Preoperative Cardiac Risk Assessment and Management

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Module Updated: 2012-09-28
CME Expiration: 2015-09-28

Author
Temple A. Ratcliffe, MD, FACP

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1. Elements of Risk

Appreciate the comorbid conditions associated with adverse perioperative cardiovascular outcomes and the purpose of cardiac risk stratification.\(^6\)

1.1 Recognize the importance of the clinical evaluation in estimating the risk for cardiac complications in all patients who are undergoing noncardiac surgery.\(^6\)

Recommendations

- Consider the following principles that relate to perioperative risk for cardiac complications:
  - The likelihood of surgery increases with age, and the average age of the population is increasing.
  - Up to one third of patients who undergo surgery have significant CAD.
  - Some populations (e.g., the elderly, patients with peripheral vascular disease) are at increased risk for perioperative cardiac events.
  - Nonreversible postoperative cardiac complications (e.g., MI, cardiac death) occur in 2% to 3% of elective surgical patients over the age of 60.
  - Different types of surgery carry different risks. Operations that involve major fluid shifts or prolonged operating times increase risk.
  - Traditionally, vascular and thoracic surgeries have been the riskiest, followed by orthopedic, abdominal, and otolaryngologic procedures, with the lowest risk seen in urologic and ophthalmologic operations.

Evidence

- In 2006, 46 million procedures were performed on inpatients in the U.S. The proportion of inpatients increased from 9% in 1970 to 38% in 2006 (1).

- In a 1995 report from a surgical database of 83,958 veterans, which is generally an older male population, the overall 30-day postoperative mortality rate was 3.1%. Cardiac complications occurred in 4.5% of patients (MI, 0.7%; cardiopulmonary resuscitation, 1.5%; pulmonary edema, 2.3%) (2).

- In a 2009 report from the American College of Surgeons National Surgical Quality Improvement Program database of 84,730 patients who underwent inpatient surgery from 2005 to 2007, the overall postoperative mortality rate ranged from 3.5% in very-low-mortality hospitals to 6.9% in very-high-mortality hospitals (hospitals were sorted by quintile). Rates of myocardial infarction were low at 0.4 to 0.5% across hospital quintiles, but when MI occurred, 27.3% to 39.5% of patients died (3).

Rationale

- Accurate estimation of perioperative risk for cardiac complications and efforts to decrease that risk may decrease the burden of morbidity and mortality after surgery.

1.2 Be aware of the benefits and harms of preoperative cardiac evaluation.\(^6\)

Recommendations

- Use the risk information obtained from a cardiac risk assessment to provide informed consent and to optimize care to establish lower morbidity and mortality rates.

- Include patient- and procedure-related risk factors (as outlined in this module) in an overall assessment of perioperative risk for cardiac complications.

- Recognize that injudicious use of preoperative cardiac risk stratification can lead to unnecessary testing, possibly ineffective or harmful interventions, and avoidable delays in surgery.
Evidence

- Information on clinical risk screening can sort patients accurately into low- and high-risk categories (4; 5). There is good-quality evidence that noninvasive testing can further clarify the risk in a subset of intermediate-risk patients (4; 6), although it is not needed in all patients.
- Perioperative cardiac evaluation can identify an additional 5% to 10% of patients for whom CABG offers a long-term survival benefit and is based on prospective, uncontrolled studies (7; 8).
- There is no direct evidence that cardiac risk stratification lowers morbidity or mortality rates.

Rationale

- Perioperative risk information helps the patient, physician, and surgeon with decision making and facilitates measures that can decrease cardiac morbidity and mortality rates.
2. Whom and How to Assess

Determine which patients require cardiac perioperative risk assessment, and tailor assessment to the clinical situation.

2.1 Determine whether the patient has an active cardiac condition or has undergone recent PCI.

Recommendations

- Be aware that active cardiac conditions include
  - Acute coronary syndromes
  - Decompensated heart failure
  - Uncontrolled arrhythmias
  - Severe valvular disease (aortic stenosis or mitral stenosis)
- Defer all but the most emergent procedures in these patients until the active cardiac condition has been treated.
- If the patient has had a recent PCI, modify the timing of surgery and perioperative antiplatelet treatment accordingly.

Evidence

- The 2007 ACC/AHA guidelines for preoperative evaluation recommended assessing for the presence of active cardiac conditions (9).

Acute coronary syndromes, heart failure, arrhythmias:

- In a 1983 study of 364 patients who underwent surgery within 0 to 3 and 4 to 6 months after an acute MI, the risk for perioperative reinfarction was 36% and 26%, respectively (10). However, the risk is likely lower in the current era.
- In a retrospective analysis of 1532 patients with heart failure, 1757 patients with CAD, and 44,512 control patients undergoing major noncardiac surgery, the risk-adjusted operative mortality (death before discharge or within 30 days of surgery) was 11.7%, 6.6%, and 6.2%, respectively (P<0.001 for heart failure vs. CAD), and the risk-adjusted 30-day readmission rate was 20.0%, 14.2%, and 11.0%, respectively (P<0.001) (11).

Aortic stenosis:

- In a 2005 descriptive literature review, patients with severe aortic stenosis undergoing noncardiac surgery had a significantly higher risk (OR, 3.2 to 6.8) than patients without aortic stenosis of cardiac complications (12).
- Among 570 patients who underwent transthoracic echocardiography as a subgroup of a larger prospective clinical cohort of 4315 patients scheduled for major noncardiac surgery, a peak instantaneous aortic gradient of ≥40 mm Hg was associated with an increased risk for postoperative cardiac complications (OR, 6.3 [CI, 1.5 to 26]) (13).
- In a blinded, good-quality, cross-sectional study that evaluated the use of the physical exam to diagnose severe aortic stenosis (valve area <1.2 cm²), absence of radiation of systolic murmur was shown to rule out severe aortic stenosis (likelihood ratio, 0.10), and the presence of three or four associated findings (slow carotid upstroke, reduced carotid volume, maximal murmur intensity at the second right intercostal space, reduced intensity of the second heart sound) ruled in severe aortic stenosis (likelihood ratio, 40.0) (14).

