Preoperative cardiac evaluation

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Each year in the United States nearly 30 million patients are estimated to undergo noncardiac surgery, and about one third of these patients have coronary artery disease (CAD) or risk factors for CAD [1]. About 1 million of those patients have perioperative cardiac complications that result in more than $20 billion in health care expenditures [1]. The current standards for preoperative cardiac evaluation of these patients are the guidelines published by the American College of Cardiology (ACC) and the American Heart Association (AHA), initially in 1996 [2] and updated in 2002 [3]. These guidelines were developed based on a review of the then-available literature and the opinions of experts from the disciplines of anesthesiology, cardiology, electrophysiology, vascular medicine, vascular surgery, and noninvasive cardiac testing. The guidelines provided an eight-step algorithm for stratifying patients’ risks and triaging patients to surgery or cardiac evaluation.

Unless the proposed surgery is emergent, in which case the patient needs to be taken to the operating room without any delay for preoperative cardiac evaluation, the ACC/AHA guidelines consider five factors in determining whether or not a patient should undergo further cardiac testing for risk stratification. The five factors are (1) recency of coronary revascularization, if any; (2) recency of the last favorable cardiac evaluation; (3) presence of patient comorbidities, classified as major, intermediate, or minor clinical predictors; (4) the patient’s functional status; and (5) the risk of the proposed surgery.

If the proposed surgery is not emergent, patients are not deemed to need any further cardiac evaluation if they have had coronary revascularization within the past 5 years or a favorable cardiac evaluation within the last 2 years without any intervening change in symptoms. Lacking these two criteria, one needs to consider comorbidities, functional status, and the risk of the proposed surgery. Among comorbidities, major clinical predictors are unstable coronary syndromes, acute (<1 week) or recent (<1 month) myocardial infarction (MI), decompensated

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congestive heart failure (CHF), significant arrhythmias, and severe valvular diseases. Intermediate clinical predictors are stable angina, history of MI more than 1 month ago, history of CHF, diabetes mellitus, and chronic renal insufficiency with serum creatinine greater than 2 mg/dL. All other risk factors (eg, advanced age, hypertension, history of stroke) are considered to be minor clinical predictors by the ACC/AHA guidelines and do not figure into the triage decision. As for the patient’s functional status, application of the guidelines requires distinguishing whether or not it is poor. A patient has poor functional status if she or he is unable to perform activities of greater than 4 metabolic equivalents (METS) without becoming symptomatic of chest pain or shortness of breath. One MET is the resting metabolic rate or the amount of oxygen consumed while sitting at rest, which is 3.5 mL/kg/min. Examples of activities that require less than four METS include driving (2 METS), cooking (2.5 METS), bowling (2–4 METS), walking for exercise at 5 km/hr or less (<3.3 METS), raking leaves (3–4 METS), and golfing while riding a cart (2–3 METS) [4]. Example of activities that require more than 4 METS include walking at 7 km/hr (5.3 METS), walking up stairs (4.7 METS), snow shoveling (5.1 METS), and washing windows (4.9 METS) [4].

The risk of the proposed surgery is classified as high, intermediate, or low depending on if the perioperative cardiac event rate is greater than 5%, 1% to 5%, or less than 1%. CHF, MI, and cardiac death are considered to be cardiac events. Examples of high-risk surgeries include peripheral vascular bypass surgery, aortic surgery, and emergency major operations, especially in the elderly. Examples of intermediate-risk surgeries include carotid endarterectomy, intraperitoneal and intrathoracic surgery, orthopedic surgery, head and neck surgery, and prostate surgery. Whether a given surgery should be classified as high-, intermediate-, or low-risk depends, in part, on institutional morbidity and mortality data, which might not always be available. Application of the ACC/AHA guidelines should be tailored to each institution’s risks whenever possible.

