ORIGINAL ARTICLE

Strategies for perioperative risk assessment in patients undergoing noncardiac surgery vary among physicians and are aimed to estimate the risk and minimize complications. We propose simplistic guidelines for assessing and modifying risk for patients undergoing a wide variety of procedures.

Cardiac Risk Assessment for Noncardiac Surgery: Current Concepts

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INTRODUCTION

Surgical procedures may be complicated by cardiovascular disease, which is often clinically occult prior to surgery. Thus, coronary artery disease (CAD) accounts for most deaths in patients undergoing noncardiac surgery.[1] Strategies for perioperative risk assessment are designed to estimate the risk and minimize complications in a rational fashion. Approximately, 5% of the elderly population in US undergo noncardiac surgery each year, and about one-third of these are at risk for CAD with estimated in-hospital and long-term complications occurring in 1.5 million patients.[1,2] A wide variability exists in regards to the physician's approach to preoperative risk assessment for cardiac events in patients undergoing noncardiac surgery. This article reviews the available literature and provides simplistic guidelines for assessing and modifying risk for patients undergoing a wide variety of surgical procedures.

PERIOPERATIVE RISK OF EVENTS

A large number of surgical procedures (including high-risk procedures) are performed in the elderly population, which has been increasing steadily.[1] While patients with no prior history of myocardial infarction (MI) have low risk of perioperative MI (0.1%–0.6%), those with a history of prior MI are at a significantly higher risk (2.8%–7%).[3-6] Occurrence of MI within 3 months increases the risk of a perioperative cardiac event to 37%, MI within 3-6 months to 16%, and 4% in patients ≥ 6 months past their MI.[5] More recent data suggests a lower risk than reported earlier, but still elevated above normal in patients with recent MI. The majority of perioperative MIs are known to occur in the first three days with peak incidence on day two.[4,6] Most lack the classic presentation with chest pain, but rather have an atypical presentation such as new

REPRINTS

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onset congestive heart failure (CHF), hypotension, arrhythmias, nausea, or altered mental status. Perioperative MI is associated with high mortality ranging from 26%–70%.[1-7] Therefore, it is imperative to identify those patients at risk for untoward outcomes after surgery by using a systematic stepwise strategic preoperative evaluation, using guidelines such as those of the ACC/AHA task force.[7-10]

A STEPWISE APPROACH FOR PERIOPERATIVE RISK ASSESSMENT OF A PATIENT UNDERGOING NONCARDIAC SURGERY

The following questions need to be asked for assessing risk for patients undergoing noncardiac surgery:[8-10]

1. What is the urgency of the surgery?
2. Has prior revascularization been performed in the patient?
3. Has the patient been evaluated for CAD in the past 2 years?
4. What clinical risk factors are present?
5. What is the patient's functional capacity?
6. What is the probability of cardiac complications for a patient based on the type of surgery and the institutional experience?
7. Is stress testing or other diagnostic procedure necessary?
8. Do the benefits of operation outweigh the probability of cardiac complications after surgery?
9. What is needed to reduce the probability of cardiac complications after surgery in terms of modifying preoperative, intraoperative, and postoperative care?
10. What long-term risk stratification and management strategies should be implemented?

What is the Urgency of Noncardiac Surgery? The urgency of surgery is dictated by patient- or surgery-specific factors, and in such instances, there may not be time for further cardiac assessment. Efforts should then be focused to help minimize perioperative cardiovascular risk by perioperative surveillance (daily electrocardiograms, hemodynamic monitoring and cardiac enzyme measurements) in selected unstable patients and by aggressive perioperative medical management that includes the use of β-adrenergic blocking drugs to reduce heart rate to between 50 and 60 beats/minute. Selected patients, at high risk of long-term coronary events, should undergo risk stratification after their complete recovery from surgery.[8-10]

Has Prior Revascularization Been Performed in the Patient? Patients, who have undergone complete revascularization in the form of coronary artery bypass surgery (CABG) in past 5 years or percutaneus transluminal coronary angioplasty (PTCA) in past 6 months to 5 years and who are functionally active and free of clinical evidence of ischemia in the interim, have a very low likelihood of perioperative cardiac events.[8-11] Such patients may proceed to surgery without further cardiac testing.

