We reviewed the approach to preoperative cardiac risk assessment, incorporating new information regarding the pathophysiologic features of perioperative myocardial ischemia and recent clinical trials. Relevant articles were identified from a MEDLINE search, followed by bibliography review of the articles identified. The multifactorial risk indexes are valuable in stratifying risks among unselected patients undergoing noncardiac surgery, but they underestimate the risks in selected groups, particularly patients with peripheral vascular disease. The preoperative evaluation of patients with coronary artery disease and risk reduction strategies for high-risk patients are considered. There are no prospective randomized clinical data comparing preoperative revascularization to intensive medical therapy and clinical decisions must be individualized. Risks particular to patients with congestive heart failure and valvular heart disease are also reviewed. Patients with congestive heart failure can undergo noncardiac surgery safely, if their cardiac disease is well-compensated. Patients with aortic stenosis have high risks, and management strategies include valve replacement, aortic valvuloplasty, and aggressive medical treatment. These modalities have not been compared prospectively, and clinical decisions must be individualized. Preoperative arrhythmias are important risk factors, although they appear to confer risk only when due to underlying heart disease. A thorough, targeted history and physical examination supplemented with judicious laboratory studies are usually sufficient to assess a patient’s risk for upcoming noncardiac surgery. The clinical history should identify risk factors that predict cardiac complications, and special attention should be given to those risk factors that can be modified before surgery. New developments in perioperative medicine will likely lead to postoperative interventions to reduce silent myocardial ischemia and clinical complications.

Each year, approximately 25 million people in the United States undergo noncardiac surgery. Approximately 8 million of these have cardiac disease or major cardiac risk factors or are older than 65 years. Therefore, it is not surprising that cardiac complications occur when these patients are subjected to stress during the 3- to 4-day perioperative period. Current estimates of serious perioperative cardiac morbidity vary between 1% and 10%, depending on the subset of patients and the type of surgical procedure. About 4% of patients suffer serious perioperative cardiac morbidity following noncardiac surgery.1

Primary care physicians can perform comprehensive preoperative evaluations without subspecialty referral. Preoperative assessment considers the type of surgery (ie, anatomy, fluid shifts, amount of blood loss, and emergency, urgent, or elective procedure), underlying medical illnesses, the pathophysiologic state of the patient, and whether this state can be optimized before surgery.

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Arch Fam Med. 1998;7:164-173

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surgery. Underlying such an evaluation is an understanding of the physiologic changes that occur with anesthesia. Therefore, we will review the cardiovascular effects of general and regional anesthesia briefly before discussing in more detail the preoperative evaluation for patients with cardiac disease.

Induction of general anesthesia and unconsciousness is achieved with intravenous anesthetics such as propofol. Once a state of unconsciousness is induced, anesthesia is maintained with inhaled and intravenous anesthetics with or without muscle relaxants. The most common agents used for general anesthesia maintenance are the volatile liquids—halothane, enflurane, isoflurane, sevoflurane, and desflurane. Although each of these drugs has unique properties, their cardiovascular effects will be discussed in general terms. The inhaled anesthetic agents reduce arterial blood pressure by decreasing systemic vascular resistance, myocardial contractility, and stroke volume. Patients with a history of congestive heart failure and impaired myocardial contractility are particularly sensitive to drug-induced myocardial depression. The decrease in myocardial contractility can be partially offset by preoperative volume loading via the Frank-Starling mechanism.

The inhaled anesthetics protect the myocardium from ischemic injury. The mechanisms for this protection are unclear, but coronary artery dilatation, diminished myocardial oxygen consumption, and cellular metabolic changes are thought to play significant roles. However, myocardial ischemia may develop in patients with coronary artery disease and minimal reserves when surgical manipulation activates the sympathetic nervous system, increasing blood pressure, heart rate, and myocardial oxygen consumption. The inhaled anesthetics can sensitize the myocardium to the effects of circulating catecholamines and increase ventricular irritability and premature ventricular extrasystoles.

Regional anesthetic techniques include spinal, epidural, intravenous, and peripheral nerve blocks. In contrast to general anesthesia, regional anesthesia is not easily reversed once established. Regional techniques occasionally fail to provide adequate analgesia, and general anesthesia is then required. Preoperative risk assessment, therefore, must consider the possibility of regional and general anesthesia.

