A Cost-Effective Approach to Perioperative Care for the Primary Care Physician

Frank Lefevre, MD, Martin J. Arron, MD, Vinky Chadha, MD, and Steven L. Cohn, MD, FACP

The goals of cost-effective medical care in the perioperative period are to maximize beneficial patient outcomes while avoiding excessive use of medical tests and procedures that are unlikely to contribute to improved outcomes. This article will review some general principles of cost-effective perioperative care for the primary care physician with a focus on preoperative cardiac risk assessment. Taking a systematic approach to the preoperative workup, performing thorough risk stratification using clinical examination and standardized risk stratification tools, avoiding excessive use of resources in low-risk individuals, and considering the long-term as well as the short-term impact of perioperative interventions are important goals that practitioners need to keep in mind.

Preoperative Clinical Evaluation

History and Physical Examination

A general history and physical examination should be performed with particular attention directed toward detecting cardiopulmonary disorders, which are responsible for the majority of perioperative medical complications.

The medical history should seek evidence for a current or past history of coronary artery disease (CAD) as well as risk factors, symptoms, and signs that indicate an increased likelihood of previously unrecognized heart disease. Exercise capacity should be carefully assessed because it reflects the degree of physiologic stress that a patient can safely tolerate and may help direct further preoperative testing.

The integrity of the respiratory system should be thoroughly assessed. Chronic bronchitis, emphysema, and asthma are among the most common pulmonary disorders found in surgery patients. The physician should determine the severity of symptoms, frequency of attacks, and use of oral and inhaled medications, including dose and duration of corticosteroid use. Symptoms that might represent uncharacterized lung disease should be sought. Other important factors relevant to the assessment of the respiratory system include tobacco use, recurrent pulmonary infections, and aspiration. A detailed review of preoperative pulmonary assessment has recently been published by Smetana et al [1].

The history also should assess current or prior liver disease as well as risk factors for liver disease, such as alcohol use and exposure to hepatitis. The patient with significant liver disease is at increased risk for perioperative complications. A thorough discussion of surgery in the setting of liver disease can be found in a review by Patel [2]. The patient and family history of bleeding should be elicited, as well as any history of clotting disorders or thromboembolic disease. Endocrine diseases, particularly diabetes mellitus and thyroid disease, are common in patients presenting for surgery. Patients with diabetes should be questioned about the symptoms of hyperglycemia, which include polyuria, polydipsia, and weight loss. Diabetic patients should also be assessed for the presence of diabetic end-organ damage; those with renal insufficiency, peripheral or autonomic neuropathy, and atherosclerotic vascular disease are at increased risk for postoperative complications. A more complete discussion of the approach to surgery in patients with diabetes has been recently published by Jacober and Sowers [3]. A social history should be taken to detect behaviors or activities that may adversely impact surgery, such as alcohol abuse.

Physical examination should focus on detecting signs of cardiopulmonary disease and other organ systems that are impacted by the underlying disease process and/or the surgical procedure. Vital signs, especially pulse and blood pressure, should be carefully recorded under standardized conditions. Signs of fluid overload or congestive heart failure, such as jugular vein distension, the presence of an S₃ gallop, pulmonary rales, and peripheral edema, should be thoroughly assessed. Heart and lung examinations should be performed in detail. The adequacy of peripheral arterial circulation...
should be assessed, and physical examination signs of chronic liver disease should be sought. In patients with diabetes, especially when long-standing, evidence of end-organ damage such as retinopathy or neuropathy should be sought. In elderly patients, a determination of cognitive status, such as with the mini-mental state examination, should be made.

