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Cardiac risk in noncardiac surgery: The preoperative period

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INTRODUCTION

In the aging population, cardiac disease plays a major role as a risk factor among patients undergoing noncardiac surgery[1]. More than one million patients with known coronary artery disease (CAD) will undergo noncardiac surgery in the United States on an annual basis[2]. There are three million additional noncardiac surgical patients who have risk factors for CAD and approximately four million other patients who are greater than 65 years of age (who are at increased risk of cardiac morbidity). Annually, about 50,000 out of 25 million patients undergoing noncardiac surgery have perioperative myocardial infarction (MI) (0.2%). Patients with known CAD have a 1.1% perioperative incidence of MI in noncardiac surgery. The mortality following perioperative MI has been reported as 26-70%[2]. Thus, it is important to identify those patients who have increased risk of perioperative cardiac morbidity and mortality in order to correct conditions that might positively alter outcome. It is controversial whether preoperative interventions, such as drug therapy or myocardial revascularization, will be beneficial.

The main goals of the preoperative assessment of the cardiac patient for noncardiac surgery are risk stratification and the potential reduction of this risk by various interventions. These interventions may include modifying drug therapy or the surgical approach, more intensive intraoperative monitoring, anesthetic techniques, and possible myocardial revascularization. A proper preoperative assessment entails the collection of information about the patient's medical history and physical condition, the ordering and interpretation of appropriate tests, education of the patient and family members, selection of preanesthetic medication and obtaining informed consent[3,4].

ASSESSMENT OF PREOPERATIVE RISK

General classification. Several cardiac risk stratification models are available. The Dripps-ASA classification of physical status[5] has 5 different categories and has been widely applied to surgical patients[5,6]. Patients with asymptomatic cardiac disease are assigned to ASA class II. If they have angina controlled by the treatment, they belong to group III. Patients with unstable angina belong to group IV and patients with acute myocardial infarction with cardiogenic shock belong to group V. The predictive value of this classification regimen, however, is limited.

Functional classifications. The New York Heart Associations functional classification[7] (Table I) of limited exercise tolerance is as follows: Class 1 refers to patients who are symptomatic only with strenuous exercise; Class 2 are symptomatic with moderate exercise; Class 3 are symptomatic with limited exercise (climbing one flight of stairs or walking one or two blocks); and the Class 4 patient has symptoms at rest and with any activity. The Canadian Cardiovascular Society Functional classification of Angina Pectoris (CCVSA) is similar to the NYHA classification[8]. (Table I).

General risk scores. Goldman et al.[9,10] developed multifactorial clinical risk indices for patients undergoing noncardiac surgery by identifying risk factors that predicted perioperative cardiac complications or death. The patients were assigned to four risk classes based on the risk points: Class I, 0-5 points, class II, 6-12 points, class III, 13-25 points and class IV over 25 points. The risk of perioperative cardiac complications ranged from less than 1% in Class I to approximately 78% in the Class IV. Detsky et al.[11] modified the original Goldman multifactorial index by adding more variables (Canadian Cardiovascular Society angina class[8], unstable angina, and history of pulmonary edema).

Table 1. New York Heart Association and Canadian Cardiovascular Society functional classification of angina

NYHA[7]		CCVSA[8]	
Class 1	No symptoms with ordinary physical activity	Class I	Ordinary physical activity does not cause angina
Class 2	Symptoms with ordinary activity. Slight limitation of activity.	Class II	Slight limitation with ordinary activity.
Class 3	Symptoms with less than ordinary activity. Marked limitation of activity	Class III	Marked limitations of ordinary activity
Class 4	Symptoms with any physical activity or even at rest	Class IV	Inability to carry on any physical activity without discomfort

A high score in either risk index was predictive of a poor postoperative outcome. However, they were not as accurate in predicting cardiac morbidity in low risk patients (Goldman Class I and II).[12,13] Lette et al. [14] found that neither risk index predicted adverse outcomes in low risk patients. The Revised Cardiac Risk Index (RCRI) described by Lee, however, is the most commonly used currently[15].