Epidural and spinal techniques produce the greatest physiologic changes. Venodilation occurs with both techniques and can result in decreased preload, decreased cardiac output, and hypotension. Patients with volume depletion and higher-level blocks have the greatest decreases in blood pressure. If the block is sufficiently high (involving T2 to T5), a compensatory tachycardia in response to hypotension does not occur because cardiac sympathetic fibers are blocked. Preoperative volume loading can attenuate the hypotension accompanying regional anesthesia; however, postoperative congestive heart failure may occur as the anesthetic wears off and venous tone returns to normal.

Many clinicians believe that regional is safer than general anesthesia in high-risk patients. There are few data to support this opinion. Prospective randomized studies comparing general and regional anesthesia have shown no differences in mortality, cardiopulmonary complications, or postoperative cognition. There may, however, be differences that influence the choice of anesthetic technique. Recent studies have suggested improved vessel patency when lower extremity vascular surgery is performed under regional anesthesia. Other data suggest the incidence of proximal deep venous thrombosis may be reduced when regional anesthesia is used for lower extremity joint replacement. Although primary care physicians should have a working knowledge of the physiologic changes that occur during anesthesia to perform a complete preoperative evaluation, the choice of anesthetic technique should be determined by the anesthesiologist.

PREOPERATIVE RISK STRATIFICATION

Preoperative risk stratification depends not only on patient characteristics but also on the proposed surgery. Some operations are more dangerous than others, with risks related to the following 2 important factors: the type of surgery and the degree of hemodynamic stress associated with surgery-specific procedures. High-risk operations include major emergency surgery (particularly in elderly patients), major and peripheral vascular surgery, and other prolonged procedures associated with large amounts of fluid shifts and blood loss. Intermediate-risk procedures include carotid endarterectomy, head and neck procedures, intraperitoneal and intrathoracic, orthopedic, and prostate surgery. Low-risk procedures include endoscopic and superficial procedures and cataract and breast surgery.

The degree of perioperative risk is further refined when patient-dependent variables are considered. Strategies incorporating clinical variables can identify patients at increased risk for postoperative cardiac complications. With preoperative risk factors is therefore inherently limited. We will review preoperative risk stratification and new developments in the pathogenesis of postoperative cardiac complications. The value of risk assessment based solely on preoperative risk factors is therefore inherently limited. We will review preoperative risk stratification and new developments in the pathogenesis of postoperative cardiac complications. Although progress has been made in identifying high-risk patients, relatively few data exist regarding risk reduction strategies. Where such data are available, we will review them and propose management strategies.

In 1977, Goldman et al published a landmark study of a multifactorial index of cardiac risk. Among 1001 consecutive patients undergoing noncardiac surgery, the authors reported 9 variables associated with an increased risk for postoperative cardiac complications (defined as cardiac death, myocardial infarction [MI], pulmonary edema, or ventricular tachycardia). Each risk factor was weighted and assigned a point score, as follows: presence of a third heart sound or jugular venous distention, 11 points; MI within the previous 6 months, 10 points; more than 5 premature ventricular extrasystoles, 8 points; surgery involving the coronary circulation, 7 points; chronic heart failure or angina at rest, 5 points; the previous 6 months, 10 points; MI within the previous 6 months, 10 points; more than 5 premature ventricular extrasystoles, 8 points; surgery involving the coronary circulation, 7 points; chronic heart failure or angina at rest, 5 points; diabetes, 4 points; the previous 6 months, 10 points; MI within the previous 6 months, 10 points; more than 5 premature ventricular extrasystoles, 8 points; surgery involving the coronary circulation, 7 points; chronic heart failure or angina at rest, 5 points; diabetes, 4 points; age older than 65 years, 3 points; and hypertension, 2 points. Each variable was assigned a weight reflecting its relative importance. The authors used this weight to calculate a patient’s risk score, which was then used to predict the probability of postoperative cardiac complications. The authors found that patients with a score of 3 or more were at high risk for postoperative cardiac complications. This study provided a valuable tool for assessing the risk of postoperative cardiac complications and has been widely used in clinical practice.

