6 RISK STRATIFICATION, PREOPERATIVE TESTING, AND OPERATIVE PLANNING

Cyrus J. Parsa, M.D., Andrew E. Luckey, M.D., Nicolas V. Christou, M.D., F.A.C.S., and Alden H. Harken, M.D., F.A.C.S.

> In the midst of [the lungs] is seated a hot organ, the heart, which is the origin of life and respiration. It imparts to the lungs the desire of drawing in cold air, for it raises a heat in them; but it is the heart which attracts. If, therefore, the heart suffer primarily, death is not far off.
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> —Aretaeus of Cappadocia

Although no one truly wants to undergo a surgical procedure, the results of surgery can be highly gratifying to both patient and surgeon when the right operation is performed accurately, expeditiously, and for the right reasons on the right patient at the right time. In attempting to bring about this state of affairs, surgeons must consciously and honestly balance the physiologic, psychological, social, and financial burdens of surgery against the anticipated benefits.[1] Although surgeons are not the only medical professionals who perform this kind of balancing act, they are probably the most conspicuous.

Currently, the measures of both anticipated surgical risk and expected outcome are being assessed in an increasingly sophisticated manner under the umbrella of health care quality.[2] Mortality alone is no longer considered a sufficient indicator of the success or failure of treatment. Cost is no longer addressed only in absolute terms but is (appropriately) related to years of life saved. Therapeutic morbidity is now taken into account in figuring the cost of each quality-adjusted life year (QALY) saved. Age is considered not merely in terms of distance from the beginning of life but also, more importantly, in terms of proximity to the end of life.

It goes without saying that in balancing risks against benefits, surgeons as a group should make use of the best available evidence. In the end, however, it is the responsibility of the surgeon to examine, digest, and individualize the morass of medical material relevant to each patient's disease and expected surgical outcome. This is key for developing not only the surgeon's ability to provide care but also the patient's ability to respond to it. Sensitive communication of the nature and severity of the disease and clear explanation of the proposed treatment are integral parts of the therapeutic process. A knowledgeable patient who participates in his or her treatment will recover faster. Finally, it is incumbent on the surgeon to honor the extraordinary trust inherent in his or her relationship with the patient by providing ongoing psychological and social support during surgical therapy—even after such support might be deemed excessive. A patient must not be allowed to relinquish hope.

The emerging focus on evidence-based care highlights the importance of accurate preoperative cardiac risk assessment, risk stratification, and optimization of risk parameters to formulate effective perioperative risk reduction strategies. Accordingly, our main aims in this chapter are (1) to assess approaches to the delineation of surgical risk, (2) to outline current thinking on the appropriate use of preoperative testing, (3) to highlight the importance of the patient's mental and emotional satisfaction with care as a component of outcome, and (4) to describe ways of reducing perioperative cardiac risk.

Tools for Assessment of Surgical Risk

Continuing refinement of the methods employed to stratify preoperative risk is permitting surgeons to "handicap" both patients and surgical procedures with greater and greater precision.[3,4] It is clear, for example, that outcome assessment must incorporate a so-called sickness quotient—typically expressed in terms of the ratio of observed outcome to expected outcome (O/E)—into the assessment of therapeutic value.[5] Obviously, if a surgeon operates exclusively on Olympic-level athletes with single-organ disease (or no disease at all), his or her patients will almost always do very well (or at least survive); one who operates on a more varied group of patients will have quite different results.

The most widely used classification system is the one developed by the American Society of Anesthesiologists (ASA), which is based on the patient's functional status and comorbid conditions (e.g., diabetes mellitus, peripheral vascular disease, renal dysfunction, and chronic pulmonary disease) [*see Table 1*].[6] The ASA index generally associates poorer overall health with increased postoperative complications, longer hospital stay, and higher mortality. ASA classes I and II correspond to low risk, class III to moderate risk, and classes IV and V to high risk.

Besides functional capacity and comorbid conditions, age has also been shown to be a determinant of operative risk, as has the type of operation being performed (with vascular procedures and prolonged, complicated thoracic, abdominal, and head and neck procedures carrying higher levels of risk).

HISTORY AND PHYSICAL EXAMINATION

The initial history, physical examination, chest x-ray, and electrocardiographic assessment should focus on the identification of potential respiratory or cardiac disorders [*see Table 2*],[7] emphasizing evaluation of the patient's cardiac status. High-risk cardiac conditions include recent myocardial infarction (MI), decompensated heart failure, unstable angina, symptomatic dysrhythmias, and symptomatic valvular heart disease. Underlying cardiac conditions, even if apparently stable at the time of assessment, may become manifest during perioperative stresses.[8] Such conditions include stable angina, distant MI, previous heart failure, and moderate valvular disease. Abnormal ECG findings include atrial fibrillation, left or right bundle-branch block, left ventricular hypertrophy, premature ventricular complexes, pacemaker rhythm, Q waves, or ST changes. In a retrospective analysis of 23,036 patients undergoing noncardiac surgery, the preoperative ECG was shown to improve the predictive value of perioperative cardiac events in comparison to clinical risk stratification alone.[9] This predictive benefit was not apparent, however, in low-risk patients undergoing low-risk procedures.[9]

The review of symptoms should identify serious comorbid conditions such as diabetes, cerebrovascular disease, peripheral vascular disease, renal insufficiency, blood dyscrasias, and pulmonary disease. The goal should be to codify clinical and laboratory factors insofar as is possible.

Table 1 American Society of Anesthesiologists' Physical Status Classification: Nonemergency Surgery[6]

Classification	Description	Examples
Class I	Normal, healthy patient	An inguinal hernia in a fit patient or a fibroid uterus in a healthy woman
Class II	Patient with mild systemic disease—a mild to moderate systemic disorder related to the condition to be treated or to some other, unrelated process	Moderate obesity, extremes of age, diet-controlled diabetes, mild hypertension, chronic obstructive pulmonary disease
Class III	Patient with severe systemic disease that limits activity but is not incapacitating	Morbid obesity, severely limiting heart disease, angina pectoris, healed myocardial infarction, insulin-dependent diabetes, moderate to severe pulmonary insufficiency
Class IV	Patient with incapacitating systemic disease that is life threatening	Organic heart disease with signs of cardiac insufficiency; unstable angina; refractory arrhythmia; advanced pulmonary, renal, hepatic, or endocrine disease
Class V	Moribund patient not expected to survive 24 hr without an operation	Ruptured aortic aneurysm with profound shock, massive pulmonary embolus, major cerebral trauma with increasing intracranial pressure

Smoking

Cigarette smoking is the leading cause of preventable death in the United States.[10] According to the American Heart Association (AHA), smokers made up a 40% smaller percentage of the U.S. population in 2003 than they did in 1965.[11] Nevertheless, approximately one third of surgical patients are still smokers. Smoking is clearly a risk factor for perioperative complications,[12] including pulmonary complications, circulatory complications, and an increased incidence of surgical site infection. Numerous mechanisms contribute to the deleterious effects of smoking: smoking inhibits clearance of pulmonary secretions, adversely affects the immune system and collagen production, and contributes to wound hypoxia (thereby increasing susceptibility to infection).[13] Some studies have suggested that even passive smoking can reduce blood flow velocity in the coronary arteries of healthy young adults.[14]

A 2002 trial demonstrated that preoperative smoking cessation reduced the incidence of postoperative complications from 52% to 18%.[12] A 2003 study reported similar results: patients who stopped smoking 4 weeks before operation had significantly lower postoperative wound infection rates than patients who continued to smoke up to the time of operation.[13] Ideally, cessation of smoking at least 4 to 6 weeks before operation is recommended. Preoperative counseling of patients on smoking cessation not only can reduce postoperative complications but also can serve as the impetus for permanent smoking cessation and consequent improvement in overall long-term health status.[15,16]

Alcohol Abuse

Although well-defined criteria for alcohol abuse and dependence exist,[17] the effects of chronic alcohol abuse and dependence on perioperative risk have not been as thoroughly studied as the effects of smoking.[17] The pathogenic mechanism is certainly multifactorial but is postulated to involve ethanol-mediated suppression of the immune system; this immune suppression is reversible, at least during abstinence in nonsurgical patients. Other deleterious effects of chronic alcohol ingestion include alcoholic cardiomyopathy, decreased platelet count and function, reduced fibrinogen level, and compromised wound healing. Various alcohol abstinence periods, ranging from 1 week to 3 months, have been reported to decrease these adverse effects.[18]

Preoperatively, efforts should be made to identify patients who abuse or are dependent on alcohol. Once identified, these patients may be managed with abstinence counseling, substance abuse therapy, pharmacologic intervention, detoxification and rehabilitation programs, or a combination of two or more of these methods.[19]

Long-term abuse of alcohol is often associated with central nervous system impairment and hepatic dysfunction, as well as malnutrition. Alcohol abusers, even those who exhibit no overt alcohol-related organ dysfunction, experience greater morbidity than nonabusers and exhibit longer recovery times.[18]

PREOPERATIVE TESTING

It was once generally agreed that surgical patients should undergo a series of routine screening tests before operation. This approach has proved not only unhelpful but also confusing and expensive. Perhaps predictably, it has been observed that the more tests are ordered, the more abnormal values are obtained. On the reasonable assumption that a test performed in a healthy person will yield an abnormal result 5% of the time, when 10 such tests are ordered, there is a 50% probability of an abnormal test result.[20] When an SMA-20 is ordered, the probability of an abnormal test result is quite high. Moreover, although these abnormalities are reported, they rarely alter the physician's behavior or result in cancellation or postponement of the operation [*see Table 3*].[20] Accordingly, current practice is to a take a much more selective approach to preoperative laboratory evaluation. Preoperative testing can provide predictive data when judiciously employed.