Cardiac Surgical Indices. There are several risk indices available for patients undergoing cardiac surgery. These are more complex than the manual indices described above: Parsonnet[16], Hannan[17] and Higgins[18], have developed a risk index that uses logistic regression models to stratify patients' morbidity and mortality risk. The Parsonnet model has been widely used. Edwards[19] has developed a risk index that is based on the Bayesian approach. There is also a simple manual 7-factor index available for individual cardiac patients[20]. Many of the risk factors are similar for patients undergoing noncardiac surgery[21,22]. In the future, there may be risk stratification systems for predicting morbidity and mortality that are applicable to both cardiac and noncardiac patients.

CLINICAL EVALUATION

Clinical history and physical examination are the basis of the preoperative assessment, but additional testing will be required depending on the patient's underlying diseases and the planned procedure. A complicating factor in this process is the trend towards more day-of-admission and outpatient surgery. Patients who are categorized as ASA class III or IV that are scheduled to undergo day-of-admission or ambulatory surgery are especially problematic for the anesthesiologist. The anesthesiologist should have all of the pertinent preoperative data in advance of the operative procedure. Automated questionnaires are available to obtain the patients' medical history in a standardized way. These have been shown to be similar in quality to general preoperative physician-derived health status measures[23]. These preoperative questionnaires may assist in the development of a preoperative diagnostic testing strategy, and intraoperative plan.

The physician evaluating a cardiac patient must find answers to these basic questions:

1. Is this patient at increased risk for perioperative morbidity and mortality?
2. What further diagnostic workup is necessary, if any?
3. What should be done preoperatively in order to minimize the risk of adverse events?
4. Should the surgery be altered, postponed or canceled?

PREOPERATIVE DEMOGRAPHIC PREDICTORS OF CARDIAC MORBIDITY

Age

Age is one of the risk factors for cardiac morbidity. Aging is associated with coronary artery disease, diabetes mellitus, peripheral vascular disease, and arterial hypertension. Age may not be an important independent risk factor per se, but its association with other disease processes makes it a useful *univariate* predictor of cardiac risk. Elderly patients with a reduced level of activity are more difficult to evaluate because diagnostic criteria for cardiac risk are often exercise-related. In addition, physically active patients have been shown to have fewer complications[24]. Patients with incapacitating disease with systemic manifestations are at very high risk.

Previous myocardial infarction

The urgency of the surgery, the relative risks and benefits of the procedure, and the patient's cardiac status should be considered carefully when surgery is planned following a recent myocardial infarction (MI). Patients with a history of a previous MI (at any time in the past) have 5-8% greater risk of perioperative reinfarction, and the reinfarction mortality rate was 36-70% in the 1970's-80's[2,25]. In those studies, the risk of reinfarction diminished with time since the original MI. MI within 3 months had a reinfarction rate up to 30%, within 3-6 months up to 15%, and MI beyond 6 months had only a 6% reinfarction rate. Nevertheless, these are older data and were largely related to transmural MI's in the era prior to beta-blocker therapy.

Rao and colleagues[26] showed that the incidence and mortality of myocardial reinfarction was reduced significantly in a group of patients undergoing surgery during the latter half of a retrospective study. The authors attributed the improvement in outcome to more intensive perioperative monitoring in the OR and intensive care unit. They determined that only 5.7% of the patients undergoing noncardiac surgery within 3 months of a myocardial infarction suffered perioperative reinfarction; this declined to 2.3% during the 3-6 month post-MI interval. In most of the other studies, the reinfarction rates have been higher: 5-8% in patients with remote (> 6 months) infarction[2,27], to 6-40% in those with recent MI (< 6 months).

Given this impressive association of recent MI with cardiac risk, it is necessary to generate recommendations for patients presenting for elective noncardiac surgery. In general, emergency, life-saving surgery should be performed; truly elective surgery should be delayed for some period of time-probably 6 weeks through 3 months following the MI. In semi-urgent cases, the patients' should have an extensive preoperative evaluation in consultation with a cardiologist. The patient should be informed of the increased risk associated with the procedure.

Cardiologists have a somewhat different view in that recent MI is defined as an «unstable coronary syndrome» that occurred 7-30 days previously. Unstable coronary syndromes are «active cardiac conditions for which the patient should undergo evaluation and treatment before noncardiac surgery»[28].

