Preoperative Evaluation of the Cardiac Patient for Noncardiac Surgery

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Perioperative cardiac events continue to represent a significant cause of morbidity in patients undergoing noncardiac surgery. The evaluation of the high risk patient should begin with an assessment of the probability of coronary artery disease and exercise tolerance. Decisions to undergo further evaluation, including noninvasive testing, should be based upon the perioperative morbidity and mortality rate for the planned surgical procedure. In patients with significant coronary artery stenoses and a high probability of perioperative cardiac morbidity, coronary artery bypass grafting, percutaneous transluminal coronary angioplasty, and preoperative optimization of hemodynamics in an intensive care unit have all been advocated as means of reducing risk.

As our population ages, an increasing proportion of the patients who present for noncardiac surgery have either overt or asymptomatic cardiovascular disease. Based upon demographic data, it is estimated that this represents approximately 7 million of the 25 million Americans anesthetized annually [1, 2].

This review will emphasize pre-and post-operative evaluation of patients with cardiovascular disease. The areas to be covered include: (1) coronary artery disease (CAD), (2) risk factors for CAD, (3) congestive heart failure (CHF), (4) preoperative cardiovascular testing strategies, and (5) perioperative interventions for patients-at-risk.

The assessment of the high risk surgical patient should be approached in an orderly manner. It is important to evaluate the patient for the probability of CAD. The patient may present with definite CAD or may have a high probability of CAD by virtue of their risk factors. For example, patients with angina or a previous MI have definite CAD. Patients with diabetes, hypertension, advanced age, tobacco use, hypercholesterolemia, or peripheral vascular disease are at risk for CAD, with the probability of CAD a function of the interaction of each risk factor. It is next important of assess ventricular function. The simplest way is to determine the patient's exercise tolerance. Finally, the decision to perform further evaluation should be based upon the perioperative morbidity and mortality rate for the planned surgical procedure.

CORONARY ARTERY DISEASE

Coronary artery disease, as manifested by a prior myocardial infarction or angina, is estimated to be present in over 6 million Americans [3]. A history of coronary artery disease has been associated with an increased risk of perioperative morbidity or mortality in

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*bAbbreviations used: CAD, coronary artery disease; CHF, congestive heart failure; MI, myocardial infarction; LVH, left ventricular hypertrophy; ICU, Intensive Care Unit; CABG, coronary artery bypass grafting; PTCA, percutaneous transluminal angioplasty; DTI, dipyridamole thallium test.
multiple studies [4–8]. In assessing the probability and extent of coronary artery disease, the starting point begins with an extensive history. Patients with unstable angina have an active process occurring at the point of an atherosclerotic plaque, and should not undergo surgery unless delay and further medical or surgical treatment of the coronary artery disease is impossible [8]. In the patient with stable classic anginal pain, the probability of coronary artery disease and myocardium-at-risk approaches 100%. However, the probability that the disease will progress or result in a MI varies. The patient with a prior MI without symptoms may have extensive coronary artery disease, but may also have infarcted the only area of myocardium-at-risk. In asymptomatic patients, the probability of coronary artery disease depends upon the presence of co-existing risk factors.

Traditionally, an MI within six months of surgery has been associated with a high rate of reinfarction in multiple studies [6, 9, 10]. Rao et al. [9], and more recently Shah et al. [11] from the same institution, demonstrated that the rate of reinfarction has been reduced in the modern era. They attributed the improved outcome to the use of beta-blockade, invasive monitoring, and prolonged Intensive Care Unit stays. Although the six month interval continues to be quoted in the anesthetic literature, significant changes in the care of the acute myocardial infarction patient may change the degree of risk. Patients are undergoing coronary angioplasty or receiving thrombolitics, thereby changing the characteristics of the coronary circulation and the extent of the myocardium-at-risk. We believe that the perioperative risk of a patient with a recent MI is not simply a function of the interval between the MI and surgery, but requires further stratification based upon the ongoing extent of myocardium-at-risk.