Recent coronary stenting:

- In a small case series, 8 of 25 patients (32%) who underwent noncardiac surgery within 2 weeks from bare-metal stent implantation died because of acute MI (6 patients) or bleeding (2 patients). No events occurred among 15 patients undergoing noncardiac surgery 3 to 6 weeks after stent implantation (15).
In a large, single-institution cohort, 8 of 207 patients (3.9%) undergoing noncardiac surgery within 2 months from coronary stent implantation died. The risk for cardiac complications ranged from 3.8% to 7.1% during the first 6 weeks after receiving a stent, whereas there were no events in the 39 patients who had surgery 6 to 8 weeks after receiving a stent (16).

A study followed 27 patients undergoing noncardiac surgery within 3 weeks from bare-metal stent implantation; perioperative mortality was 86% (6 of 7 patients) among patients in whom a thienopyridine was stopped for more than 5 days compared with 5% (1 of 20 patients) among those who continued to receive a thienopyridine during surgery (17).

Major cardiac events or bleeding occurred in 8 of 16 patients (50%) undergoing noncardiac surgery within 42 days after receiving a bare-metal stent, and in none of 40 patients who underwent surgery more than 42 days after receiving a bare-metal stent (18).

Bare-metal stent thrombosis occurred in 2 of 93 patients (2.2%) undergoing noncardiac surgery within 2 years from bare-metal stent placement. Stent thrombosis occurred at 1 and 28 days after implantation, and in both patients aspirin and clopidogrel were withheld before surgery (19).

Compared with bare-metal stents, drug-eluting stents may carry an increased risk for late (more than 30 days after implantation) or very late (1 year or more after implantation) stent thrombosis, which may be higher in the perioperative setting. Perioperative drug-eluting stent thrombosis has been reported up to 21 months after implantation (20).

In a small study, none of 38 patients undergoing 41 major and 18 minor surgeries had perioperative MI or death, which could be partly explained by a delay in surgery (median delay, 9 months) and the continuation of antiplatelet therapy in a large proportion of patients (21).

In a study of 99 patients undergoing noncardiac surgery within 2 years from implantation of a drug-eluting stent, perioperative stent thrombosis occurred in 3 patients (3%), in all of whom aspirin and clopidogrel were withheld (19).

Rationale

Patients with acute coronary syndromes, decompenated heart failure, and significant arrhythmias (e.g., high-grade atrioventricular block, Mobitz II atrioventricular block, third-degree atrioventricular block, symptomatic ventricular arrhythmias, newly recognized ventricular tachycardia, supraventricular arrhythmias with uncontrolled ventricular rate, or symptomatic bradycardia) have a very high risk for perioperative cardiac complications.

Patients with severe aortic stenosis as judged by clinical exam and echocardiography who are undergoing noncardiac surgery have a high risk for perioperative complications (heart failure, MI, cardiac death) that may be modified by preoperative (aortic valve replacement) or perioperative (intensive hemodynamic monitoring and management) interventions.

Patients with coronary stents may develop perioperative stent thrombosis, a complication that carries high morbidity and mortality, making preoperative identification of such patients critical.

Comments

Patients with acute coronary syndrome are likely to benefit most from preoperative coronary revascularization. The results of the Coronary Artery Revascularization Prophylaxis (CARP) trial showed no benefit of coronary revascularization for many patients with stable, nonsurgical CAD (e.g., no left-main or three-vessel obstructive CAD) (22).

Although hemodynamic optimization of patients with heart failure before noncardiac surgery appears logical, there are no prospective or retrospective studies to examine the effects of such an intervention.

The risk for perioperative stent thrombosis depends on the type of coronary stent and the interval between stent implantation and surgery. For bare-metal stents, the risk is low after 4 to 6 weeks from implantation. For drug-eluting stents, a longer interval is required, at least 12 months, due to delayed stent endothelialization. The risk for perioperative stent thrombosis may be reduced by delaying surgery and optimizing antiplatelet therapy.
2.2 Determine patient- and procedure-related risks in patients without an active cardiac condition.

Recommendations

- Classify the planned procedure as low-, intermediate-, or high-risk, as the type of surgery contributes independently to the perioperative risk.
  - High-risk (>5% perioperative risk of death or MI) surgeries include aortic and peripheral vascular surgery
  - Intermediate-risk (1% to 5% perioperative risk of death or MI) surgeries include intraperitoneal and intrathoracic surgeries, carotid endarterectomy, head and neck surgery, orthopedic surgery, and prostate surgery
  - Low-risk (<1% perioperative risk of death or MI) surgeries include endoscopic and superficial procedures, cataract surgery, breast surgery, and ambulatory surgery
- Obtain a history and do a physical examination in all patients.
- Order laboratory testing based on the patient's individual clinical condition.
- Order an ECG in
  - Patients undergoing vascular surgery, particularly those with clinical risk for heart disease
  - Patients with known heart disease, peripheral arterial disease, or cerebrovascular disease undergoing intermediate risk procedures
- **High-value care:** Do not obtain preoperative chest radiography in the absence of clinical suspicion for intrathoracic pathology.
- Classify the patient as high-, intermediate-, or low-risk by using the Revised Cardiac Risk Index (RCRI).
- Consider using the American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) Cardiac Risk calculator for a more precise estimate of perioperative risk.
- Consider using the Vascular Study Group of New England Cardiac Risk Index (VSG-CRI) for patients undergoing vascular surgery.
- See table History, Physical Examination, and Laboratory Items Useful in Determining Risk for Cardiac Complications in Patients Who Are Undergoing Noncardiac Surgery.
- See module Revised Cardiac Risk Index.
- See module Preoperative Evaluation.