Table 2 Minimal Preoperative Test Requirements* at the Mayo Clinic[7]

Age (yr)	Tests Required
< 40	None
40–59	Electrocardiography, measurement of creatinine and glucose
≥ 60	Complete blood cell count, electrocardiography, chest roentgenography, measurement of creatinine and glucose

*In addition, the following guidelines apply. (1) A complete blood cell count is indicated in all patients who undergo blood typing and who are crossmatched. (2) Measurement of potassium is indicated in patients taking diuretics or undergoing bowel preparation. (3) Chest roentgenography is indicated in patients with a history of cardiac or pulmonary disease or with recent respiratory symptoms. (4) A history of cigarette smoking in patients older than 40 years who are scheduled for an upper abdominal or thoracic surgical procedure is an indication for spirometry (forced vital capacity).

Table 3 Effect of Abnormal Screening Test Results on Physician Behavior[20]

Screening Test	Abnormal Test Results (%)	Resulting Management Change (%)
Hemoglobin level	5 (for < 10 g/dl; < 9 g/dl was rare)	Abnormal result rarely led to change
Total leukocyte count	< 1	Abnormal result rarely led to change
Bleeding time	3.8	Abnormal result rarely led to change
Coagulation time	4.8	
Partial thromboplastin time	15.6	
Chest x-ray	2.5–3.7	2.1
ECG	4.6–31.7	0–2.2
Sodium, potassium	1.4 2.5 5.2	Abnormal result rarely led to change
Urinalysis	1–34.1	0.1–2.8

Serum creatinine,[21] glucose, and glycosylated hemoglobin levels[22] are strong predictors of perioperative cardiac events. There are some data suggesting that high concentrations of plasma N-terminal pro–brain natriuretic peptide (NT-proBNP) predict adverse postoperative cardiac outcome as well.[23]

Identification of Factors Affecting Cardiac Risk

Perhaps the simplest and most cost-effective component of preoperative cardiac risk stratification is identification of clinical risk factors with subsequent optimization of potentially modifiable factors. Numerous cardiac risk indices have been created over the past three decades. During that period, risk stratification criteria have evolved from the Goldman criteria, which represented the first substantial effort at stratification, to the Revised Cardiac Risk Index (RCRI) developed by Lee and associates,[24] which is currently the most widely applied risk stratification system. The RCRI identifies six predictors of major cardiac complications (i.e., myocardial infarction, cardiogenic pulmonary edema, cardiac arrest, and cardiac death); scores range from 0 to 5, and the likelihood of major perioperative complications increases with rising scores [*see Table 4*].[21] This index has weaknesses—namely, its exclusion of emergency surgical patients, as well as neurosurgical patients; its overrepresentation of thoracic, vascular, and orthopedic patients; and its simplistic classification of surgical procedures into only two categories, high risk or non–high risk.[25] Despite these weaknesses, however, the predictive accuracy of the RCRI has been validated in large cohorts.[24]

Whereas the RCRI documents factors that affect cardiac risk, the updated guidelines developed by the American College of Cardiology (ACC) and the AHA [*see* American College of Cardiology/American Heart Association Task Force Guidelines, *below*] serve as a national quality initiative for utilization of the RCRI and optimization of perioperative risk by either medical or, in rare cases, surgical means. As currently understood, the goal of a cardiac consultation is to determine the most appropriate testing and treatment strategies for optimizing patient care while avoiding unnecessary testing. This understanding represents a definite paradigm shift from the stratification and revascularization strategies employed between the 1970s and the early 1990s.

Unfortunately, the guidelines are not always followed in clinical practice. One survey study found that despite the availability of guidelines, 40% of cardiology consultations resulted in simple recommendations to proceed with surgery, with no modification of perioperative plans or optimization of risk factors.[26] Clinical implementation of ACC/AHA guidelines appears to be poor in Europe as well. In a survey from the Netherlands, only 21% of patients referred for noninvasive cardiac testing actually underwent a study.[27] In addition, patients selected for noninvasive testing appeared to receive more medical therapy (e.g., beta blockers, statins, and platelet inhibitors) than patients not referred for noninvasive testing did.

PREVIOUS AND CURRENT CARDIOVASCULAR DISEASE

In the United States, approximately 30% of the 27 million patients scheduled to undergo anesthesia for surgical procedures yearly are known to have risk factors for coronary artery disease (CAD).[8] Unfortunately 50,000 of these patients experience a perioperative MI.[28] The estimated incidence of perioperative cardiac complications after noncardiac surgical procedures ranges from 0.5% to 1.0%.[24] The estimated economic impact of these complications is $20 billion annually.[8]

As the age of the surgical patient population increases, so too does the prevalence of ischemic and valvular heart disease. Hence, there is a growing need for expert guidance in the preoperative evaluation of patients who are known to have or to be at risk for cardiac disease. Although the literature is replete with suggested management algorithms, no firm consensus has been reached. Much of the continuing controversy is related to the obvious difficulties of conducting large randomized, controlled clinical trials on this topic—difficulties that are confounded (albeit fortunately) by the relatively low incidence of perioperative cardiac events. The incidence of postoperative MI is 0.7% in male general surgery patients older than 50 years, but it is 3.1% in comparable vascular surgery patients, in whom the prevalence of asymptomatic CAD is predictably high.[29]

FUNCTIONAL CAPACITY

Patients who are able to exercise on a regular basis without limitations generally have sufficient cardiovascular reserve to with-

Table 4 Revised Cardiac Risk Index[21]

Six clinical risk factors:

1. High-risk surgery
2. Ischemic heart disease (MI, positive treadmill test, use of nitroglycerin, current chest pain, pathologic Q waves on ECG)
3. Congestive heart failure (documented history, pulmonary edema, paroxysmal nocturnal dyspnea, peripheral edema, S3, or chest x-ray with pulmonary vascular redistribution)
4. Cerebrovascular disease (TIA or CVA)
5. Insulin-dependent diabetes mellitus
6. Renal failure (preoperative serum creatinine > 2.0 mg/dl)

No. of Risk Factors	Risk of Major Cardiac Complication (%)
0	0.4
1	0.9
2	7.0
3+	11.0

CVA—cerebrovascular accident MI—myocardial infarction
TIA—transient ischemic attack

Table 5 MET Scores for Selected Activities (Duke Activity Status Index)

MET Score	Activity
1–4	Light activities of daily home life (e.g., eating, getting dressed, using the toilet, cooking, washing dishes) Walking 1–2 blocks on level ground at 2–3 mph
5–9	Climbing one flight of stairs Walking up a hill Walking on level ground at rate > 4 mph Running a short distance More strenuous household chores (e.g., scrubbing floors, moving furniture) Moderate recreational activities (e.g., hiking, dancing, golf)
≥ 10	Strenuous athletic activities (e.g., tennis, running, basketball, swimming) Heavy professional work

stand stressful operations. Those with limited exercise capacity often have poor cardiovascular reserve, which may become manifest after noncardiac surgery. Poor functional status (and exercise capacity) is associated with worse short- and long-term outcomes in patients undergoing noncardiac operations.[30] Even outside the surgical arena, patients with poor functional status have shorter life spans overall.

Functional capacity is readily expressed in terms of metabolic equivalents (METs). One MET is equivalent to the energy expended (or the oxygen used) in sitting and reading (3.5 ml O_2/kg/min). For a 70 kg person, one MET amounts to 245 ml O_2/min. Multiples of the baseline MET value can then be used to quantify the aerobic demands posed by specific activities, as in the Duke Activity Status Index [*see Table 5*].[31]

Functional status has been shown to correlate strongly with the results of exercise treadmill testing.[31] Subsequent studies have indicated that perioperative cardiac and long-term risks are increased in patients who are unable to meet the 4-MET demand associated with most normal daily activities, as signaled by a poor performance on a treadmill test protocol.[31] Thus, the surgeon's assessment of the patient's exercise capacity is a practical, inexpensive, and accurate predictor of that patient's ability to tolerate a surgical stress.

