

Cardiac Risk Stratification and Protection



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KEYWORDS

• Cardiac evaluation • Preoperative evaluation • Cardiac risk assessment

KEY POINTS

- Preoperative history and physical examination should be directed at assessment of known cardiac conditions (ischemic heart disease, heart failure), comorbidities that increase the chance of perioperative cardiac complications (diabetes requiring insulin, renal insufficiency, cerebrovascular disease), and patient functional status.
- Guidelines for perioperative cardiovascular evaluation are continuously updated by the American College of Cardiology and the American Heart Association and provide an algorithmic approach to this evaluation.
- Guidelines for the use of beta-blockers and statins in the perioperative period are in evolution.

INTRODUCTION

Cardiac risk assessment is important in the preoperative evaluation of surgical patients. The heart, although seemingly simple in its 4-chamber design, must be thoroughly evaluated before surgery because of the significant risks that can be incurred. It is estimated that cardiovascular complications cause half of all morbidity and mortality experienced in the perioperative period for patients undergoing noncardiac surgery, with even higher rates among vascular patients.¹

Cardiovascular disease is the leading cause of death in the United States. Thus, it is no surprise that it is a significant contributing factor to perioperative morbidity and mortality.^{2,3} The population of persons aged 65 years and older is estimated to increase 25% to 35% in the next 30 years, and this is the age group in which the largest number of operations is performed.⁴ It is also estimated that the number of surgical

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procedures in this age group will increase from 6 million to 12 million over the next 30 years.⁴

Every year, approximately 27 million patients undergo a noncardiac operation in the United States; 8 million, or 30%, have significant underlying coronary artery disease (CAD) or other cardiac conditions at the time of their procedure.^{1,3,5} Of people undergoing noncardiac surgery, 1 million, or 3%, of these patients will experience perioperative cardiac complications.^{3,6} The mortality after perioperative myocardial infarction (MI) has been quoted to be as high as 40% to 50% and tends to occur on postoperative day 3.⁵

Because of the risk of a cardiac event, emphasis must be placed on the preoperative cardiac evaluation. The goal of the preoperative evaluation is to screen broadly for undiagnosed disease or to find evidence of known conditions that are poorly controlled. The preoperative evaluation also helps determine if an additional cardiac work-up is necessary for patients. It also helps define realistic risks and goals for the forthcoming procedure, involves additional care teams, and helps determine whether the procedure is a realistic option. There are some cases when canceling an operation is necessary so that an underlying cardiac problem can be evaluated and managed to improve the safety of patients.⁷

Operations with major extracellular shift causing hemodynamic stress, prolonged operative times, or extensive anatomic dissections or that are performed on an urgent or emergent basis place patients at the highest risk for a cardiac event (Table 1).^{2,4,5} Patients can be placed into low-, intermediate-, or high-risk groups, with cardiac event rates being 1% or less, 1% to 5%, or 5% or more, respectively. Patients need to be medically optimized in the preoperative period, if possible.⁸ Some patients may never

Risk^{a,b}	Example
High ($\geq 5\%$ cardiac risk)	Emergent major operations, particularly elderly Aortic or major vascular surgery Peripheral vascular surgery Upper abdominal
Intermediate (1%–5% cardiac risk)	Intraperitoneal and intrathoracic surgery Carotid endarterectomy Head and neck surgery Gynecologic surgery Neurosurgery Orthopedic surgery Urologic surgery
Low ($\leq 1\%$ cardiac risk)	Endoscopic procedures Superficial procedures Cataract surgery Breast surgery Ambulatory surgery

^a Cardiac events include fatal and nonfatal cardiac events.

^b This table incorporates perioperative cardiovascular events within 30 days after surgery.¹²

Adapted from Fleisher LA, Beckman JA, Brown KA, et al. 2009 ACCF/AHA focused update on perioperative beta blockade incorporated into the ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. *Circulation* 2009;120:169–276; and Mukherjee D, Eagle KA. Perioperative cardiac assessment for noncardiac surgery: eight steps to the best possible outcome. *Circulation* 2003;107:2771–74.

be medically stable enough for such surgery, and the discussion of the benefits versus the risks of surgery must be explored.

Overall, the goal of any operation is to perform a procedure that will improve the patient's life. The objective of the perioperative evaluation is to find patients who are best suited for the procedure and will have the best outcome by minimizing morbidity and mortality. All patients require a history and physical examination, and this may be the only necessary evaluation for some patients. However, other patients may require further evaluation by a cardiologist or internist; some may even need an invasive cardiac procedure before a noncardiac surgery to optimize cardiac function to avoid perioperative events, such as MI, stroke, renal failure, and death. It is a delicate balance to determining which patients need this additional evaluation while avoiding unnecessary testing that delays surgical treatment and increases the cost of care.⁹

The objective of this article is to give a broad overview of the preoperative cardiac risk stratification and current recommendations for preoperative care. By far the most common cardiac issue confronted by the surgeon in the preoperative evaluation in noncardiac surgery is ischemic heart disease, so it is necessary to be familiar with how to perform an adequate preoperative cardiac evaluation to minimize this risk.¹⁰ This article reviews a brief history of prior cardiac risk stratification indexes, explores the current practice guidelines by the American College of Cardiology (ACC) and the American Heart Association (AHA) Task Force, reviews current methods for preoperative evaluation, discusses revascularization options, and evaluates perioperative medication recommendations.