Arch Fam Med/Vol 7, Mar/Apr 1998

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contractions per minute documented at any time before surgery, 7 points; rhythm other than sinus or presence of premature atrial contractions on the preoperative electrocardiogram (ECG), 7 points; being older than 70 years, 5 points; intraperitoneal, intrathoracic, or aortic operation, 3 points; emergency operation, 4 points; significant valvular aortic stenosis (AS) based on results of the physical examination, 3 points; and poor general medical condition, including potassium level of less than 3.0 mmol/L, serum bicarbonate level of less than 20 mmol/L, serum urea nitrogen level of greater than 17.8 mmol/L (50 mg/dL), creatine level of greater than 2287.5 µmol/L (30 mg/dL), Pco₂ of less than 40 mm Hg, Pco₂ of less than 50 mm Hg, elevated results of liver function tests, or any condition causing the patient to be chronically bedridden, 3 points. A patient's risk is divided into 4 categories based on their point total (Table 1) This multifactorial index has been validated in prospective studies of unselected patients undergoing general surgical procedures, confirming its usefulness. In 1986, Detsky et al24,25 revised the original index by changing the point scores for several factors and adding variables, including a history of class III or IV angina, an MI more than 6 months before surgery, and previous pulmonary edema, all of which conferred risk. This revised index score reflects a pretest probability of postoperative complications. Using a nomogram, the pretest probability is combined with a likelihood ratio based on operationspecific complication rates to determine the posttest probability of postoperative complications. The revised index is useful because it emphasizes that not all surgeries carry the same risk. Although both indexes identify high-risk patients undergoing noncardiac surgery, they both underestimate postoperative complications in patients with significant vascular disease. The cardiac evaluation of patients undergoing major vascular surgery is beyond the scope of this article but has been reviewed elsewhere. For most patients undergoing elective surgery, a thorough history, physical examination, and ECG are sufficient to assess perioperative cardiac risks. Further workup is necessary in few patients (eg, those unable to exercise and those who cannot provide adequate history).

High-risk patients should undergo further diagnostic testing only when the results of such tests will change management strategies and lead to improved outcomes. Among most ambulatory patients, the test of choice is exercise ECG testing, which provides an estimate of functional capacity and detects myocardial ischemia. In patients with an abnormal resting ECG (eg, left bundle branch block, left ventricular hypertrophy with strain pattern, or digitalis effect), other techniques such as exercise echocardiography or exercise myocardial perfusion imaging should be considered. In patients unable to exercise, a pharmacologic stress test should be used. Dipyridamole thallium and dobutamine hydrochloride echocardiography studies are the most commonly used pharmacologic stress tests.22 A recent meta-analysis showed no differences in the ability of these techniques to predict postoperative cardiac complications. Thus, when further testing is necessary, the choice of tests should be determined by patient characteristics and local expertise.22,39,40

### PERIOPERATIVE MYOCARDIAL ISCHEMIA

Continuous ECG monitoring with ST segment analysis has provided insight into the pathophysiologic features and frequency of perioperative myocardial ischemia. The Perioperative Ischemia Research Group used continuous ECG monitoring before, during, and after noncardiac operations and found that myocardial ischemia occurred most frequently during the early postoperative period (20% in the preoperative, 25% in the intraoperative, and 41% in the postoperative periods). Among a large number of variables, postoperative ischemia had the strongest univariate and the only multivariate associations with clinical cardiac complications. Other investigators have confirmed the strong association between postoperative ischemia and clinical cardiac complications. Postoperative ischemia has been well-characterized. Its peak incidence is within 48 hours of surgery, which correlates with the peak incidence of postoperative MI. The ischemic episodes are not associated with tachycardia and follow a circadian rhythm, with most ischemia occurring in the early morning hours. Postoperative ischemia is more severe than ischemia detected at other times and is clinically silent more than 90% of the time. Silent postoperative myocardial ischemia has been reported to be present for more than 50 minutes before each clinical event. Thus it has been proposed, although not yet studied, that postoperative monitoring of high-risk patients for 48 hours may allow clinicians to intervene and decrease myocardial ischemia. Recent studies have demonstrated that perioperative β-blocker therapy reduces perioperative ischemia and improves long-term outcomes. Another study demonstrated that high-dose narcotic analgesia can decrease postoperative ischemia. These early results suggest that perioperative treatment of high-risk patients should include β-blockers and aggressive pain control. Postoperative myocardial ischemia is still incompletely understood, and ongoing research will provide further insights into its pathogenesis, prevention, and treatment.