TYPE OF SURGICAL PROCEDURE

Procedure-specific risk for noncardiac surgery can be classified as low, intermediate, or high [*see Table 6*].[32] High-risk procedures include major emergency surgery, particularly in the elderly; aortic and other major vascular operations; peripheral vascular surgery; and any operation that is expected to be prolonged and to be associated with large fluid shifts or substantial blood loss. Intermediate-risk procedures include intraperitoneal and intrathoracic operations, carotid endarterectomy, head and neck procedures, orthopedic surgery, and prostate operations. Low-risk procedures include endoscopic and superficial procedures, cataract operations, and breast surgery. Current guidelines generally focus on high-risk surgical procedures, with vascular surgery receiving the lion's share of the attention—not surprisingly, given data that 30% of the patients undergoing major vascular procedures in observational series harbor significant CAD.[33] Cardiac complications remain the leading cause of perioperative morbidity and mortality in patients undergoing vascular operations.[34]

Although randomized trials indicate that endovascular repair of aortic aneurysms yields better short-term survival than conventional repair, the perioperative survival advantage is not sustained after the first postoperative year, which suggests that the adverse effects of underlying CAD and other pathophysiologic factors in this population outweigh the benefits of a seemingly lower-risk procedure.[35] The type of surgical procedure performed is undoubtedly an important aspect of risk stratification, but it is only one part of the complete picture and must be considered in the light of the individual patient's RCRI.

SPECIALIZED TESTING

Recognition of the limitations of routine testing [*see* Preoperative Testing, *above*] led to specialized preoperative cardiac testing.[36] Since the 1980s, innumerable studies have attempted to establish the utility of this approach, but results have varied markedly across studies, making interpretation and recommendation difficult.[37] No single test can replicate all of the components of surgical stress. Therefore, the challenge is to develop a preoperative assessment approach that makes appropriate use of specific tests tailored to specific patients undergoing specific procedures.

Options for further testing include noninvasive resting cardiac imaging and noninvasive stress cardiac imaging. The simplest form of cardiac imaging is resting echocardiography, which provides an approximate assessment of left ventricular dysfunction and valvular problems (e.g., aortic stenosis). Cardiac computed tomography and magnetic resonance imaging continue to evolve and are capable of providing additional data, but they are more costly. Preoperative cardiac exercise or pharmacologic stress testing is recommended for assessment of a significant change in clinical status, demonstration of focal myocardial ischemia before revascularization, evaluation of the efficacy of medical management, and prognostic assessment after an acute coronary syndrome. The presence of CAD will become manifest as a transient regional mismatch between oxygen delivery and consumption during physiologic or pharmacologic stress.

Testing modalities are somewhat institution specific and are

Table 6 Selected Surgical Procedures Stratified by Degree of Cardiac Risk[24]

Degree of Cardiac Risk	Type of Procedure
Low (< 1%)	Endoscopic procedures Ambulatory procedures Ophthalmic procedures Aesthetic procedures Reconstructive procedures Endocrine procedures Gynecologic procedures Breast procedures Dental procedures
Low intermediate (1%–5%)	Minor vascular procedures (e.g., carotid endarterectomy) Abdominal procedures Thoracic procedures Neurosurgical procedures Otolaryngologic procedures
High intermediate (1%–5%)	Orthopedic procedures Urologic procedures
High (> 5%)	Emergency procedures (intermediate or high risk) Major vascular procedures (e.g., peripheral vascular surgery, AAA repair) Extensive surgical procedures with profound estimated blood loss, large fluid shifts, or both Unstable hemodynamic situations

AAA—abdominal aortic aneurysm

beyond the scope of this chapter; useful references are available elsewhere.[38-42] General sensitivity and specificity data have been accumulated for exercise electrocardiography (85% and 77%, respectively), myocardial perfusion scintigraphy (87% and 64%), dobutamine stress echocardiography, and radionuclide ventriculography, all of which are essentially equivalent with respect to their ability to detect myocardial ischemia.[43-45] Perfusion scintigraphy surpasses echocardiography for detection of single-vessel disease and quantification of the ischemic territory.[46] Notably, dobutamine echocardiography and nuclear perfusion stress testing for perioperative MI or death exhibit negative predictive values approaching 100% but yield positive predictive values lower than 20%.[47] Hence, a positive study is a weak harbinger of a perioperative cardiac event. A more recently developed testing method is dobutamine stress MRI; however, institutional experience with this modality remains limited, and the available literature on its use is sparse.

Current guidelines discourage routine preoperative noninvasive cardiac testing for most intermediate-risk preoperative patients. In a 2006 study, 1,476 patients were stratified according to their RCRI scores.[48] Of these, 770 patients on beta-blocker therapy with tight heart rate control met the criteria for intermediate risk. This intermediate-risk group was split and randomly assigned to receive either cardiac stress testing or continued beta-blocker therapy. Some degree of ischemia was noted in 25.8% of the patients in the testing group, but analysis of the 30-day outcomes after operation found no difference between the two groups with respect to the incidence of major cardiac adverse events. The major difference was that the members of the no-testing group underwent their respective operations 3 weeks sooner than the members of the testing group.

In general, the indications for specialized testing are the same in the operative setting as in the nonoperative setting. When selecting noninvasive cardiac stress tests for the occasional patient, one should anticipate that the patient will most likely require coronary revascularization after coronary angiography. The timing of these interventions, however, depends on the urgency of the noncardiac procedure, the risk factors present, and specific considerations associated with the procedure. Coronary revascularization before noncardiac surgery has sometimes been advocated as a way of enabling the patient to get through a noncardiac procedure, but it is appropriate only for a small subset of very high–risk patients.[49]

Optimization of Cardiac Status

MEDICAL INTERVENTION

Over the past decade, the scope of perioperative efforts to reduce cardiac risk with cardioprotective therapy has changed. At present, the emphasis is on plaque stabilization, reduction of myocardial oxygen demand (e.g., reduction of delivery-consumption mismatch) and myocardial protection, with revascularization reserved for a discrete subset of patients who would almost require cardiac intervention regardless of any elective preoperative evaluation. It is hypothesized that the likelihood of coronary artery plaque rupture may be increased by perioperative stressors such as amplified sympathetic activation, vasospasm, disruption of coagulation homeostasis, and oxygen supply-demand mismatch.[50]

Although there remains some controversy regarding the appropriate management of patients identified preoperatively as having significant but stable CAD, current data supporting the use of medical therapy have led to reductions in the extent of preoperative cardiac assessment, thereby decreasing the time from surgical diagnosis to surgical therapy. Documented coronary stenoses account for only 50% of perioperative MIs; the remaining 50% occur in vascular distributions unrelated to documented coronary stenoses.[51,52] The presence of severe stenosis is more a marker of disease (and thus a subset of patients at risk) than a finite predictor of endangered myocardial territory. In part, preoperative cardiac stress testing identifies this at-risk subset, even though the stenotic lesion may not be the cause of the postoperative ischemic event. The inability to assess the propensity for coronary plaque rupture proves to be the main challenge in both risk stratification and risk factor modification.

Whereas the data on risk stratification approaches are relatively plentiful, the data on risk modification strategies are still evolving, and in some ways controversial. In what follows, we summarize the current data on beta blockade and statin therapy. Antiplatelet therapy, calcium channel blockade, and the use of angiotensin-converting enzyme (ACE) inhibitors are discussed in greater detail in the ACC/AHA guidelines [*see* American College of Cardiology/American Heart Association Guidelines, *below*].[53]

Beta Blockade

The purported advantages of beta-blocker therapy include prolongation of diastole (and thus improved coronary artery perfusion), reduction of ischemic ventricular dysrhthymias, and reduction of sympathetic tone.[54] However, the argument for preoperative use of beta blockers to modify cardiac risk remains controversial, despite the plethora of available data. One problem is that because perioperative cardiac events are so rare among patients enrolled in randomized, controlled trials of perioperative beta blockade, any absolute reduction in cardiac risk is difficult to detect.

Whereas some randomized, controlled trials have supported the use of preoperative beta blockade in patients at risk for CAD,[55,56] subsequent studies have yielded less encouraging results. The Perioperative Beta Blockade (POBBLE) trial enrolled 103 patients undergoing vascular surgery at four centers in the United Kingdom; patients already receiving beta-blocker therapy were excluded.[57] A selective $beta_1$ blocker was administered to all average- or lower-risk vascular surgical patients at admission and for 7 days after operation. Postoperative myocardial ischemia was noted in 30% of the patients. Perioperative beta blockade did not reduce the incidence of major cardiac adverse events (during a 30-day follow-up period) either in this study[57] or in a 2005 meta-analysis of published randomized trials.[58]

A meta-analysis of 22 randomized trials (including a total of 2,437 patients enrolled between 1980 and 2004) that evaluated beta-blocker therapy in patients undergoing noncardiac surgery also did not document a reduction in the incidence of major cardiac adverse events.[58] The duration of beta blockade in the 22 studies ranged from a brief intravenous infusion in preoperative holding to a 30-day regimen postoperatively. Notably, despite the variations in the agent given, the duration of therapy, the inception of therapy, and the target heart rate achieved, the meta-analysis lacked sufficient statistical power to detect a 20% reduction in adverse cardiac events. To detect a difference of this magnitude, a higher patient enrollment would have been necessary. The authors concluded that "the current evidence for perioperative beta-blocker is insufficient and inconclusive." Similarly, the Diabetic Postoperative Mortality and Morbidity (DIPOM) trial, which included 921 patients with diabetes who were undergoing noncardiac surgery, failed to show that metoprolol significantly reduced the risk of death and cardiac morbidity.[59]

