Perioperative Cardiac Evaluation: Assessment, Risk Reduction, and Complication Management

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KEYWORDS

- Preoperative care • Perioperative • Risk assessment
- Postoperative complication • Stent • Angioplasty
- Transluminal • Percutaneous coronary
- Coronary artery bypass • β-Adrenergic blockers
- Statin • Surgical procedures • Operative

Cardiac complications contribute significantly to perioperative morbidity and mortality in the elderly. The incidence of major cardiac outcomes (cardiac death, nonfatal myocardial infarction [MI], and nonfatal cardiac arrest) as a result of noncardiac surgery ranges from 1.5% (in unselected patients) to 4% (in patients with, or at risk for, cardiac disease).[1]

Practice patterns among clinicians who perform preoperative evaluations vary widely, in part, because of a lack of consensus on how best to assess cardiac risk. Many risk assessment methods have been proposed in the past 30 years,[2–5] but the Lee Revised Cardiac Risk Index (RCRI) has been shown to have better diagnostic performance compared with the others.[4,6] However, the Lee RCRI does not give recommendations on which patients should have further cardiac testing. The result has been a general tendency toward overuse of cardiac testing.

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Given the striking practice variation and high costs associated with many preoperative cardiac risk assessment and evaluation strategies, the use of practice guidelines, based on currently available knowledge, can serve to foster more efficient and cost-effective approaches to perioperative evaluation. The American College of Cardiology, together with the American Heart Association, published the "Guideline on Perioperative Cardiovascular Evaluation and Care for Non-cardiac Surgery (ACC/AHA Guideline)" in 1996, with subsequent revisions in 2002 and 2007.[6] These guidelines are based on best evidence, where evidence exists in the literature and on expert opinion where there are gaps in the available evidence. The 2007 revision of the guidelines was simplified and modified to incorporate the independent predictors of cardiac risk identified in the Lee RCRI.

PREOPERATIVE CARDIAC RISK ASSESSMENT

To use the ACC/AHA guideline for the assessment of a patient's perioperative cardiac risk, the following information is needed:

(1) What comorbid conditions does the patient have that may contribute to increased cardiac risk?
(2) Does the patient have any active cardiac conditions that may contribute to this risk?
(3) What is the perioperative cardiac risk of the surgery itself?
(4) What is the patient's functional status?

What Comorbid Conditions does the Patient have?

A careful clinical history is necessary to identify any active cardiac conditions or clinical risk factors associated with increased risk for postoperative cardiac outcomes.

Active cardiac conditions are defined as:

- Unstable coronary syndromes, such as unstable or severe angina or recent MI (within the last 30 days)
- Decompensated systolic or diastolic heart failure
- Significant arrhythmias, such as high-grade atrioventricular block, Mobitz II atrioventricular block, third-degree atrioventricular heart block, symptomatic ventricular arrhythmias, supraventricular arrhythmias (including atrial fibrillation) with uncontrolled ventricular rate (greater than 100 bpm at rest), symptomatic bradycardia, and newly recognized ventricular tachycardia.
- Severe valvular disease, such as severe aortic stenosis (AS) (mean pressure gradient >40 mm Hg, aortic valve area <1 cm^2, or symptomatic) and symptomatic mitral stenosis (progressive dyspnea on exertion, exertional presyncope, or heart failure).

Clinical risk factors associated with increased risk for postoperative cardiac outcomes are the independent risk factors identified in the Lee RCRI:[4]

- History of ischemic heart disease (suggestive history, symptoms, or Q-waves on ECG)
- History of prior or compensated heart failure (suggestive history, symptoms, or examination findings)
- History of stroke or transient ischemic attack
- Insulin-dependent diabetes mellitus
- Renal insufficiency (serum creatinine >2 mg/dL)

What is the Risk of the Surgery Itself?