Evidence

- The 2011 appropriateness criteria from the American College of Radiology stated that routine chest radiographs are not needed before surgery.
- The 2007 ACC/AHA guidelines on cardiac risk assessment recommended classifying the procedure-related risk and using history and physical exam to assess the patient's individual risk (9).
- Surgical issues that increase risk are emergency surgery (23) and type of surgery, with vascular and orthopedic surgery posing the greatest risk followed by general and thoracic surgery and then urologic, otolaryngologic, and ophthalmologic surgery (24).
- RCRI performs well predicting major perioperative cardiovascular complications in patients undergoing elective, noncardiac surgery (25; 26)
- The ACS-NSQIP Cardiac Risk calculator uses the type of surgery, ASA class, age, abnormal creatinine level, and dependent functional status to calculate a percentage risk for perioperative myocardial infarction or cardiac arrest. It was found to be superior to the RCRI, but does require the use of a computerized algorithm (27).
Emerging evidence suggests that the VSG-CRI is superior to the RCRI in predicting cardiac events and mortality for patients undergoing vascular surgery (25; 28).

Rationale
- The history and physical examination with targeted laboratory laboratory evaluations can classify patients accurately as low, intermediate, or high risk. Approximately 10% of patients are at high operative risk after clinical evaluation, approximately 30% are at low risk, and 60% are at intermediate risk.
- More comorbidities, including a history of ischemic heart disease, a history of compensated or previous heart failure, a history of cerebrovascular disease, diabetes mellitus, or renal insufficiency, are associated with higher perioperative risk.

Comments
- The elements of the clinical assessment described in the specific recommendations reflect coronary disease and poor left ventricular function and have been shown to predict cardiac events postoperatively (7).
- Clinicians should inquire not only about typical anginal symptoms but also about other exertional symptoms that may represent anginal equivalents.
- Additionally, orthopnea, paroxysmal nocturnal dyspnea, pedal edema, transient ischemic attacks, previous strokes, murmurs, syncope, a complete diabetic history, and any previous problems with surgery are other historical variables that are important for the general perioperative management of the patient, even if they do not predict adverse cardiac events directly.

2.3 Recognize that many low-risk patients and patients requiring emergency surgery do not need further preoperative cardiac testing

Recommendations
- Do not do an extensive cardiac evaluation in
  - Patients who need emergency surgery
  - Patients who do not have an active cardiac condition and need low-risk surgery
  - Patients who do not have an active cardiac condition, have no cardiac symptoms, and have good exercise capacity (≥4 metabolic equivalent levels)

Evidence
- The 2007 ACC/AHA guidelines noted that patients requiring emergency surgery should not undergo preoperative cardiac testing (9).
- A large trial that randomly assigned 19,577 patients who underwent cataract surgery to receive either routine preoperative medical testing or testing dictated by history and clinical exam found no reduction in adverse postoperative events in the routine testing group (29).
- Both self-reported and physician-evaluated functional status are predictive of postoperative myocardial ischemia and combined cardiac, pulmonary, and neurologic outcomes, but the predictive ability of functional status for irreversible cardiac outcomes such as MI has not been well defined. In a well-conducted prospective evaluation of 600 consecutive outpatients evaluated in a preoperative internal medicine clinic before noncardiac surgery, self-reported exercise tolerance of less than four blocks or less than two flights of stairs predicted a combined outcome of cardiac, pulmonary, and neurologic outcomes (20.4% vs. 10.4%; P<0.001; OR, 1.94 [CI, 1.19 to 3.17]). There was also a nonsignificant trend toward more cardiovascular events (OR, 1.81 [CI, 0.94 to 3.46]) (30).
- In a prospective evaluation of 83 patients undergoing major thoracic or upper abdominal surgery, 89% of patients who were unable to climb one flight of stairs (18 steps) developed a postoperative cardiopulmonary complication. Progressively increased exercise tolerance was correlated with
progressively improved negative predictive values of postoperative cardiopulmonary complications (31).

Rationale

- If emergency surgery is required, then no further cardiac testing should be done before surgery, as no coronary revascularization can be done. However, such patients might still benefit from aggressive perioperative management.
- Low-risk surgeries (e.g., endoscopic and superficial procedures, cataract surgery, breast surgery, and ambulatory surgery) are associated with a perioperative complication risk less than 1%, which is unlikely to be modified by preoperative cardiac testing in patients without active cardiac disease.
- Patients with good exercise capacity who do not have an active cardiac condition can proceed to surgery without further cardiac testing.

Comments

- Vigilance in the form of a meticulous history and physical exam is required to ensure patients do not have previously unrecognized active cardiac conditions.
- Patients with serious comorbidities may require evaluation for other, noncardiac reasons (e.g., the ability to lie flat) before undergoing low-risk surgery.
- Patients who are not at increased cardiac risk might have other, noncardiac issues (e.g., thyroid status, anticoagulation) that need to be addressed at the time of surgery.

2.4 Consider further cardiac testing in selected patients undergoing noncardiac surgery.

Recommendations

- Perform noninvasive cardiac testing in patients
  - With symptoms of coronary ischemia
  - With three or more clinical cardiac risk factors and poor functional capacity (<4 METS) who are undergoing intermediate- or high-risk surgery
  - Consider testing patients with poor functional capacity but only one or two clinical risk factors who are undergoing intermediate or high risk surgery
- In patients requiring testing, consider doing one of the following noninvasive tests:
  - Exertional stress testing/stress thallium
  - Dipyridamole thallium or its equivalent (e.g., Cardiolite sestamibi)
  - Dobutamine stress echocardiography

Evidence

- According to the 2007 ACC/AHA guidelines, further noninvasive cardiac testing can be considered in patients with symptoms (e.g., angina or exertional dyspnea) or poor or unknown exercise capacity and at least one clinical risk factor. It is more strongly recommended for patients with three or more clinical risk factors who are undergoing vascular surgery (9).
- A good-quality 2001 prospective study of 204 intermediate-risk consecutive patients undergoing noncardiac surgery showed that ST-segment depression of 0.1 mV or more on a preoperative exercise stress electrocardiogram is a statistically significant independent predictor of perioperative cardiac events (OR, 5.2 [CI, 1.5 to 18.5], P=0.01) (32).
- A good-quality 2002 meta-analysis of vascular surgery patients undergoing dipyridamole perfusion imaging determined that semiquantitative analysis of scans improved risk prediction of postoperative events: normal scans predicted lower postoperative complication rates (post-test probability of MI or cardiac death of 3.1%, assuming a pretest probability of 7%; likelihood ratio,
0.42 [CI, 0.20 to 0.88]), and 50% or more reversibility predicted a post-test probability of MI or cardiac death of 45% (likelihood ratio, 11 [CI, 5.8 to 20]) (33).