Laboratory Testing
In the past 2 decades, numerous studies have demonstrated that up to 70% or more of laboratory tests ordered preoperatively are not necessary [4,5]. In asymptomatic patients, the rate of significant, unexpected abnormalities is extremely low. In one study [6] of 2000 patients undergoing preoperative testing, abnormalities that might impact on the risk of surgery were discovered in only 0.22% of cases. The majority of these abnormalities were not acted upon and did not result in any adverse surgical outcomes. Based on results from a multicenter study, Apfelbaum [6] concluded that routine preoperative testing was more likely to harm asymptomatic patients than to benefit them. These studies have likely altered the preoperative test ordering patterns of physicians, resulting in somewhat less unnecessary testing. In a study by Macario et al [7] that looked at the preoperative test ordering patterns of physicians at 3 institutions, there was a modest decline between 1979 and 1987 in unnecessary testing, from 66.9% to 60.1%. The decrease in testing was irregular, however, and varied widely by institution and type of operation. Factors involved in perpetuating unnecessary testing may include convention, lack of understanding of the predictive value of routine testing, medicolegal concerns, and a lack of cross-departmental consensus on the appropriate level of testing.

There is evidence that foregoing preoperative laboratory testing in low-risk patients does not adversely affect outcomes. Narr et al [8] reviewed preoperative screening tests for healthy patients undergoing elective surgery at the Mayo Clinic. Abnormalities that warranted further assessment were found in 1.2% of patients (47/2382). No surgical procedure was delayed as a result of abnormal test results, and there was no association found between abnormal tests and adverse surgical outcomes. More recently, Schein et al [9] rigorously tested the value of routine preoperative testing in patients undergoing cataract surgery. In this multicenter, randomized controlled trial, patients were randomly allocated to receive either a standard battery of preoperative tests or no testing (unless indicated by the clinical presentation of the patient). The rate of adverse outcomes was identical in both groups, and there was no evidence of benefit for the group that received routine testing.

Recommendations for the use of preoperative laboratory testing are available (Table 1). However, there is a fair amount of variability among these recommendations regarding the clinical factors that should prompt testing. There currently are no universally accepted guidelines for preoperative testing, and there is no empiric evidence available to define the optimal evaluation strategy. Institution-specific recommendations that are based on available evidence and expert recommendations are likely to be most successful in reducing unnecessary laboratory testing [8,13], especially when developed by clinicians involved in perioperative assessment and care.

Unnecessary duplication of previously performed tests is widespread and should be avoided. In one study in which 7549 preoperative tests were ordered [14], slightly less than half of duplicated tests were performed in the previous year. Of 3096 tests that were duplicated, only 13 (0.4%) repeat values were outside the acceptable range for surgery. The authors concluded that clinicians could safely substitute prior testing within the last year for preoperative testing if there were no clinical indications for repeat testing.

Preoperative Risk Assessment
Risk Stratification Tools
Risk stratification models can aid clinicians in making decisions about the need for ancillary testing once an initial clinical evaluation has been performed. The American Society of Anesthesiologists (ASA) Classification of Physical Status was the first clinical index developed to predict risk. Introduced in 1941, it was revised to its current form in 1962 [15]. Patients are categorized into one of 5 major classes based upon the presence and manifestations of concomitant medical disorders and whether emergency surgery is required. The utility of this index is limited by intraobserver variability in rating and variations in the predictive power for postoperative complications.

Two more recent cardiac risk assessment tools are summarized in Table 2. The original Cardiac Risk Index [16] was the first validated multivariate model developed to predict cardiac complications in a general surgical population; Detsky and colleagues [17] published a modified version of this index in 1986. Table 3 shows the ability of these instruments to predict postoperative complication rates. In 1999, Lee et al derived and validated a new index for risk of cardiac complications based on a study of 4315 patients undergoing major noncardiac surgery [18]. They 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, and serum creatinine level greater than 2.0 mg/dL. 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 was 11.0%. The revised cardiac risk index performed more accurately than the ASA and the orig-
inal and modified cardiac risk indices. Other multivariate models have been developed specifically for the vascular surgery population [19,20].

Despite their utility, formal risk stratification models are underused. Devereaux et al [21] estimated that less than one third of clinicians use a validated cardiac risk index in the evaluation of preoperative cardiac risk.