Has the Patient Been Evaluated for CAD in the Past Two Years? In patients who have been evaluated in the past two years with either invasive or noninvasive techniques with favorable findings, no further cardiac work-up is generally necessary, assuming they have been free of cardiac symptoms after the test. Patients with changing symptoms and/or signs of ischemia should be considered for further evaluation.[8-10]

What Clinical Risk Factors Are Present? Baseline history, physical examination, and electrocardiogram (ECG) provide sufficient data to estimate cardiac risk. Table 1 lists clinical predictors of adverse cardiac outcomes based on the work of several authors.[9,12-14] Prior studies have combined various clinical features associated with poor prognosis into composite scores to help quantitate the risk of postoperative events.[14,15] More recent studies have used more simplistic algorithms.[8,16] If a patient has a major clinical predictor as listed in Table 1, and is scheduled for an elective surgery, it is best to postpone surgery until the cardiac problem is clarified (sometimes by coronary arteriography) and treated appropriately.[7-10] Patients with moderate or excellent functional capacity and one or more intermediate predictors of clinical risk can undergo low and intermediate risk surgery (Table 2) with low perioperative event rates. On the other hand, patients with poor functional capacity or a combination of high-risk surgery and moderate functional capacity and intermediate predictors of cardiac risk (especially if two or more) should be evaluated by further noninvasive cardiac testing. Patient with minor or no clinical predictors of risk and with moderate or excellent functional capacity (≥ 4-6 metabolic equivalents) can generally safely undergo most noncardiac surgeries.[8-10]

What is the Patient's Functional Capacity? Functional status reliably predicts future cardiac events[17] and should be assessed by history in all preoperative patients. Functional capacity is usually expressed as metabolic equivalent (MET) levels; one MET being equivalent to the oxygen consumption (VO_2) of a 70 kg, 40-year old man in a resting state (= 3.5 mL/kg/min). Functional capacity may be classified as excellent (> 7 METs), moderate (4 to 7 METs), poor (< 4 METs) or unknown. Table 3 repre-

TABLE 1

Clinical Predictors of Increased Perioperative Cardiavascular Risk (Myocardial Infarction, Congestive Heart Failure, Death)[9,14,15]

Major

- Unstable or severe angina (Canadian Class III or IV)
- Recent myocardial infarction (> 7 days but ≤ 30 days) with evidence of important ischemic risk by clinical symptoms or non-invasive testing.
- Decompensated congestive heart failure.
- Symptomatic arrhythmias including high grade atrioventricular block, symptomatic ventricular arrhythmia in presence of underlying heart disease and supraventricular arrhythmias with uncontrolled ventricular rate.

Intermediate

- Mild angina (Canadian Class I and II)
- Prior myocardial infarction by history or ECG
- Compensated or prior congestive heart failure
- Diabetes mellitus

Minor

- Advanced age
- Abnormal ECG (left ventricular hypertrophy, left bundle branch block, ST-T abnormalities)
- Rhythm other than sinus (e.g., atrial fibrillation)
- Low functional capacity
- History of stroke
- Uncontrolled systemic hypertension.

sents a sample of activities that characterizes each functional class.[8,18,19] Poor functional capacity is a marker for increased perioperative cardiac and long-term events. These patients should be considered for noninvasive cardiac risk assessment before elective cardiac surgery depending on the type of surgery and presence of clinical risk predictors, as discussed above. Patients with moderate or excellent functional capacity and low clinical predictors of risks or patients with combination of intermediate predictors of cardiac risk, low or intermediate risk surgery, combined with preserved functional capacity can generally proceed to elective surgery without undergoing further cardiac work-up. Patients with intermediate predictors of clinical risk facing high-risk

TABLE 2

Surgery Specific Cardiac Risk (Combined Risk of Cardiac Death and Non-Fatal MI)[9,14,16,20,22]

High (Reported cardiac risk often > 5%)

- Emergent major operation particularly in elderly
- Aortic and other major vascular
- Peripheral vascular
- Anticipated prolonged surgical procedures associated with large fluid shifts and/or blood loss

Intermediate (Reported cardiac risk generally < 5%)

- Carotid endarterectomy
- Head and neck
- Intraperitoneal and intrathoracic
- Orthopedic
- Prostate