- A prospective, blinded study of 80 intermediate-risk vascular surgery patients not included in the above meta-analysis due to publication date failed to find any correlation between semiquantitative analysis of scans and cardiac events but may have had insufficient power to detect equivalence (34).

- Two prospective, fair-quality studies suggest that echocardiography does not add prognostic information to the clinical assessment (35; 36).

- In a 2001 review of 570 patients who underwent transthoracic echocardiography as a subgroup of a larger prospective clinical cohort of 4315 patients scheduled for major noncardiac surgery, echocardiography provided risk stratification information above and beyond that obtained by clinical evaluation if using risk indexes among patients with two or more risk variables but not among low-risk patients (likelihood ratio was 6.0 for systolic dysfunction on echocardiography, 3.0 for moderate to severe hypertrophy, and 3.3 for moderate to severe mitral regurgitation) (13).

- The DECREASE-II trial randomly assigned 770 intermediate-risk patients scheduled for major vascular surgery to preoperative cardiac testing vs. no testing. All patients received β-blockers in the perioperative period. Twelve of 386 patients in the testing group underwent preoperative coronary revascularization. The 30-day incidence of death or MI was similar in the testing and no-testing group (1.8% and 2.3%, respectively, P=0.62). Moreover, preoperative testing delayed surgery by 3 weeks (37).

- Conventional exercise stress testing has not been shown to improve risk discrimination afforded by clinical exam (38; 39; 40; 41; 42) in older studies.

**Rationale**

- The goal of preoperative risk testing is to identify the few patients with left main or three-vessel CAD who might derive survival benefit from coronary artery bypass surgery.

- Whether preoperative noninvasive testing improves postoperative outcomes remains uncertain. A prospective, randomized, controlled trial did not show any benefit from stress testing in intermediate-risk patients undergoing vascular surgery.

- Further noninvasive cardiac stress testing should be considered only if it will change management.
3. Interventions to Decrease Risk

Consider interventions that have been shown to reduce perioperative cardiac risk.

3.1 Consider preoperative aortic valve replacement and/or intensive perioperative hemodynamic monitoring and management in patients with severe aortic or mitral stenosis undergoing noncardiac surgery.

Recommendations

- In patients with severe aortic stenosis,
  - Recommend aortic valve replacement in symptomatic patients or in those who are developing LVD; avoid balloon valvuloplasty, unless the patient is not a good candidate for aortic valve replacement.
  - When emergency surgery is required, initiate intensive management to prevent tachycardia with β-blockers, prevent decrease in preload with adequate fluids, and prevent hypotension with α-adrenergic pressors.
- See module Perioperative Valvular Disease Risk Assessment.

Evidence

- Among 570 patients who underwent transthoracic echocardiography as a subgroup of a larger prospective clinical cohort of 4315 patients scheduled for major noncardiac surgery, a peak instantaneous aortic gradient of ≥40 mm Hg was associated with an increased risk for postoperative cardiac complications (OR, 6.3 [CI, 1.5 to 26]) (13).
- In a blinded, good-quality, cross-sectional study that evaluated the use of the physical exam to diagnose severe aortic stenosis (valve area <1.2 cm²), absence of radiation of systolic murmur was shown to rule out severe aortic stenosis (likelihood ratio, 0.10), and the presence of three or four associated findings (slow carotid upstroke, reduced carotid volume, maximal murmur intensity at the second right intercostal space, reduced intensity of the second heart sound) ruled in severe aortic stenosis (likelihood ratio, 40.0) (14).

Rationale

- Patients with severe aortic stenosis undergoing noncardiac surgery have very high perioperative risk and are likely best treated by preoperative aortic valve replacement. Perioperative hemodynamic collapse can occur in patients with severe aortic stenosis because of tachycardia that reduces filling of the left ventricle, decrease in cardiac preload that also reduces filling of the left ventricle, and hypotension that reduces myocardial perfusion.
- Physical exam is key in identifying the presence and estimating the severity of aortic stenosis.
- Patients with findings suggestive of aortic stenosis should undergo transthoracic echocardiography to confirm the diagnosis and accurately estimate the severity of aortic stenosis.

3.2 Consider measures to prevent perioperative stent thrombosis in patients with recent coronary stenting.

Recommendations

- Delay elective noncardiac surgery in patients who have undergone recent coronary stenting 4 to 6 weeks for bare-metal stents and at least 12 months for drug-eluting stents.
• Optimize antiplatelet therapy with aspirin and clopidogrel in the perioperative period by continuing it or reinstating it after the procedure as soon as possible.

Evidence
• In all case series of patients with bare-metal stents and drug-eluting stents undergoing noncardiac surgery, the risk for stent thrombosis was highest when surgery was done early (within 2 to 6 weeks from implantation for bare-metal stents [15; 16; 17; 18; 19] or for an unknown period of time [at least 12 months] from implantation for drug-eluting stents [19]).

• Although perioperative stent thrombosis has been reported in patients receiving antiplatelet therapy, most of the reported cases occurred in patients in whom both aspirin and clopidogrel were withheld. For example, aspirin and clopidogrel were both stopped in 5 patients (2 with bare-metal stents and 3 with drug-eluting stents) with perioperative stent thrombosis in one study (19). In another study of 27 patients undergoing noncardiac surgery within 3 weeks from implantation of a bare-metal stent, perioperative mortality was 86% (6 of 7 patients) among patients in whom a thienopyridine was stopped for >5 days, compared with 5% (1 of 20 patients) among patients who continued to receive a thienopyridine during surgery (17).

Rationale
• Delaying surgery after stent implementation and optimizing antiplatelet therapy in the perioperative period decreases the risk for perioperative stent thrombosis.