A large-scale observational study comprising 782,969 patients showed that perioperative beta blockade was associated with risk reduction in high-risk patients undergoing vascular surgery.[60] The study compared the outcomes of 119,632 patients who received beta blockers during a surgical admission with the outcomes of risk-adjusted patients who did not receive beta blockers. Follow-up was restricted to the period of hospitalization. The risk of death with beta-blocker therapy followed a steep gradient that was correlated with the RCRI score. Patients with scores of 0 and 1 experienced 43% and 13% increases in the risk of death, respectively. Patients with RCRI scores of 2 or higher, however, exhibited reductions in mortality ranging from 10% to 43%, a result echoing those of previous studies.[61] Beta blockers appeared to be harmful in low-risk patients, neutral in intermediate-risk patients, and beneficial in high-risk patients.[60]

Although it did not include preoperative patients, the Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) trial concluded that patients with stable multivessel coronary artery disease fared just as well with maximal medical management (aspirin plus statin therapy) as they would have with coronary revascularization.[62] This noninferiority result was also supported by the findings of the Medicine, Angioplasty, or Surgery Study (MASS II).[63]

The current ACC/AHA guidelines recommend perioperative beta blockade for high-risk patients undergoing vascular surgery; they also include a probable recommendation for high-risk patients undergoing intermediate-risk procedures. Beta-blocker therapy should be considered for intermediate-risk patients on the basis of whether they are undergoing intermediate-risk or high-risk procedures. Such therapy should also be considered for low-risk patients who are undergoing vascular surgery.[64] Routine incorporation of tight heart rate control with beta blockade in all patients at intermediate risk, though a consensus recommendation in the current ACC/AHA guidelines, remains controversial.[65]

The multicenter Perioperative Ischemic Evaluation (POISE) trial, currently under way, may provide the long-awaited answers to many questions surrounding beta-blocker therapy.[66] The aim of this study is to evaluate the ability of metoprolol to prevent major acute cardiac events in 10,000 patients undergoing noncardiac operations. Patients will receive either a selective $beta_1$ blocker or placebo, starting 2 to 4 hours before operation and continuing through a 30-day postoperative period. At last report, 8,351 patients had been enrolled. Preliminary results presented at the 2007 AHA Annual Scientific Session indicated that the occurrence of the primary composite end point (cardiovascular death, MI, or cardiac arrest) was reduced in the metoprolol group compared with the placebo group; however, total mortality was increased in the metoprolol group.[67] The metoprolol group also exhibited increased rates of significant hypotension and significant bradycardia.

It is reasonable to consider continuing beta blockade in low- and intermediate-risk patients who were already taking beta blockers before their preoperative evaluation. At present, however, the data do not appear to support routine initiation of beta-blocker therapy during preoperative screening in low- and intermediate-risk populations; further investigation is warranted and is currently under way.

Statin Therapy

Researchers have demonstrated that statins exhibit potential pleiotropic effects beyond their known role in cholesterol reduction, including increased expression of endothelial nitric oxide synthase, decreased production of endothelin 1, decreased generation of reactive oxygen species, and reduced levels of inflammatory cytokines, adhesion molecules, and C-reactive protein.[68,69] The pathologic significance of coronary plaque instability and rupture as a mediator of MI has been widely emphasized.[50] Several studies have validated statin therapy as a means of preventing cardiovascular events by improving the lipid profile and stabilizing coronary plaques.[70,71] A particular focus has been placed on statin therapy in vascular surgery patients. Reports indicate 30% to 42% reductions in acute coronary syndromes and death perioperatively in patients receiving statin therapy.[72]

Observational data, as well as data from randomized trials, support the use of statin therapy in vascular surgery patients.[73] A 2004 randomized trial found that the incidence of adverse cardiovascular events during a 6-month follow-up period was 68% lower among vascular surgery patients who received atorvastatin than in those who received a placebo.[74]

The Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography (DECREASE)-IV trial is designed to investigate the efficacy of combination therapy with fluvastatin and bisoprolol in 6,000 patients scheduled to undergo noncardiac, nonvascular surgical procedures.[75] The results of this trial are expected to be available in early 2008.

An issue that confounds both studies on statin therapy and studies on beta blockade is that both statins and beta blockers, as well as aspirin, are prescribed to patients in trials examining the specific role each individual agent plays in risk modification. Although observational registry data are important for hypothesis generation, they are difficult to interpret. Whereas one agent may be beneficial, its presence hints that other confounding risk modifiers (e.g., the effects of aspirin, beta blockers, or ACE inhibitors) are also likely to be present. To tease out the true effect of a single agent may be difficult; in some cases, attempting to do so may even be ill advised. In the aforementioned large-scale observational study examining beta blocker therapy,[60] 9.9% of the patients were also on statin therapy. In summary, whether the observed benefits with respect to perioperative risk prevention are best explained by tight beta-blocker therapy alone or by a combination of beta blockade and the pleiotropic effects of statins is currently unknown, but research is ongoing.[75]

REVASCULARIZATION

Referral patterns for preoperative coronary revascularization are highly variable.[76] A retrospective analysis of the Coronary Artery Surgery Study (CASS) Registry found that in patients with CAD who were scheduled to undergo a noncardiac operation, the incidence of nonfatal MI was lower in those who had previously undergone coronary artery bypass grafting (CABG) than in those who were managed medically.[77] Some authorities, however, question whether preoperative coronary revascularization confers any overall risk benefit in this setting, given the independent mortality associated with CABG (approximately 2%). Current data tend to refute the idea that preoperative revascularization is advantageous, even when the lower procedural risk associated with percutaneous coronary interventions is taken into account.

The results of the prospective, multicenter Coronary Artery Revascularization Prophylaxis (CARP) trial, sponsored by the Cooperative Committee of the Department of Veterans Affairs (VA), do not support a revascularization strategy for most patients.[78] In this trial, patients with one stenosis greater than 70% were randomly assigned to two groups, one undergoing revascularization (percutaneous revascularization in 59%, CABG in 41%) and the other receiving medical therapy alone. Medical therapy was optimized in both groups: 84% of the patients in the revascularization group and 86% of those in the no-revascularization group received beta blockers, 77% of the former and 70% of the latter received aspirin, and 54% of the patients in each group received statins. The study lacked sufficient statistical power to test the short-term benefit of prophylactic revascularization against that of optimized medical therapy; however, no differences in mortality were noted either in the perioperative period or at follow-up 2.7 years later. The incidence of perioperative MI in the prophylactic revascularization group was comparable to that in the optimal medical therapy group (12% versus 14%). No differences in outcome between the two groups were noted with respect to the burden of disease (i.e., one-, two-, or three-vessel disease).

One caveat to interpreting the CARP trial is that a substantial number of enrolled patients would have been stratified as intermediate risk on the basis of their RCRI scores and would not have met current ACC/AHA criteria for revascularization (unless they were symptomatic). Most of these patients had one- or two-vessel disease with preserved left ventricular function. A second caveat is that because study enrollment took place within the VA health system, 98% of the patients enrolled were male. A final caveat is that patients with left main coronary stenosis, severe aortic stenosis, severe left ventricular dysfunction, or unstable coronary syndromes were excluded from the study. In some ways, it appears that the CARP trial supports the COURAGE trial's findings that stable CAD can be managed medically and that prophylactic revascularization confers no survival benefit. One might reasonably wonder, however, whether the design of the CARP trial, involving a very low event rate in a small patient population, masked a marginal benefit. Did the trial have sufficient statistical power to detect a difference, to prove equivalency, or simply to show similarity? Although it is generally advisable to refrain from retrospective subgroup analysis, it is nevertheless noteworthy that in 37 patients with three or more cardiac risk factors and extensive ischemia evident on stress imaging, there was a favorable trend toward a long-term survival benefit after revascularization. The CARP study focused primarily on therapy: it was not designed to address the issue of whom to screen or to elaborate a diagnostic algorithm for elective vascular patients.

A follow-up study by the same VA study group employed a post hoc subgroup analysis of the CARP enrollment.[79] The investigators found CABG to be superior to percutaneous coronary therapy with respect to the completeness of revascularization and the incidence of postoperative MI. Other investigators have also cited the greater extent of revascularization as an advantage of CABG over percutaneous revascularization.[80]

Retrospective data from the Bypass Angioplasty Revascularization Investigation (BARI) trial suggest that percutaneous coronary revascularization in advance of noncardiac surgery may confer protection from adverse perioperative events, similar to the protection afforded by CABG.[81] This study was not designed to determine the optimal strategy in severely ill patients with extensive CAD immediately before major vascular surgery. The intent of revascularization was to relieve cardiac symptoms, not to provide prophylaxis against perioperative cardiac events. In the BARI trial, the median interval between coronary revascularization and noncardiac surgery was 29 months.