The surgery-specific cardiac risk of noncardiac surgery is related to 2 important factors. First, the type of surgery itself may identify a patient with greater likelihood of underlying heart disease (ie, vascular surgery). Second, the degree of hemodynamic cardiac stress is associated with the surgery itself. Certain operations may be associated with profound alterations in heart rate, blood pressure, vascular volume, pain, blood loss, and others. Examples of surgeries and their surgery-specific cardiac risk for cardiac death and nonfatal MI are outlined in **Table 1**.

It is important to keep in mind that these categories identify average risk for patients who undergo these different surgical procedures. Within each risk category, morbidity and mortality may vary depending on the surgical location and the extent of the procedure. For example, some abdominal procedures may be short with minimal fluid shifts (such as a routine cholecystectomy in a patient who has not had previous abdominal surgery), whereas other abdominal procedures may be associated with prolonged duration, large fluid shifts, and greater potential for postoperative myocardial ischemia and respiratory depression (such as the fourth abdominal surgery in a patient who has cancer). Therefore, clinical judgment must be exercised to correctly assess the risk of the surgical procedure. Sometimes, this requires that the clinician do a little research by contacting the surgeon to clarify how involved the surgery is expected to be.

What is the Patient's Functional Status?

Oxygen uptake is considered the best measure of cardiovascular fitness and exercise capacity. One metabolic equivalent (MET) is a unit of sitting/resting oxygen uptake. Functional capacity is measured by the number of METs a person can achieve on a regular basis. Perioperative cardiac and long-term risks are increased in patients who are unable to meet a 4-MET demand during most daily activities. If the patient has not had a recent exercise test, functional status can be estimated using a validated

Table 1
Cardiac risk[a] stratification for noncardiac surgical procedures

High risk>5%	Emergent major operations, particularly in elderly Aortic and major vascular surgery Peripheral vascular surgery Prolonged surgery,[b] large fluid shifts, or blood loss
Intermediate risk>1% to <5%	Carotid endarterectomy Endovascular abdominal aortic aneurysm repair Head and neck surgery Intraperitoneal or intrathoracic surgery Orthopedic surgery Prostate surgery
Low risk<1%	Endoscopic procedures Superficial procedures Cataract surgery Breast surgery

[a] Combined incidence of cardiac death and nonfatal myocardial infarction.
[b] Prolonged surgery is loosely defined as >3 hours.

Adapted from L Fleisher, J Beckman, K Brown, et al. ACC/AHA 2007 Guidelines on perioperative cardiovascular evaluation and care for non-cardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2007;50:e170; with permission.

method of assessing functional capacity obtained from the patient's history.[7] Energy expenditures for activities, such as eating, dressing, walking around the house, and dishwashing range from 1 to 4 METs; climbing a flight of stairs, walking on level ground at 4 miles per hour, running a short distance, scrubbing floors, and playing a game of golf (without a cart) range from 4 to 10 METs. A functional capacity of 4 METs is considered the minimum requirement for a patient undergoing a major surgical procedure. Functional capacity may be difficult to assess in patients who are elderly, with multiple medical comorbidities or significant orthopedic issues. Patients with these limitations will sometimes require more formal functional testing to determine functional capacity.

Using the ACC/AHA Guideline

Once the patient has been interviewed and examined and important information has been collected, the 5-step ACC/AHA approach can be used to help guide clinical decision making regarding the need for additional cardiac workup before the planned surgical procedure (**Fig. 1**).

Step 1: Does the patient need emergency surgery? If so, the patient needs to proceed to the operating room without delay, and perioperative management and surveillance for ischemia can be done postoperatively.

Step 2: Does the patient have an active cardiac condition? If an active cardiac condition is identified, a cardiology consultation and further diagnostic testing are often pursued before the planned surgical intervention.

Step 3: Is the patient scheduled for low-risk surgery? If so, the patient can proceed to surgery without any additional cardiac testing. The risk for perioperative cardiac complications in low-risk surgeries is <1%, even in high-risk patients. Additional testing rarely results in a change in perioperative management.