EVOLUTION OF RISK STRATIFICATION

Introduced in 1963, the American Society of Anesthesiologist's (ASA) Physical Classification System (**Table 2**)³ was one of the first classifications systems used to assess the general risk for patients undergoing surgery. It is known from the National Surgical Quality Improvement Program that patients with an ASA score of 3 have increased odds for perioperative morbidity and mortality (3.4 odds ratio [OR], 95% confidence interval [CI] 2.7–4.7) and those with an ASA score of 4/5 have even higher odds of complications (8.1 OR, 95% CI 6.0–11.0).³ Although this classification system is a significant independent predictor of perioperative complications, it is still recommended that patients undergoing a procedure more involved than a skin biopsy should have a thorough risk assessment.^{3,8}

Table 2
ASA classification system

ASA Class	Description
I	Healthy patients
II	Mild/well-controlled diseases
III	Severe/multiple systemic diseases that limit activity but not incapacitating
IV	Life-threatening diseases that are incapacitating
V	Severely ill patients who may not survive without surgery in 24 h
VI	Brain dead patients for organ procurement
E	Emergency operation

From Saklad M. Grading of patients for surgical procedures. *Anesthesiology* 1941;2:281–4.

Over the past 50 years, the derivation of a standard cardiac risk index system has been evaluated and modified. Starting in 1977, the first set of multifactorial risk factors was evaluated by Goldman and colleagues,¹¹ and the original cardiac index (or the Goldman Cardiac Index) was created (Table 3).^{12,13} This system was later updated in 1986 by Detsky and colleagues,¹⁴ which also created a point system to identify patients with high cardiac risk, and incorporated patients with CAD, angina, recent MI, and heart failure (HF) (Table 4).¹³ A few years later in 1989, Eagle and colleagues¹⁵ evaluated patients who had undergone cardiac evaluation with nuclear medicine and found 5 predictive cardiac risk factors for patients undergoing vascular procedures, and they created the Eagle Cardiac Index (Table 5).¹⁶

Finally, in 1999 Lee and colleagues¹⁷ derived and validated the Revised Cardiac Risk Index (RCRI) after evaluating 4315 patients aged 50 years and older and incorporated 6 criteria to estimate patients' overall risk in noncardiac operations (Table 6). This system was found to be relatively inexpensive and less time consuming compared with other indices and has been used in the most current recommendations created by the ACC/AHA Task Force, which is described next.^{12,18}

PERIOPERATIVE CARDIAC EVALUATION FOR NONCARDIAC SURGERY

In 2009, the ACCF/AHA Task Force published their most recent guidelines for perioperative cardiovascular evaluation for patients undergoing noncardiac surgery. This set of guidelines has been evaluated and updated since 1996, and it has served as an excellent protocol for surgeons in determining the extent of preoperative evaluation necessary in order to optimize care.^{4,5,10} These clinical recommendations were updated in 2002 and extensively revised in 2007.¹⁰ It has been shown that as many as 40% of cardiology consultations offer no further intervention and recommend proceeding with surgery.⁴ Therefore, the surgeon acts as an important filter in determining which patients would benefit from further cardiac evaluation rather than sending all patients to a cardiologist or internist preoperatively.

Patients with known CAD or new onset of signs or symptoms suggestive of CAD need a baseline cardiac assessment.⁴ The surgeon is tasked with determining what additional work-up is necessary in conjunction with a detailed perioperative history and physical. Specifically, determining the additional work-up needed in those patients older than 50 years is emphasized because the RCRI (see Table 6) was derived from this patient population.¹⁷

Table 3
The Goldman Cardiac Index

Risk Factor	Points	Cardiac Complication Rate
1. Third heart sound or jugular venous distention	11	0–5 points: 1%
2. Recent MI within 6 mo	10	6–12 points: 7%
3. Nonsinus rhythm or premature atrial contraction on electrocardiogram	7	13–15 points: 14% >26 points: 78%
4. >5 premature ventricular contractions	7	
5. Age >70 y	5	
6. Emergency operations	4	
7. Poor general medical conditions	3	
8. Intrathoracic, intraperitoneal, or aortic surgery	3	
9. Important valvular aortic stenosis	3	

From Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. *N Engl J Med* 1977;297:845–50.

Risk Factor^a	Points
1. Class 4 angina	20
2. Suspected critical aortic stenosis	20
3. MI within 6 mo	10
4. Alveolar pulmonary edema within 1 wk	10
5. Unstable angina within 3 mo	10
6. Class 3 angina	10
7. Emergency situation	10
8. MI >6 mo	5
9. Alveolar pulmonary edema resolved >1 wk	5
10. Rhythm or other than sinus or PACs on ECG	5
11. >5 PVCs any time before surgery	5
12. Poor general medical status	5
13. Age >70 y	5

Abbreviations: ECG, electrocardiogram; PACs, premature atrial contractions; PVCs, premature ventricular contractions.

^a Greater than or equal to 15 points equals a high risk of cardiac complications.

From Detsky AS, Abrams HB, Forbath N, et al. Cardiac assessment for patients undergoing noncardiac surgery: a multifactorial clinical risk index. *Arch Intern Med* 1986;146:2131–4.