In an observational study of 314 preoperative patients stratified according to the ACC/AHA guidelines, 1.8% of the patients underwent diagnostic coronary catheterization, with 0% requiring revascularization before the anticipated procedure.[82] Identifying asymptomatic intermediate-risk patients who are candidates for revascularization is a low-yield endeavor that probably should not be a primary focus of the preoperative evaluation. Widespread noninvasive testing to identify asymptomatic CAD may not be a rational strategy.[83]

Percutaneous intervention carries a certain level of inherent risk as well. A registry analysis of patients undergoing percutaneous revascularization followed by elective noncardiac surgery revealed that 2.6% of patients experienced a major adverse cardiac event within a 30-day perioperative period; such events were strongly associated with interruption of antiplatelet therapy.[84,85]

The DECREASE-V pilot study examined the population at the highest preoperative risk: patients with multiple cardiac risk factors who were scheduled for either elective open abdominal aortic repair or infrainguinal arterial reconstruction.[86] A total of 1,808 patients were screened. Those with three or more risk factors (430 patients) underwent stress imaging (dobutamine echocardiography or stress nuclear imaging). All patients received beta blockers, titrated to a heart rate of 60 to 65 beats/min. Of the 430 high-risk patients, 101 (23%) manifested extensive ischemia on their functional studies and were randomly assigned to treatment with either revascularization (49 patients) or continued medical management (52 patients). Percutaneous revascularization was performed in 32 of the 49 patients in the revascularization group, CABG in the remaining 17. Anticoagulation and antiplatelet therapy was continued after percutaneous revascularization and during the index surgical procedure. To demonstrate a 20% relative risk reduction with prophylactic revascularization, the study would have to be considerably larger. At least 9,000 patients would have to be screened, and at least 2,000 of them would have to exhibit three or more clinical risk factors for a functional study to be warranted. A study of this magnitude, though not impossible, is unlikely to be done. Therefore, optimal preoperative management of this high-risk population should still depend to a large extent on clinical suspicion and cardiology consultation.[86]

Coronary angiography is an invasive procedure that even today is associated with a mortality of 0.01% to 0.05% and a morbidity of 0.03% to 0.25%.[87] It is indicated only for patients who have unstable coronary syndromes, those who are undergoing intermediate- or high-risk noncardiac procedures after equivocal noninvasive test results, and those who may have an indication for elective coronary revascularization.[49] Although antecedent myocardial revascularization appears to reduce the risk associated with subsequent noncardiac surgery,[8] the efficacy of elective preoperative revascularization remains controversial. This latter measure probably is not beneficial; in fact, the incidence of complications during or after revascularization is often comparable to that during or after the noncardiac surgical procedure itself. Routine angiography is indicated only when invasive delineation of CAD would be indicated in the absence of the noncardiac surgical problem.

Optimal perioperative evaluation and management of patients with multiple risk factors and extensive stress-induced ischemia remain controversial. The ACC/AHA guidelines (see below) suggest that coronary angiography and subsequent coronary revascularization should be limited to cases where the necessity for these measures is clearly defined, independent of the need for vascular surgery. A caveat to this recommendation is the lack of controlled clinical trials addressing optimal perioperative management of patients with left main disease, severe left ventricular dysfunction, unstable angina pectoris, or aortic stenosis. The studies done to date have been limited to patients with stable single- or multiple-vessel CAD and relatively well preserved ventricular function.

American College of Cardiology/American Heart Association Task Force Guidelines

Comprehensive identification of patients who are at substantial risk for perioperative cardiac morbidity remains a difficult task. As noted [*see* Tools for Assessment of Surgical Risk, Preoperative Testing, *above*], routine preoperative testing has significant inherent limitations. An evaluation strategy that avoids these limitations has been developed by combined task forces from the ACC and the AHA to clarify current recommendations for national quality initiatives in perioperative stratification and risk modification.[46] This strategy bases diagnostic and therapeutic approaches on clinical screening for disease state and functional capacity. It employs specialized testing conservatively—that is, only when the additional information provided by the proposed test is likely to have an impact on outcome. The consensus guidelines recommend aggressive medical management to provide myocardial protection in the perioperative period and thereby mitigate cardiac risk. The ACC/AHA strategy has proved to be both efficient and cost-effective in vascular surgery patients. The most recent update of the guidelines was published in the latter part of 2007.[53]

The ACC/AHA guidelines take the form of a five-step algorithm designed to guide patient risk stratification and subsequent determination of appropriate cardiac evaluation; this algorithm is available on the ACC's web site (www.acc.org/clinical/guidelines/perio/update/fig1.htm). Step 1 of the algorithm is concerned with assessing the urgency of the operation. Step 2 involves looking for the presence of active cardiac conditions, including unstable coronary syndromes, decompensated heart failure, significant dysrhythmias, and severe valvular disease. If any of these conditions are present and the operation is elective, the patient should be evaluated and treated according to ACC/AHA guidelines. If, however, no such active cardiac conditions are present, step 3 of the algorithm, which is concerned with estimating the risk of the proposed operation, is activated. If the proposed operation is low risk, it may proceed without further intervention. If it is intermediate or high risk, step 4, which involves determining the patient's functional status, is activated. If the patient is asymptomatic and functional status is good, the planned operation may proceed without further intervention. If the patient is symptomatic or functional status is poor (defined as the inability to perform activities involving energy expenditures greater than 4 METs) or undetermined, further investigation is necessary.

Step 5, the final step of the algorithm, involves determining whether the patient has a major clinical predictor of cardiac risk specifically. As defined by the ACC/AHA task force,[46] clinical cardiac risk factors include a history of ischemic heart disease, a history of compensated or previous heart failure, a history of cerebrovascular disease, diabetes mellitus, and renal insufficiency. Patients with no clinical risk factors may proceed to surgery. Patients with one or two clinical risk factors who are undergoing a vascular procedure and patients with one or more clinical risk factors who are undergoing an intermediate-risk operation have the option of either proceeding with surgery after appropriate beta blockade or receiving additional evaluation if the results of the evaluation might change management. Patients with three or more clinical risk factors who are undergoing a vascular operation should receive further evaluation if the results might change management.

Identification of Factors Affecting Noncardiac Risk

RESPIRATORY STATUS

Testing of pulmonary function may be indicated on the basis of physical findings (e.g. cough, wheezing, dyspnea on exertion, rales, or rhonchi) or a history of cigarette smoking. Limited pulmonary reserve may be revealed by observing the patient for dyspnea while he or she is climbing one or two flights of stairs. Forced expiratory volume can be directly measured with a handheld spirometer whenever there is a question of possible pulmonary compromise.[88] Once identified, patients with pulmonary insufficiency [*see 8:5 Pulmonary Insufficiency*] may benefit from a preoperative program that includes smoking cessation,[11] use of bronchodilators, physiotherapy, and specific antibiotics.

NUTRITIONAL STATUS

In 1936, Studley demonstrated that weight loss was a robust predictor of operative risk.[89] Loss of more that 15% of body weight during the previous 6 months is associated with an increased incidence of postoperative complications, including delayed wound healing, decreased immunologic competence, and inability to meet the metabolic demand for respiratory effort. Peripheral edema and signs of specific vitamin deficiencies are suggestive of severe malnutrition. A huge multicenter VA hospital study found that hypoalbuminemia was consistently the most reliable indicator of morbidity and mortality [*see Table 7*].[90] A decrease in serum albumin concentration from greater than 4.6 g/dl to less than 2.1 g/dl was associated with an increase in mortality from less than 1% to 29% and an increase in morbidity from 10% to 65%. Again, in these regression models, albumin concentration was the strongest predictor of mortality and morbidity after surgery.[90]

A global nutrition assessment has been shown to identify patients who are increased risk as a result of nutritional deficiencies.[91] Persons with macronutrient deficiencies may benefit from preoperative nutritional supplementation[92] [*see 8:22 Nutritional Support*]; however, such supplementation should be employed selectively and tailored to the particular patient population involved.[93] A trial done by a study group from the VA determined that preoperative nutritional intervention was necessary only in the most severely nutritionally depleted patients (i.e., those who had lost more than 15% of their body weight).[94]

ENDOCRINE STATUS

The endocrine-related conditions most relevant in the perioperative period are hypothyroidism, hyperthryroidism, diabetes mellitus, pheochromocytoma, and adrenal insufficiency (in particular, iatrogenic adrenocortical insufficiency secondary to steroid use within the preceding 6 months). All of these conditions should

Table 7 Preoperative Predictors of Morbidity and Mortality in General Surgical Patients[2,4]

Rank	Predictor of Morbidity	Predictor of Mortality
1	Albumin concentration	Albumin concentration
2	ASA class	ASA class
3	Complexity of operation	Emergency operation
4	Emergency operation	Disseminated cancer
5	Functional status	Age
6	History of COPD	DNR status
7	BUN > 40 mg/dl	Platelet count < 150,000/mm^3
8	Dependency on ventilator	Weight loss > 10%
9	Age	Complexity of operation
10	WBC count > 11,000/mm^3	BUN > 40 mg/dl

be normalized to the extent possible before elective surgery, whether by hormone replacement, by adrenergic blockade, or by administration of stress-dose steroids [*see 8:10 Endocrine Problems*].

Diabetes Mellitus

As of 2003, 10.9 million persons were known to have diabetes mellitus in the United States, and another 5.7 million were estimated to be harboring the disease without being aware of it.[11] In diabetic patients, the risk of CAD is two to four times higher than it is in the general population.[95] Diabetes is one of the six significant morbidities cited by Lee and associates as conferring a high level of cardiac risk.[21] Diabetic autonomic neuropathy is associated with an impaired vasodilator response of coronary resistance vessels to increased sympathetic stimulation.[96] Moreover, diabetes is frequently associated with silent ischemia; if detected by Holter monitoring, it has a positive predictive value of 35% for perioperative cardiac events.[97] The incidence of ischemic events in asymptomatic diabetic patients is similar to that in patients with stable CAD.[98] Accordingly, clinicians should lower their threshold for cardiac testing when managing diabetic patients.