Comments
• Because the risk for stent thrombosis is highest when surgery is done soon after stent placement, delaying surgery for 4 to 6 weeks in patients with bare-metal stents and for 12 or more months in patients with drug-eluting stents would likely decrease the perioperative risk.

• A review examined data about the frequency of stent thrombosis after noncardiac surgery, including the impact of delay from surgery and discontinuation of antiplatelet therapy. The authors also reviewed data about the impact of preoperative revascularization in patients known to require noncardiac surgery (44).

• Continuing aspirin and/or clopidogrel during surgery may not be acceptable for certain types of surgery (such as neurosurgery), but may be acceptable during other low-risk procedures (such as teeth extraction and cataract surgery), as suggested in the 2007 AHA/ACC/SCAI/ACS/ADA advisory (45).

3.3 Consider preoperative coronary revascularization in selected patients with CAD undergoing noncardiac surgery.

Recommendations
• Consider preoperative coronary revascularization in patients undergoing noncardiac surgery if they are high risk or if they have unstable symptoms, such as unstable angina refractory to medical therapy.

• Consider either CABG or PCI before planned surgery, but avoid the use of coronary stenting, especially drug-eluting stents, to obviate the probability of later perioperative stent thrombosis.

Evidence
• Controlled trials have shown that coronary revascularization improves long-term symptoms and prolongs survival in certain patients with CAD in the nonoperative setting, including those with unstable angina that is refractory to medication; left-main coronary stenosis; triple-vessel disease with impaired left ventricular function; and possibly two-vessel CAD with proximal left anterior descending involvement (and LVD) as outlined in the ACC/AHA guidelines on CABG (46).

• In a retrospective analysis of the Coronary Artery Surgery Study registry, in 1961 patients undergoing high-risk surgery, previous CABG was associated with fewer postoperative deaths.
(1.7% vs. 3.3%, \(P=0.03\)) and MIs (0.8% vs. 2.7%, \(P=0.002\)) compared with medically managed coronary disease (47). However, the postoperative mortality difference was less than the rate of mortality from the bypass itself (2.3% overall for the Coronary Artery Surgery Study registry patients).

- The CARP trial examined the value of preoperative coronary artery revascularization among 510 stable patients undergoing high-risk vascular surgery (abdominal aortic aneurysm repair or lower-extremity arterial bypass surgery) (22). All randomized patients had angiographically documented CAD. Patients were randomly assigned to revascularization (CABG in 41% and PCI in 59%, at the discretion of the treating physician) or no revascularization before surgery. Perioperative medical therapy was excellent; 85% of patients received β-blockers, 72% received aspirin, and 54% received a statin. There was no benefit from preoperative revascularization in preventing perioperative myocardial infarction (8.4% in both groups, \(P=0.99\)), or death after a median of 27 months from randomization (22% in revascularized vs. 23% in non-revascularized patients, \(P=0.98\)). A post-hoc analysis of the CARP trial showed that patients receiving CABG were less likely to have perioperative MI compared with patients receiving PCI (48).

- The Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echo (DECREASE) study, a randomized, controlled trial of 101 high-risk patients with extensive coronary ischemia undergoing vascular surgery, did not show any benefit from preoperative revascularization during 1 year of follow-up (49).

- A prospective study randomly assigned 208 consecutive patients with a revised cardiac risk index ≥2 scheduled for major vascular surgery to stress testing or routine coronary angiography. Patients in the routine coronary angiography group underwent more frequent preoperative coronary revascularization (58.1% vs. 40.1%; \(P=0.01\)) and had lower incidences of death and major cardiovascular events during a mean follow-up of nearly 6 years (50).

**Rationale**

- The determination as to whether the patient is a candidate for coronary revascularization should be made on the same clinical grounds that govern the need for coronary revascularization in the nonoperative setting.

- Coronary revascularization is rarely needed just to get a patient through surgery.

- Although retrospective studies had suggested that coronary revascularization reduces the perioperative risk, no benefit for revascularization was shown in the largest published randomized, controlled trial, the Coronary Artery Revascularization Prophylaxis (CARP) trial. Two smaller randomized trials had conflicting results.

**Comments**

- The CARP trial suggests that preoperative coronary revascularization is likely not beneficial for most non-high-risk, stable patients undergoing noncardiac surgery. Although not supported by evidence, preoperative coronary revascularization may be beneficial in high-risk patients excluded from CARP, such as patients with acute coronary syndromes, and patients with left-main disease or three-vessel disease with reduced ejection fraction, as outlined in the ACC/AHA guidelines on CABG (46). This is further supported by the results of a prospective, randomized study (50).

- Coronary revascularization can be accomplished by CABG or PCI. Selecting the optimal revascularization strategy depends on the urgency of noncardiac surgery and the coronary anatomy. If noncardiac surgery can be delayed, patients with left-main and three-vessel disease with reduced ejection fraction would likely be best treated with CABG, which has been shown to reduce mortality in these patients (46). Patients with one- or two-vessel disease may be treated by either PCI or CABG, depending on whether the coronary anatomy is favorable for PCI. Noncardiac surgery should be delayed in patients receiving stents to reduce the risk for perioperative stent thrombosis.
• When PCI with stent implantation is considered to be the preferred revascularization option, the type of stent used should be carefully selected. Bare-metal stents are preferable in patients in whom noncardiac surgery is planned with 6 to 12 months. If noncardiac surgery may be delayed for >6 or ideally 12 months, then drug-eluting stents can be considered, although it is unclear how long is enough to minimize the risk for perioperative stent thrombosis.

• If noncardiac surgery cannot be delayed, preoperative CABG cannot be done, and coronary revascularization is absolutely required (usually because of acute coronary syndromes), PCI without stent implantation may be the best option. PCI without stent implantation can be accomplished by balloon angioplasty alone or by coronary atherectomy. Ideally, 1 to 2 weeks should elapse between balloon angioplasty and noncardiac surgery to allow for healing of the treated coronary artery. In a retrospective study of 350 patients undergoing noncardiac surgery within 2 months after balloon angioplasty, the perioperative mortality rate was 0.9%, and the repeat revascularization rate was 2.9% (51), suggesting that preoperative balloon angioplasty may be safe. A major limitation of such a strategy is that patients undergoing balloon angioplasty may occasionally require stent implantation to treat a complication, such as dissection or vessel closure or to improve a suboptimal angiographic result. Also, patients who undergo balloon angioplasty are more likely to develop restenosis within the treated coronary segment, which could be treated with repeat PCI and stent implantation if noncardiac surgery has not been accomplished in the interim.