The initial history and physical examination of patients is key in determining what diseases patients may have been treated for or discovering a new underlying disease, and it is required in all nonemergent patient populations. When determining a cardiac history, patients should be questioned about any history of unstable coronary syndromes, angina, MI, HF, valvular disease, or arrhythmia (**Table 7**).^{4,9,19} If patients have a known cardiac history, it should also be determined what prior interventions have been undertaken, including pacemaker placement, percutaneous coronary intervention, or cardiac surgery.²⁰ Many times, patients have associated diseases like diabetes, hypertension, or renal disease; these should also be documented.⁸

During the history and physical examination, the patients' baseline functional capacity should be determined.²¹ Functional capacity correlates positively with

Risk Factor (Each 1 Point)	Score	Risk of Cardiac Complications (95% CI)
1. Age >70 y		
2. Diabetes	0	3.1% (0%–8%)
3. Angina	1–2	29.6% (16%–44%)
4. Q waves on electrocardiogram	≥3	50.0% (29%–71%)
5. Ventricular arrhythmia		

From Eagle KA, Brundage BH, Chaitman BR, et al. Guidelines for perioperative cardiovascular evaluation for noncardiac surgery. Report of the American College of Cardiology/American Heart Association task force on practice guidelines. Committee on Perioperative Cardiovascular Evaluation for Noncardiac Surgery. *Circulation* 1996;93(6):1278–317; with permission.

Risk Factors (1 Point Each)	Score	Risk of Cardiac Complications (95% CI)
1. HF		
2. Cerebrovascular disease	0	0.4% (0.05–1.5)
3. Ischemic heart disease	1	0.9% (0.4–2.1)
4. Diabetes requiring insulin	2	7% (3.9–10.3)
5. Creatinine >2.0 mg/dL	≥3	≥11% (5.8–18.4)
6. Undergoing suprainguinal vascular, intraperitoneal, or intrathoracic surgery		

All risk factors are based on history of these diseases or active diseases found on physical examination or study.⁴

From Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999;100:1043–90; with permission.

oxygen uptake found on treadmill testing.²⁰ The functional capacity is expressed as metabolic equivalents (METs), whereby resting (also called basal) oxygen consumption is roughly 1 MET.^{5,21,22} Functional capacity is generally classified as excellent (>10 METs), good (7–9 METs), moderate (4–6 METs), or poor (≤4 METs).²¹ Perioperative cardiac risks are increased in patients unable to reach 4 METs.^{1,2,5,22} Patients who cannot walk 4 blocks or climb 2 flights of stairs, for example, are considered to have poor functional capacity.^{18,21,23}

Condition	Examples
Unstable coronary symptoms	Stable or severe angina Recent or acute MI
Decompensated HF	
Significant arrhythmias	High-grade atrioventricular block Mobitz II atrioventricular block Third-degree heart block Symptomatic ventricular arrhythmias Supraventricular arrhythmias with uncontrolled rate (>100 beats per min) Symptomatic bradycardia Newly recognized ventricular tachycardia
Severe valvular disease	Severe aortic stenosis (mean pressure gradient >40 mm Hg, valve area <1 cm ² , symptomatic) Symptomatic mitral stenosis (dyspnea, exertional syncope, HF)

Adapted from Fleisher LA, Beckman JA, Brown KA, et al. 2009 ACCF/AHA focused update on perioperative beta blockade incorporated into the ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. *Circulation* 2009;120:169–276; and Fleisher LA. Cardiac risk stratification for noncardiac surgery: update on the American College of Cardiology/American Heart Association 2007 guidelines. *Cleve Clin J Med* 2009;76(4):9–15.

When evaluating patients by physical examination, vital signs, carotid pulse and bruits, auscultation of the lungs, auscultation of heart for S3 and S4 sounds or arrhythmias, abdominal palpation, and extremity evaluation are all crucial in determining the cardiac status of patients and can also be key to discovering underlying disease.^{4,20} If patients have known comorbidities, such as diabetes or hypertension, evaluation of medical control of these conditions also needs to be performed.⁹ Diabetes is the most common comorbidity associated with cardiac disease; if present, suspicion should be heightened for CAD.¹³ Also, preoperative hemoglobin A_{1c} is of value because it may alter perioperative diabetic management.^{9,13} If laboratory or radiographic data are available, it should be reviewed. The decision to perform additional preoperative testing should be based on the findings of the history, physical examination, and clinical judgment of the surgeon.^{8,9,20}

Fig. 1 represents the preoperative cardiac evaluation algorithm for noncardiac surgery as proposed in the “2009 Updated ACCF/AHA Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery.”⁴ As can be seen, there are 5 steps in the algorithm that can help the surgeon tailor the cardiac evaluation for preoperative patients.