Hemoglobin A_{1c} has been cited as an independent marker for poor perioperative outcomes in patients undergoing noncardiac surgery.[22] Asymptomatic diabetic patients with two or more cardiac risk factors should be evaluated by means of stress testing if their functional capacity is low or if they are to undergo a vascular procedure or any major operation. Only those diabetics who have good functional capacity and are undergoing minor or intermediate-risk procedures should proceed directly to operation. This is a more aggressive interventional approach than is followed for the general population. It should be kept in mind that, common assumptions notwithstanding, perioperative beta blockade is not precluded in diabetic patients and can offer substantial protection against ischemia. A 2003 study reported a 50% reduction in cardiovascular and microvascular complications in diabetic patients who underwent intensive glucose control, exercise therapy, and preventive medical management.[99]

HEMATOLOGIC STATES

The most practical tool for detecting hypocoagulable or hypercoagulable states [*see 1:4 Bleeding and Transfusion and 6:6 Venous Thromboembolism*] is a careful history. Risk factors for postoperative phlebothrombosis and possible pulmonary embolism include Virchow's well-known triad: hypercoagulability (e.g., from antithrombin deficiency, oral contraceptives, or malignancy), stasis (e.g., from venous outflow obstruction, immobility, or congestive heart failure), and endothelial injury (e.g., from trauma or operation). A thromboelastogram is an effective screening tool in patients with suspected abnormalities. Prothrombin time, partial thromboplastin time, and platelet count constitute sufficient preoperative testing in a patient with a suspected bleeding problem. Antithrombin, protein C, protein S, and factor V Leiden levels constitute sufficient preoperative screening in a patient with suspected hypercoagulable disease. Perioperative anemia is known to be a risk factor for poor outcome[100] and was associated with increased mortality in a 2007 VA study.[101]

Assessment of Physical and Mental Happiness

Calculation of the risks and benefits of surgical (or, indeed, any) therapy has become a much more complex process than it once was. Simple assessment of survival or basic quality of life is no longer sufficient: more sophisticated measures are required.

Generic instruments now exist that are aimed at evaluating a patient's level of productive assimilation into his or her environment. The Short Form–36 (SF-36) is designed to assess physical and mental happiness in eight domains of health: (1) physical function (10 items); (2) physical role limitations (4 items); (3) bodily pain (2 items); (4) vitality (4 items); (5) general health perceptions (5 items); (6) emotional role limitations (3 items); (7) social function (2 items); and (8) mental health (5 items). The underlying assumption is that mental and physical functions are readily separable aspects of health, but of course, this is not really the case.[102,103] Predictably, patients' responses on the SF-36 tend to be strongly influenced by the type of operation they had. For example, a patient who has undergone total hip arthroplasty will feel better immediately afterward; one who has undergone lung resection for cancer may not feel particularly well immediately afterward but, ideally, will be relieved of a cancer scare; and one who has undergone abdominal aneurysm repair will feel worse immediately afterward, though conscious of an improved life expectancy. Less predictably, however, patients' perceptions of their own surgical outcomes are equally strongly influenced by when questions are posed during the postoperative period.[104] The answers obtained 6 months after operation differ from those obtained at 1 month or 12 months. If the questions are asked several times, the answers change; indeed, the mere asking of the question may change the answer.[105] For an outcome measure to be effective by current standards, it must be not only feasible, valid, and reliable but also sensitive to change.[106,107]

An outcome tool that has been further refined to focus specifically on cardiovascular capacity and disease is the Specific Activity Scale (SAS). Unfortunately for assessment purposes, attempts to use the SAS and the SF-36 simultaneously have yielded significantly divergent results. Such results underscore the complexities of standardizing tests of ability, intelligence, and happiness.[108]

Quality is subjective. Some patients are happy when they seemingly have every reason to be unhappy; others are unhappy when they seemingly have every reason to be happy. Scientific tools for collectively examining psychosocial productivity in groups of patients may still be largely lacking, but this does not mean that surgeons have no methods of evaluating and enhancing a given patient's prospects for comfort. Indeed, any surgeon whose contribution to patient management stops with superb operative technique, or even with exemplary perioperative care added to technique, is not making optimal use of his or her privileged position. By incorporating a patient's values into the anticipated outcome, surgeons are uniquely positioned to achieve the best possible outcome-to-value ratios.

PATIENT EDUCATION

Education of the patient about the postoperative care plan plays a major role in modifying his or her response to the operative experience. Classic studies have shown that well-informed patients require less analgesia in the postoperative period and experience significantly less pain than less well informed patients.[109] Subsequent investigations have supported these conclusions. Perioperative information facilitates coping, reduces preoperative anxiety, and may enhance postoperative recovery.[110] Such information can be provided orally or in the form of booklets or videotapes.

Epidemiology of Surgical Risk

In a 1999 prospective study, a team of VA investigators examined the outcomes of surgical procedures in an effort to identify variables related to poor surgical results. Initial results were reported from 23,919 patients who underwent one of 11 noncardiac operations performed by surgeons from five specialties (general surgery, urology, orthopedic surgery, vascular surgery, and neurosurgery).[111] The authors concluded that prolonged hospital stay could be related to advanced age, diminished functional status, and higher ASA class. Other preoperative patient characteristics were associated with increased morbidity and mortality [*see Table 7*].[112]

Changing Paradigms of Cost-effectiveness

It is now clear that postoperative survival, by itself, is no longer an adequate assay of surgical success. Risk must be stratified before operation, and the degree of risk must be evaluated in the light of both the quantity and the quality of life to be expected after operation. Cost must then be appropriately factored in: a modern health care system will want to know the cost of a risk-stratified, quality-adjusted postoperative year of life. A 1999 study assessed the cost-effectiveness of various cardiac diagnostic strategies in terms of cost in relation to each QALY saved.[113] Although the question this study was designed to answer was slightly different from what surgeons typically address before noncardiac surgery, several instructive findings emerged:

1. For a 55-year-old man with typical chest pain, the incremental cost-effectiveness ratio for routine coronary angiography versus exercise echocardiography was $36,400/QALY saved.
2. For a 55-year-old man with atypical chest pain, the incremental cost-effectiveness ratio for exercise electrocardiography versus no testing was $57,700/QALY saved.
3. The incremental cost-effectiveness ratio for exercise echocardiography in comparison with stress electrocardiography was $41,900/QALY saved.

The literature makes it very clear, however, that none of the available diagnostic strategies are more cost-effective than communication with the patient.