3.4 Consider perioperative β-blockers to prevent cardiac events in patients with known coronary disease or at high risk for coronary disease. Continue β-blockers perioperatively in patients already receiving them.

Recommendations
• Consider perioperative β-blocker therapy in patients
  • With known coronary artery disease
  • At high risk for coronary artery disease due to multiple risk factors
• If initiating β-blockers, give ample time (if feasible) before the scheduled surgical procedure to allow adequate time (e.g., 1 week or longer) for titration and to ensure tolerability, and consider using long-acting (e.g., atenolol, bisoprolol, metoprolol succinate) over short-acting β-blockers (e.g., metoprolol tartrate).
• Note the following contraindications to administration:
  • Heart rate <55 beats/min
  • Systolic BP <100 mm Hg
  • Active, decompensated congestive heart failure
  • Bronchospasm (e.g., asthma, COPD)
  • High-degree atrioventricular heart block

Evidence
• The 2009 update of the 2007 ACC/AHA guideline on perioperative cardiac evaluation recommends continuing β-blockers in patients who are already receiving them and considering β-blockers in patients at high risk for cardiac complications or those undergoing high-risk surgery (52).
• A 2008 systematic review of the effect of perioperative β-blockers on mortality included 33 trials with 12,306 patients and found that treatment with β-blockers did not lead to improved all-cause or cardiovascular mortality. Treatment was associated with a decrease in nonfatal MI (NNT, 63) and an increase in nonfatal stroke (NNH, 293) (53; 54).
• Initial randomized clinical trials of perioperative β-blockade in selected patients showed that mortality rate and nonfatal cardiac events were significantly reduced with treatment with intravenous atenolol (55) and oral bisoprolol (56) in high-risk and vascular surgery patients, respectively.
• However, subsequent studies yielded mixed results. In one randomized, controlled trial of 103 patients, patients with no previous history of MI undergoing infrarenal vascular surgery were randomly assigned to perioperative metoprolol or placebo, and no difference was observed in 30-day cardiovascular events or mortality (57). Another randomized, controlled trial of 496 patients undergoing elective vascular surgery again showed no improvement in a combined CV endpoint and increased bradycardia and hypotension in the β-blocker group (58). Finally, another randomized, controlled trial did not find benefits with metoprolol succinate in 921 diabetic patients aged >39 years undergoing elective, noncardiac surgery (59).

• A cohort study conducted in 329 U.S. hospitals involving 782,969 patients over age 18 undergoing noncardiac surgery showed that the effect of perioperative treatment with β-blockers on mortality varied with cardiac risk as determined by use of a revised cardiac risk index. β-blockers reduced mortality in those at high risk but not among those at low risk (60).

• In 2008, a randomized, controlled trial (POISE) of perioperative metoprolol succinate in 8351 patients undergoing noncardiac surgery with or at risk for CAD found excess risk for death and stroke despite improvements in other CV endpoints (61). Fewer patients in the metoprolol group than in the placebo group had a myocardial infarction (4.2% vs 5.7%; P=0.0017). However, there were more deaths (3.1% vs 2.3%; P=0.0317) and strokes (1.0% vs 0.5%; P=0.0053) in the metoprolol group compared with the placebo group.

• A 2011 cohort study found that patients who were on β-blockers chronically before elective, noncardiac surgery had improved outcomes when compared with patients whose β-blockers were started acutely (62).

Rationale
• β-blockers slow postoperative heart rate and reduce postoperative ischemic events. They also may confer an antiarrhythmic benefit and blunt sympathetic surges.
• Patients already on β-blockers should continue taking them in the perioperative period.
• β-blocker prophylaxis appears to be most beneficial in patients at higher cardiac risk.

Comments
• Although randomized, controlled data are mixed, it is reasonable to initiate β-blockers in patients at high risk for MI who are not at high risk for stroke.
• Significant uncertainty remains regarding the effect of previous revascularization on β-blocker benefit, which subgroups benefit most from β-blockade, whether the effect is one of the whole class of drugs (long-acting vs. short-acting), and whether perioperative administration of β-blockers reduces early (1- to 3-month) postoperative mortality among nonvascular patients.

3.5 Consider initiating or continuing HMG-CoA reductase inhibitors (statins) in patients undergoing noncardiac surgery who are at increased cardiac risk.

Recommendations
• Consider starting statins in patients undergoing noncardiac surgery who are at risk for postoperative MI.
• Continue statins in all patients already receiving them.

Evidence
• A 2012 Cochrane review of the effect of preoperative statin therapy in patients undergoing cardiac surgery included 11 randomized, controlled trials with 984 participants. Perioperative statins had no effect on perioperative stroke or mortality but did decrease the rate of perioperative atrial fibrillation (OR, 0.40 [CI, 0.29 to 0.55] and the length of stay in the intensive care unit (63).
**Preoperative Cardiac Risk Assessment and Management**

- A 2010 meta-analysis of the effect of statin therapy before procedures on perioperative cardiac events included 21 trials involving 4805 patients. Statin therapy before noncardiac (but not cardiac) surgery reduced postoperative MI (RR, 0.57 [CI, 0.46 to 0.70]) (64).
- Patients receiving a statin before noncardiac surgery should continue receiving it in the perioperative period. Postoperative statin discontinuation was associated with a higher incidence of troponin I elevation in the postoperative period in 491 patients in a small, retrospective study (65).