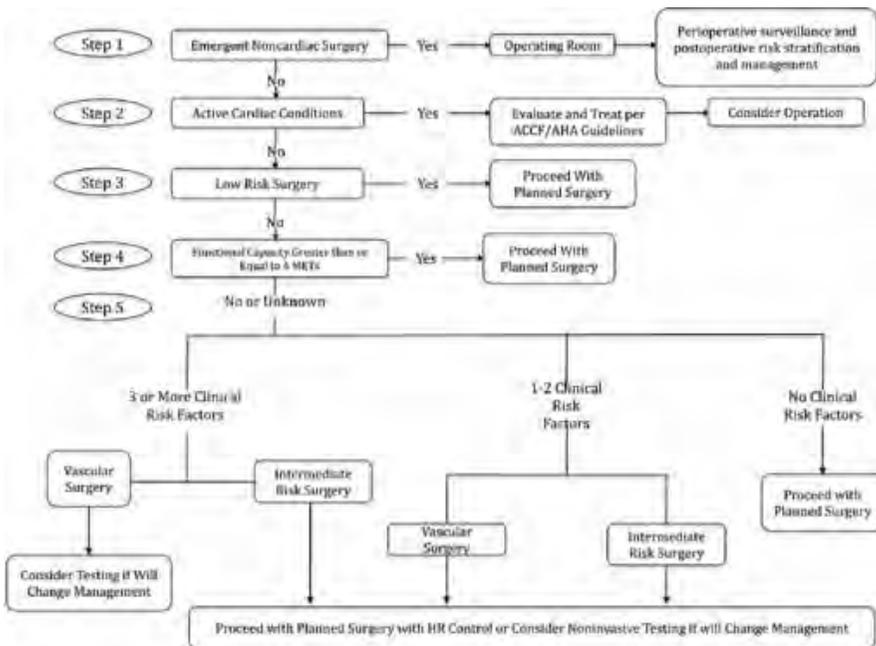


Fig. 1. ACCF/AHA's perioperative guidelines algorithm for noncardiac surgery. Encompasses active clinical conditions, known cardiovascular disease, or cardiac risk for patients aged 50 years and older. HR, heart rate. ^a Active cardiac conditions as described in [Table 7](#). ^b Low-, intermediate-, and high-risk surgeries as described in [Table 1](#). ^c Risk factors as described in [Table 6](#). (Adapted from Fleisher LA, Beckman JA, Brown KA, et al. 2009 ACCF/AHA focused update on perioperative beta blockade incorporated into the ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. *Circulation* 2009;120:169–276; with permission.)

Step 1

Determining if the surgery is emergent is step 1 of the algorithm. If so, it is recommended that patients immediately proceed to the emergent operation; only the most necessary tests and interventions are performed.⁴ These tests and interventions may be limited to simple evaluations, such as vitals, essential laboratory values, electrocardiogram (ECG), and urine analysis, so the procedure will not be delayed. Cardiac complications are 2 to 5 times more likely to occur with emergent surgical procedures.^{4,24} Because these surgical emergencies eliminate the ability for a preoperative cardiac optimization, a more thorough investigation and monitoring must be performed once patients are stable postoperatively.⁴ If there is concern for a cardiac abnormality, it is suggested that transesophageal echocardiography be used intraoperatively to evaluate for a potential cardiac event in emergent patients.⁸

Step 2

Step 2 is determining if patients have an active cardiac condition, which is a substantial perioperative risk.^{10,13} Active cardiac conditions are defined in these guidelines as unstable coronary syndromes, decompensated HF, significant arrhythmias, and severe valvular disease, with examples given in **Table 7**.⁴ An acute MI is defined as within 7 days, and recent MI is between 7 days to 1 month before evaluation.³ It is generally recommended to wait 4 to 6 weeks after MI before performing elective surgery; however, this recommendation has not been supported by any clinical trials.³ If patients present with any of these active cardiac conditions, they need to be evaluated and treated per the ACCF/AHA's guidelines before any operation is undertaken.^{4,13}

Step 3

The third step is determining the cardiac risk associated with the proposed operation. For step 3, if patients are undergoing a low-risk procedure and have no known active cardiac conditions, it is generally recommended to proceed with the operation.⁴ As shown in **Table 1**, low-risk operations have a combined morbidity and mortality rate 1% or less even in high-risk patients.⁴ Interventions based on cardiovascular testing before low-risk procedures rarely result in a change in management, so it is appropriate to proceed to surgery without additional testing or new pharmacologic therapy.^{8,10}

Step 4

If patients are undergoing an intermediate- or high-risk surgery (see **Table 1**), their functional capacity must be determined. In step 4, it is recommended that patients with a functional capacity greater than or equal to 4 METs can proceed with the operation without additional evaluation.⁴

As described earlier, the functional capacity evaluates a patient's ability to perform daily activities and is a reliable predictor of cardiac events.^{3,4} One of the benefits of this algorithm is that it takes into account that the perioperative and long-term cardiac risks are increased in patients unable to meet a 4-MET minimum.^{3,23} In a series evaluating 600 patients undergoing noncardiac surgery, Reilly and colleagues²³ showed that self-reported poor exercise tolerance (≤ 4 METs) was associated with increased perioperative cardiac risk and the likelihood of a serious complication occurring was inversely related to the number of blocks that could be walked or flights of stairs that could be climbed. In their study, patients reporting poor exercise tolerance had more perioperative complications compared with patients with good functional

capacity (20.4% vs 10.4%; $P < .001$), including myocardial ischemia and cardiovascular and neurologic events.²³

Step 5

If the patients' functional capacity is unknown or less than 4 METs, the number of clinical risk factors as described by the RCRI (see **Table 6**) helps determine if the patients require further cardiac evaluation. For step 5 of the algorithm, if patients have no clinical risk factors, then they are able to proceed with the planned operation.⁴

If patients have 1 to 2 clinical risk factors, the ACCF/AHA's guidelines recommend 2 possible options. The first is to proceed with surgery with heart rate control with beta-blockade. Alternatively, the physician can consider preoperative cardiac testing if it is thought that it will result in a change in patient management.^{4,10}

In patients with 3 or more clinical risk factors, the surgery associated cardiac risk (see **Table 1**) is important in determining the care. For the patient population undergoing intermediate-risk surgery, there are insufficient data to determine the best strategy.⁴ However, there are 2 suggestions: proceed with surgery with beta-blockade or undergo further cardiac testing if it is expected to result in a change in patient management.^{4,10} In the same population undergoing vascular or other high-risk surgery, there is a higher incidence of underlying CAD; therefore, additional cardiac testing is recommended if it will change management.⁴ Faggiano and colleagues⁶ found that intensive cardiac preoperative evaluation with noninvasive diagnostic tests in patients undergoing high-risk surgery had reductions in cardiac morbidity and mortality and recommended noninvasive preoperative testing for patients in this population.