Angina pectoris

Patients with stable angina have also been demonstrated to have increased risk for MI and sudden death in ambulatory surgery. In nonambulatory noncardiac surgery, the issue of cardiac risk is controversial[2]. Exercise tolerance should be assessed carefully; the NYHA or CCVSA angina classification should be determined. If the patient is unable to climb one flight of stairs without chest pain, a diagnostic test (e.g., exercise stress test or dyridamole-thallium imaging) is probably indicated. (see below) Some patients have silent (painless) myocardial ischemia and are at a greater risk for MI than patients with symptomatic angina. Several large prospective studies[25,29,30] have provided the consensus that preoperative and postoperative myocardial ischemia, but not intraoperative myocardial ischemia, is associated with perioperative cardiac morbidity. A very large percentage of this perioperative ischemia was silent in nature.

Unstable angina is generally a contraindication for elective noncardiac surgery. Shah et al[31] showed that 28% of patients with unstable angina had an adverse event perioperatively. Canadian Cardiovascular Society Class III and IV are considered unstable coronary syndromes requiring preoperative cardiovascular evaluation by the American College of Cardiology/American Heart Assocation[28].

Congestive heart failure

There are about 2 million patients in the US with congestive heart failure (CHF). Preoperative CHF (left ventricular dysfunction) is a major risk factor for perioperative morbidity. Low left ventricular ejection fraction, low cardiac output, high left ventricular end diastolic pressure, and echocardiographically measured regional wall motion abnormalities are sensitive indicators of left ventricular dysfunction. It has been shown that symptomatic congestive heart failure is a predictor of perioperative pulmonary edema[10,32]. New York Heart Association Class IV and new onset and worsening CHF are active cardiac conditions requiring evaluation[28].

Cardiac arrhythmia

A history of cardiac arrhythmias is associated with an increased likelihood of postoperative CHF. Frequent premature ventricular contractions or non-sinus rhythm (atrial fibrillation or atrial flutter) are predictive of perioperative cardiac morbidity in noncardiac surgery. Complete (third-degree) heart block, left bundle branch block and second degree heart block (Mobitz II) increase risk in perioperative period as well[33]. Active cardiac conditions are defined as high-grade atrioventricular block, Mobitz II atrioventricular block, third-degree atrioventricular heart block, symptomatic ventricular arrhythmias, supraventricular arrhythmias (including atrial fibrillation) with uncontrolled ventricular rate (hr greater than 100 beats per minute at rest), symptomatic bradycardia, and newly recognized ventricular tachycardia[28].

Hypertension

Hypertension is a major risk factor for coronary artery disease. About 60 million people in the USA have hypertension. Coexisting hypertension increases the risk of perioperative MI in patients with a previous MI[34]. Patients with untreated, uncontrolled hypertension should treated prior to elective surgery. Antihypertensive therapy, especially beta-blocking agents and calcium channel blockers should always be continued until the operation, although many will discontinue diuretics and angiotensin-converting enzyme inhibitors. There are no evidence-based guidelines on this subject.

Diabetes mellitus

Patients with diabetes mellitus, especially type I, have been shown to have greater risk for postoperative myocardial ischemia(21). Furthermore, diabetic patients are more likely to have silent ischemia because of altered neural pain pathways in the heart. Diabetes is also associated with postoperative congestive heart failure and wound infections(2,27). Many diabetic patients also have renal insufficiency.

Valvular heart disease

Patients with aortic stenosis (AS) are at fourteen-fold greater risk for postoperative mortality as compared to patients without AS(9). The larger the pressure gradient across the aortic valve (especially > 100 mmHg), the greater the risk for hemodynamic instability. Severe or symptomatic aortic stenosis and symptomatic mitral stenosis are considered active cardiac conditions. *Mitral valve prolapse* (MVP) is no longer considered an infective endocarditis risk.

Miscellaneous

Smoking will increase the risk of CAD and postoperative respiratory complications, especially in the patients with chronic obstructive pulmonary disease (COPD)(33).