In assessing the extent of coronary artery disease, it is important to determine the patient's exercise tolerance. Patients with an extensive exercise tolerance clinically demonstrate good myocardial reserve. In contrast, the patients who develop dyspnea with exertion have a high probability of extensive coronary artery disease and limited myocardial reserve. These patients do not require further testing to confirm the diagnosis of CAD unless further interventions such as coronary artery bypass grafting are planned.

**RISK FACTORS FOR CORONARY ARTERY DISEASE**

As noted above, there are several risk factors which place the patient at a higher probability of coronary artery disease [6, 12]. Diabetes has traditionally been one of the strongest risk factors for atherosclerotic disease, as well as leading to the silent nature of the disease. Recent studies have suggested that signs of autonomic dysfunction, rather than peripheral neuropathy, is the best predictor of silent myocardial ischemia [13]. In addition, patients with autonomic dysfunction may have exaggerated blood pressure response to anesthetic agents. Therefore, a simple assessment of the autonomic function of the diabetic patient provides important information for their perioperative care.

**HYPERTENSION**

Of the cardiovascular diseases, hypertension is the most prevalent, affecting more than 59 million patients. Forty percent of patients who are aware that they have hypertension, are either untreated or inadequately managed with pharmacologic therapy [14]. Therefore, a large percentage of patients with hypertension can present for preoperative anesthesia evaluation with poor control of their disease. Hypertension is also an important marker as a risk factor for congestive heart failure and ischemic heart disease. Hypertension results in: 1) an increased systemic vascular resistance, 2) decreased intravascular volume, 3) exaggerated pressor response and 4) edema. The criteria for the diagnosis of hypertension has recently changed. The newest report from the Joint National Committee on hypertension presents a new classification schema which includes
both systolic and diastolic levels [15]. This recording format is used to convey the impact of the cardiovascular risks of higher BP. Most hypertension is essential; in selected patients as indicated by history, physical examination and baseline laboratory data, a more extensive workup may reveal a primary and treatable cause of hypertension (e.g., renal artery stenosis). Recently, the absence of circadian variation in BP has been identified as a major risk factor in patients with hypertension. Lack of circadian variation is associated with LVH [16]. The presence of LVH in a patient with essential hypertension is an important prognostic indicator of cardiovascular morbidity.

Commonly, hypertension on admission to the hospital is regarded as a "normal" response to the stress of hospital admission. However, this group of patients may represent an untreated or inadequately managed subset of hypertensive patients. A study examining this problem revealed that these patients generated the highest mean arterial BP (MAP) in response to laryngoscopy and intubation [17]. In addition, myocardial ischemia was observed, and 75% of the patients in this group required vasodilator therapy. In contrast, those patients with normal admission BP, or adequately treated hypertension, had an uneventful peri-induction course.

In the perioperative period, uncontrolled or poorly controlled hypertension is associated with an increased incidence of ischemia, myocardial infarction, dysrhythmias, and stroke [18]. Adequate preoperative treatment is associated with a reduced incidence of serious cardiovascular complications. Anti-hypertensive therapy has a salutary effect with regard to the anesthetic management of hypertensive patients. Even a single dose of beta antagonist administered 90 min. prior to induction of anesthesia results in a significant reduction in the incidence of intraoperative hypertension and myocardial ischemia, as well as postoperative cardiac morbidty [19, 20].

Current consensus when managing hypertensive patients suggests continuation of antihypertensive maintenance of drug therapy throughout the perioperative period; this includes maintenance of the patient's routine anti-hypertensive medication with the anesthetic premedication. The recent approval of intravenous diltiazem offers an agent with excellent anti-ischemic properties to the choices for intraoperative management [21].