Low (Reported cardiac risk generally < 1%)

- Endoscopic procedures
- Superficial procedures
- Cataract
- Breast

TABLE 3

Functional Capacity Assessment from Clinical History[8-10,18,19]

Excellent (Activities requiring > 7 METs)

- Carry 24 lb up 8 steps
- Carry objects that weigh 80 lb
- Outdoor work (shovel snow, spade soil)
- Recreation (ski, basketball, squash, handball, jog/walk 5 mph)

Moderate (Activity requiring > 4 METs but < 7 METs)

- Have sexual intercourse without stopping
- Walk at 4 mph on level ground
- Outdoor work (garden, rake, weed)
- Recreation (roller skate, dance, fox trot)

Poor (Activity requiring < 4 METs)

- Shower/dress without stopping, strip and make bed, dusting, dish washing
- Walk at 2.5 mph on level ground
- Outdoor work (clean windows)
- Recreation (play golf, bowl)

surgery should be considered for noninvasive cardiac evaluation risk preoperatively.[8-10]

What is the Probability of Cardiac Complications for a Patient Based on the Type of Surgery and the Institutional Experience? The specific type of surgery determines the probability of cardiac complications.[4,5,9,14,16,20] Surgical procedures are classified as high, intermediate or low risk as outlined in Table 2.[9] Emergency surgery is associated with a four- to five-fold increase in risk compared to elective surgery.[14] In addition, patients undergoing aortic, peripheral and other major vascular surgeries or operations associated with large fluid shifts and/or blood loss have relatively high probability (nearly two- to three-fold increase) of cardiac complications. Risk classification of various surgeries should be considered along with the predictors of clinical risk and functional capacity in properly risk stratifying patients prior to noncardiac surgery.[8-10]

Is Stress Testing or Other Diagnostic Procedures Necessary? Simple strategies for preoperative noninvasive testing, proposed by Eagle and his colleagues and other investigators, have been reiterated in current ACC/AHA task force recommendations.[8,9,16] Patients classified as low clinical risk generally do not need any risk stratification. Those with major predictors of high clinical risk have a high probability of left main or triple vessel CAD and deserve consideration for a more aggressive approach, including, in selected patients, preoperative coronary angiography and coronary revascularization. The intermediate clinical risk group warrants noninvasive testing.[21] Noninvasive testing is aimed at identifying the degree of ischemic burden, inducible arrhythmias, as well as the functional capacity of a patient.

Current Evidence for Diagnostic Testing in Perioperative Risk Assessment. *Exercise electrocardiogram.* The role of exercise stress testing in preoperative assessment has been validated in numerous studies.[22-29] McPhail et al.[29] reported using preoperative exercise testing in 100 patients undergoing vascular surgery. The highest cardiac complication rate (33%) was evident in patients with exercise-induced ischemia and low workload. Cutler et al.[24] documented that the ability to attain 75%–85% of their maximal predicted heart rate (MPHR) (high workload) is predictive of a low perioperative cardiac event rate. Poor functional capacity associated with ischemia identifies patients at high risk for perioperative cardiac events.[30] Ischemia in patients with excellent functional capacity appears to confer a small increase in risk.[8] Baseline ECG abnormalities and/or inability of patients to exercise secondary to their diseases or comorbidities limits the widespread use of exercise ECG in all patients.

Pharmacological stress test and myocardial perfusion imaging. The utility of preoperative dipyridamole-thallium imaging for risk stratification was first defined by Boucher et al.[31] and since been validated in numerous studies.[16,32-37] The positive predictive value has been consistently low, between 4% and 20%. This is attributed in part to the fact that stress testing results are now utilized for risk modification in the form of preoperative coronary revascularization, adjustment of medical management, aggressive monitoring, selection of a different surgical or anesthetic approach and for certain patients, cancellation of elective surgery.[8-10] On the other hand most studies have reported a consistently high negative predictive value, at or above 95% for this technique. Presence of thallium redistribution, especially in increasing numbers of segments, identifies patients at high risk of perioperative cardiac complications,[32,36] whereas fixed defects identifies patients at intermediate risk, particularly for late cardiac events.[35]

Dobutamine stress echocardiography. Dobutamine stress echocardiography has been less extensively studied as compared to dipyridamole-thallium. Available data support its utility and safety with acceptable patient tolerance.[36-40] The degree of wall motion abnormality and/or wall motion change at low infusion rates of dobutamine identified high-risk patients. The positive predictive and negative predictive values for unambiguous endpoints (MI and death) were comparable to that of dipyridamole-thallium at 7% to 23% and 93% to 100%, respectively.