Ancillary Testing to Refine Risk Assessment
Tests available for further risk stratification include exercise

<table>
<thead>
<tr>
<th>Table 1. Selected Indications for Preoperative Laboratory Testing by Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>&gt; 40 yr</td>
</tr>
<tr>
<td>Major surgery</td>
</tr>
<tr>
<td>Known anemia</td>
</tr>
<tr>
<td>Renal disease</td>
</tr>
<tr>
<td>Anticoagulant use</td>
</tr>
<tr>
<td>Other diseases</td>
</tr>
<tr>
<td>associated with anemia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular disease</td>
<td>Renal disease</td>
<td>Diabetes</td>
<td>Diabetes</td>
<td>Hypertension</td>
<td>Thyroid disease</td>
<td>O ther diseases</td>
<td>Poor nutrition</td>
<td>Diuretic use</td>
<td></td>
</tr>
<tr>
<td>Other diseases</td>
<td>Renal disease</td>
<td></td>
<td></td>
<td></td>
<td>Poor nutrition</td>
<td>Poor nutrition</td>
<td>Diuretic use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>associated with anemia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males &gt; 65 yr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large expected blood loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malignancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticoagulant use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking &gt; 20 pack-yr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Major surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of anemia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic bleeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CNS = central nervous system; ECG = electrocardiogram; N.R. = no recommendation made; PT/PTT = prothrombin time/ partial thromboplastin time; TB = tuberculosis.
stress testing, pharmacologic stress testing, and coronary angiography. Relatively few studies have addressed the ability of exercise electrocardiography to predict perioperative cardiac risk, although some studies have evaluated the prognostic importance of functional capacity and the electrocardiographic response to exercise. Patients who cannot reach 75% to 85% of their maximum predicted heart rate or tolerate 4 metabolic equivalents (METs) of work during an exercise test appear to be at substantially elevated risk of postoperative cardiac events [22,23]. In some studies, the presence or absence of ST-segment depression during exercise testing is predictive of the likelihood of adverse outcomes [24], but in other studies it has not been found to be predictive [22,25]. Overall, the data suggest that patients who can reach 75% to 85% of their maximum predicted heart rate without developing ST-segment depression appear to be at low risk.

Dipyridamole thallium scintigraphy and dobutamine stress echocardiography have been extensively studied as methods of perioperative cardiac risk stratification. The studies have focused primarily on patients scheduled for vascular surgery, although a limited number of studies have addressed risk in nonvascular patients [26,27]. The majority of studies have demonstrated that these tests have high sensitivity and moderate specificity for cardiac complications [23], although this has not been a universal finding [28,29]. The risk of perioperative myocardial infarction or cardiac death appears exceedingly low if the test results are normal and increased if a reversible defect is demonstrated [23]. For example, a normal dipyridamole thallium stress test has a negative predictive value of 95% to 100%, while the presence of a reversible perfusion defect has a positive predictive value of only 4% to 20%. The predictive value of dobutamine stress echocardiography is comparable to that of dipyridamole thallium scintigraphy [30].

Advances in noninvasive testing, refinements in surgical and anesthetic techniques, and improvements in postoperative care have reduced the need for coronary angiography. The incidence of mortality or serious morbidity following cardiac catheterization is 0.01% to 0.05% and 0.03% to 0.25%, respectively [31]. Recent guidelines developed by the American College of Cardiology and the American Heart Association (ACC/AHA) [23] contain recommendations on

