Grand Rounds

Preoperative Cardiovascular Evaluation for Noncardiac Surgery

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Abstract

Cardiovascular complications following noncardiac surgery constitute an enormous burden of perioperative morbidity and mortality. Annually, more than one million operations are complicated by adverse cardiovascular events, such as perioperative myocardial infarction or death from cardiac causes. In order to combat this problem, cardiac evaluation prior to noncardiac surgery should ask two questions about the patient: What is the risk of cardiac complications during and after surgery? How can that risk be reduced or eliminated?

Risk assessment evaluates patients' co-morbidities and exercise tolerance, as well as the type of surgery to be performed, to determine the overall risk of perioperative cardiac complications. Previous or current cardiac disease, diabetes and renal insufficiency all confer higher risks for perioperative cardiac complications. Poor exercise tolerance and high-risk surgical procedures (e.g., vascular, prolonged thoracic or abdominal operations) also predict worse perioperative outcomes. Noninvasive stress testing is widely used to help predict risk of perioperative complications, but the poor predictive power of these tests hampers their usefulness.

After estimating the risk of cardiac complications, one should take measures to reduce it. Beta blockade has shown clear benefits in risk reduction. At this time, there are no data suggesting benefits of percutaneous coronary intervention or coronary artery bypass grafting in reducing noncardiac surgical risk. In addition, angioplasty with stenting and its attendant need for anticoagulation can expose patients to increased risk of perioperative bleeding. Thus, the use of coronary revascularization prior to noncardiac surgery should be reserved for those patients with an independent cardiac need for the procedure, such as unstable angina or stable angina refractory to medical therapy.

In summary, patients with low clinical risk factors and good functional status, undergoing a low or intermediate risk surgery, have an excellent prognosis and may proceed to surgery without further delay. In addition, stable patients who have previously undergone coronary revascularization may also safely undergo surgery. Patients requiring urgent surgery should proceed immediately, since the consequences of delay usually outweigh the benefits of preoperative risk assessment. However, elective surgery should be indefinitely deferred for those patients with unstable coronary syndromes, since consequences of the cardiac disease usually negate the benefits of surgery. Controversy involves the intermediate or high clinical risk patient considering high-risk, but elective, surgery. Noninvasive testing offers only limited assistance in estimating risk for these patients. The best risk reduction strategy for these patients is perioperative beta blockade use. The role of coronary revascularization specifically to reduce perioperative cardiac complications remains unproven.

Key Words: Coronary artery disease, perioperative care, percutaneous coronary intervention, coronary artery bypass grafting, intra-operative complications, postoperative complications, risk assessment, risk factors, surgical procedures.

CARDIOVASCULAR COMPLICATIONS following noncardiac surgery constitute an enormous burden of perioperative morbidity and mortality. Approximately 30 million patients have surgery annually in the United States and almost one-third of them have coronary artery disease (CAD) or risk factors for its development. More than one million operations are complicated by adverse cardiovascular events, such as perioperative myocardial infarction (MI) or death from cardiac causes (1). In high-risk populations, such as patients undergoing vascular surgery, the incidence of perioperative MI can reach 34% (2, 3). Perioperative MI causes substantial morbidity and prolonged hospitalizations, and has mortality rates as high as 25–40% (2, 3). The economic effects of these complications are also sobering, with annual costs estimated at $20 billion (4).

Given these numbers, it is hardly surprising that surgeons and anesthesiologists frequently consult cardiologists to "clear" a patient for noncardiac surgery. Cardiac evaluation prior to noncardiac surgery should ask two questions about the patient: What is the risk of cardiac complications

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during and after surgery? How can that risk be reduced or eliminated? While the questions may be straightforward, the answers are far from clear.

Cardiac Risk Assessment

Ideal risk evaluation has several components. It should be accurate, meaning the clinical criteria used to evaluate patients are significant predictors of adverse cardiac outcomes. Risk evaluation should also be efficient, so that each clinical variable collected adds independent and useful information to the overall risk assessment. Finally, it should be timely, providing information quickly, so as not to cause unnecessary delays in the decision to perform or postpone the planned surgery. These considerations are also important in the use of provocative tests of cardiac function. Such testing should accurately stratify patients into lower- and higher-risk groups, add independent information to the overall risk assessment, and avoid unnecessary delays or added risks in the process (1).