### CHRONIC STABLE ANGINA

The early studies of perioperative cardiac risk did not identify chronic
stable angina as a risk factor for postoperative complications. Other studies, however, question this conclusion. Detsky et al proposed that chronic stable angina may be associated with an increased risk for complications. Their findings showed that patients with chronic stable angina who were unable to walk 2 blocks at a normal pace (Canadian Cardiovascular Society angina class III and IV) are at increased risk for cardiac complications following noncardiac surgery. Shah et al recently reported that 11% (18/158) of patients with chronic stable angina suffered MI after noncardiac surgery. These patients were not stratified according to their functional status, and cardiac mortality rates were not reported. Thus, some patients with chronic stable angina are at increased risk for postoperative cardiac complications. The incidence of complications will vary depending on the patient’s preoperative exercise tolerance, surgical procedure, and vigilance with which postoperative cardiac events are searched. Thus, definitive recommendations are difficult to make, and decisions should be individualized. Based on the information available, patients who have good exercise tolerance (able to walk 2 blocks at a normal pace [Canadian Cardiovascular Society angina class I and II]) and a truly stable anginal pattern can undergo surgery safely without further diagnostic workup (Figure).

The question of preoperative coronary revascularization for patients with ischemic heart disease is often raised. Coronary artery bypass grafting (CABG) specifically to decrease postoperative complications should be considered differently from a CABG for indications with known survival benefit. There is no question that CABG should be performed before elective noncardiac surgery in patients who have independent indications for coronary revascularization. Whether coronary revascularization specifically decreases postoperative cardiac complications, however, is unclear, and there are few prospective data to guide clinical decisions. Several authors have reported minimal complications in patients who have undergone CABG and then later noncardiac surgery. In the largest study, 1600 patients enrolled in the Coronary Artery Surgery Study registry who subsequently required noncardiac operations underwent analysis. Patients were separated into the following 3 groups based on findings on their coronary angiograms and their subsequent treatment: those without coronary artery disease, those with coronary artery disease who underwent CABG, and those with significant coronary artery disease who received medical treatment. Surgical mortality following noncardiac operations was then determined for each group. Patients without coronary artery disease had an operative mortality of 0.5%. Patients with significant coronary artery disease who underwent CABG, and those with significant coronary artery disease who received medical treatment had an operative mortality of 2.4%. These results are often cited in favor of recommending CABG before noncardiac surgery to decrease periop-

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operative complications. These studies, however, do not address the value of CABG for this indication because of their inherent selection bias. Patients were enrolled when they presented for their second surgical procedure. All patients had survived CABG and were considered candidates for a second major operation. If CABG is recommended specifically to decrease the incidence of surgical complications, morbidity and mortality related to CABG should be included in the overall morbidity and mortality rates. The operative mortality for CABG in the Coronary Artery Surgery Study population was 1.4%. Thus, the combination of cardiac and noncardiac surgery may result in a total mortality of 2.3%, which is similar to the perioperative mortality rate associated with noncardiac surgery alone. These mortality estimates are obtained by combining data from different reports (Table 2). Unfortunately, there are no prospective randomized studies to solve this problem. In the absence of prospective data, there is no convincing evidence that prophylactic CABG decreases perioperative morbidity or mortality rates in patients undergoing noncardiac surgery.

Percutaneous transluminal coronary angioplasty (PTCA) has been advocated as an alternative to CABG. It is associated with less morbidity and mortality than CABG and has been recommended before major surgical procedures if significant coronary artery disease is identified. This recommendation is based on anecdotal experience, as there are few data regarding the efficacy of PTCA before noncardiac operations. One report included 148 patients who underwent PTCA and incidentally required noncardiac surgery at a later date. Sixteen cardiac complications, including 1 death, and 7 ischemic events were reported in the postoperative period, for an overall cardiac morbidity of 11%. The Mayo Clinic described a retrospective uncontrolled series of 55 patients who underwent PTCA before a noncardiac operation in an attempt to diminish postoperative cardiac morbidity. Their postoperative MI rate was 5.6%, and postoperative mortality was 1.9%. The postoperative mortality of 1.9% may not be significantly different from the 2.4% mortality in patients undergoing noncardiac surgery without previous revascularization. The PTCA studies are retrospective and without control groups, so it is difficult to assess the effect of prophylactic PTCA has on postoperative cardiac complications.