References

1. Harken AH: Enough is enough. Arch Surg 134:1061, 1999
2. Khuri SF, Daley J, Henderson W, et al: The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. Ann Surg 228:491, 1998
3. Iezzoni LI: Using risk-adjusted outcomes to assess clinical practice: an overview of issues pertaining to risk adjustment. Ann Thorac Surg 58:1822, 1994
4. Khuri SF, Daley J, Henderson W, et al: Risk of adjustment of postoperative morbidity rate for the comparative assessment of the quality of surgical care: results of the National Veterans Affairs Surgical Risk Study. J Am Coll Surg 185:315, 1997
5. Hammermeister KE, Johnson RR, Marshall G, et al: Continuous assessment and improvement in quality of care: a model from the Department of Veterans Affairs' Cardiac Surgery. Ann Surg 219:281, 1994
6. Dripps RD, Echenhoff JE, Vandom D: Introduction to Anesthesia: The Principles of Safe Practice. WB Saunders Co, Philadelphia, 1988, p 17
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 66:155, 1991
8. Mangano DT, Goldman L: Preoperative assessment of patients with known or suspected coronary disease. N Engl J Med 333:1750, 1995
9. Noordzij PG, Boersma E, Bax JJ, et al: Prognostic value of preoperative electrocardiography in patients undergoing non-cardiac surgery. Am J Cardiol 97:1003, 2006
10. Centers for Disease Control and Prevention: Annual smoking-attributable mortality, years of potential life lost, and economic costs—United States, 1995–1999. Morbid Mortal Wkly Rep 51:300, 2002 http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5114a2.htm
11. American Heart Association: Statistical fact sheet—risk factors: tobacco smoke. http://www.americanheart.org/downloadable/heart/1046699147169FS17TOB3.pdf
12. Moller AM, Villebro N, Pedersen T, et al: Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. Lancet 359:114, 2002
13. Sorensen LT, Karlsmark T, Gottrup F: Abstinence from smoking reduces incisional wound infection: a randomized controlled trial. Ann Surg 238:1, 2003
14. Otsuka R, Watanabe H, Hirata K, et al: Acute effects of passive smoking on the coronary circulation in healthy young adults. JAMA 286:436, 2001
15. Warner DO: Tobacco control for anesthesiologists. J Anesth 21:200, 2007
16. Warner DO: Tobacco dependence in surgical patients. Curr Opin Anaesthesiol 20:279, 2007
17. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, 4th ed. American Psychiatric Association, Washington, DC, 1995
18. Tonnesen H, Kehlet H: Preoperative alcoholism and postoperative morbidity. Br J Surg 86:869, 1999
19. Gordon AJ, Olstein J, Conigliaro J: Identification and treatment of alcohol use disorders in the perioperative period. Postgrad Med 119:46, 2006
20. MacPherson DS: Preoperative laboratory testing: should any tests be "routine" before surgery? Med Clin North Am 77:289, 1993
21. Lee TH, Marcantonia ER, Mangione CM, et al: Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 100:1043, 1999
22. Noordzij PG, Boersma E, Schreiner F, et al: Increased preoperative glucose levels are associated with perioperative mortality in patients undergoing noncardiac, nonvascular surgery. Eur J Endocrinol 156:137, 2007
23. Yeh HM, Lau HP, Lin JM, et al: Preoperative plasma N-terminal pro-brain natriuretic peptide as a marker of cardiac risk in patients undergoing elective non-cardiac surgery. Br J Surg 92:1041, 2005
24. Boersma E, Kertai MD, Schouten O, et al: Perioperative cardiovascular mortality in noncardiac surgery: validation of the Lee cardiac risk index. Am J Med 118:1134, 2005
25. Boersma E, Schouten O, Bax JJ, et al: Assessment of cardiac risk before non-cardiac general surgery. Heart 92:1866, 2006
26. Katz RI, Cimino L, Vitkun SA, et al: Preoperative medical consultations: impact on perioperative management and surgical outcome. Can J Anaesth 52:697, 2005
27. Hoeks SE, Scholte Op Reimer WJ, Lenzen MJ, et al: Guidelines for cardiac management in noncardiac surgery are poorly implemented in clinical practice: results from a peripheral vascular survey in the Netherlands. Anesthesiology 107:537, 2007
28. Fleisher LA, Eagle KA: Lowering cardiac risk in noncardiac surgery. N Engl J Med 345:1677-82, 2001
29. Ashton CM, Petersen NJ, Wray NP, et al: The incidence of perioperative myocardial infarction in men undergoing noncardiac surgery. Ann Intern Med 118:504, 1993
30. Myers J, Prakash M, Froelicher V, et al: Exercise capacity and mortality among men referred for exercise testing. N Engl J Med 346:793, 2002
31. Hlatky MA, Boineau RE, Higginbotham MB, et al: A brief self-administered questionnaire to determine functional capacity (the Duke Activity Status Index). Am J Cardiol 64:651, 1989
32. Eagle KA, Brundage BH, Chaitman BR, et al: Guidelines for perioperative cardiovascular evaluation for noncardiac surgery. Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Committee on Perioperative Cardiovascular Evaluation for Noncardiac Surgery. Circulation 93:1278, 1996
33. Hertzer NR, Beven EG, Young JR, et al: Coronary artery disease in peripheral vascular patients: a classification of 1000 coronary angiograms and results of surgical management. Ann Surg 199:223, 1984
34. Kertai MD, Klein J, van Urk H, et al: Cardiac complications after elective major vascular surgery. Acta Anaesthesiol Scand 47:643, 2003
35. Blankensteijn JD, de Jong SE, Prinssen M, et al: Two-year outcomes after conventional or endovascular repair of abdominal aortic aneurysms. N Engl J Med 352:2398, 2005
36. Boucher CA, Brewster DC, Darling RC, et al: Determination of cardiac risk by dipyridamole–thallium imaging before peripheral vascular surgery. N Engl J Med 312:389, 1985
37. Mangano DT: Assessment of the patient with cardiac disease: an anesthesiologist's paradigm. Anesthesiology 91:1521, 1999
38. Raby KE, Goldman L, Creager MA, et al: Correlation between preoperative ischemia and major cardiac events after peripheral vascular surgery. N Engl J Med 321:1296, 1989
39. Gauss A, Rohm HJ, Schauffelen A, et al: Electrocardiographic exercise stress testing for

cardiac risk assessment in patients undergoing noncardiac surgery. Anesthesiology 94:38, 2001

40. Froelicher VF, Lehmann KG, Thomas R, et al: The electrocardiographic exercise test in a population with reduced workup bias: diagnostic performance, computerized interpretation, and multivariate prediction. Ann Intern Med 128:965, 1998
41. Mangano DT: Preoperative assessment of the patient with cardiac disease. Curr Opin Cardiol 10:530, 1995
42. Mangano DT, Browner WS, Hollenberg M, et al: Association of perioperative myocardial ischemia with cardiac morbidity and mortality in men undergoing noncardiac surgery. N Engl J Med 323:1781, 1990
43. Kertai MD, Boersma E, Bax JJ, et al: A meta-analysis comparing the prognostic accuracy of six diagnostic tests for predicting perioperative cardiac risk in patients undergoing major vascular surgery. Heart 89:1327, 2003
44. O'Keefe JH Jr, Barnhart CS, Bateman TM: Comparison of stress echocardiography and stress myocardial perfusion scintigraphy for diagnosing coronary artery disease and assessing its severity. Am J Cardiol 75:25D, 1995
45. Kim C, Kwok YS, Heagerty P, et al: Pharmacologic stress testing for coronary disease diagnosis: a meta-analysis. Am Heart J 142:934, 2001
46. Shaw LJ, Marwick TH, Berman DS, et al: Incremental cost-effectiveness of exercise echocardiography vs SPECT imaging for the evaluation of stable chest pain. Eur Heart J 27:2448, 2006
47. Eagle KA, Berger PB, Calkins H, et al: ACC/AHA guideline update for perioperative cardiovascular evaluation of noncardiac surgery—executive summary: a report of the ACC/AHA task force on practice guidelines (Committee to Update the 1996 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). J Am Coll Cardiol 39:542, 2002
48. Poldermans D, Bax JJ, Schouten O, et al: Should major vascular surgery be delayed because of preoperative cardiac testing in intermediate-risk patients receiving beta-blocker therapy with tight heart rate control? J Am Coll Cardiol 48:964, 2006
49. Mukherjee D, Eagle KA: Perioperative cardiac assessment for noncardiac surgery: eight steps to the best possible outcome. Circulation 107:2771, 2003
50. Schouten O, Poldermans D: Cardiac risk in noncardiac surgery. Br J Surg 94:1185, 2007
51. Poldermans D, Boersma E, Bax JJ, et al: Correlation of location of acute myocardial infarct after noncardiac vascular surgery with preoperative dobutamine echocardiographic findings. Am J Cardiol 88:1413, 2001
52. Dawood MM, Gupta DK, Southern J, et al: Pathology of fatal perioperative myocardial infarction: implications regarding pathophysiology and prevention. Int J Cardiol 57:37, 1996
53. Fleisher LA, Beckman JA, Brown KA, et al: ACC/AHA 2007 Guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac surgery). Circulation 116:e418, 2007
54. Cruickshank JM: Beta-blockers continue to surprise us. Eur Heart J 21:354, 2000
55. 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 341:1789, 1999
56. Mangano DT, Layug EL, Wallace A, et al: Effect of atenolol on mortality and cardiovascular morbidity after noncardiac surgery. Multicenter Study of Perioperative Ischemia Research Group. N Engl J Med 335:1713, 1996
57. Brady AR, Gibbs JS, Greenhalgh RM, et al: Perioperative beta blockade (POBBLE) for patients undergoing infrarenal vascular surgery: results of a randomized double-blind controlled trial. J Vasc Surg 41:602, 2005
58. Devereaux PJ, Beattie WS, Choi PT, et al: How strong is the evidence for the use of perioperative (beta) blockers in non-cardiac surgery? Systematic review and meta-analysis of randomized controlled trials. BMJ 331:313, 2005
59. Juul AB, Wetterslev J, Kofoed-Enevoldsen A, et al: The Diabetic Postoperative Mortality and Morbidity (DIPOM) trial: rationale and design of a multicenter, randomized, placebo-controlled, clinical trial of metoprolol for patients with diabetes mellitus who are undergoing major noncardiac surgery. Am Heart J 147:677, 2004
60. Lindenauer PK, Pekow P, Wang K, et al: Perioperative beta-blocker therapy and mortality after major noncardiac surgery. N Engl J Med 353:349, 2005
61. 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 285:1865, 2001
62. Boden WE, O'Rourke RA, Teo KK, et al: Optimal medical therapy with or without PCI for stable coronary disease. N Engl J Med 356:1503, 2007
63. Hueb W, Lopes NH, Gersh BJ, et al: Five-year follow-up of the Medicine, Angioplasty, or Surgery Study (MASS II): a randomized controlled clinical trial of 3 therapeutic strategies for multivessel coronary artery disease. Circulation 115:1082, 2007
64. Fleisher LA, Beckman JA, Brown KA, et al: ACC/AHA 2006 guideline update for perioperative cardiovascular evaluation for noncardiac surgery: focused update on perioperative beta-blocker therapy—a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Update the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). J Am Coll Cardiol 47:2343, 2006
65. Eagle KA, Lau WC: Any need for preoperative cardiac testing in intermediate-risk patients with tight beta-adrenergic blockade? J Am Coll Cardiol 48:970, 2006
66. The Poise Trial Investigators: Rationale, design, and organization of the Perioperative Ischemic Evaluation (POISE) trial: a randomized controlled trial of metoprolol versus placebo in patients undergoing noncardiac surgery. Am Heart J 152:223, 2006
67. Devereaux PJ: The Perioperative Ischemic Evaluation (POISE) trial. American Heart Association Annual Scientific Session, Orlando, Florida, November 2007 http://www.cardiosource.com/clinicaltrials/trial.asp?TrialID=1629
68. Takemoto M, Liao JK: Pleiotropic effects of 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors. Arterioscler Thromb Vasc Biol 21:1712, 2001
69. Feringa HH, Schouten O, Karagiannis SE, et al: Intensity of statin therapy in relation to myocardial ischemia, troponin T release, and clinical cardiac outcome in patients undergoing major vascular surgery. J Am Coll Cardiol 50:1649, 2007
70. Heart Protection Study Collaborative Group: MRC/BHF Heart protection study of cholesterol lowering with simvastatin in 6 high-risk individuals: a randomized placebo controlled trial. Lancet 360:7, 2002
71. Albert MA, Danielson E, Rifai N, et al: Effect of statin therapy on C-reactive protein levels. The Pravastatin Inflammation/CRP Evaluation (PRINCE): a randomized trial and cohort study. JAMA 286:64, 2001
72. Kapoor AS, Kanji H, Buckingham J, et al: Strength of evidence for perioperative use of statins to reduce cardiovascular risk: systematic review of controlled studies. BMJ 333:1149, 2006
73. Poldermans D, Bax JJ, Kertai MD, et al: Statins are associated with a reduced incidence of perioperative mortality in patients undergoing major noncardiac vascular surgery. Circulation 107:1848-51, 2003
74. Durazzo AE, Machado FS, Ikeoka DT, et al: Reduction in cardiovascular events after vascular surgery with atorvastatin: a randomized trial. J Vasc Surg 39:967, 2004
75. Schouten O, Poldermans D, Visser L, et al: Fluvastatin and bisoprolol for the reduction of perioperative cardiac mortality and morbidity in high risk patients undergoing non-cardiac surgery: rationale and design of the DECREASE IV study. Am Heart J 148:1047, 2004
76. Pierpont G, Moritz T, Goldman S, et al: Disparate opinions regarding indications for coronary artery revascularization prior to elective vascular surgery. Am J Cardiol 94:1124, 2004
77. Foster ED, Davis KB, Carpenter JA, et al: Risk of noncardiac operation in patients with defined coronary disease: the coronary artery surgery study (CASS) registry experience. Ann Thorac Surg 41:42, 1986
78. Raghunathan A, Rapp JH, Littooy F, et al: Postoperative outcomes for patients undergoing elective revascularization for critical limb ischemia and intermittent claudication: a subanalysis of the Coronary Artery Revascularization Prophylaxis (CARP) trial. J Vasc Surg 43:1175, 2006
79. Ward HB, Kelly RF, Thottapurathu L, et al: Coronary artery bypass grafting is superior to percutaneous coronary intervention in prevention of perioperative myocardial infarctions during subsequent vascular surgery. Ann Thorac Surg 82:795, 2006
80. van den Brand MJBM, Rensing BJW, Morel MM, et al: The effect of completeness of revascularization on event-free survival one year in the ARTS trial. J Am Coll Cardiol 39:559, 2002
81. Hassan SA, Hlatky NA, 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 110:260, 2001
82. Almanaseer Y, Mukherjee D, Kline-Rogers EM, et al: Implementation of the ACC/AHA Guidelines for Preoperative Cardiac Risk Assessment in a general medicine preoperative clinic: improving efficiency and preserving outcomes. Cardiology 103:24, 2005
83. Wesorick DH, Eagle KA. The preoperative cardiovascular evaluation of the intermediate-risk patient: new data, changing strategies. Am J Med 118:1413.e1, 2005
84. Schouten O, van Domburg RT, Bax JJ, et al: Noncardiac surgery after coronary stenting: early surgery and interruption of antiplatelet therapy are associated with an increase in major adverse cardiac events. J Am Coll Cardiol 49:122, 2007