CONGESTIVE HEART FAILURE

The impact of CHF on perioperative morbidity and mortality is often minimized, even though it was associated with the highest risk of morbidity in the Goldman Cardiac Risk Index [6]. Currently, 2.3 million Americans have CHF, with 400,000 added each year. The mortality rate of CHF is between 15–60% with 200,000 deaths each year. The etiology of CHF is multifactorial and may be the result of a cardiomyopathy, diastolic dysfunction, or ischemic left ventricular dysfunction. The first two etiologies may lead to a reversible process during the perioperative period, and careful fluid management is critical in these patients. If the etiology of CHF is myocardial ischemia, then irreversible myocardial necrosis and cardiac pump failure is a significant possibility. Therefore, the extent of myocardium-at-risk for ischemia should be discerned in the patient with CHF.

PREOPERATIVE TESTING STRATEGIES

The decision to perform further preoperative testing depends upon the reason for the testing. Although the definitive diagnosis of coronary artery disease is potentially useful in all high risk patients, the cost of such routine testing would be prohibitive and be associated with some risk. Therefore, testing must be reserved for those patients in whom care would be modified based upon the test results.

The risk of developing perioperative myocardial ischemia and cardiac morbidity should be used as a starting point in any decision algorithm [1]. For example, procedures
such as transurethral resection of the prostate or minor orthopedic procedures are associated with a low incidence of cardiac morbidity [22]. Except for patients with unstable angina, no supplemental cardiovascular tests are required. In contrast, patients undergoing high aortic cross-clamp procedures have an extremely high incidence of ischemia and cardiac morbidity and cardiovascular testing would be useful in all patients with clinical risk factors [23].

Multiple testing modalities have been suggested as part of the preoperative evaluation. The predictive value of a test in a particular patient is a function of the sensitivity and specificity of the test, and the pre-test probability of disease [24]. In patients with a very high pre-test probability of disease, noninvasive testing adds very little additional information. In such patients, coronary angiography may be the appropriate first test.

Exercise stress testing is frequently the first test in the diagnostic evaluation of coronary artery disease. An ECG stress test progressively increases myocardial work with graded exercise. Indicators of ischemia include development of angina, ECG changes (e.g., ST segment deviation, the appearance of dysrhythmias, conduction defects, etc.) and hemodynamic abnormalities. The presence of signs of left ventricular dysfunction, i.e., hypotension or dyspnea, should alert the clinician to the increased risk of perioperative cardiovascular dysfunction. In addition, the exercise tolerance the patient demonstrates is an important determinant of risk. McPhail et al. [25] demonstrated that the inability to achieve 85% of peak maximal heart rate is the best predictor of subsequent cardiac morbidity in high risk patients undergoing arterial reconstruction.

Many high risk patients have stress tests in accordance with practice guidelines developed by the American College of Cardiology and American Heart Association. They recommend symptom limited exercise testing or cardiac catheterization for almost all patients within 6–8 weeks following an acute MI [26]. However, the ECG exercise test is of limited value as a screening device in the asymptomatic population. Finally, ECG stress testing data should be viewed with caution since sensitivity and specificity will be different in men and women.

In patients with pre-existing ECG abnormalities, or when the result of the ECG stress test is ambiguous or yields an unexpected result, nuclear imaging can be added to exercise testing. Traditionally, planar imaging combined with thallium-201 has been used. More recent studies use SPECT (single photon emission computerized tomography) imaging combined with technetium-99, which provides better localization and quantitation of the perfusion defect. At rest, a severe coronary stenosis (>90%) must be present for the thallium test to be positive. "Cold" spots or perfusion defects appear 30–60 min. post-radioisotope injection. A period of redistribution occurs at 2–4 hrs. A repeat image is ordered at 4 hrs. Cold spots that are present at 1 hr but disappear at 4 hrs (reversible) indicate areas at risk for myocardial ischemia. Although defects in the 1-hr and 4-hr tests were thought to indicate infarcted tissue, more recent studies suggest that a significant percentage of these persistent defects represent severe ischemia [27].