### Table 2. Original and Modified Goldman Cardiac Risk Indices

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Original Index [16]</th>
<th>Points</th>
<th>Modified Index [17]</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic heart disease</td>
<td>MI within 6 months</td>
<td>10</td>
<td>MI within 6 months</td>
<td>10</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>S, gallop or jugular venous distention</td>
<td>11</td>
<td>Pulmonary edema within 1 week</td>
<td>10</td>
</tr>
<tr>
<td>Cardiac dysrhythmia</td>
<td>Rhythm other than sinus or PACs on preoperative ECG</td>
<td>7</td>
<td>Rhythm other than sinus or PACs on preoperative ECG</td>
<td>5</td>
</tr>
<tr>
<td>Aortic valve disease</td>
<td>Important aortic stenosis</td>
<td>3</td>
<td>Suspected critical aortic stenosis</td>
<td>20</td>
</tr>
<tr>
<td>Poor general medical status</td>
<td>Any of: PO2 &lt; 60 mm Hg, PCO2 &gt; 50 mm Hg, K &lt; 3.0 mmol/L, HCO3 &lt; 20 mEq/L, BUN &gt; 50 mmol/L, Cr &gt; 3.0 mg/dL, abnormal AST, signs of chronic liver disease, bedridden from noncardiac causes</td>
<td>3</td>
<td>Any of: PO2 &lt; 60 mm Hg, PCO2 &gt; 50 mm Hg, K &lt; 3.0 mmol/L, HCO3 &lt; 20 mEq/L, BUN &gt; 50 mmol/L, Cr &gt; 3.0 mg/dL, abnormal AST, signs of chronic liver disease, bedridden from noncardiac causes</td>
<td>5</td>
</tr>
<tr>
<td>Age</td>
<td>&gt; 70 yr</td>
<td>5</td>
<td>&gt; 70 yr</td>
<td>5</td>
</tr>
<tr>
<td>Type of surgery</td>
<td>Intraperitoneal, intrathoracic, or aortic operation</td>
<td>3</td>
<td>Not applicable</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Emergency operation</td>
<td>4</td>
<td>Emergency operation</td>
<td>10</td>
</tr>
</tbody>
</table>

AST = aspartate transaminase; BUN = blood urea nitrogen; CCS = Canadian Cardiovascular Society; CR = creatinine; ECG = electrocardiogram; K = potassium; MI = myocardial infarction; PAC = premature atrial contraction; PVC = premature ventricular contraction.
the use of preoperative coronary angiography. Patients with unstable angina, recurrent angina despite appropriate medical therapy, and high-risk results on noninvasive testing are candidates for angiography. Patients scheduled for high-risk surgery (Table 4) who have major clinical predictors of adverse outcome and indeterminate results on noninvasive testing also are candidates for coronary angiography. Possible indications for coronary angiography include intermediate-risk results during noninvasive testing, indeterminate test results during noninvasive testing in a low-risk patient undergoing a high-risk procedure, urgent noncardiac surgery in a patient recovering from myocardial infarction, and perioperative myocardial infarction.

Effect of Prior Treatment on Risk

Patients who have undergone technically successful coronary artery bypass surgery within the 6 years preceding their planned noncardiac surgery appear to have a substantially reduced rate of cardiac complications [23,32]. In some studies, the risk of surgery approaches that of patients without heart disease. Unfortunately, the utility of preoperative coronary artery bypass grafting (CABG) in reducing cardiac complications is reduced by the risks inherent to the angiogram and the revascularization procedure [23,32,33]. In many cases, the risk of the initial noncardiac surgery may be less than or equal to the combined risks of the coronary angiogram, coronary bypass procedure, and subsequent noncardiac surgery.

Several retrospective case series have documented that patients who had a prior successful percutaneous transluminal coronary angioplasty (PTCA) were at relatively low risk of perioperative cardiac complications [33]. The risk of postoperative death or myocardial infarction in patients with prior PTCA ranges from 0% to 2.6% and 0% to 7.0%, respectively [23,34]. The optimal timing of surgery following PTCA is not clearly defined. It is likely that there is a cardioprotective effect during the interval from 6 months to 5 years after a technically successful procedure in physically active, asymptomatic patients [23]. However, patients with a recent angioplasty are at risk of acute closure. Although initial studies demonstrated that surgery could be safely performed within 2 weeks of a successful balloon angioplasty, the patients studied did not receive intracoronary stents. A recent retrospective review of 40 patients who underwent preoperative PTCA with intracoronary stent placement demonstrated a high rate of postoperative complications. Twenty percent of patients died, 18% had a myocardial infarction, and 28% experienced severe bleeding [35]. All of the deaths and myocardial infarctions and the majority of bleeding episodes occurred in patients who had surgery within 14 days of the stent placement. Based upon these data, elective surgery following angioplasty involving an intracoronary stent should be postponed for a minimum of 14 days.