Overview of Recommendations

Although this algorithm is useful for directing the surgeon in the preoperative cardiac evaluation for patients, it must be remembered that morbidity and mortality vary significantly between procedures and institutions.^{4,19} A study performed at the University of Michigan demonstrated that the implementation of these guidelines in an internal medicine preoperative assessment clinic led to a more appropriate use of preoperative stress testing and beta-blocker therapy, while keeping the rate of cardiac complications low.¹⁶

The ACCF/AHA's guidelines give a framework for the perioperative intervention strategy, but patient risks and preoperative care must be individualized. In the end, it is up to the surgeon to determine the risk incurred by the patients and when there is a need for further evaluation.

SUPPLEMENTAL CARDIAC EVALUATION

After working through the aforementioned algorithm, the surgeon must determine if supplemental testing is necessary. This section explores the ACCF/AHA Task Force's recommendations for supplemental cardiac evaluation.

Electrocardiogram

The standard 12-lead ECG is a frequent starting point for perioperative testing. According to the ACCF/AHA, preoperative resting ECG testing guidelines are as follows:

- ECG is recommended for patients with at least 1 clinical risk factor who are undergoing vascular or intermediate-risk surgery.
- ECG is recommended for patients with known congestive HF, peripheral artery disease, or cerebrovascular disease who are undergoing an intermediate or high-risk procedure.

- ECG is reasonable to perform in patients with no risk factors undergoing vascular surgery.
- ECG is not indicated in asymptomatic patients undergoing low-risk procedures.^{4,9,18}

The general consensus is that an ECG, if necessary, be performed within 30 days of the procedure.²⁰ In the aforementioned recommendations, clinical risk factors are defined as those from the RCRI (see **Table 6**). When Lee and colleagues¹⁷ developed the RCRI, the presence of a pathologic Q wave on the preoperative ECG was associated with a 2.4-fold increased risk of fatal and nonfatal events.¹² One single-center study showed that patients with abnormal preoperative ECGs had higher rates of perioperative cardiovascular events compared with those with normal ECGs (16.0% vs 6.4%; $P < .001$), and prolonged QTc interval was associated with a 13% increased risk of perioperative cardiac event.¹²

Exercise Stress Testing: Evaluation of Myocardial Ischemia and Functional Capacity

If patients are found to have an abnormal ECG or the functional capacity has not yet been evaluated, exercise stress testing can be used to identify the presence of myocardial ischemia, to determine a patient's functional capacity, and to evaluate hemodynamic response.^{10,13,22} The exercise stress test is preferred over the pharmacologic stress test because of its ability to determine all of these factors.^{3,10,22} Of the patients who undergo exercise stress testing who have a normal ECG and do not have a cardiac history, 20% to 50% will have an abnormal exercise ECG. A total of 35% to 50% of patients with a prior history of MI or who have an abnormal resting ECG will have abnormalities on exercise stress testing.⁴ When performing the exercise stress test, the onset of myocardial ischemia at low exercise workloads is associated with a significantly increased risk of perioperative cardiac events.²⁰

According to the ACCF/AHA Task Force, the following are recommendations regarding noninvasive stress testing before noncardiac surgery:

- It is reasonable to perform noninvasive stress testing in patients with 3 or more clinical risk factors and a functional capacity 4 METs or less who require vascular surgery if it will alter preoperative management.
- It may be considered for patients with 1 to 2 clinical risk factors and a functional capacity of 4 METs or less who require intermediate-risk or vascular surgery.
- Noninvasive stress testing is not useful for patients with no clinical risk factors undergoing intermediate-risk surgery or patients undergoing low-risk surgery.⁴

Some patients are unable to exercise to increase myocardial oxygen demand to a level needed for optimal cardiac stress evaluation, and attempts to determine myocardial ischemia must be done with pharmacologic stress testing.¹³ The most commonly used methods are the dobutamine stress echocardiography (DSE) and intravenous dipyridamole myocardial perfusion imaging with thallium-201 and technetium-99m.^{1,4,13} DSE and dipyridamole nuclear imaging have high negative predictive values, 90% to 100% and 97% to 100%, respectively, in evaluating for ischemia.^{1,5} Studies have shown that reversible perfusion defects (demonstrating jeopardized myocardium) indicate the greatest risk of a cardiac event, and the risk of events increases with extent of the reversible defect.⁴ Conversely, studies show that a fixed perfusion defect does not serve as a predictor of perioperative cardiac events.⁴

If perfusion defects are found via exercise, dobutamine, or dipyridamole testing then it may be necessary for patients to undergo additional evaluation by angiography.²⁵ Angiography is used to define anatomic abnormalities requiring intervention but

should only be performed if it will alter perioperative management.^{3,13} Overall, stress testing should no longer be considered a routine step in the preoperative evaluation unless it will significantly affect patient management.¹⁰

PERIOPERATIVE THERAPY: REVASCULARIZATION WITH CORONARY ARTERY BYPASS GRAFT AND PERCUTANEOUS CORONARY INTERVENTION

If patients are found to have significant CAD in the preoperative evaluation, the next determination to be made is if they require revascularization. Some patients may undergo coronary artery bypass grafting (CABG), whereas others may receive percutaneous coronary intervention (PCI). The ACCF/AHA Task Force has class I, level A recommendations that show coronary revascularization before noncardiac surgery is useful in

- Patients with stable angina who have significant left main coronary artery stenosis
- Patients with stable angina who have 3-vessel disease
- Patients with stable angina who have 2-vessel disease with significant proximal left anterior descending stenosis and either ejection fraction of 50% or less or demonstrable ischemia on noninvasive testing
- Patients with high-risk unstable angina or non-ST segment elevation MI or with acute ST-elevation MI⁴