CARDIAC RISK OF INDIVIDUAL PROCEDURES

Two characteristics of the surgery are important: site and urgency. Intrathoracic and open upper abdominal surgery have a higher risk for cardiac morbidity than peripheral surgical procedures(35). Peripheral vascular surgery has been shown to carry similar risk to aortic surgery(36). Major vascular surgery carries a special risk for perioperative morbidity(13). Open abdominal aortic reconstruction in patients with aortic occlusive disease has one of the highest risks for cardiac morbidity. These patients have often CAD. The cross-clamping of aorta is associated with significant hemodynamic changes. The patients should be evaluated carefully and their hypertension should be under control(13). The performance of emergency surgery increases the risk of perioperative cardiac morbidity(37). The length of the operation is also important. If the surgical procedures last longer than 2 hours, the risk of perioperative mortality is higher(2,38).

The following table from reference 28 details the cardiac risk of procedures types as specified by the ACC/AHA:

PREOPERATIVE THERAPY

Preoperative therapy of a patient with CAD for noncardiac surgery should focus on the alleviation of the myocardial ischemia and on optimal treatment of congestive heart failure and arrhythmias. The important principles are the optimization of the balance between myocardial oxygen supply and demand, the prevention of hypercoagulability, and the prevention of coronary vasospasm.

In ischemic heart muscle, oxygen demand exceeds the oxygen supply. The hemoglobin level would be optimal in the range of 10-12 g/dL to have optimal oxygen supply for the heart, although transfusion to achieve this goal is not evidence-based. In patients with valvular heart disease high Hb levels (increased viscosity) may cause decreases in blood flow through the stenotic valve orifice. The principles are to increase the oxygen supply by increasing the coronary blood flow and decrease the oxygen demand by decreasing the heart rate.

Table. Cardiac risk* stratification for noncardiac surgical procederes.

Risk stratification	Procedure examples
Vascular (reported cardiac risk often more than 5%)	Aortic and other major vascular surgery peripheral vascular surgery
Intermediate (reported cardiac risk generally 1 to 5%)	Intraperitoneal and intrathoracic surgery Carotid endarterectomy Head and neck surgery Orthopedic surgery Prostate surgery
Low† (reported cardiac risk generally less than 1%)	Endoscopic procedures Superficial procedure Cataract surgery Breast surgery Ambulatory surgery

* Combined incidence of cardiac death and nonfatal myocardial infarction.
† These procedures do not generally require further preoperative cardiac testing.

The major anti-anginal drugs in use today are the beta-adrenergic blocking drugs, the calcium-channel blocking agents and (to a lesser extent) nitrates. It is critical to continue anti-anginal therapy throughout the perioperative period in order to avoid withdrawal effects and to prevent perioperative ischemia. Some studies have shown that beta-blockers are more effective in preventing perioperative myocardial ischemia than calcium-channel blockers[29,30]. The only Class I ACC/AHA indication for beta-blockers in the perioperative period is preoperative beta-blocker therapy. The following table from reference 28 specifies ACC/AHA recommendations for perioperative beta-blocker therapy:

Surgery	No clinical risk factors	1 or more clinical risk factors	CHD or high cardiac risk	Patients currently taking beta blockers
Vascular	Class IIb, level of evidence: B	Class IIa, level of evidence: B	Patients found to have myocardial ischemia on preoperative testing: Class I, level of evidence: B* Patients without ischemia or no previous test: Class IIa, level of evidence: B	Class I, level of evidence: B
Intermediate risk		Class IIb, level of evidence: C	Class IIa, level of evidence: B	Class I, level of evidence: C
Low risk				Class I, level of evidence: C

Patients with long-term anticoagulant therapy (for atrial fibrillation, prosthetic heart valves, deep vein thrombosis, or prior cerebral embolism) should discontinue their warfarin (coumadin) therapy 3-5 days prior to surgery (if major surgery). If there is a risk of embolism, heparin should be started intravenously before the operation and discontinued approximately six hours prior to surgery (or reversed using protamine). In emergency situations, the effects of warfarin may be reversed by intravenous vitamin K (10-25 mg i.m. or i.v. slowly). The effect of vitamin K is evident 12-24 hours after parenteral injection. Ideally, aspirin should be discontinued one week before major operations in order to allow recovery of platelet function. The prothrombin time (PT), activated partial thromboplastin time (aPTT), and platelet count are sufficient to guide therapy in most patients[39]. See below for a discussion of the management intracoronary stents and perioperative antiplatelet therapy.