Risk evaluation is only the first step in preoperative evaluation. Once this risk is quantified, clinicians must then be able to act on the information. Are there interventions to significantly reduce risk? Do these interventions expose the patient to potential harm or cause unnecessary delays in surgery? Does the benefit of the intervention justify the risks? The availability of effective interventions also has implications for clinical risk assessment; if there is no therapy to attenuate cardiac risk, then the value of obtaining additional testing is questionable. With careful consideration of these principles, preoperative risk assessment and reduction can serve as powerful tools to enable clinicians to optimize patients' cardiac health during the perioperative period.

The most recent American College of Cardiology (ACC)/American Heart Association (AHA) practice guidelines recommend assessment of patients' co-morbidities and exercise tolerance, as well as the type of surgery to be performed, to determine the overall risk of perioperative cardiac complications (5). Based on this assessment, selected patients should undergo provocative cardiac testing; others may require interventions to mitigate risk.

Clinical Risk Indices

Over the past 25 years, several models for assessing perioperative cardiac risk have been described. In 1977, Goldman et al. described a cardiac risk index for patients undergoing general, orthopedic, or urologic surgeries. Evidence of cardiac ischemia or failure, arrhythmias, older age, valvular disease, poor medical condition, or need for high-risk surgery identified patients at high risk for perioperative cardiac complications (6). Nine years later, Detsky et al. described a risk index with enhanced predictive power for patients undergoing vascular or general surgeries (7).

Most recently, Lee et al. offered a cardiac risk index that provided an effective yet simple method of assessing risk (2). The authors studied 4,315 patients, aged 50 years or older, who had undergone elective major noncardiac surgeries. Approximately half of the patients were assigned to a derivation cohort to establish predictive clinical variables, while the other half were assigned to a validation cohort to test the index. Six independent predictors of cardiac complications were identified: high-risk surgery (procedures with a 5% or higher risk of cardiac complications, such as vascular and prolonged intraperitoneal or intrathoracic operations); history of ischemic heart disease; history of congestive heart failure; history of cerebrovascular disease; preoperative treatment with insulin; and preoperative serum creatinine > 2.0 mg/dL.

When patients were stratified by these criteria, rates of major cardiac complications with 0, 1, 2, or 3+ criteria were 0.5%, 1.3%, 4%, and 9%, respectively, in the derivation cohort. There was no significant difference in complication rate between those with 0 or 1 clinical factor, but meaningful differences in complications occurred between these groups and the two higher-risk groups. When the model was applied to the validation cohort, the model's predictive power remained. In another assessment of its power, the index was compared to the Goldman and Detsky risk indices using Receiver Operating Curves (ROC). The Lee index had significantly greater predictive power than the other two indices.

Despite its predictive power, Lee's model is not without flaws. It is underpowered to investigate the relationship between risk class and cardiac complications for patients undergoing abdominal aortic surgery. Since the study was conducted with patients at a single teaching hospital, the ability to generalize its findings is somewhat limited. The index was also designed to be simple, using only dichotomous variables to assess risk. Thus, some accuracy may have been sacrificed in the pursuit of simplicity—perhaps a reasonable tradeoff in pursuit of a practical prediction tool. Despite these limitations, the Lee index remains a valuable tool for predicting risk. Based on this and related studies, the ACC/AHA guidelines currently classify patients at intermediate clinical risk for complications if they suffer from a previous MI, angina, heart failure, diabetes, or renal insufficiency (5).

Functional Capacity Assessment

The guidelines also recommend that a patient's functional capacity be incorporated into the overall risk assessment (5). This recommendation comes from a study of 600 outpatients undergoing non-cardiac surgery (8). Patients were classified with good or poor exercise tolerance based on their self-reported ability to either walk 4 blocks or climb 2 flights of stairs. Significant differences in the clinical characteristics of these two groups were noted; the poor-exercise-tolerance group had higher numbers of patients with congestive heart failure, hypertension, and diabetes. Not surprisingly, calculation of the Detsky cardiac risk index for these patients (the Lee index had not been published at the time of this study) illustrated higher risk scores in the poor exercise tolerance group (7). During the perioperative period, the rates of major adverse cardiac events (i.e., cardiac death and MI) were similar for the two groups. However, minor complications, such as myocardial ischemia and neurological events, occurred with greater frequency in the poor exercise tolerance group. Accordingly, exercise capacity assessment has a role in preoperative risk calculation.