85. Reddy PR, Vaitkus PT: Risks of noncardiac surgery after coronary stenting. Am J Cardiol 95:755, 2005

86. Poldermans D, Schouten O, Vidakovic R, et al: A clinical randomized trial to evaluate the safety of a noninvasive approach in high-risk patients undergoing major vascular surgery: the DECREASE-V Pilot Study. J Am Coll Cardiol 49:1763, 2007

87. Mason JJ, Owens DK, Harris RA, et al: The role of coronary angiography and coronary revascularization before noncardiac surgery. JAMA 273:1919, 1995

88. Kispert JF, Kazmers A, Roitman L: Preoperative spirometry predicts perioperative pulmonary complications after major vascular surgery. Am Surg 58:491, 1992

89. Studley HO: Percentage of weight loss: basic indicator of surgical risk in patients with chronic peptic ulcer. JAMA 106:458, 1936

90. Gibbs J, Cull W, Henderson W, et al: Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from the National VA Surgical Risk Study. Arch Surg 134:36, 1999

91. Detsky AS, McLaughlin JR, Baker JP, et al: What is subjective global assessment of nutritional status? J Parenter Enteral Nutr 11:8, 1987

92. Parsa MH, Habif DV, Ferrer JM, et al: Intravenous hyperalimentation: indications, technique, and complications. Bull N Y Acad Med 48:920, 1972

93. Detsky AS, Baker JP, O'Rourke K, et al: Perioperative parenteral nutrition: a meta-analysis. Ann Intern Med 107:195, 1987

94. The Veterans Affairs Total Parenteral Nutrition Cooperative Study Group: Perioperative total parenteral nutrition in surgical patients. N Engl J Med 325:525, 1991

95. ADA—American Diabetes Association. Consensus development conference on the diagnosis of coronary heart disease in people with diabetes. Diabetes Care 21:1551, 1998

96. Di Carli MF, Bianco-Batlles D, Landa ME, et al: Effects of autonomic neuropathy on coronary blood flow in patients with diabetes mellitus. Circulation 100:813, 1999

97. Fleisher LA, Rosenbaum SH, Nelson AH, et al: The predictive value of preoperative silent ischemia for postoperative ischemic cardiac events in vascular and nonvascular surgery patients. Am Heart J 122:980, 1991

98. Haffner SM, Lehto S, Rönnemaa T, et al: Mortality from coronary heart disease in subjects with type 2 diabetes and in nondiabetic subjects with and without prior myocardial infarction. N Engl J Med 339:229, 1998

99. Gaede P, Vedel P, Larsen N, et al: Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. N Engl J Med 348:383, 2003

100. Nelson AH, Fleisher LA, Rosenbaum SH: Relationship between postoperative anemia and cardiac morbidity in high-risk vascular patients in the intensive care unit. Crit Care Med 21:860, 1993

101. Wu WC, Shifftner TL, Henderson WG, et al: Preoperative hematocrit levels and postoperative outcomes in older patients undergoing noncardiac surgery. JAMA 297:2481, 2007

102. Simon GE, Revick DA, Grothaus L, et al: SF-36 Summary Scores: are physical and mental health truly distinct? Med Care 36:567, 1998

103. Ware J, Kosinski M, Bayliss MS, et al: Comparison of methods for the scoring and statistical analysis of SF-36 health profile and summary measures: summary of results from the Medical Outcomes Study. Med Care 33:AS265, 1995

104. Mangione CM, Goldman L, Orav J, et al: Health-related quality of life after elective surgery. J Gen Intern Med 12:686, 1997

105. Dorman P, Slattery J, Farrell B, et al: Qualitative comparison of the reliability of health status assessment with the Euroqol and SF-36 questionnaires after stroke. Stroke 29:63, 1998

106. Kaegi L: Medical outcomes trust conference presents dramatic advances in patient-based outcomes assessment and potential applications in accreditation. Jt Comm J Qual Improv 25:207, 1999

107. Hobart JC, Lampling DL, Thompson AJ: Evaluating neurological outcome measures: the bare essentials. J Neurol Neurosurg Psychiatry 60:127, 1996

108. Stambler BS, Ellenbogen KA, Sgarbossa EB, et al: Quality of life and clinical outcomes in elderly patients treated with ventricular pacing as compared with dual-chamber pacing. N Engl J Med 338:1097, 1998

109. Egbert LD, Bant GE, Welch CE, et al: Reduction of postoperative pain by encouragement and instruction of patients: a study of doctor-patient rapport. N Engl J Med 207:824, 1964

110. Daltroy LH, Morlino CI, Eaton HM, et al: Preoperative education for total hip and knee replacement patients. Arthritis Care Res 11:469, 1998

111. Collins TC, Daley J, Henderson WH, et al: Risk factors for prolonged length of stay after major elective surgery. Ann Surg 230:251, 1999

112. Khuri SF, Daley J, Henderson W, et al: Relation of surgical volume to outcome in eight common operations: results from the VA National Surgical Quality Improvement Program. Ann Surg 230:414, 1999

113. Kuntz KM, Fleishmann KE, Hunink MG, et al: Cost-effectiveness of diagnostic strategies for patients with chest pain. Ann Intern Med 130:709, 1999