Step 4: Does the patient have good functional capacity without symptoms? In highly functional asymptomatic patients, management will rarely be changed based on the results of any further cardiovascular testing. Consider using β-blockade for perioperative heart rate control in patients with known cardiovascular disease or at least 1 clinical risk factor (controversy exists regarding β-blocker recommendation; see the section on β-blockers). If the patient cannot achieve 4 METs on a regular basis, is symptomatic, or has unknown functional capacity, then the presence of clinical risk factors will determine the need for further evaluation.

Step 5: Does the patient have clinical risk factors associated with increased perioperative cardiac risk (ischemic heart disease, prior or compensated heart failure, stroke or transient ischemic attack, insulin-dependent diabetes mellitus, or renal insufficiency)?

- No clinical risk factors: proceed with surgery
- 1 or 2 clinical risk factors: proceed with surgery with heart rate control using β-blockers (controversy exists regarding β-blocker recommendation; see the section on β-blockers) or noninvasive testing can be considered if it would change management.
- 3 or more clinical risk factors:

  Intermediate risk surgery: Can proceed with heart rate control using β-blockers or noninvasive testing can be considered if it would change management.

  Vascular surgery or extensive surgical procedure: Consider noninvasive testing to further risk stratify, but only if it would change patient management.

What Role does Age Play in Perioperative Risk?

Postoperative cardiac complications, noncardiac complications, mortality, and hospital length of stay have been shown to increase with age.[8] However, age has not been consistently shown to be an independent predictor of major cardiac complications,[4,9–13] and there are limited prospective data available as to whether advanced age independently predicts short- and long-term mortality in surgical patients. It remains unclear if age is an independent predictor of major cardiac complications or whether age simply correlates with increased prevalence and severity of other co-morbid conditions that have been found to be independent predictors of major cardiac complications. A recent prospective cohort of 1,693 elderly patients who underwent major vascular surgery[14] showed that age was associated with an increased number of cardiac risk factors according to the Lee RCRI. This study reports that not only were the Lee RCRI risk factors predictive of short- and long-term mortality, but age itself was identified as an independent predictor. However, compared with the other cardiac risk predictors, age was only weakly predictive (odds ratio [OR] 1.05; 95% confidence interval [CI] 1.02-1.09) in this subset of high-risk surgical patients (overall in-hospital mortality 8%; long-term mortality 28.5%). The available data, in total, suggest that age may be independently predictive of clinically significant major cardiac complications and postoperative mortality, albeit to a minimal degree compared with other predictors, and age may be more predictive in those undergoing vascular surgery procedures.

What is the Utility of B-Type Natriuretic Peptide in Predicting Perioperative Risk?