Ambulatory electrocardiographic monitoring. Studies using preoperative ambulatory ECG monitoring have demonstrated a negative predictive value similar to that of dipyridamole thallium.[41-44] However, current evidence does not support its sole use to identify patients to be referred for coronary angiography.[9]

Coronary angiography in perioperative evaluation for patients undergoing noncardiac surgery. Coronary angiography should be performed in patients who have unstable angina, angina refractory to medical treatment, high-risk results on noninvasive testing and/or a nondiagnostic test in high-risk patients undergoing high-risk noncardiac surgery. It should be considered on an individual basis in patients with intermediate-risk results during noninvasive testing, a nondiagnostic test in a low-risk patient undergoing high-risk surgery, urgent noncardiac surgery in a patient convalescing from MI and in patients who sustain a perioperative MI.[8,45]

Do the Benefits of Operation Outweigh the Probability of Cardiac Complications After Surgery? All information obtained from such a systematic stepwise approach for preoperative cardiac risk assessment for noncardiac surgery should then be utilized to decide whether the risk of perioperative cardiac events is sufficiently low to proceed with surgery. For patients identified at high cardiac risk who are not coronary revascularization candidates, this may result in a decision to perform a less extensive procedure or cancel the surgery. Once a decision is made to proceed with noncardiac surgery, the next goal is to attempt to modify cardiac risk by additional therapies, including coronary revascularization in high-risk individuals. The perioperative complication rate of revascularization must be carefully weighed against the risk of cardiac complications in such individuals.[8-10]

What Is Needed To Reduce the Probability of Cardiac Complications After Surgery in Terms of Modifying Preoperative, Intraoperative, and Postoperative Care? *Role of preoperative coronary artery bypass surgery.* Retrospective studies have suggested protection against postoperative cardiac complications and improved 5-year survival after noncardiac surgery in patient who have had prior CABG.[12,13,46-48] Eagle et al.[49] reexamined the value of CABG on patients undergoing specific noncardiac surgery among the patients enrolled in the CASS registry. Nonrevascularized patients undergoing high-risk surgery, including abdominal, vascular, thoracic, and head and neck procedures each had a combined MI/death rate of greater than 4%. Prior CABG was associated with a reduced incidence of postoperative death (1.7% versus 3.3%, $P = .03$) and MI (0.8% versus 2.7%, $P = .002$) as compared with the medical treatment group. Patients undergoing low risk procedures, such as urologic, orthopedic, breast and skin operations had low mortality of less than 1% regardless of prior revascularization. Prior CABG was also found to be more protective in patients with more severe angina and/or multivessel CAD.[49]

Patients with prior CABG usually require no further preoperative testing unless they have developed new coronary symptoms or are beyond 5 years of their CABG.[6-8] Indications for prior CABG in patients requiring noncardiac surgery includes acceptable coronary revascularization risk and viable myocardium with left main CAD, triple-vessel CAD in conjunction with left ventricular dysfunction, two-vessel CAD with proximal left anterior descending stenosis, and angina refractory to maximal medical management.[50]

Role of preoperative coronary angioplasty. To our knowledge, no randomized trial has addressed perioperative cardiac risk reduction following preoperative PTCA. Based on retrospective series with small numbers of patient, a select group of symptomatic patients facing high-risk surgery may benefit from preoperative PTCA.[51-53] The noncardiac surgery should probably be timed several days after PTCA as arterial recoil and acute thrombosis may occur within first few days and hypercoaguability may increase the risk of thrombosis. On the other hand, delaying surgery beyond one or two months following PTCA may increase the risk because of the possibility of restenosis. However, since the incidence of coronary restenosis is reduced beyond 6 months, patients who are asymptomatic and physically very active between 6 months to 5 years do not generally require further preoperative risk assessment before noncardiac surgery.[8-10]