The American Heart Association has published suggested regimens for prophylaxis against bacterial endocarditis and these should be reviewed prior to surgery to assure that proper prophylaxis is administered. The most recent version of these guidelines has more limited inclusion criteria such that fewer patients and generally only dental procedures qualify for prophylaxis against endocarditis.[40]

PREOPERATIVE DIAGNOSTIC TESTING

Electrocardiography is routinely recommended for patients with symptomatic heart disease prior to surgery. Exercise electrocardiography (treadmill) testing is advantageous in selected patients because it is one of the least invasive methods of detecting significant CAD[41]. Exercise treadmill testing increases myocardial workload progressively, thus provoking ischemia. There are several protocols available for performing the test, but the most commonly used is the Bruce protocol[33]. The heart rate and cardiac output increase during exercise. Contractility and wall tension are determinants of oxygen consumption, which increases fourfold with maximal exercise. A reduction in coronary reserve with ischemic heart disease results in myocardial ischemia and/or dysrhythmias.[2] Electrocardiographic changes in the ST-segment (depression $\geq$ 0.1 mV or elevation $\geq$ 0.2 mV 80 seconds after the J-point) are diagnostic of CAD and clinical signs of left ventricular dysfunction are also considered positive findings. The electrocardiographic lead where the ST-segment changes first appeared should be monitored perioperatively if possible. The perioperative heart rate and blood pressure should not exceed the values at which ischemic events occurred during the test. Some patients are not able to perform lower extremity exercise due to peripheral vascular disease, arthritis, or other problems with the lower extremities. Those patients may have exercise testing using arm ergometry.

Radionuclide methods to assess myocardial perfusion and viability may be used with and without pharmacologic agents (see below) or exercise to induce myocardial ischemia[42]. There are different techniques that can be used: Thallium scintigraphy, Technetium (sestamibi or teboroxime) imaging or radionuclide ventriculography[5,43,44]. The most commonly used agent in nuclear imaging is Thallium-201 (Tl-201). There are two methods of imaging: planar imaging and the newer SPECT (single photon emission computed tomography) technology[43]. Thallium-201 is a cyclotron-produced radionuclide with a half life of 72 hours. It mimics potassium (K+) and is taken up by viable myocardial cells.

Thallium can be injected intravenously and cardiac blood pool activity rises rapidly and falls more gradually as the thallium is extracted by the tissues. Approximately 5% of an injected Th-201 dose is distributed to the myocardium. The myocardium extracts about 80-90% of the thallium passing through the coronary circulation. The time to peak myocardial thallium activity is delayed in the resting heart compared with the exercise-stressed or pharmacologically stressed heart. The initial uptake of Tl-201 is relatively homogenous in patients without CAD. Nonviable (scarred) and ischemic myocardium does not take up Tl-201, and, therefore a defect is detectable in the imaging. Following the initial distribution of Tl-201, the myocardial Tl-201 activity may change with cessation of exercise-induced or pharmacologically-induced myocardial ischemia. Regions with *reversible* myocardial ischemia will have delayed uptake, and regions (distal to coronary artery stenoses) have a slower clearance than normal regions. Thallium-201 redistribution, however, can occur only if the tissue is viable. The following parameters are studied in Tl-201 stress imaging: the size of the defect, left ventricular cavity size, and lung uptake. Several studies have shown that thallium redistribution is predictive of postoperative cardiac morbidity and mortality when selected patients with intermediate cardiac risk (by Goldman cardiac risk index criteria) are evaluated[41-43]. The utility of these tests is restricted by their costs and availability, and their predictive value in consecutive prospective series of unselected patients with intermediate cardiac risk has not been proven.

PHARMACOLOGIC STRESS TESTS

Not all patients are able to exercise (e.g., those with claudication, abdominal aortic aneurysm, musculoskeletal or neurological disease). For these patients, there are pharmacologic stress tests that simulate the stress of exercise[45,46].