Taking the above information into consideration, the clinical history is of the utmost importance when evaluating a patient with angina before surgery. Assessing whether the patient's ischemic symptoms are truly stable is much more important than extensive diagnostic testing. Assessment of exercise tolerance and the frequency and intensity of anginal symptoms and anginal equivalents should be sought. Self-reported frequency of anginal symptoms, however, can be misleading, because many patients voluntarily reduce their activity level to avoid symptoms. Patients whose exercise tolerance has diminished as a result of symptoms cannot be considered to have stable angina and may warrant further evaluation (Figure).

Table 2. Postoperative Mortality Rates*

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Patients</th>
<th>Population</th>
<th>Intervention</th>
<th>Mortality, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foster et al, 1986</td>
<td>1600</td>
<td>No CAD</td>
<td>NCS alone</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAD</td>
<td>NCS with previous CABG</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAD</td>
<td>NCS with medical therapy</td>
<td>2.4</td>
</tr>
<tr>
<td>Principal investigators of CASS and their associates, 1981</td>
<td>780</td>
<td>CAD</td>
<td>CABG</td>
<td>1.4</td>
</tr>
<tr>
<td>Allen et al, 1991</td>
<td>148</td>
<td>CAD</td>
<td>NCS with previous PTCA</td>
<td>1</td>
</tr>
<tr>
<td>Huber et al, 1992</td>
<td>55</td>
<td>CAD</td>
<td>NCS with previous PTCA</td>
<td>1.9</td>
</tr>
</tbody>
</table>

* Reprinted by permission of the Western Journal of Medicine, Potyk. CAD indicates coronary artery disease; NCS, noncardiac surgery; CABG, coronary artery bypass grafting; CASS, Coronary Artery Surgery Study; and PTCA, percutaneous transluminal coronary angioplasty.

UNSTABLE ANGINA

Unstable angina represents an important risk factor for postoperative cardiac complications and is associated with a poor prognosis in patients undergoing CABG and noncardiac surgery. A recent series reported that 28% of patients with unstable angina suffered MI after noncardiac surgery. Elective noncardiac surgery should be postponed in patients with unstable angina until the ischemia has been stabilized. Medical therapy, coronary catheterization, and revascularization may all be necessary to stabilize the patient. There are no data to indicate the optimal interval between angina stabilization and surgery. If surgery is emergent or urgent, clinical decisions should be individualized weighing the risks and benefits of proceeding. If surgery is elective, an interval of 2 to 3 months seems prudent (Figure).

RECENT MI

The patient who has recently suffered an acute MI is at increased risk for postoperative cardiac complications. Early studies reported recurrent MI or cardiac death in 30% of patients undergoing surgery within 3 months of an acute MI and in 15% of patients undergoing noncardiac surgery from 3 to 6 months after an acute MI. After 6 months, the risk for reinfarction or death fell to and remained constant at about 5%.

Other data suggest that patients with recent MI undergoing noncardiac surgery are at increased risk, but that the risks are not as high as indicated above. Wells and Kaplan reported no reinfarctions among 48 patients who had surgery within 3 months of an MI. Using aggressive hemodynamic monitoring during the perioperative period, Rao et al reported 6% reinfarction rate among those having surgery within 3 months of an MI, and 2% among those having surgery 3 to 6 months after an MI. The study by Rao et al has been criticized because a large proportion of patients underwent minor operations with minimal hemodynamic stress. Shah et al recently reported reinfarction rates according...
to the type of surgery and found that even major operations were associated with reinfarction rates comparable to those reported by Rao et al (emergency and vascular surgeries, however, were exceptions and carried higher risks).

These data have led to general recommendations that elective surgery be delayed for 6 months after an acute MI. Risk stratification after an MI, however, allows an individualized approach recognizing the wide clinical spectrum and outcomes after an MI. When surgery is semielective, but prolonged delay may be deleterious (as with a potentially resectable malignant neoplasm), surgery can be considered 4 to 6 weeks after an MI if the patient is at low risk based on results of post-MI exercise testing and left ventricular ejection fraction. Higher-risk patients should be considered for coronary angiography and revascularization before urgent noncardiac surgery. In cases of urgent or emergency surgery, patients with a recent MI should be treated aggressively with β-blockers and invasive hemodynamic monitoring22,50,65,66 (Figure).