Surgical Risk

The nature of the planned surgical procedure is an important factor in risk assessment. Vascular surgeries are especially prone to cardiac complications, with rates exceeding 5%, presumably due to the high concurrence of CAD and peripheral vascular disease (PVD), the masking of CAD symptoms secondary to the exercise impairment associated with PVD, as well as the length of operation and substantial fluid shifts inherent in such surgeries (10). Additionally, several large surveys have demonstrated that perioperative cardiac mortality is elevated among patients who undergo major thoracic, abdominal, or vascular surgery, especially when they are 70 years old or older (11 – 15).

Noninvasive Diagnostic Testing

As with clinical risk assessment, noninvasive diagnostic testing must be used judiciously. Effective testing should be accurate, add useful information to the overall risk assessment, and avoid unnecessary delays in surgery. In addition, testing should be performed only when it will lead to therapies that are proven to reduce perioperative cardiac risk (1).

Myocardial perfusion imaging. Stress myocardial perfusion imaging is widely used to assess perioperative risk. By virtue of vasodilator use, perfusion imaging can be used for nearly all patients, even those whose medical conditions preclude exercise (e.g., PVD). A positive test result occurs when heterogeneity in radionuclide activity is demonstrated in different segments of the myocardium. Whether this finding can reliably predict cardiac risk is unclear. In reports of patients undergoing vascular surgery, the percentage of patients with positive perfusion tests ranged from 23 – 69%, but the positive predictive value of the test for perioperative cardiac complications was only 4 – 20% (5). The negative predictive value, in contrast, remained uniformly high at approximately 99% (5). Thus, though a negative perfusion test result can offer substantial reassurance to patients and physicians alike, the predictive power of a positive test is poor.

In addition, even when perfusion imaging provides an accurate prediction of increased risk, it may not add independent prognostic value beyond that of clinical risk stratification. Vanzetto et al. illustrated effective stratification of high-risk patients undergoing abdominal aortic surgery using perfusion imaging. Patients with a normal scan had a cardiac event rate of 2%, while those with thallium redistribution had a rate of 23% (16). Another study, by Bartels et al., closely paralleled the ACC/AHA guidelines in its assessment of patients, allowing both high- and intermediate-risk patients with a low functional capacity to receive thallium imaging. Abnormal results prompted further cardiac management (not specified), and the subsequent rate of perioperative cardiac complications did not differ significantly across risk groups (17). Though these results offer support for the use of perfusion imaging, the lack of a control group and the heterogeneity of cardiac management of those patients with abnormal scans weaken these conclusions.

Importantly, a large, blinded, prospective study by Baron et al. revealed that myocardial perfusion imaging did not provide independent prognostic value beyond that of clinical risk stratification. Definitive clinical evidence of CAD and age over 65 years old were better predictors of cardiac complications (18).

Dobutamine stress echocardiography. Dobutamine stress echocardiography (DSE) is another test widely used to predict perioperative risk. DSE evaluates left ventricular regional wall motion at rest and during dobutamine stress. The test's adrenergic stimulation offers a better approximation of the stress encountered during the perioperative period than that provided by vasodilators (1). Unfortunately, the accuracy of the test in predicting cardiac complications is similar to that of perfusion imaging. The data indicate that the range of positive test results for patients undergoing vascular surgery is 9 – 50%, with a positive predictive value for cardiac complications ranging from 7 – 25%. The negative predictive value ranges from 93 – 100% (5). However, DSE does appear to add incremental information to risk assessment in certain selected cases. A study by Boersma et al. illustrated that stress-induced ischemia on DSE independently predicted perioperative cardiac complications in high-risk patients undergoing vascular surgery. Furthermore, those with more extensive ischemia (> 4 wall segments involved) carried a higher risk of complications than did those with more limited ischemia (19). The recent ACC/AHA guidelines corroborate this finding, stating that the weight of the evidence supports the use of DSE for assessing preoperative risk for properly selected patients, especially those undergoing peripheral arterial revascularization (5).