Dipyridamole and adenosine are coronary vasodilators that may be administered intravenously in stable patients who are unable to exercise. These agents are arteriolar vasodilators that are capable of inducing myocardial ischemia in tissue zones that are dependent on collateral perfusion. The explanation for this is as follows. Myocardial tissue distal to a significantly stenosed coronary artery may be receiving perfusion via a collateral vessel from a region that is perfused by a normal coronary artery. This potentially ischemic tissue is maximally vasodilated at resting conditions in order to preserve the pressure gradient that is supplying blood through the collateral vessel. Arteriolar vasodilators will cause decreased resistance to blood flow through the myocardial tissue that is supplied by the normal coronary artery (which is normally moderately constricted at resting conditions). The vasodilation in the normal tissue bed will decrease the perfusion pressure across the collateral vessel and induce myocardial ischemia in the collateral-dependent zone of myocardium-a coronary steal syndrome. The phenomenon is reversible when the vasodilator's effect on the normal tissue bed subsides upon withdrawal of the agent. Adenosine has a very short half life (10 seconds) and must be administered by infusion. Dipyridamole exerts its action by blocking cellular reuptake of adenosine. Patients with asthma cannot be tested with dipyridamole, because it is associated with severe bronchoconstriction[43].

Dobutamine is a beta-adrenergic agonist that will cause an increase in myocardial oxygen demand by its inotropic and chronotropic effects and will induce myocardial ischemia in patients with CAD. It can be infused as an alternative to dipyridamole, adenosine, or exercise. Dobutamine has been used as the pharmacological stressor in *stress echocardiography*, in which wall motion abnormalities assessed using two-dimensional echocardiography serve as the indicator of myocardial ischemia[47,48].

IS PREOPERATIVE MYOCARDIAL REVASCULARIZATION REQUIRED?

Coronary angiography and possible revascularization (CABG, or percutaneous intervention) should be considered for patients scheduled for major surgery if the revascularization is reasonable within the context of the patient's long-term cardiovascular disease profile. The McFalls study found no beneficial effects of preoperative myocardial revascularization in a randomized prospective trial of patients with significant coronary artery disease[49]. There is no evidence to support the principle that preoperative myocardial revascularization should be done solely to reduce the cardiovascular risk of noncardiac surgery.

SURGERY IN PATIENTS WITH INTRACORONARY STENTS

Patients with intracoronary stents on dual anti-platelet therapy represent a very complex subset of patients in whom evidence-based recommendations are very preliminary. The urgency of the planned surgery, the ability to conduct the surgery without discontinuing dual antiplatelet therapy, the coronary anatomy, and other cardiovascular risk factors must all be considered. Reference [3] summarizes expert opinion on the matter as detailed in the table below.

- Dilatation without stenting: 2-4 wk of dual-antiplatelet therapy
- Surgery postponed for 2-4 wk (vital surgery only)
- PCI and BMS: 4-6 wk minimum of dual-antiplatelet therapy
- Elective surgery postponed ≥ 6 wk, but not for more than 12 wk, when restenosis may begin to occur
- PCI and DES: 12 mo of dual-antiplatelet therapy
- Elective surgery postponed for ≥ 12 mo
- In patient in whom coronary revascularization with PCI is appropriate for mitigation of cardiac symptoms and who need elective noncardiac surgery in the subsequent 12 mo, a strategy of balloon angioplasty or BMS placement followed by 4 to 6 wk of dual-antiplatelet therapy is probably indicated
- Aspirin: lifelong therapy, whichever is the revascularization technique

(From 2007 AHA/ACC Science Advisory and Society of Cardiovascular Angiography DES task force recommendations for timing of noncardiac surgery after PCI and 2007 ACC/AHA recommendations for preoperative coronary revascularization and chassot P-G. Delabays a spahn DR. periperative antiplatelet therapy: the case for continuing therapy in patients at risk of myocardial infarction. Br J Anaesth 2007;99:316-328).
PCI = percutaneous coronary intervention; BMS = bare-metal stent; DES = drug-eluting stent.

Ideally, the cardiologist, surgeon, and anesthesiologist should come to agreement on a treatment plan in consultation with the patient such that the relative risks and benefits of all treatment options are considered. Regional anesthesia techniques may not be feasible if dual antiplatelet therapy must be continued in the perioperative period(50).

IS THE PATIENT READY FOR SURGERY?

The American Heart Association/American College of Cardiology Guidelines are the most definitive source for guiding the evaluation and management of perioperative cardiac risk. Every clinician should review and use these guidelines as the ultimate source for current thinking on the subject(28).

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