CONGESTIVE HEART FAILURE

Goldman et al23 identified congestive heart failure as an important risk factor for postoperative cardiac morbidity and mortality. The decreased myocardial contractility caused by inhaled anesthetics exacerbates the cardiomyopathic state, and it is easy to understand why congestive heart failure predicts postoperative cardiac complications.2,3,23-25 To date, there are no data comparing the perioperative outcomes of patients with diastolic vs systolic dysfunction. This is important because the therapies differ markedly. The following data refer to patients with systolic dysfunction. In the initial study by Goldman et al,23 patients presenting for surgery with a third heart sound or jugular venous distention had a 20% incidence of cardiac death and a 14% incidence of serious cardiac complications. Detsky et al24,25 refined this early work by identifying pulmonary edema within 1 week of surgery and in the remote past as independent risk factors for cardiac events. Charlson et al27 added to these studies by identifying intraoperative blood pressure fluctuations as a risk factor for postoperative congestive heart failure.

Left ventricular ejection fraction determinations have been proposed to identify patients at increased risk for postoperative cardiac complications. As a functional assessment, the ejection fraction was thought to predict how well the heart could withstand the stresses of surgery. Pasternack et al67 reported that patients with ejection fractions of greater than 55% were at low risk for postoperative myocardial complications, whereas those with ejection fractions of less than 35% had a 75% incidence of postoperative MI. More recent studies have suggested that patients with ejection fractions of less than 35% can undergo major surgery with acceptable 30-day mortality rates, whereas others have shown no correlation between ejection fraction and postoperative cardiac complications.68-71 Thus, ejection fraction determinations may supplement the history and physical examination but should not be the primary tool to identify high-risk patients before surgery. The physiologic state of the patient, ie, how well compensated the congestive heart failure is at the time of surgery, is the primary determinant of postoperative outcome. Patients with compensated heart failure (history of heart failure, but presently without jugular venous distention, rales, and a third heart sound) have a 5% to 7% incidence of cardiac complications, while those with decompensated disease have an 18% to 31% incidence of postoperative events.23 Patients with decompensated heart failure should have surgery delayed if possible until their condition is optimized with medical therapy. Detsky et al24,25 indicate these patients should be stabilized for longer than 1 week before undergoing surgery. The optimal interval between an episode of pulmonary edema and elective noncardiac surgery is unclear, although 4 to 6 weeks seems prudent.

The routine use of pulmonary artery catheters in patients with a history of congestive heart failure is controversial.77-72-74 Patients with stable, well-compensated disease do not require pulmonary artery catheterization, whereas patients with decompensated congestive heart failure and patients undergoing procedures associated with large fluid shifts may benefit from invasive hemodynamic monitoring to guide therapy.

VALVULAR HEART DISEASE

Aortic stenosis has been identified as an important risk factor for postoperative cardiac complications. Hemodynamically significant AS has been associated with a 13% risk for perioperative death.23-25 Aortic stenosis frequently occurs in older individuals who have other serious comorbidities. Because of the increasing prevalence of this lesion, the preoperative assessment of a patient with AS will be considered in detail.

Significant AS should be suspected clinically if the patient has a history of chest pain, syncope, or congestive heart failure or if physical examination reveals the classic murmur with diminished carotid upstrokes.73 When hemodynamically significant AS is suspected, an echocardiogram should be obtained before surgery. A valve area of less than 1.0 cm² or a gradient of more than 50 mm Hg across the valve suggests that critical AS may be present.

The optimal management of patients with significant AS who require noncardiac surgery has not been defined. Aortic valve replacement is the definitive therapy for patients with symptomatic critical AS being considered for elective surgery. Balloon valvuloplasty of the aortic valve has been advocated as a way to reduce the hemodynamic consequences of AS. Several authors have described small, nonrandomized series of patients with severe AS who underwent percutaneous aortic balloon valvuloplasty before necessary noncardiac surgery. Combining studies, 14 patients underwent successful valvuloplasty (average increase in valve area, 0.25 cm²) followed by noncardiac surgery. Transient intraoperative hypotension requiring pressors developed in 1 patient, but there

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were no other perioperative complications related to aortic stenosis. Valvuloplasty carries risks and is associated with a high rate of restenosis, limiting long-term success rates.