Determining which intervention is necessary is often at the discretion of the cardiology consultant, and risks and benefits must be weighed. Generally, patients who need CABG before noncardiac procedures are found to have high-risk coronary anatomy.⁴ Studies have shown that patients with previous successful coronary bypass have a low perioperative mortality rate with noncardiac procedures and that their mortality rate is comparable to the surgical risk for other patients who have no clinical CAD.^{4,5} These patients also have lower rates of perioperative MI compared with those patients undergoing PCI, which is attributable to more thorough revascularization with the CABG.¹⁸

After a CABG procedure, it is recommended that patients wait 4 to 8 weeks before proceeding with noncardiac surgery.¹⁰ For patients recommended for a CABG, it must be remembered that the benefit of the noncardiac operation should outweigh the morbidity and mortality of both the cardiac revascularization and the planned noncardiac procedure.^{5,8}

PCI is another method of coronary artery revascularization in the preoperative period. There are currently 3 methods of percutaneous revascularization: balloon angioplasty, bare metal stents, and drug-eluting stents (DES). Coronary stents are now used in more than 80% of PCIs.² Each of these comes with different risks and benefits; but studies have found PCI before noncardiac surgery is of no value in preventing perioperative events, except in those patients who have an acute coronary syndrome, such as ST-elevation MI, unstable angina, and non-ST-elevation MI. In these situations, PCI would independently be recommended per the ACC/AHA's guidelines.^{1,2,4} This intervention usually includes patients with significant left main CAD and those with 3-vessel CAD.¹⁰ Once again, the cardiology consultant exercises the discretion in determining the type of intervention. Selection of patients for a CABG procedure versus PCI is beyond the scope of this article, but the topic is addressed in the ACCF/AHA's practice guidelines for PCI and CABG.²⁶⁻²⁸

If patients undergo balloon angioplasty for an acute coronary condition, it is recommended that the elective noncardiac procedure be delayed at least 2 to 4 weeks

so sufficient time is allowed for the healing of the vessel injury at the balloon treatment site.⁴ This type of intervention can be used for patients requiring urgent operations.² Patients that undergo this treatment should be kept on aspirin from the time of intervention through the perioperative period, if possible.⁴ It is recommended that if patients require an elective noncardiac operation, that it be performed within 8 weeks of the balloon angioplasty because of the risk of restenosis at the angioplasty site and subsequent increased risk of perioperative cardiac events.⁴

The bare-metal stent is the next PCI option, and it can be used for mitigation of cardiac symptoms in patients requiring an elective noncardiac operation within 12 months.⁴ Following bare-metal stent placement, it is recommended that dual antiplatelet therapy with a thienopyridine (ticlopidine or clopidogrel) and aspirin be administered for at least 4 to 6 weeks.^{25,29} The risk of thrombosis of the bare-metal stent is highest at 2 weeks after placement and rare beyond 4 weeks of placement.^{8,29} Following 4 weeks of dual antiplatelet therapy, aspirin should be continued lifelong, and thienopyridine therapy can be stopped.^{18,30} Elective noncardiac operations should be delayed 4 to 6 weeks after the placement of bare-metal stents to allow for partial endothelialization of the stent, but these operations should be undertaken before 12 weeks when restenosis begins to occur.^{4,5,30} It is recommended to allow 1 week after stopping thienopyridine therapy before surgery because of the increased risk of bleeding, although aspirin should be continued if possible.⁴ Aspirin increases surgical bleeding by about 20%; however, if such bleeding can be tolerated during the procedure, then aspirin should be continued because the cardioprotective risks usually outweigh the risk of bleeding.^{10,18}

The final PCI option is the DES, which is designed to reduce neointimal hyperplasia and lower restenosis rates.⁴ These stents can be coated with sirolimus or paclitaxel, which actually can increase the risk of thrombosis and delay endothelialization and healing of the vessel.^{4,31-33} For this reason, the US Food and Drug Administration's current recommendation is that dual antiplatelet therapy with a thienopyridine and aspirin be continued for 12 months after DES placement as long as patients are not at significant risk for bleeding.^{4,33}

It has been shown that premature discontinuation of dual antiplatelet therapy with DES is associated with a markedly increased risk of stent thrombosis and subsequent MI or death.^{8,18,31,32} After 12 months, it is recommended to continue with lifelong aspirin therapy. This therapy should be continued through the perioperative period of an elective noncardiac procedure.^{18,29,33} Overall, elective noncardiac surgery should not be performed within 12 months of DES placement because of the increased risk of thrombosis with discontinuation of dual antiplatelet therapy.³³

The type of intervention, the time frame before surgery, and the medical interventions required for each PCI are listed in **Table 8**. If thienopyridines must be discontinued prematurely before major surgery, then aspirin should be continued and thienopyridine therapy resumed as soon as possible.^{4,10,19} It has been shown that a hypercoagulable condition develops 7 to 10 days after discontinuation of antiplatelet therapy and places patients at risk for a thrombotic cardiac event.^{4,10,19}

As mentioned earlier, there is no current evidence that PCI before an elective noncardiac surgery is beneficial; patients that have indications for PCI in the preoperative setting are the same as those developed by the ACCF/AHA Task Force, regardless of an impending surgical procedure.⁴ It is also not recommended that routine prophylactic coronary revascularization be performed in patients with stable CAD before noncardiac surgery.⁴

Two trials form the basis of these recommendations, with the first being the Coronary Artery Revascularization Prophylaxis (CARP) trial.⁴ The purpose of the CARP trial

Intervention	Time Since PCI	Recommendation
Balloon angioplasty	<14 d	Delay for elective or nonemergent surgery
	>14 d	Proceed to operating room with aspirin
Bare-metal stent	<30–45 d	Delay for elective or nonemergent surgery
	>30–45 d	Continue on dual antiplatelet therapy Proceed to operating room with aspirin
DES	<1 y	Delay for elective or nonemergent surgery
	>1 y	Continue on dual antiplatelet therapy Proceed to operating room with aspirin