In summary, the appropriate use of noninvasive testing in the assessment of perioperative cardiac complications is controversial. The low positive predictive value of both myocardial perfusion imaging and DSE greatly hampers their accuracy. Whether or not additional information regarding cardiac risk can be derived from these tests is also unclear, although the evidence seems to imply a greater role for DSE than for myocardial perfusion in stratifying high-risk patients. The greatest concern, however, lies with the next step. Once the risk of cardiac complications is estimated, what interventions can mitigate it?

Therapy to Reduce Perioperative Risk

Medical Therapy

Several medical treatments have been proposed to help reduce cardiac risk in noncardiac surgeries. The most extensively studied treatment is beta blockade. Mangano et al. studied the effects of atenolol administered to high-risk patients two days prior to their noncardiac surgeries (20). There was no difference between the atenolol and control groups in perioperative cardiac complications, but a long-term mortality benefit in the atenolol group was demonstrated at 6 months. Poldermans et al. studied the perioperative use of bisprolol in elective major vascular surgery (3). Patients with at least one clinical risk factor and demonstrable ischemia by dobutamine stress echo were given bisprolol an average of 37 days prior to their surgeries and to achieve a resting heart rate at or below 60 beats per minute (bpm). Notably, patients with extensive wall motion abnormalities on echo, arguably the highest-risk patients, were excluded from the study. Nonetheless, perioperative MI and death from cardiac causes were reduced by 91% in the bisprolol group.

Using the same cohort of patients from the Poldermans study, Boersma examined the effect of bisprolol, as stratified by clinical risk score and DSE results. In patients with fewer than 3 clinical risk factors (low or intermediate risk in the revised cardiac risk index), bisprolol significantly reduced cardiac complications compared to controls. Similarly, patients with 3 or more clinical risk factors and a DSE with wall motion abnormalities in 4 or fewer segments also demonstrated a significant decrease in cardiac complications with the use of bisprolol. However, high clinical risk patients with wall motion abnormalities in 5 or more segments did not benefit from perioperative use of bisprolol (19). Taken together, these two studies illustrated that bisprolol, started well before noncardiac surgery, can substantially reduce perioperative cardiac complications in all but the highest-risk patients. Questions remain as to whether these findings extend to all types of beta blockers, as well as the optimal initiation time of therapy. In addition, patients with severe left ventricular dysfunction were excluded from these studies, so the role of perioperative beta blockade in this population is unknown (1). Nonetheless, the convincing findings of Poldermans and Boersma confirm a salutary role for beta blockade in a substantial number of cardiac patients.

Other medical therapies under investigation include alpha-2 receptor agonists, nitrates, calcium channel blockers, and statins. Patients with established CAD undergoing vascular surgery were treated perioperatively with the alpha-2 agonist mivazerol. Compared to controls, there was a significant reduction in MI and death from cardiac causes (21). However, these results were not duplicated in another placebo-controlled, randomized, blinded study of mivazerol (22). In that study, no differences in perioperative death or MI were observed between treatment and control groups, although significantly less myocardial ischemia occurred in the mivazerol group. Studies with clonidine did not illustrate a reduction in death and MI, although a lower incidence of intraoperative myocardial ischemia was noted (23). Nitrate use to reduce intraoperative ischemia has had uneven effects, with no apparent reduction in incidence of MI or cardiac death (24, 25). Studies of calcium channel blockers have been too small to draw meaningful conclusions on their use (26). Finally, Poldermans et al. studied the use of statin therapy in patients undergoing major vascular surgery at a single medical center (27). The statin group had a significant reduction in perioperative mortality compared to the placebo group. More recently, an observational study by Lindenauer et al. supported these findings by illustrating a reduction in death perioperatively for patients receiving statins (28). Despite these initial promising studies, beta blockade is the only medical therapy with conclusive evidence of cardiac risk reduction at the current time.