When the proposed surgery is not emergent and the patient has not had a recent coronary revascularization or a recent favorable cardiac evaluation, there are three indications for further cardiac evaluations according to the ACC/AHA guidelines: (1) presence of a major clinical predictor; (2) presence of an intermediate clinical predictor or poor functional status, if the proposed surgery is high-risk; and (3) presence of an intermediate clinical predictor and poor functional status, if the proposed surgery is intermediate-risk. A pervading consideration in the application of ACC/AHA guidelines is that “in general, indications for further cardiac testing and treatments (in the operative setting) are the same as those in the nonoperative setting” [3]. That is, if there is no indication for cardiac testing independent of the proposed surgery, the test should probably not be performed just because the patient is about to have an operation.

Evidence is mounting that verbatim application of the ACC/AHA guidelines might not be warranted [5]. In the following sections there is discussion of the value of noninvasive cardiac tests versus clinical variables in preoperative risk stratification, the implication of risk modification by perioperative β-adrenergic blockade on preoperative cardiac evaluation, and the effect of preoperative pro-
phylactic coronary revascularization. Lastly, preoperative evaluation of patients who have cardiac valvular diseases is discussed.

**Noninvasive cardiac tests**

Noninvasive cardiac tests assess myocardial function or perfusion. Tests of myocardial systolic function include transthoracic echocardiography and radionuclide scanning, in which the left ventricular ejection fraction (LVEF) is often reported as if it were the sine qua non of myocardial function. While a few small studies [6,7] have reported a correlation between preoperative LVEF and perioperative cardiac events, larger series have generally found that echocardiographic measurement of a low LVEF might be specific of cardiac complications, and thus, have a high negative predictive value (ie, when the EF is not low, cardiac complications are unlikely), but is not a sensitive indicator, so it has a low positive predictive value (ie, even when the EF is low, cardiac complications are still infrequent) [8]. In a position paper, the American College of Physicians recommends against noninvasive assessment of resting LVEF by radionuclide angiography or transthoracic echocardiography to predict perioperative cardiac risk [9].

Many patients who have a clinical diagnosis of CHF and normal systolic function might have diastolic dysfunction [10]. A detailed assessment of diastolic function can be provided by echocardiography, and a scoring system has been proposed [11], but so far no studies have examined the prognostic value of preoperative diastolic dysfunction in noncardiac surgical patients.

Noninvasive tests of myocardial perfusion might be classified by the type of stress applied to elicit transient and reversible ischemia or by the mode of detecting the ischemic area [12]. Stress can be applied by exercise (eg, treadmill, sitting or supine bicycle, or handgrip), by a pharmacologic agent that increases chronotropy and inotropy (eg, dobutamine, atropine), or by a pharmacologic agent that can cause malredistribution of coronary blood flow (eg, dipyridamole, adenosine). A significant fraction of the high-risk population cannot exercise to an adequate level and will require pharmacological stress testing. An ischemic event might be suggested or detected by the patient’s reporting of symptoms, appropriate ECG changes (horizontal or downsloping ST segment depression of $\geq 0.1$ mV or ST elevation of $\geq 0.15$ mV in two contiguous leads [13]), reversible wall motion abnormalities on echocardiography, or reversible perfusion defects on radionuclide imaging with thallium or technetium.

Dobutamine stress echocardiography (DSE) and dipyridamole thallium imaging (DTI) have high negative predictive values that approach 100% but have low positive predictive values that are generally less than 20% [14]. The likelihood ratio of a positive test, which indicates how much the odds of a cardiac event increase when the test is positive, is computed as sensitivity/(1–specificity), whereas the likelihood ratio of a negative test, which indicates how much the odds of a cardiac event decrease when the test is negative, is computed as (1–sensitivity)/specificity. For a test to be considered to be useful in risk strati-
fication, the likelihood ratio of a positive or negative test should be greater than 10 or less than 0.2, respectively, because these numbers indicate a substantial change in risk from the pretest level [14]. While the likelihood ratios of negative DSE and DTI are often good, the likelihood ratios of positive tests are usually much less than 10, so these tests might not yield any useful information for risk stratification [14].

Furthermore, in a review of 85 patients [15], even when DSE was obtained in accordance with the ACC/AHA guidelines, the test was positive in only 4.7% of the patients. Thus, even when the guidelines are followed, not only is it unlikely that the stress test will be positive, but even when the test is positive, the likelihood of an adverse event is too low for the test to be considered to be discriminating in most circumstances.