An Integrated Approach to Preoperative Cardiac Risk Assessment

Guidelines developed by the ACC/AHA [23] published in 1996 provide a stepwise approach to preoperative cardiac risk assessment (Figure). The protocol relies on assessment of clinical markers, prior coronary evaluation and treatment, functional capacity, and surgery-specific risk to determine...
which patients are candidates for cardiac testing. The guidelines classify surgical procedures as high-, intermediate-, or low-risk (Table 4). As there is a large amount of variability in mortality rates within each risk group among different patient populations, physicians, and institutions, it is often difficult to determine the precise cardiac risks associated with specific surgical procedures. The physician assessing preoperative risk should consult with the surgeon and anesthesiologist if the surgery-specific risk of cardiac complications is not well-defined.

In 1997, the American College of Physicians (ACP) released their guidelines for assessing and managing the perioperative risk for coronary artery disease (CAD) associated with major noncardiac surgery [31], which concur in most respects with the ACC/AHA guidelines. For example, both maintain that patients should routinely be clinically assessed for known operative risk factors and that noninvasive testing should not be used routinely. They differ, however, with regard to the utility of noninvasive cardiac testing in intermediate-risk patients and the role of functional capacity assessment. The ACP guidelines recommend against noninvasive testing in patients at intermediate risk except in those undergoing vascular surgery. The ACC/AHA guidelines advocate more aggressive noninvasive testing with either exercise or pharmacologic stress tests, especially for patients undergoing high-risk surgery or with poor functional capacity. In addition, the ACC/AHA guidelines encourage the use of a patient’s functional capacity in risk stratification while ACP makes no recommendation for or against clinical assessment of functional status. The ACP guidelines also advocate more widespread use of β blockers; this difference may be attributed to the fact that newer data supporting use of β blockers became available after the ACC/AHA guidelines were released.

While both guidelines include a comprehensive review of the literature, ACC/AHA use evidence primarily from the vascular surgery literature and extrapolate to other surgery, whereas ACP derives its conclusions and recommendations largely on a limited number of high-quality studies and considers the bodies of evidence for vascular and nonvascular surgery separately. It is likely that use of either algorithm will reduce variability in the preoperative workup, minimize adverse outcomes, and reduce costs [36]. There is no evidence that one protocol is superior to the other in achieving better clinical outcomes or reducing costs.

**Perioperative Management of the High-Risk Patient**

**Revascularization**

In the absence of clinical trials on preoperative revascularization, decision analyses have attempted to model the short- and long-term impact of coronary revascularization [33,36,37]. These studies have demonstrated a limited potential for this intervention to reduce the incidence of postoperative cardiac complications. The short-term benefits of prophylactic coronary revascularization appear limited to a small subgroup of patients who are at very high risk for cardiovascular complications following noncardiac surgery and who can undergo coronary revascularization with a relatively low rate of serious complications. Thus, indications for coronary revascularization before noncardiac surgery are identical to those in the nonoperative setting. If the patient is likely to obtain a long-term benefit from revascularization, the intervention should probably be performed prior to elective surgery [23,37].

**β Blockers**

Two recent prospective, randomized placebo-controlled trials have documented the efficacy of perioperative β blockers in reducing perioperative ischemia, postoperative myocardial infarction, and cardiac death [38,39] in moderate- and high-risk patients. In one study [38], patients with known CAD or multiple risk factors for CAD were treated with either atenolol or placebo immediately preceding noncardiac surgery and up to 7 days postoperatively. Patients receiving atenolol had reduced overall mortality (10% versus 21%, \( P < 0.019 \)) and a reduced rate of adverse cardiovascular events (17% versus 32%, \( P = 0.008 \)) for up to 2 years following surgery. Poldermans et al [39] treated high-risk patients (clinical risk factors and demonstrable ischemia on dobutamine stress echocardiography) undergoing major vascular surgery with the cardioselective β blocker bisoprolol or placebo. Therapy was initiated a minimum of 7 days preoperatively and continued for 30 days postoperatively. The group receiving bisoprolol had a lower cardiovascular mortality (3.4% versus 17%, \( P = 0.02 \)) and a lower rate of nonfatal myocardial infarction (0% versus 17%, \( P < 0.001 \)) in the 30-day period following surgery.