Coronary Artery Bypass Grafting

No randomized, controlled trials show benefit of coronary artery bypass grafting (CABG) surgery in attenuating the risks of noncardiac surgery (4). However, several observational studies have examined the incidence of perioperative cardiac complications among noncardiac surgical patients who had previously undergone CABG surgery for coronary artery disease. Fleisher et al. found that CABG revascularization in anticipation of aortic surgery was not associated with improved perioperative survival, but that it benefited long-term mortality (29). Eagle et al. examined CABG patients from the Coronary Artery Surgical Study (CASS) database who had undergone subsequent high-risk noncardiac surgeries. Compared to patients without previous CABG, the revascularized patients experienced significantly fewer cardiac complications perioperatively (30). More recently, an analysis of the Bypass Angioplasty Revascularization Investigation (BARI) trial found that patients revascularized, either by CABG or percutaneous coronary intervention (PCI) had similarly low rates of postoperative cardiac complications. Taken together, these retrospective studies imply a low risk of cardiac complications for patients who have recently undergone CABG surgery. Accordingly, the ACC/AHA guidelines recommend that asymptomatic patients who have undergone CABG in the previous five years should proceed directly to noncardiac surgery without further preoperative evaluation (5).

Despite these findings, CABG is not recommended for asymptomatic patients *solely* for the purpose of reducing the risks of noncardiac surgery. The risk of CABG surgery, combined with the delay in needed noncardiac surgery, usually outweighs the potential risks of proceeding with surgery. Two studies, one by Mason et al. and the other by Fleisher et al., validated this concept. Both demonstrated that performing CABG prior to vascular surgeries can be harmful—chiefly by exposing the patients to multiple surgeries and their risks (31, 32). Thus, CABG surgery should be performed, and noncardiac surgery delayed, *only* if there are independent indications for CABG surgery.

Percutaneous Coronary Intervention

In many centers, findings of ischemia or CAD during noninvasive testing lead to coronary catheterization and potentially to PCI (usually balloon angioplasty with stenting) of associated plaques. Although a trial assessing the role of PCI and CABG in reducing surgical risk is currently underway, currently no data suggest benefit of PCI in reducing noncardiac surgical risk (5, 33). Several cohort studies have illustrated a low incidence of cardiac complications in PCI patients during noncardiac surgery, but none of those studies had control groups (34–36). Interestingly, Posner et al. showed no benefit of PCI in preventing perioperative cardiac complications when performed within 90 days of surgery (37). More recently, Landesberg et al. investigated the role of revascularization in reducing cardiac risk (38). The study compared two groups of patients with high clinical risk and moderate-to-severe reversible thallium perfusion scans undergoing major vascular surgery. One group received coronary revascularization, while the other proceeded directly to surgery. The revascularization group had significant long-term survival at 5 years. However, the study failed to report the incidence of perioperative MIs, and there was no significant mortality benefit noted at either 30 days or 1 year. In light of these limited findings, the use of PCI prior to noncardiac surgery should be reserved for those patients with an independent need for the procedure (i.e., those with unstable angina or stable angina refractory to medical therapy).

In summary, the risk of cardiac events during noncardiac surgery can be mitigated, but only with beta blockade. As investigation continues, there may be roles for other drug therapies, as well as for coronary revascularization. However, as new methods of risk reduction emerge, each must be evaluated in the context of its benefits, risks and delays to the planned surgery.

Noncardiac Surgery Safety and Coronary Stenting

The recent use of coronary stenting in the treatment of CAD introduces a new wrinkle in preoperative evaluation. Placement of coronary stents causes complete denudation of the arterial endothelial surface, greatly increasing the risk of thrombosis (39, 40). Fortunately, this risk is attenuated with the use of combined antiplatelet therapy (aspirin and clopidogrel) and improvements in stent deployment. Currently, the incidence of stent thrombosis is less than 1% (41).