Rather, the study by Lee et al [16] suggests that simple consideration of clinical risk factors might be sufficient in risk stratification. Lee et al first identified six clinical factors that predicted major cardiac complications in a derivation cohort of 2893 patients undergoing elective noncardiac surgery. These factors were (1) high-risk surgery, (2) history of CAD, (3) no history of revascularization, (4) history of CHF, (5) preoperative use of insulin, and (6) preoperative serum creatinine greater than 2 mg/dL. The authors then validated the six factors in a validation cohort of 1422 patients, in whom the cardiac event rates with zero, one, two, or greater than or equal to three of the six risk factors were 0.4%, 0.9%, 7%, and 11%, respectively. Therefore, patients who have two or more risk factors can be considered to be at high risk.

**Risk modification by perioperative β-adrenergic blockade**

Patients who have suspected or known CAD can undergo major noncardiac surgery with relative safety when they are given a β-adrenergic blockade perioperatively [17–19]. Poldermans et al [19] studied 112 high-risk patients undergoing elective abdominal aortic or infrainguinal vascular reconstruction who had new reversible wall motion abnormalities during preoperative DSE. The patients received bisoprolol or placebo perioperatively. Bisoprolol reduced 30-day mortality from 17% to 3.4% and nonfatal MI from 17% to 0%. The benefit of perioperative bisoprolol lasted until at least 2 years after surgery [20]. The beneficial effect of perioperative β-adrenergic blockade has been demonstrated not only with bisoprolol [19,20] but also with atenolol [17,18], esmolol [21], labetalol [22], oxprenolol [22], and metoprolol [23], so it might be a class effect rather than particular to a specific β-adrenergic blocking agent. More important than which agent is used might be how it is used. Raby et al [21] advocated using a β-adrenergic blocking agent to keep the heart rate 20% below each patient’s ischemic threshold (ie, the lowest heart rate at which the patient has been demonstrated to experience myocardial ischemia). Such a regimen was shown to be beneficial in a small cohort (n = 26) of patients undergoing vascular surgery. Tailoring the dose of the β-adrenergic blocker to each patient might be logical, but no rationale for
choosing a target rate 20% below the ischemic threshold has been presented. Furthermore, in many patients the ischemic threshold is not known. A reasonable rule of thumb might be that the anesthesiologist should use a β-adrenergic blocker perioperatively to achieve a heart rate that is as low as possible without causing inadequate levels of coronary perfusion pressure. If the ischemic threshold is known, the pressure should be greater than or equal to 20% below it.

Reduction of perioperative cardiac complications with β-adrenergic blockade means that the positive predictive value and the likelihood ratio of a positive result for any preoperative cardiac test are also reduced. Boersma et al [24] reanalyzed the patient population (n = 1351) screened for Poldermans et al’s study [19]. Important clinical predictors of adverse cardiac outcome in this population were age greater than or equal to 70 years, current or prior angina pectoris, history of MI, history of CHF, or history of cerebrovascular accident. Among patients who had less than three clinical risk factors, β-adrenergic blockade lowered the perioperative cardiac complication rate from 2.3% to 0.8%; the results of DSE had no significant additional prognostic value. Among patients who had three or more clinical risk factors and perioperative β-adrenergic blockade, cardiac event rates differed significantly depending on the result of DSE (2% for a negative result versus 10.6% for a positive result). This difference was mostly accounted for by those who had evidence of extensive ischemia (ie, five or more ischemic segments), in whom the cardiac complication rate was 36%, whereas patients who had fewer ischemic segments (one to four) had a 2.8% complication rate, which is not significantly different from that of patients who had a negative test. Thus, with anticipated use of perioperative β-adrenergic blockade, a stress test such as DSE might be indicated if the patient has three or more clinical risk factors such as those identified by Boersma et al [24] or Lee et al [16], but even then a positive result might have prognostic value only if it shows evidence of diffuse CAD.

“Prophylactic” coronary revascularization?