Unless there are contraindications to their use, β blockers should be administered to patients who have been receiving these agents preoperatively, those with known ischemic heart disease, and those with a high likelihood of having CAD [40,41]. Effective β-adrenergic receptor blockade should be established preoperatively, continued intraoperatively, and discontinued postoperatively after the stress inherent to surgery has remitted. The optimal duration of preoperative and postoperative therapy is not well defined. Intravenous nitroglycerin may be useful in select high-risk patient populations [23], and a calcium channel antagonist, particularly a nondihydropyrimidine such as diltiazem, may be considered for select patients who have contraindications or are unable to tolerate β blockers [42].

**Other Therapies**

Therapy for congestive heart failure, cardiac dysrhythmias,
CLINICAL REVIEW

Figure. Stepwise approach to preoperative cardiac risk assessment. CHF = congestive heart failure; ECG = electrocardiogram; MET = metabolic equivalent; MI = myocardial infarction. (Adapted with permission from reference 23.)
and valvular heart disease should be optimized prior to surgery. Corrective valve surgery or balloon valvuloplasty are usually reserved for patients who would require them independent of the need for noncardiac surgery [23]. The use of pulmonary artery catheters to monitor hemodynamics and direct perioperative therapy is controversial. Patients most likely to benefit from their use include individuals who are scheduled to undergo a procedure associated with significant hemodynamic stress and who have comorbid medical disorders that impair their ability to tolerate these physiologic derangements [23]. Endocarditis prophylaxis should be employed as recommended by organizations such as the American Heart Association [43]. Pacemakers, implanted defibrillators, and antiarrhythmia devices should be assessed preoperatively and appropriate precautions taken to assure proper functioning during the intraoperative and postoperative periods [23].

**Postoperative Management**

Despite advances in surgical technique, anesthesia, and perioperative management, serious complications still occur, primarily consisting of neurologic, cardiac, and pulmonary disorders. In order to minimize the frequency and severity of these complications, vigilant postoperative monitoring is essential. As with preoperative assessment, unnecessary testing in low-risk postoperative patients should be avoided. In many low-risk patients, close clinical follow-up with attention to the expected course of recovery will provide the optimal level of care; however, more intensive monitoring and postoperative testing should not be withheld for patients at high risk. Two care issues relevant to the postoperative patient are the utility and appropriateness of cardiac monitoring following surgery and optimal use of deep venous thrombosis (DVT) prophylaxis.

**Cardiac Monitoring**

Cardiac monitoring with electrocardiography and the measurement of cardiac enzymes should be utilized judiciously in the postoperative period [23]. The routine use of these tests in low-risk patients is usually unnecessary and will result in an excessive number of erroneous diagnoses of perioperative myocardial ischemia and infarction. Patients without heart disease who have undergone low- or moderate-risk procedures should be tested only if symptoms or signs of cardiac dysfunction develop. The utility of routine electrocardiographic testing of asymptomatic patients at moderate risk for postoperative complications is unclear.

The highest risk period for postoperative ischemia and infarction is the first 24 hours following surgery, and most postoperative MIs occur within 48 hours of surgery. Unfortunately, the vast majority of perioperative ischemic episodes are asymptomatic, and typical symptoms of infarction are often absent. In one study, more than 50% of patients with electrocardiographic changes and cardiac enzyme concentrations indicative of myocardial infarction did not experience chest pain [44]. New cardiac rhythm disturbances, hypotension, hypertension, congestive heart failure, and delirium may be the primary manifestation of perioperative infarction, particularly in geriatric patients.

Patients with documented or suspected heart disease and patients who are undergoing high-risk surgical procedures should have an electrocardiogram immediately after surgery and daily for the next 2 days. While postoperative surveillance with serial electrocardiography plays a crucial role in the detection of myocardial ischemia and infarction, it is often not definitive. New Q waves are highly specific markers of infarction, but these findings are not very sensitive. Evidence of ST-segment depression or T-wave inversions are more sensitive findings in patients with postoperative ischemia but lack specificity, particularly in the postoperative setting.