Others have questioned the necessity of preoperative valve replacement and valvuloplasty, particularly for patients with minimal or no symptoms. A heightened awareness of the potential risks for patients with AS undergoing surgery, together with improved diagnostic capabilities and advanced anesthetic management techniques, may enable these patients to undergo surgery safely without other interventions. O’Keefe et al described a series of 23 patients with severe AS who underwent elective noncardiac surgery under general or spinal anesthesia. There was no cardiac mortality among this group, but transient hypotension developed in 5 patients, who responded to fluids and pressors. The authors concluded that selected patients with severe AS can undergo noncardiac surgery with acceptable risks if invasive hemodynamic monitoring and vigilant anesthetic management techniques are used. Although aortic valve replacement before noncardiac surgery is preferred when feasible, situations arise in which this is not possible (urgent or emergency surgery or the patient refuses or is not a candidate). Under these circumstances, aortic valvuloplasty can be considered as a temporizing measure, but it is not clear whether balloon valvuloplasty or aggressive anesthetic management alone results in fewer complications. In the absence of prospective comparative data, clinical decisions should be individualized after considering the nature and urgency of the problem and after discussions with the patient, surgeon, and anesthesiologist.

Patients with mitral stenosis require elevated filling pressures and adequate filling time to ensure adequate left ventricular volume and cardiac output. Symptoms of significant mitral stenosis include dyspnea on exertion and congestive heart failure. The hemodynamic changes associated with anemia and surgery, particularly tachycardia, can result in pulmonary edema and cardiogenic shock. An echocardiogram should be obtained for symptomatic patients. Mitral valve replacement should be considered for symptomatic patients with a valve area of less than 1.0 cm². Pulmonary artery catheterization may be helpful in these patients if large volume shifts are anticipated, and the anesthesiologist should be alerted of the possible need for negative chronotropic drugs to treat tachycardias resulting in hemodynamic compromise.

The left ventricle in patients with chronic aortic insufficiency or mitral regurgitation is subjected to high volume loads that in time result in impaired myocardial contractility. Patients with regurgitant lesions are not as sensitive to the subtle hemodynamic shifts that affect patients with stenotic lesions. If patients with valvular insufficiency do not have signs or symptoms of congestive heart failure, they can undergo noncardiac surgery safely, usually without invasive hemodynamic monitoring. Those with mild to moderate left ventricular dysfunction should receive medical treatment and delay surgery until after 4 to 6 weeks of optimization. Pulmonary artery catheterization may be considered if large fluid shifts or significant loss of blood is expected. In patients with severe left ventricular dysfunction, valve replacement and lesser or alternative surgical options should be considered.

Patients with prosthetic heart valves and those with atrial fibrillation often use oral anticoagulants. These patients are at risk for thromboembolic complications when anticoagulation therapy is discontinued during the perioperative period. The risks for bleeding and thrombosis must be balanced, and anticoagulation therapy should be continued for at least 3 months. The risk-benefit assessment should include the type of valve, position, cardiac rhythm, and history. Ball-cage prosthetic heart valves (Starr-Edwards type) or older, pivoting disk valves (Bjork-Shiley type) are more thrombogenic than newer valves (St Jude type). Valves in the mitral position are associated with more thromboembolic complications than those in the aortic position. Atrial fibrillation is also associated with increased thrombotic risk, particularly when associated with mitral valve disease. Although some evidence suggests that minor procedures such as dental surgery and cataract surgery can be performed without discontinuing anticoagulation therapy, most procedures require interruption of therapy to avoid excessive bleeding. The international normalized ratio (INR) decreases exponentially beginning 24 to 36 hours after the last warfarin sodium dose, with a slower rate of decline in the elderly. The risk for perioperative thrombotic complications with a normal INR has not been defined, nor has the perioperative INR value associated with the lowest risk for excessive operative bleeding. The optimal INR at the time of surgery is likely to vary according to the type of surgery (variables include accessible site, enclosed space [ie, central nervous system or the spine], and vital structure [ie, retina]) and the anticipated amount of blood loss. Assuming that an INR of less than 1.5 is associated with an acceptable risk for perioperative bleeding, patients with an INR of 2.0 to 3.0 will have an INR of less than 1.5 approximately 4 to 5 days after discontinuation of warfarin therapy. Therefore, warfarin therapy should be discontinued 4 to 5 days before elective surgery (longer for elderly individuals). Following surgery, warfarin or heparin sodium therapy can be restarted, the choice depending on the risk for thrombosis. Patients at high risk for thrombosis should be admitted for intravenous heparin therapy while the INR is falling. These patients should have the heparin therapy discontinued 6 hours before surgery and then restarted postoperatively.

Questions regarding the need for prophylactic antibiotics to prevent bacterial endocarditis are common. Although this is an important topic, a complete discussion of endocarditis prophylaxis is beyond our scope. Excellent reviews are avail-
able, and primary care physicians should be familiar with the American Heart Association recommendations for endocarditis prophylaxis. All patients with valvular lesions should be considered for bacterial endocarditis prophylaxis.