A significant number of high risk patients with CAD cannot perform an exercise stress test. In these individuals, pharmacologic stress testing is employed. These tests rely on decreasing myocardial oxygen supply through coronary blood flow redistribution (dipyridamole); or, increasing myocardial oxygen consumption (dobutamine) [28]. Dipyridamole is a coronary vasodilator administered to patients who cannot perform exercise on a treadmill due to peripheral vascular disease. The dipyridamole thallium test (DTI) not only supplies important diagnostic information, but also has been shown to have significant prognostic capabilities in selected subsets of surgical patients [29–35]. However, a recent report has urged caution in applying the results of the test to surgical patients. Mangano et al. [36] were unable to demonstrate a significant predictive value of
a positive scan when studied in consecutive vascular surgery patients with the anesthetic care team unaware of the results. An accompanying editorial questions their methodology and study endpoints. One group suggests that DTI is of limited value for single vessel coronary disease (left main or right coronary arteries) or proximal triple vessel disease [37]. More recent studies suggest that improvements in protocol (repeat thallium injection) and quantitative measurements of redistribution will improve the predictive value of the test [38, 39]. Additionally, the presence of increased lung uptake is a sign of left ventricular dysfunction and identifies those patients at increased risk for subsequent morbidity.

Ambulatory electrocardiography (AECG), by use of a Holter monitor type device, allows ECG detection of symptomatic ischemic events (angina) as well those that are clinically silent (no angina). Advocates of this technology claim it is more useful than current diagnostic tests both for diagnosis and risk assessment [40–43]. In one recent study comparing DTI and AECG, the positive and negative predictive values of the tests were similar [44]. The significantly lower cost of AECG monitoring makes it very attractive in risk stratification. However, an American Heart Association task force evaluating this technology stated that more data is required before AECG becomes an acceptable part of routine diagnostic test methods for CAD [45].

More recent attention has focused on the assessment of ventricular dysfunction. Although a very poor ejection fraction is associated with an increased risk of perioperative morbidity, there is considerable controversy regarding the predictive value of a moderate ejection fraction [34, 46, 47]. Increasing evidence suggests that it is the dynamic response to stress that is the best predictor of outcome. In patients who are able to exercise, a good exercise tolerance is associated with good outcomes irrespective of the risk for ischemia. Several recent studies have reported the best positive and negative predictive values in the literature using pharmacologic echocardiography stress testing [48–52]. Further studies are required to confirm these new findings.

In choosing the appropriate test, cost-benefit analysis must be considered. Table 1 lists representative sensitivities, specificities and cost of the more commonly ordered cardiac diagnostic tests. Additionally, the predictive value of the test for the individual institution should be determined, since not all tests are performed as well by all laboratories.

Appropriate sequencing of diagnostic tests not only improves sensitivity and specificity for the diagnosis of CAD, but also improves risk stratification. From the preceding discussion, it is apparent that patients can be divided into three risk groups: low, intermediate and high. In a group of patients (n = 200) undergoing major vascular surgery, Eagle et al. [53] described a low risk group who had no clinical variables (e.g., angina, diabetes, Q waves on ECG, etc) for the presence of CAD [50]. Only 3% (2/64) sustained a post-

| Test                          | Sensitivity(%) | Specificity(%) | Cost($) |
|-------------------------------|----------------|----------------|--------|
| AMBULATORY ECG (24HR)         | 70             | 85             | 280    |
| ECG STRESS TEST               | 65             | 80             | 450    |
| STRESS ECHO                   | 80             | 85             | 600    |
| THALLIUM (planar)             | 90             | 80             | 1200   |
| THALLIUM (SPECT)              | 90             | 90             | 1200   |
| DIPYRIDAMOLE THALLIUM         | 90             | 90             | 1200   |
| CARDIAC CATHETERIZATION       | 95             | 95             | 2500   |
operative ischemic event. In contrast, the high risk group (three or more clinical factors), 50% (10/20) had clinically significant post operative cardiac morbidity. A majority of the patients (n = 116) had one or two clinical variables present and were assigned to the intermediate risk group. On the basis of the presence or absence of thallium redistribution on their dipyridamole thallium test, this group could be further subdivided into low (n = 64) and high risk (n = 54) subsets. Only 3% (2/64) patients without thallium redistribution had a post operative cardiac event. In comparison, those with thallium redistribution had 30% (16/54) postoperative cardiac event rate. The authors concluded that preoperative DTI, helps stratify those patients who were determined to be at intermediate risk by clini-
PROPOSED ALGORITHM FOR PATIENTS UNDERGOING SURGERY ASSOCIATED WITH A HIGH RISK OF PERIOPERATIVE MYOCARDIAL ISCHEMIA