The value of a positive preoperative stress test might lie in the identification of (1) prohibitively high-risk patients, leading to cancellation of the proposed non-cardiac surgery; or (2) patients amenable to therapeutic maneuvers with reduction in risk of the noncardiac surgery. Revascularization by percutaneous transluminal coronary angioplasty (PTCA) with or without stenting or by coronary artery bypass graft surgery (CABG) might confer a long-term, symptom-free survival benefit in a subset of patients who have CAD [25–28]; however, the pathophysiology of perioperative MI differs somewhat from that of an MI in a nonoperative setting in that atherosclerotic plaque rupture and subsequent thrombus formation is not as important, and the significance of an imbalance in the myocardial oxygen supply:demand ratio (such as occurs with tachycardia) is greater in the perioperative period [14]. To triage the patient for coronary revascularization prior to noncardiac surgery to reduce the perioperative cardiac risk of the latter surgery,
three conditions should be satisfied: (1) the combined risk of coronary angiography and coronary revascularization should not exceed the risk of the proposed noncardiac surgery performed without revascularization; (2) coronary revascularization should significantly lower the cardiac risk of the subsequently performed noncardiac surgery, with the magnitude of risk reduction preferably greater than the risk of coronary angiography and revascularization; and (3) the recovery time from coronary revascularization should be short enough that the proposed noncardiac surgery, especially if it is urgent, is not unduly delayed. When these conditions are not met, any indicated revascularization can be performed after the noncardiac surgery.

Regarding the first two conditions, Mason et al [29] performed a decision analysis study in 1995 using the then-available literature data (before studies such as Poldermans et al’s [19], which demonstrated the benefit of perioperative β-adrenergic blockade in major noncardiac surgery) to compare the strategy of proceeding directly to major vascular surgery without any workup (strategy A) to that of coronary angiography followed by selective coronary revascularization before vascular surgery (strategy B). If CAD is found to be inoperable, cancellation of vascular surgery (strategy B-1) or proceeding with vascular surgery nonetheless (strategy B-2) were the options. They found that the overall mortality of strategy A (3.5%) would be lower than that of strategy B-2 (3.8%) and comparable to that of strategy B-1 (3.4%), and that the nonfatal MI or stroke rate as well as the cost of care would be lower with strategy A (5.0%) than with strategy B-1 (6.7%) or B-2 (7.0%).

Comparing more recent data, the national average mortality rate from CABG in the United States was about 3% in 1998 [30]. The mortality rate was higher if the surgery was accompanied by valve replacement (7% for CABG and aortic valve replacement and 12% for CABG and mitral valve replacement) if the surgery was emergent (6% for pristine emergent CABG and 13.5% for re-do emergent CABG), for re-do surgeries (5.4% for elective re-do surgeries), for women (3.9% versus 2.3% for men), and for the elderly (4.1% for patients in their 70s and 6.7% for patients in their 80s). Survivors of CABG who then underwent noncardiac surgery were reported to have a mortality of 1.7% [31]. These numbers can be compared with the data of Poldermans et al [19], which showed that patients who have positive preoperative DSE who undergo high-risk surgery could have a relatively low 30-day mortality rate of 3.4% and a nonfatal MI rate of 0% with the perioperative use of a β-adrenergic blocker in the absence of revascularization. These numbers would compare favorably to the sum of the mortality of CABG and noncardiac surgery in survivors of CABG. Thus, except possibly in patients who have three or more clinical risk factors and DSE (or a similar test) showing extensive CAD, the strategy of proceeding with vascular surgery with β-adrenergic blockade might be superior to that of prophylactic coronary revascularization.

