32. Wijeysundera DN, Beattie WS. Calcium channel blockers for reducing cardiac morbidity after noncardiac surgery: a meta–analysis. Anesth Analg 2003;97:634–41.
33. Mangano DT, Browner WS, Hollenberg M, et al. Association of perioperative myocardial ischemia with cardiac morbidity and mortality in men undergoing noncardiac surgery. The Study of Perioperative Ischemia Research Group. N Engl J Med 1990;323:1781–8.
34. Charlson ME, MacKenzie CR, Ales KL, et al. The postoperative electrocardiogram and creatine kinase: implications for diagnosis of myocardial infarction after non-cardiac surgery. J Clin Epidemiol 1989;42:25–34.
35. Charlson ME, MacKenzie CR, Ales K, et al. Surveillance for postoperative myocardial infarction after noncardiac

operations. Surg Gynecol Obstet 1988;167:407–14.
36. Adams JE 3rd, Sicard GA, Allen BT, et al. Diagnosis of perioperative myocardial infarction with measurement of cardiac troponin I. N Engl J Med 1994;330:670–4.
37. Kaboli P, Henderson MC, White RH. DVT prophylaxis and anticoagulation in the surgical patient. Med Clin North Am 2003;87:77–110.
38. White RH, Zhou H, Romano PS. Incidence of symptomatic venous thromboembolism after different elective or urgent surgical procedures. Thromb Haemost 2003;90:446–55.
39. Geerts WH, Heitz JA, Clagett GP, et al. Prevention of venous thromboembolism. Chest 2001;119(1 Suppl):132S–175S.
40. Hull RD, Graham FP, Stein PD, et al. Extended out-of-hospital low-molecular-weight heparin prophylaxis against deep venous thrombosis in patients after elective hip arthroplasty: a systematic review. Ann Intern Med 2001;135:858–69.
41. Arozullah AM, Daley J, Henderson WG, Khuri SF. Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery. The National Veterans Administration Surgical Quality Improvement Program. Ann Surg 2000;232:242–53.
42. Smetana GW. Preoperative pulmonary evaluation. N Engl J Med 1999;340:937–44.
43. Hall JC, Tarala RA, Hall JL. A case-control study of postoperative pulmonary complications after laparoscopic and open cholecystectomy. J Laparoendosc Surg 1996;6:87–92.
44. Winslow ER, Brunt LM. Perioperative outcomes of laparoscopic versus open splenectomy: a meta-analysis with emphasis on complications. Surgery 2003;134:647–55.
45. Arozullah AM, Conde MV, Lawrence VA. Preoperative evaluation for postoperative pulmonary complications. Med Clin North Am 2003;87:153–73.