Role of medical therapy. Small studies have evaluated the use of perioperative β-adrenergic blocking drugs in reducing cardiac risk.[54-56] Stone et al.[54] gave oral β-blockers two hours before the induction of anesthesia in a small randomized trial of patients with mild hypertension. The control group had higher incidence of ischemia as compared with treatment group (28% versus 2%). Similarly, the incidence of perioperative ischemia and MI has been shown to be reduced by metoprolol.[55,56] More recently, Mangano et al.[57] showed that vascular surgery patients randomized to atenolol versus placebo had a reduced cardiac event rate over the first year or two after surgery. Many consider this the strongest evidence yet favoring perioperative use of β-blockers. It should be noted that, an accompanying editorial[58] identified several concerns about the baseline differences between the atenolol and placebo groups. Finally, Froehlich et al.[59] recently reported protection against cardiac death after vascular surgery in patients treated with β-blockers in a large observational study.[59] Thus, in patients with strong suspicion for CAD, β-blockers should be given in perioperative period starting at least 24 hours prior to the procedure. Few data exist to support the use of calcium channel blockers or nitroglycerin. Currently, these are recommended for high-risk patients previously on such drugs or for those who have active signs of myocardial ischemia without hypotension.[9]

Choice of anesthetic drugs. The choice of anesthetic has not been found to play a significant role in the development of postoperative cardiac complications.[60-63] Because general anesthetics have a negative inotropic action, spinal anesthesia may be preferred

for patients with severe left ventricular dysfunction or history of CHF. Pain management in the perioperative period is crucial towards reducing cardiac risk. Adequate pain control reduces catecholamine surges which are likely responsible for increasing myocardial oxygen demand, induction of coronary vasospasm, increasing the tendency for plaque rupture and development of a hypercoaguable state.

Role of intraoperative monitoring. Pulmonary artery catheters are indicated for patients with limited ventricular reserve undergoing procedures that are likely to cause major hemodynamic shifts.[64] There is little data to recommend their use for the purposes of monitoring for ischemia.[9] The routine use of intraoperative transesophageal echocardiography is not recommended to monitor and guide therapy during noncardiac surgery because of lack of robust data. Literature supporting intraoperative ST-segment monitoring via telemetry or ambulatory monitoring in high-risk patients is limited.

Monitoring for perioperative myocardial infarction. Few studies have examined the optimal strategy for the diagnosis of perioperative MI.[65] A protocol using an ECG immediately after surgery and on first and second postoperative days has highest sensitivity; whereas routine measurements of serial creatine kinase-MB (CK-MB) had a higher false positive rate and does not increase the sensitivity. Higher levels of CK-MB elevation have been associated with worse survival.[66] Current recommendations favor monitoring for signs of cardiac dysfunction in patients with evidence of CAD. In such patients undergoing surgical procedures associated with high cardiac risk, ECG at baseline, immediately after surgery and on the first two postoperative days should be performed. Measurement of cardiac enzymes (CK-MB and Traponin) should be reserved for patients at high risk or those who demonstrate clinical, ECG or hemodynamic evidence of cardiovascular dysfunction.[8]

What Long-Term Risk Stratification and Management Strategies Should Be Implemented? Postoperative care involves assessment and treatment of modifiable cardiac risk factors, including hypertension, hyperlipidemia, smoking, obesity, hyperglycemia, and physical inactivity. Patients who sustain a perioperative MI or develop evidence of ischemia should be carefully investigated as they have substantial cardiac risk over the subsequent 5 to 10 years. Noninvasive testing to assess left ventricular function and inducible ischemia should be undertaken to identify patients who may benefit from revascularization or optimization of medical therapy.[8-10]

NONCARDIAC SURGERY IN PATIENTS WITH SPECIFIC CARDIOVASCULAR DISEASE

Valvular Heart Disease. Severe aortic stenosis (AS) poses a high risk during noncardiac surgery.[14] Patients with severe symptomatic AS should undergo aortic valve replacement before noncardiac surgery. In some instances balloon aortic valvuloplasty is justified before elective noncardiac surgery. A retrospective study suggests that selected patients with asymptomatic severe AS could safely undergo noncardiac surgery provided hemodynamics were carefully monitored.[67] Heart rate should be controlled to ensure sufficient diastolic filling period and avoid pulmonary congestion in patients with mild to moderate mitral stenosis. Patients with severe mitral stenosis benefit from balloon mitral valvuloplasty or surgical repair before high-risk surgery. Patients with aortic and mitral regurgitation benefit from volume control and afterload reduction. A slow heart rate increases diastolic filling per minute and can exacerbate left ventricular volume overload owing to aortic regurgitation. Faster heart rates are better tolerated in this condition.