A third prerequisite for prophylactic coronary revascularization is that its benefit should be realized in such a time frame that the proposed noncardiac surgery is not unduly delayed. Posner et al [32] reported that the risk of adverse
cardiac outcomes after noncardiac surgery might be reduced by prior PTCA, but only if the interval between PTCA and the noncardiac surgery was more than 90 days. Furthermore, Kaluza et al [33] noted that if noncardiac surgery is performed within 40 days of PTCA with a stent, the risk of stent thrombosis and death in the perioperative period might be prohibitively high (eight deaths [six from MI and two from major bleeding complications] in 40 patients, or 20% mortality in their report). Typically, ticlopidine and aspirin are started 3 to 5 days before PTCA with stenting and continued for 14 to 30 days depending on the risk of stent thrombosis. The risk of stent occlusion drops off sharply after the initial 30 days. Major surgery might be associated with activation of the procoagulant system, and the risk of stent occlusion might be increased by surgical stresses. What might have been adequate antiplatelet therapy in the nonsurgical period might not prove to be adequate during the perioperative period. Thus, undergoing a major noncardiac surgery during the early poststenting period poses a significant dilemma in that discontinuation of the antiplatelet therapy increases the risk of stent thrombosis and MI, whereas its continuation (with or without an additional anticoagulant regimen such as heparin) increases the risk of major bleeding complications. In summary, the available data suggest that if the proposed noncardiac surgery cannot be delayed for 30 to 40 days after PTCA, revascularization by PTCA might not be recommended to reduce the cardiac risk.

Regarding the early post-CABG period, Reul et al [34] reported a 2.7% cardiac death rate (overall mortality 3.9%) in 255 patients who had simultaneous CABG and peripheral vascular surgery, a 2.2% cardiac death rate (overall mortality 3.6%) in 279 patients who had CABG then peripheral vascular surgery 5 days to 3 weeks after CABG within the same hospitalization, and a 0% cardiac death rate (0.2% overall mortality) in 559 patients who had a CABG then a peripheral vascular surgery during a subsequent hospitalization 1 month to 10 years after CABG. In the author and colleagues’ review of patients undergoing aortic or peripheral vascular bypass surgeries within 1 month of CABG (n = 36), the 30-day mortality rate was 19%, which was much higher than a historical control of a little more than 1% in 4210 other patients undergoing similar operations (P < 0.05) [35]. These data suggest that if the patient requires noncardiac surgery that cannot be delayed 30 days or longer and also has indications for coronary revascularization, performing coronary revascularization by PTCA or CABG might not result in improved short-term survival.

**Patients who have valvular diseases**

In the ACC/AHA guidelines, a severe valvular disease is considered to be a major clinical predictor of cardiac risk and should lead to consideration of delay or cancellation of the proposed noncardiac surgery and consideration of echocardiography, cardiac catheterization, or possible valve surgery. As in the case of patients who have CAD, the decision analysis for patients who have significant valvular diseases should consider the relative risks and benefits of the strategy
of proceeding directly to noncardiac surgery versus the strategy of diagnostic workup and therapeutic interventions for the valvular abnormality followed by the noncardiac surgery. The initial diagnostic workup of transthoracic echocardiography carries negligible risks and might provide valuable information regarding the aortic valve and, to a lesser extent, the mitral valve. Better delineation of the mitral valve might require transesophageal echocardiography. Any additional intervention with angiography and valve surgery carries significant mortality and morbidity risks.

In the management of patients who have a significant valve disease who present for major noncardiac surgery, it is important that the clinician be aware of the pathophysiologic implications of the disease and manage the patient accordingly rather than subjecting the patient to corrective intervention before the noncardiac surgery. O’Keefe et al reported on their experience with 48 patients who had severe aortic stenosis (AS; mean valve area 0.6 cm²) who were not candidates for (or refused) aortic valve replacement and who needed noncardiac surgery [36]. There was only one cardiac event with no deaths for a complication rate of about 2%, which compares favorably with the 4% average mortality rate for aortic valve replacement reported for 1998 by the Society of Thoracic Surgeons using its national database [30]. More recently, Raymer and Yang compared 55 patients who had significant AS (mean valve area 0.9 cm²) with case-matched controls who had similar preoperative risk profiles other than AS who were undergoing similar surgeries [37]. Cardiac complication rates were not significantly different between the groups. Thus, patients who have severe AS can undergo indicated noncardiac surgery safely provided that the presence of severe AS is recognized and they receive intensive intraoperative and perioperative care with full knowledge of the implications of AS.

Data are lacking regarding patients who have severe mitral stenosis or severe valvular regurgitation who undergo noncardiac surgery without prior valve surgery. In case reviews of patients who had severe idiopathic hypertrophic subaortic stenosis, there was a relatively high incidence of postoperative CHF (10–17%), but not MI or cardiac death [38,39].

References


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