The impact of noncardiac surgery on stent thrombosis, and thus the optimal delay of the surgery after coronary stenting, is unknown. Surgery promotes, and by necessity requires, thrombosis (41). Surgical stress activates the sympathetic nervous system, which may indirectly trigger adverse cardiac and vascular outcomes. Plasma procoagulant clotting factors increase and fibrinolysis decreases, resulting in a hypercoagulable state and potentially increasing the thrombosis risk to recently placed stents (42). In addition, the use of antiplatelet agents in the perioperative period is problematic. Their essential role in preventing stent thrombosis may simultaneously increase the risk of surgical bleeding to unacceptable levels.

Initial studies investigating noncardiac surgery soon after coronary stenting are instructive. Kaluza et al. followed 40 patients who underwent noncardiac surgery (mostly vascular) within 6 weeks of receiving a coronary stent and noted 7 MIs, 11 major bleeding episodes, and 8 deaths (43). All of the deaths and MIs, as well as most of the bleeding incidents, occurred within 2 weeks of stent placement. Predictably, most of the adverse events resulted from either in-stent thrombosis or uncontrolled bleeding due to the use of antiplatelet drugs. A larger study by Wilson et al. examined 207 patients undergoing noncardiac surgery within two months of receiving coronary stenting (41). All adverse events (MI and death from cardiac causes) occurred within 6 weeks of stent placement, although the overall rate of complications was much lower than that in the Kaluza study. No events occurred in patients undergoing surgery 7 – 9 weeks after stent placement. Based on these and related studies (44, 45), current ACC/AHA recommendations suggest delaying noncardiac surgery for a minimum of 4, and preferably 6 weeks (5).

Future innovations in PCI will require ongoing evaluation. The use of coronary brachytherapy appears to prolong the re-endothelialization of coronary arteries, which may necessitate longer waiting periods after stenting, before surgery can be performed safely (46). Similar concerns surround drug-eluting stent use, and these require investigation. The role of heparin-coated stents also needs definition. Some interventionalists advocate their use to avoid the need for oral antiplatelet therapy and its concomitant bleeding risks during surgery. Although some early trials have suggested low rates of thrombosis with these stents, no randomized controlled trials have evaluated their role in stent thrombosis prevention, either in general or in preparation for noncardiac surgery (9, 47). Further research is required before their use can be recommended.

In summary, coronary stenting in CAD treatment has significant implications for noncardiac surgery timing. At this time, guidelines recommend 6 or more weeks of recovery and antiplatelet use after PCI before undergoing surgery. The risks of surgical delay must be weighed against the benefits of PCI.

Conclusions and Recommendations

Successful perioperative evaluation and management of high-risk cardiac patients undergoing noncardiac surgery requires careful teamwork and communication among the surgeon, anesthesiologist, primary care physician, and cardiology consultant (5). In general, patients with low clinical risk factors and good functional status, undergoing a low- or intermediate-risk surgery, have an excellent prognosis and may proceed to surgery without further delay. In addition, stable patients who have recently undergone coronary revascularization may also safely undergo surgery, provided sufficient time for recovery from the revascularization procedure has elapsed. At the other end of the spectrum, patients requiring urgent surgery should proceed immediately, regardless of cardiac risk, since the consequences of delay usually outweigh the benefits of perioperative cardiac risk assessment. However, elective surgery should be deferred indefinitely for those patients with unstable coronary syndromes, since consequences of the cardiac disease usually negate the benefits of surgery.

The most controversial area of perioperative evaluation, then, lies with the intermediate or high clinical risk patient considering high-risk, but elective, surgery. Noninvasive testing appears to offer limited assistance in stratifying the risks of these patients, with the best evidence pointing to dobutamine stress echocardiography as the test of choice. Once risk is identified, the most effective intervention is the use of beta blockade. The role of coronary revascularization specifically to reduce perioperative cardiac complications remains uncertain.

Efforts to define more clearly the role of noninvasive imaging and PCI in cardiac risk estimation and reduction are needed. In addition, with improvements in our ability to diagnose and treat CAD and ischemia, incorporation of this new knowledge into risk assessment will be important.

Finally, in an era when the best practices entail not only the highest quality care for the individual but also the best use of societal resources, determination of the most cost-effective strategies to evaluate and prevent perioperative cardiac complications is crucial.

As the population continues to age, conducting effective cardiac risk assessment will become increasingly important. Knowing what to do and, equally important, what not to do, will be central to this task.

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