Patients with mechanical prostheses should have their prothrombin times reduced briefly to low or subtherapeutic range for minor procedures like dental work and superficial biopsies, and resume their anticoagulation immediately following the procedure. Patients at high risk of bleeding taking oral anticoagulants and at high risk of thrombotic complications if taken off oral anticoagulants should receive perioperative heparin. Between these two extremes, individual assessment for the risk and benefit of reduced coumadin anticoagulation versus perioperative heparin (with brief interruption surrounding surgery) should be made. Patients with valvular heart disease require appropriate antibiotic prophylaxis for endocarditis.

Arrhythmias and Conduction Defect. Cardiac arrhythmias in the perioperative period are common, and are usually indicative of underlying cardiopulmonary disease, drug toxicity, or metabolic disturbances.[14] Third degree atrioventricular block can increase operative risk and necessitates pacing.[9]

Congestive Heart Failure and Left Ventricular Dysfunction. Congestive heart failure has been identified as significant marker of cardiac risk for noncardiac surgery.[68] Every effort should be made to identify the etiology of CHF. Patients should be appropriately treated for CHF before noncardiac surgery. Close monitoring of the volume status is needed to avoid decompensation. Intravenous inotropic drugs and/or vasodilators are often useful

for a short duration in the perioperative period in the prevention and treatment of CHF.

Hypertrophic Cardiomyopathy. A decreased preload (large amount of blood or fluid loss or pain-induced tachycardia that reduces diastolic filling), reduced afterload or increase in contractility (caused by inotropic drugs) is poorly tolerated and should be avoided in patients with hypertrophic cardiomyopathy. Patients with hypertrophic cardiomyopathy are at significant risk for developing perioperative hypotension, CHF and arrhythmias and should be monitored closely.[69]

Congenital Heart Disease. Studies have demonstrated that patients with left-to-right cardiac shunts have residual hemodynamic abnormalities even after surgical repair, including decreased cardiac output response to exercise.[70,71] Vigorous treatment of CHF is required for such patients before noncardiac surgery. Patients with large left-to-right shunts, but only a slight increase in pulmonary artery resistance should undergo cardiac repair before noncardiac surgery. Patients with irreversible pulmonary artery hypertension have an extremely high risk associated with surgery and should not undergo elective procedures.

Patients with prior repair of coarctation of the aorta have a significant frequency of sudden death during follow-up due to either residual cardiac defects with CHF, rupture of a major vessel, dissecting aneurysm, or complications arising from severe atherosclerosis.[72,73] Such patients also have a high incidence of residual hypertension. Therefore, close perioperative hemodynamic monitoring is required.

Patients with tetralogy of Fallot are also prone to sudden cardiac death.[74] Monitoring and treatment of life-threatening arrhythmias such as ventricular tachycardia or atrioventricular block is recommended for such patients in the perioperative period.

Surgery in patients with cyanotic congenital heart disease with right-to-left shunts poses several unique problems. Most cyanotic patients are polycythemic, and therefore, are prone to thrombotic complications. Use of diuretics should be avoided for such patients, as dehydration may increase the blood viscosity and further increase the risk of thrombosis, particularly cerebral thrombosis. Patients with a hematocrit greater than 70% should undergo plasmapheresis before noncardiac surgery. Phlebotomy is not advisable in this circumstance, since this can decrease intravascular blood volume, increasing cyanosis. Those with a hematocrit between 55% and 65% should receive intravenous fluids starting the night before the surgery. Patients with congenital heart disease should also receive appropriate prophylaxis for bacterial endocarditis. A recent retrospective report suggests that careful monitoring and precautions as outlined earlier, patients with right-to-left shunt could undergo noncardiac surgery with fewer complications.[75] **CT**

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