Figure 2. Algorithm for patients undergoing surgical procedures with a HIGH risk of perioperative myocardial ischemia, e.g., resection of an abdominal aortic aneurysm. (Reproduced with permission Reference 1).

cal evaluation. Further, and perhaps more important, that for nearly half the patients in their series, clinical information alone predicted risk (high and low risk groups) and the use of the DPI was unnecessary.

Using this guided approach to the ordering of cardiodiagnostic tests, an algorithm can be developed to aid the clinician (Figure 1). More extensive testing implies that an operation may be delayed, canceled or postponed based on the test results. For example, consideration given to coronary revascularization or coronary angioplasty before a non-cardiac surgical procedure must include factoring the incremental risk of these procedures.

In contrast to the more traditional approach, Fleisher and Barash [1] proposed a method of stratifying risk based on the impact of the surgical procedure to increase perioperative ischemia, as described previously. This approach is based upon the concept that a certain threshold of cardiac morbidity must occur before a test has any value. If the prevalence of disease in the population is high, morbidity is low, and perioperative care would not be altered by a more definitive diagnosis of CAD, testing would add minimal or no benefit and would be associated with cost. After allocating the patient to a given risk group based on surgical procedure, the workup is performed on the basis of the presence of documented CAD, e.g., those at high risk for CAD and those with no or low risk of CAD (Figures 2-3). They suggest that the need for a confirmatory diagnosis of coronary artery disease, i.e., further testing, depends upon the perioperative morbidity and mortality rate for the planned procedure. If care will not be modified based upon the results of any test, then further evaluation may not have great utility but would add signif-

significant costs. Eagle and Boucher [54] suggest that patient subsets with expected perioperative cardiovascular event rate greater than 15% should be more extensively tested. Those subsets who exhibit a morbidity rate less than 5% do not require further screening.

PERIOPERATIVE INTERVENTIONS

Coronary revascularization prior to noncardiac surgery in patients with significant coronary artery disease has been suggested for over a decade [55]. To date, however, a randomized trial to determine the benefit of revascularization has not been performed. Hertzer et al. [56, 57] demonstrated that younger, nondiabetic patients who had CABG prior to major vascular surgery had improved long-term survival compared to a similar surgical cohort with documented coronary artery disease who did not undergo coronary revascularization. However, the decision to undergo CABG was not randomized, which represents a strong source of bias. Vascular surgery patients, the group with the greatest potential benefit from revascularization, also have a high morbidity and mortality from CABG. Therefore, only selected patients may accrue a significant benefit.

More recently, PTCA has been proposed prior to noncardiac surgery. Huber et al. [58] and Gottlieb [59] have both reported retrospective series demonstrating low perioperative cardiac morbidity rates in patients with PTCA prior to vascular surgery. The lower morbidity and mortality rates for PTCA may provide benefit with minimal risk.

A third alternative is to admit the patient to the ICU prior to noncardiac surgery and perform a "preoperative tune." Berlauk et al. [60] designed care algorithms to optimize hemodynamics using a pulmonary artery catheter prior to infrainguinal bypass surgery. In
a randomized clinical trial, they demonstrated a significantly lower morbidity and mortality in patients who had a "tune" either in the ICU or in the induction area when compared to patients who did not have a "tune" or pulmonary artery catheter placed unless clinically indicated. Further studies are needed to confirm their findings.

In summary, preoperative evaluation continues to be an important component of anesthetic practice. Once a database is established, the ideal method of intervention to reduce risk must balance the benefits and risks.

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