**Rationale**
- Statins may reduce the incidence of perioperative cardiovascular events.

**Comments**
- Treatment of supraventricular tachycardia perioperatively has not been found to be of benefit (66).
- No single anesthetic agent has been shown to be superior in preventing MI or in reducing mortality (36; 67; 68; 69).
- Studies of the perioperative treatment of hypertension have measured only surrogate physiologic outcomes (e.g., intraoperative BP fluctuations, ischemia) (70; 71).
- Statin initiation should be considered in all patients undergoing vascular surgery and in patients with one or more clinical risk factors undergoing intermediate-risk surgery (9).
- The opportunity to address other therapies of proven benefit (e.g., hypertension control, aspirin use, smoking cessation, cholesterol reduction, the use of ACE inhibitors in patients with LVD) in patients with known CAD also arises at the time of preoperative evaluation.

### 3.6 Consider α₂-adrenergic agonists in high-risk patients.

**Recommendations**
- Consider α-blockers, such as clonidine, in patients in whom β-blockers are contraindicated.
- Use other agents as needed to control BP, but recognize that they have not specifically been shown to reduce perioperative complications.

**Evidence**
- A 2009 Cochrane review of the effect of α₂-adrenergic agonists in patients undergoing surgery included 31 randomized, controlled trials that were generally of poor quality. α₂-Adrenergic agonists reduced mortality (RR, 0.66 [CI, 0.44 to 0.98]) and myocardial ischemia (RR, 0.68 [CI, 0.57 to 0.81]) but increased hypotension (RR, 1.32 [CI, 1.07 to 1.62]) and bradycardia (RR, 1.66 [CI, 1.14 to 2.41]). Benefits were greatest among patients undergoing vascular surgery (72).
- A 2003 meta-analysis evaluated the effect of α₂-adrenergic agonists in patients undergoing surgery and included 23 trials involving 3395 patients. The study found that α₂-adrenergic agonists reduced mortality (RR, 0.64 [CI, 0.42 to 0.99]) (73).
- A European, double-blind, randomized trial of 2854 patients showed benefit from an α₂-agonist (mevazerol, which is not yet available in North America) (74). The general group did not have a significant reduction in cardiac outcomes, but the a priori subgroup analysis of 904 vascular surgical patients demonstrated a significant reduction in cardiac events and all-cause mortality.
- Controlled studies that examined the benefits of perioperative medical therapies other than β-blockers have used mostly surrogate end points (e.g., postoperative ischemia) or transient cardiovascular complications (e.g., heart failure or arrhythmias) (75; 76; 77; 78; 79). In these studies, prophylactic nitrate, calcium-channel blocker, or digitalis administration has not been shown to reduce the frequency of even surrogate outcomes.
- A systematic review examined 21 trials of various pharmacologic agents that assessed ischemia, MI, 30-day cardiac mortality, and side effects when used to decrease complications in patients undergoing noncardiac surgery. β-blockers reduced ischemia during and after surgery, decreased...
the rate of cardiac death, and reduced the risk of MI in high-risk patients. α-Blockers reduced ischemia only during surgery and decreased the rate of cardiac death, but their effect on MI was not significant. Calcium-channel blockers and nitroglycerin afforded no benefit (80).

- Treatment of supraventricular tachycardia perioperatively has not been found to be of benefit (66).
- Studies of the perioperative treatment of hypertension have measured only surrogate physiologic outcomes (e.g., intraoperative BP fluctuations, ischemia) (70; 71).

### Rationale
- α₂-Agonists, such as clonidine, may reduce postoperative cardiac events by decreasing spinal sympathetic outflow but may be less effective than β-blockers.
- Transdermal clonidine may be useful in patients unable to take pills by mouth following surgery.
- α₂-Agonists may benefit patients who are undergoing vascular surgery.

### 3.7 Consider other interventions in selected patient groups.

#### Recommendations
- Consider preoperative epidural anesthesia for patients with hip fracture.
- Consider maintaining normal temperature perioperatively in elderly patients undergoing major surgery.

#### Evidence
- Among 68 patients with hip fracture randomly assigned to epidural or conventional analgesia on admission, the incidence of preoperative cardiac events was significantly reduced while patients were waiting for repair (7 of 34 vs. 0 of 34; \(P=0.01\)). β-blocker use was similar in both groups. This trial was terminated at the interim analysis because of the significant findings, but the small number of events, nonblinded interpretation of results, and unclear mechanism for the difference seen mean that further study is required (81).
- Three hundred patients over age 60 undergoing major abdominal, thoracic, or vascular procedures who were scheduled to go to the intensive care unit postoperatively and either had documented CAD or were at high risk for CAD were randomly assigned to supplemental warming with a forced-air warming cover intra- and postoperatively to maintain a core temperature of 37°C or “routine” thermal care. The control group had a lower postoperative core temperature (35.4 ± 0.1°C) than the treatment group (36.7 ± 0.1°C) and a significantly higher rate of postoperative morbid cardiac events (10 of 158 [6%] vs. 2 of 142 [1%]; \(P=0.02\)) (82).
- No single anesthetic agent has been shown to be superior in preventing MI or in reducing mortality (36; 67; 68; 69).

#### Rationale
- Perioperative epidural analgesia has been shown to suppress the stress response to surgery, which, in turn, can lead to hypercoagulability.
- Although anesthetics reduce operative cold stress, postoperatively, cold stress has been associated with adverse cardiovascular outcomes.
4. Patient Counseling

Provide patients with educational materials about perioperative assessment and the modification of perioperative cardiac risk.

4.1 Consider information available on the Internet when counseling patients about perioperative risk assessment.

Recommendations
- Review Web sites that provide information on types of surgery (see Patient Resources section).
- Note that not all of these Web sites have not been reviewed for the accuracy of their evidence.
- Ensure that patients understand that their personal risk may not be reflected accurately in general publications and that they should direct specific questions to their clinician.

Evidence
- Consensus.

Rationale
- With the proper information, patients may be able to answer their own questions.
5. Follow-up

**Monitor patients closely for immediate and long-term postoperative cardiac complications.**

5.1 **Maintain a low threshold for testing patients for evidence of ischemia and MI in the perioperative setting.**

**Recommendations**

- For asymptomatic patients at high cardiac risk, consider obtaining serial ECGs and cardiac enzymes for up to 1 week postoperatively.
- Evaluate all symptomatic patients for evidence of cardiac ischemia, even if their symptoms are atypical.