The measurement of serum concentrations of 2 cardiac enzymes, the MB isoenzyme of creatine kinase (CK-MB) and cardiac troponin I, has been used to enhance the detection of postoperative myocardial infarction [45]. The utility of CK-MB in the postoperative setting is somewhat limited. The extensive muscle damage associated with surgery frequently causes abnormalities in creatine kinase that may make interpretation of test results difficult. When compared with CK-MB, the measurement of troponin I appears equally sensitive but more specific for postoperative infarction [46]. Increased concentrations of troponin I can be detected within 4 hours of myocardial infarction and may persist for 5 to 10 days following the myocardial necrosis. Therefore, measurement of troponin I combined with results of electrocardiography is likely to be the most cost-effective method of diagnosing postoperative ischemia. A potential problem with the use of this marker, however, is that frequent, small elevations in troponin I concentration that can be detected. These elevations may represent episodes of myocardial ischemia without infarction or may be a marker for other types of myocardial injury. The clinical significance of these small elevations in troponin I are not yet clear. The approach to these abnormalities should take into account the underlying clinical risk for ongoing ischemia, considering the patient’s risk factors, the risk of the surgical procedure, and the postoperative clinical course.

**Deep Venous Thrombosis Prophylaxis**

While the precise incidence of DVT and pulmonary embolus in surgical patients is unclear, these disorders are common and associated with high levels of morbidity and mortality. In a recent review [47], the incidence of DVT in the general surgical population was approximately 28% (range, 19% to 50%), with a reported incidence of 1.5% for pulmonary...
embolism. Mechanical and pharmacologic methods are available to prevent the development of thromboembolism in surgical patients. Mechanical methods include graded compression elastic stockings, intermittent external pneumatic calf compression, and electrical stimulation of the calf muscles. Pharmacologic agents include low-dose unfractionated heparin (LDUH), low-molecular-weight heparin (LMWH), and warfarin.

Both mechanical and pharmacologic methods of prophylaxis have been found to be effective in preventing DVT in surgical patients in a large number of clinical studies. A detailed discussion of the comparative costs and benefits of the different approaches is beyond the scope of this article. In general, the most important consideration is that some form of DVT prophylaxis be given for most postoperative patients who are not ambulatory, as there is no definitive evidence showing that any of the recommended approaches is more or less cost-effective than others. Prophylaxis should generally be started preoperatively and continued until the patient is ambulatory.

Recent recommendations for DVT prophylaxis in patients undergoing general surgery [47,48] can be summarized as follows: For low-risk patients (< 40 years, minor surgery, no clinical risk factors), early ambulation without specific DVT prophylaxis is sufficient. For moderate-risk patients (> 40 years, major surgery, no additional clinical risk factors), the use of LMWH once daily or LDUH twice daily is appropriate; however, intermittent external pneumatic calf compression and elastic stockings would be acceptable alternatives. In high-risk patients (> 40 years, major surgery, additional clinical risk factors), a combination of intermittent external pneumatic calf compression or elastic stockings plus LMWH twice daily or LDUH every 8 to 12 hours may be more effective than either modality alone. In selected high-risk patients, such as high-risk orthopedic patients, the use of perioperative warfarin is an acceptable alternative.

Conclusion

Although specific data on the cost-effectiveness of most perioperative interventions are lacking, there are general principles that may be applied in attempting to maximize cost-effectiveness. Cardiac risk assessment that takes into account the clinical status of the patient and the specific risk of the surgical procedure should help guide the extent of the preoperative workup. Excessive testing for low-risk patients should be avoided. Existing guidelines for cardiac risk stratification, which advocate a selective approach to testing, should be used. Standardization of perioperative assessment and care through institution-specific guidelines and a "systems" approach is likely to improve cost-effectiveness [13,49]. Consideration of the long-term impact of proposed interventions can often be helpful, especially where the short-term impact of the intervention is uncertain or of marginal benefit. Through use of these general principles, clinicians working in this field can strive to maintain the highest quality of perioperative care at the most cost-effective level possible.

Author addresses: Drs. Lefevre, Arron, and Chadha: General Internal Medicine, 675 North St. Clair, Galter Pavilion, Suite 18-200, Chicago, IL 60611. Dr. Cohn: 450 Clarkson Avenue, Brooklyn, NY 11203-2098.

References

46. Horowitz MB, Willet D, Keffler J. The use of cardiac troponin-I (cTnI) to determine the incidence of myocardial ischemia and...