ARRHYTHMIAS

Patients with preoperative arrhythmias have been described as experiencing increased perioperative morbidity and mortality. Five or more premature ventricular contractions per minute at any time or nonsinus rhythm or premature atrial contractions detected on the preoperative ECG are associated with increased perioperative cardiovascular morbidity and death. In one study, life-threatening cardiac complications occurred in 16% of patients (7/44) with frequent premature ventricular contractions and in 10% of patients (11/112) with premature atrial contractions or non-sinus rhythm on the preoperative ECG. A more recent investigation, however, questions these results. Among 230 high-risk patients with continuous ECG monitoring, no association between preoperative ventricular arrhythmias and perioperative cardiac complications could be demonstrated. The different conclusions reached by these studies are not surprising when the results are examined in more detail. Even in the studies reporting an association between preoperative arrhythmias and postoperative cardiac events, the complications were not caused by arrhythmias. The increased morbidity and mortality were consistently due to myocardial ischemic events and postoperative congestive heart failure. The incidence of perioperative cardiac events appears to be more closely related to underlying heart disease than to preoperative arrhythmias. Therefore, the preoperative evaluation of the patient with arrhythmias should be directed toward determining the cause, diagnosing underlying cardiac disease, and detecting the presence of other perioperative risk factors. A thorough history and physical examination directed at the cardiac and pulmonary systems, together with ECG and laboratory studies to detect electrolyte or acid-base disorders, are usually sufficient.

CONDUCTION DISTURBANCES AND PACEMAKERS

Patients with underlying conduction disturbances and permanent pacemakers require a meticulous preoperative evaluation. Patients with conduction disturbances should undergo evaluation for other signs and symptoms of underlying cardiac disease. Perioperative management is determined primarily by the underlying heart disease. The indications for temporary pacemakers during the perioperative period are generally the same as those for permanent pacemakers. Patients with preexisting bundle branch block or intraventricular conduction delays generally require no special precautions in the perioperative period. An exception is the patient with left bundle branch block for whom a pulmonary artery catheter is thought to be necessary. Under these circumstances, an external pacemaker or a temporary transvenous pacing catheter should be available to treat complete heart block that may result from the presence of the catheter. Bifascicular block does not progress to complete heart block more frequently in the perioperative period than at other times, and prophylactic pacing is not indicated.

Patients with permanent pacemakers can undergo surgery safely if precautions are taken. The use of electrocautery represents a significant risk to these patients. The electrical stimulus from electrocautery may inhibit demand pacemakers, may be conducted down the lead to the heart and cause ventricular tachycardia, or may reprogram the pacemaker. These problems can be avoided by positioning the ground plate for the electrical circuit so that the electrical current travels away from the generator by keeping the electrocautery device away from the pacemaker generator as much as possible and by using the electrocautery only in short bursts. The pacemaker should be set in an asynchronous or nonsensing mode in patients who are pacemaker dependent and whose underlying rhythm is unreliable. The asynchronous mode can be achieved through reprogramming or by placing a magnet over the pacemaker generator. The pacemaker should be interrogated after surgery to ensure appropriate programming and sensing pacing thresholds.

CONCLUSION

Evaluation of patients with cardiovascular disease before elective noncardiac surgery is a challenge. Primary care physicians should be able to evaluate most perioperative risks without subspecialty referral. A thorough, targeted history and physical examination supplemented with judicious laboratory studies are usually sufficient to adequately assess a patient's risks for upcoming surgery. The clinical history should identify risk factors that predict cardiac complications, and special attention should be given to those risk factors that can be modified before surgery. Primary care physicians should follow up their patients postoperatively, with a heightened awareness of postoperative myocardial ischemia, its peak incidence, and its atypical presentations. New developments in perioperative medicine will likely lead to postoperative interventions to reduce silent myocardial ischemia and clinical complications.

Since the manuscript was accepted for publication, another review of the literature and guidelines for assessing and managing perioperative risk due to coronary artery disease associated with major noncardiac surgery have been published by the American College of Physicians. Our recommendations are consistent with these guidelines.

Accepted for publication March 19, 1997.

We thank R. Jon Auricchio, PharmD, for his thoughtful comments and review of the manuscript.

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