**Evidence**

- Important discrepancies in detection of postoperative cardiac event rates may arise from differences in surveillance strategies and definitions of outcome. Do not rely on symptoms alone for the detection of postoperative MI (83).
- Myocardial ischemia may present with atypical symptoms in the postoperative period (84).
- The 30-day postoperative period is an arbitrary designation; increased incidence of postoperative cardiac events may extend up to 6 months (55).

**Rationale**

- The postoperative period is a time of cardiac stress secondary to pain, fluid shifts, increased hypercoagulability, and other factors.
- Patients may not experience typical cardiac pain in the postoperative period in part because of altered pain sensation from analgesic use, underlying diabetes, or depressed level of consciousness secondary to anesthetic or sedatives.
- There is no single ideal protocol for detecting MI. More intensive electrocardiographic monitoring done postoperatively has been shown in a prospective study to result in a higher rate of MI detection.

**Comments**

- It is also beneficial to follow any other issues identified as part of the preoperative assessment.
References


Glossary

ACE
angiotensin-converting enzyme

BP
blood pressure

BUN
blood urea nitrogen

CABG
coronary artery bypass graft(ing)

CAD
coronary artery disease

CHF
congestive heart failure

CI
Confidence interval

COPD
chronic obstructive pulmonary disease

CV
cardiovascular

ECG
electrocardiography

JVP
jugular venous pressure

LVD
left ventricular dysfunction

MI
myocardial infarction

NNH
number needed to harm

NNT
number needed to treat

Pco₂
partial pressure of carbon dioxide

Po₂
partial pressure of oxygen

PCI
percutaneous coronary intervention

RR
relative risk

TIA
transient ischemic attack

Studies and Institutions

ACC
American College of Cardiology
AHA
American Heart Association

ASA class
American Society of Anesthesiologists physical status classification score

CARP
Coronary Artery Revascularization Prophylaxis

DECREASE
Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echo study

MaVS
Metoprolol after Vascular Surgery

NS-QUIP
National VA Surgical Quality Improvement Program

POISE
Effects of extended release metoprolol succinate in patients undergoing non-cardiac surgery

RCRI
Revised Cardiac Risk Index

VSG-CRI
Vascular Study Group of New England – Cardiac Risk Index
### Tables

#### History, Physical Examination, and Laboratory Items That Are Useful in Determining Risk for Cardiac Complications in Patients Who Are Undergoing Noncardiac Surgery

<table>
<thead>
<tr>
<th>History</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>MI (either &lt;6 months ago or &gt;6 months ago)</td>
<td></td>
</tr>
<tr>
<td>Exercise-induced shortness of breath and angina (obtain specific tolerance either by number of flights of stairs or by number of blocks on level ground)</td>
<td></td>
</tr>
<tr>
<td>Previous coronary revascularization, CHF, cerebrovascular disease, hypertension, or other heart disease (specifically aortic stenosis)</td>
<td></td>
</tr>
<tr>
<td>Diabetes (and insulin use)</td>
<td></td>
</tr>
<tr>
<td>Lung disease</td>
<td></td>
</tr>
<tr>
<td>Medication history</td>
<td></td>
</tr>
<tr>
<td>Type of surgery (emergency or not)</td>
<td></td>
</tr>
<tr>
<td>Type of anesthetic</td>
<td></td>
</tr>
</tbody>
</table>

#### Physical exam

| Heart rate and rhythm |  |
| BP |  |
| Elevated JVP |  |
| Presence of S3 |  |
| Aortic stenosis |  |
| Signs of COPD |  |
| Presence of peripheral vascular disease |  |

#### Laboratory tests (done on an individual basis)

| ECG (look for rhythm other than sinus; Q-waves; ST-segment abnormalities; LV hypertrophy; and >5 premature ventricular complexes) |  |
| Chest radiography (pulmonary edema <1 week or ever) |  |
| Blood tests (K+ <3 mmol/L, BUN >50 mmol/L, creatinine >260 µmol/L [or >2 mg/dL]) |  |
| Blood gases (P_{O2} <60 mm Hg, P_{CO2} >50 mm Hg) |  |
| B-type natriuretic peptide or pro-B-type natriuretic peptide |  |

Note: Clinicians should inquire not only about typical anginal symptoms but also about other exertional symptoms that may represent anginal equivalents. Additionally, orthopnea, paroxysmal nocturnal dyspnea, pedal edema transient ischemic attacks, previous strokes, murmurs, syncope, a complete diabetic history, and any previous problems with surgery are other historical variables that are important to obtain for the general perioperative management of the patient, even if they do not directly predict cardiac adverse events.
BP = blood pressure; BUN = blood urea nitrogen; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; ECG = electrocardiography; JVP = jugular venous pressure; LV = left ventricle; MI = myocardial infarction; P\(_{\text{CO}_2}\) = partial pressure of carbon dioxide; P\(_{\text{O}_2}\) = partial pressure of oxygen.
### Revised Cardiac Risk Index

<table>
<thead>
<tr>
<th>How many variables does the patient have?*</th>
<th>Risk of major postoperative cardiac complication†</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.4%</td>
</tr>
<tr>
<td>1</td>
<td>0.9%</td>
</tr>
<tr>
<td>2</td>
<td>7.0%</td>
</tr>
<tr>
<td>≥3</td>
<td>11.0%</td>
</tr>
</tbody>
</table>

* Variables are high-risk type of surgery, ischemic heart disease (includes any of the following: history of myocardial infarction, history of a positive exercise test, current complaint of chest pain that is considered to be secondary to myocardial ischemia, use of nitrate therapy, or electrocardiography with pathologic Q waves), congestive heart failure, and history of cerebrovascular disease, preoperative treatment with insulin, and preoperative serum creatinine >2.0 mg/dL. Patients with more than 2 variables have a postoperative cardiac complication rate of ~10% and are considered to be high risk.

† The major cardiac complications included myocardial infarction, pulmonary edema, ventricular fibrillation or primary cardiac arrest, and complete heart block.