Adapted from Fleisher LA, Beckman JA, Brown KA, et al. 2009 ACC/AHA focused update on perioperative beta blockade incorporated into the ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. Circulation 2009;120:169–276; with permission.

was to determine if the use of prophylactic coronary revascularization before a high-risk operation reduced perioperative cardiac events when compared with optimized medical management.^{13,18,34} After a mean follow-up of 30 days and 2.7 years, no difference in all-cause mortality or postoperative MI was found in either group, leaving the investigators to conclude that coronary-artery revascularization before elective vascular surgery among patients with stable cardiac symptoms was not recommended.^{10,13,18,34} This study is criticized, however, because of the exclusion of some patients with 3-vessel disease and significant ischemia, and it lacked sufficient statistical power.¹³

To further address the situation, the second trial known as the Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography (DECREASE-V) trial included these high-risk patients with evidence of significant ischemia undergoing vascular surgery.^{18,35,36} This study confirmed that preoperative revascularization conferred no benefit when performed prophylactically to prevent cardiac events, and mortality was the same in medically optimized groups at 30 days and 1 year.^{7,35,36} These studies highlight why the ACCF/AHA's guidelines indicate that routine prophylactic coronary revascularization is not recommended for patients with stable CAD before noncardiac surgery.^{4,10,13}

PERIOPERATIVE MEDICAL THERAPY

Recommended guidelines on preoperative medical therapy were most recently updated in the “2009 ACCF/AHA Focused Update on Perioperative Beta Blockade Incorporated Into the ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery” after the presentation of new clinical trials at scientific meetings of the ACCF, AHA, and European Society of Cardiology in 2008.^{4,37} The following sections discuss beta-blocker and statin usage in accordance with current guidelines.

Beta-blockers

Perioperative beta-blocker use has been a significantly investigated and discussed topic. Beta-blockers have been shown to prevent cardiac ischemia by decreasing

the heart rate and force of contraction, thereby decreasing myocyte oxygen demand.⁷ The 2009 ACCF/AHA's focused update recommends the following:

- Beta-blockers should be continued in patients undergoing surgery who are receiving beta-blocker treatment of conditions with indications for the usage.
- Beta-blockers titrated to heart rate and blood pressure are probably recommended before vascular surgery for patients who are at a high cardiac risk because of CAD or ischemia on preoperative testing.
- Beta-blockers titrated to heart rate and blood pressure are reasonable for patients that have more than one clinical cardiac risk factor (see **Table 6**) on preoperative assessment for vascular surgery.
- Beta-blockers titrated to heart rate and blood pressure are reasonable for patients who are discovered to have CAD on the preoperative assessment or have more than one clinical cardiac risk factor (see **Table 6**) who are undergoing intermediate-risk surgery (see **Table 1**).⁴

The usefulness of beta-blockers is currently uncertain in 2 patient populations. The first are patients undergoing intermediate-risk or vascular surgery who only have a single clinical cardiac risk factor (see **Table 6**).⁴ The second are patients undergoing vascular surgery with no clinical cardiac risk factors (see **Table 6**).⁴ In a 2005 study by Lindenauer and colleagues,³⁸ more than 780,000 patients were evaluated retrospectively; it was determined that beta-blocker therapy was not associated with reducing cardiac risk in low-risk patients undergoing major noncardiac surgery.

Mangano and colleagues²⁴ performed the first randomized controlled trial to show a benefit of preoperative beta-blockade in 1996. They showed that atenolol decreased the mortality in patients from 21% to 10% at 2 years postoperatively. This study, however, did not show that atenolol significantly reduced the incidence of perioperative cardiac mortality.²⁴ In 1999, Poldermans and colleagues³⁹ showed in another randomized controlled trial that bisoprolol reduced the perioperative incidence of death from cardiac causes and nonfatal MI from 34.0% to 3.4% ($P < .001$) in more than 840 high-risk patients undergoing major vascular surgery. This study emphasized the importance of the preoperative evaluation in screening for high-risk patients who could benefit from medical therapy.³⁹ The study recommended that patients identified as high-risk receive beta-blockers 1 or 2 weeks before surgery with a heart rate goal of less than 70 beats per minute preoperatively and less than 80 beats per minute postoperatively.³⁹

In 2008, Dunkelgrun and colleagues⁴⁰ further supported these 2 trials with the results of the DECREASE IV trial, which was a randomized controlled trial of bisoprolol and fluvastatin used in intermediate-risk patients undergoing noncardiac surgery.⁴¹ More than 1060 enrolled patients were at least 40 years of age, scheduled for elective noncardiac surgery, naïve to statin and beta-blocker use, and had an estimated risk of perioperative death and MI of 1% to 6%.⁴⁰ Patients were randomized to use of beta-blocker therapy, statin therapy, a combination of both statin and beta-blocker, or no medications. Patients were started on medications at a median of 34 days before surgery and continued until postoperative day 30.⁴⁰ The end points of the study were 30-day cardiac death and MI, and it was shown that low-dose beta-blockers were cardioprotective in the intermediate-risk group without any increased incidence of stroke or mortality.^{4,40} The DECREASE IV was stopped early secondary to slow enrollment, so the power of this study is limited.^{37,41} This study did demonstrate that beta-blockers need to be started well in advance of surgery to allow appropriate titration. Further, although not adequately powered to achieve

statistical significance, the study suggested patients treated with fluvastatin trended toward improved outcome.⁴⁰

In 2008, the Perioperative Ischemic Evaluation (POISE) trial results were published showing that routine administration of high-dose beta-blockers in the absence of dose titration is not useful and may actually be harmful to patients undergoing noncardiac surgery.⁴² The POISE trial was a randomized controlled trial that incorporated more than 8000 beta-blocker-naïve patients undergoing noncardiac surgery. In this trial, patients were randomized to start high-dose extended-release metoprolol 2 to 4 hours before surgery and continue for 30 days.^{10,42} Patients were kept on metoprolol as long as their heart rate was greater than 50 beats per minute and their systolic blood pressure was greater than 100 mm Hg.¹⁰ The end points evaluated were cardiovascular death, nonfatal MI, and nonfatal cardiac arrest.⁴² This study found that although there was a reduction in cardiovascular death, MI, and cardiac arrest, this was offset by an increase in the risk of stroke, hypotension, bradycardia, and total mortality.^{10,42} Overall, this study suggested that although beta-blocker therapy reduces the risk of perioperative cardiac events in high-risk patients, routine administration of high-dose, long-acting beta-blockers in beta-blocker-naïve patients without titration can actually increase mortality.^{10,37}

The POISE study did not address patients who were already on beta-blocker therapy in accordance with the ACCF/AHA's current guidelines, and it is currently recommended that patients already on beta-blockers continue throughout the perioperative period.^{10,37} Patients undergoing elective surgery for whom beta-blockers are recommended or reasonable (see earlier bullet points) should have the therapy initiated days to weeks before an elective operation, and this should be titrated to lowered heart rate without causing frank hypotension.³⁷ Beta-blockers should not be given to patients undergoing surgery who have absolute contraindications to beta-blockade.⁴

In titrating beta-blocker medications in any patient population, the ACCF/AHA's 2009 update recommends that patients be started on beta-blockers before surgery with titration to a goal heart rate between 60 and 65 beats per minute and with avoidance of frank hypotension.^{4,10,40} A meta-analysis by Cucherat⁴³ found that each slowing of 10 beats per minute, while maintaining blood pressure, reduced the risk of cardiac death by 30%.

Interruption of beta-blocker therapy may lead to recurrent angina, arrhythmias, rebound hypertension, rapid atrial fibrillation, and MI in the perioperative period.^{10,37} It has been shown that selective beta-blocker discontinuation increases the risk of MI in the first 30 days after cessation (relative risk [RR] 2.7, 95% CI 1.06–6.89) and 30 to 180 days after cessation (RR 2.44, 95% CI 1.07–5.59).⁴⁴ In more than 700 patients undergoing endovascular and open vascular surgery, it was shown that continuous beta-blocker use was significantly associated with decreased 1-year mortality compared with those who were not on beta-blockers (hazard ratio 0.4, 95% CI 0.2–0.7).⁴⁵ Overall, evidence shows that if beta-blockers are used, they should be appropriately titrated throughout the preoperative, intraoperative, and postoperative period to achieve heart rate control while avoiding hypotension. Patients already on beta-blockers should have this therapy continued through the perioperative period.⁴

Statins

Statin therapy has been shown to be effective in secondary prevention of cardiac events.⁴ These medications work by inhibiting hydroxymethylglutaryl coenzyme A and have been shown to improve endothelial function, reduce vascular inflammation, stabilize atherosclerotic plaque, lower low-density lipoprotein cholesterol, and

decrease matrix metalloproteinase and cell death.^{4,40,46} The risks of statin therapy include myopathy and rhabdomyolysis.⁴⁰ The ACCF/AHA's current 2009 guidelines for statin medications are as follows:

- Patients who take a statin and are undergoing noncardiac surgery should have this therapy continued.
- Statin therapy is reasonable for patients undergoing vascular surgery with or without a risk factor.
- Statin therapy may be considered for patients with at least 1 clinical risk (see **Table 6**) factor undergoing intermediate risk procedures.⁴

Although much of the data that currently supports statin use are primarily from retrospective studies, case control studies, and small randomized controlled studies, the evidence suggests that statins are cardioprotective when used or continued during noncardiac surgery.^{4,46} In 2005, The Statins for Risk Reduction In Surgery study retrospectively evaluated more than 1160 patients undergoing vascular surgery; it was found that patients receiving statins had significantly fewer cardiovascular complications (9.9%) than those patients who were not receiving statins (16.5%, $P = .001$).⁴⁷ Another retrospective study performed at the University of Rochester Medical Center showed through multivariate analysis that the use of statins was associated with decreased major cardiac complications, noncardiac complications, respiratory complications, and infectious complications.⁴⁸

The exact mechanism through which statins confer possible benefits is still unknown, and it is currently recommended that more randomized controlled trials with prospective data would be beneficial to support perioperative statin usage.⁴⁶⁻⁴⁸

SUMMARY

Advances in the preoperative risk assessment have helped to decrease the frequency of cardiovascular complications associated with noncardiac surgery.^{16,19} The major parameters that determine the risk of cardiac morbidity and mortality for patients undergoing noncardiac surgery are the risk of surgery, patient clinical characteristics, and patient functional capacity.¹⁰ Nonfatal and fatal cardiac events are one of the biggest sources of perioperative morbidity and mortality; therefore, optimizing patients in the preoperative period is essential for surgeons who perform noncardiac operations.²⁴ Ultimately, everything comes down to the patients, and care must be individualized. All patients require some form of preoperative screening, ranging from a simple history and physical examination to invasive procedures. Therapy with beta-blockers and statins should be reviewed and considered. Surgeons must remain current on the recommendations for preoperative evaluation in order to optimize postoperative outcomes.

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