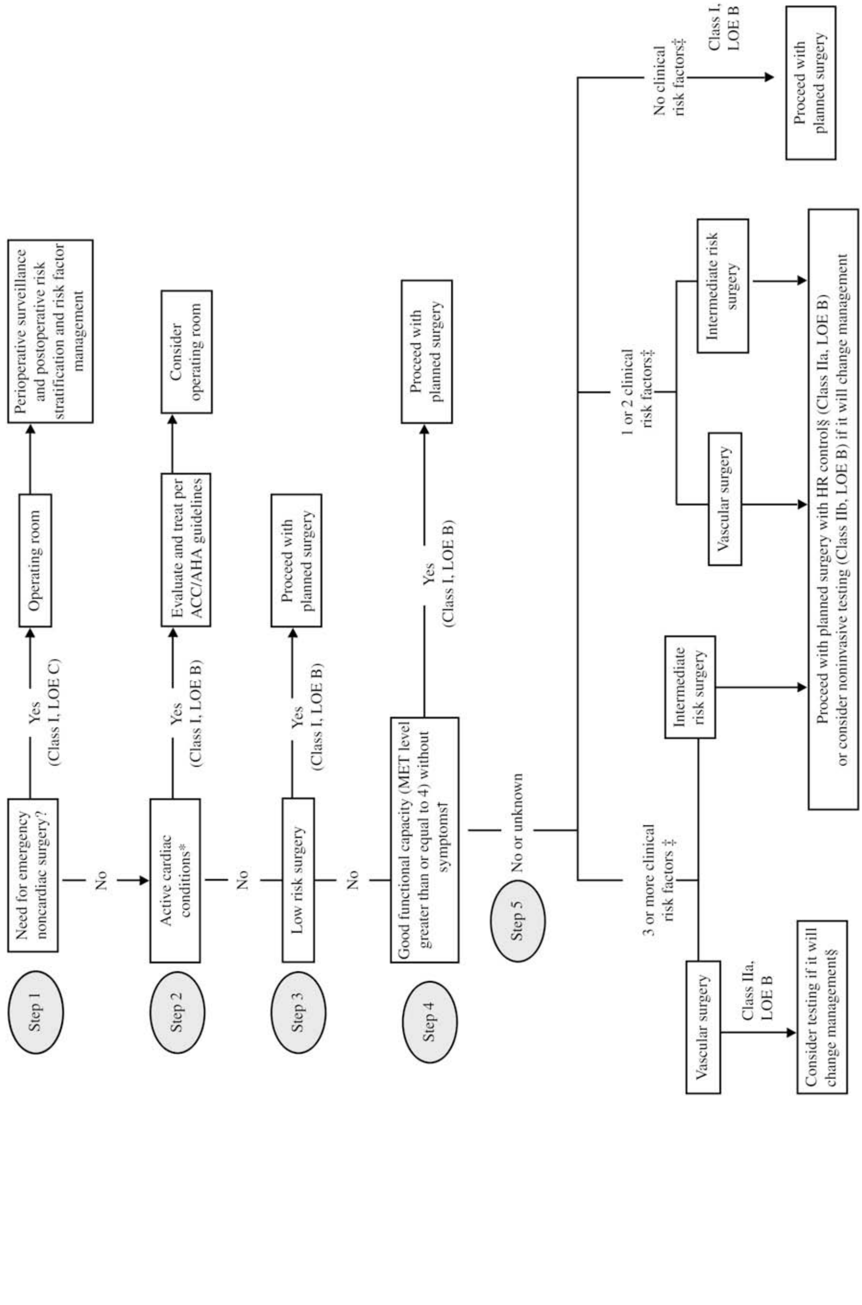
Recent studies have shown that plasma B-type natriuretic peptide (BNP) levels are useful as predictors of first cardiovascular event and death in the general population. Additionally, plasma BNP levels have been shown to be an important indicator of prognosis in heart failure and after acute MI (elevated levels identify patients at high risk for progressive ventricular dilatation, heart failure, or death). BNP levels have also been evaluated in small prospective studies as a predictor of cardiac risk in patients undergoing major noncardiac surgery. Preoperative BNP levels are higher in patients who experience perioperative death and myocardial injury,[15] and predict postoperative cardiac events in patients independently of other risk factors.[16] However, until results from larger prospective studies are published, measurement of BNP levels as a method of cardiac risk stratification before noncardiac surgery is not recommended.

PERIOPERATIVE CARDIAC RISK REDUCTION STRATEGIES

The Role of Perioperative Coronary Revascularization

For patients selected for further cardiac risk assessment with noninvasive testing, final recommendations should be made based on the results of the noninvasive test. Which patients benefit from coronary revascularization before noncardiac surgery and which do not?

For many years, the common practice had been to treat identified ischemia with an intervention to help “get the patient through” the surgical procedure safely. However, this paradigm has shifted in recent years. The reason for this shift has been attributed to more recent evidence that aggressive medical management is associated with similar short- and long-term outcomes as coronary intervention in most patients with stable coronary artery disease. The coronary artery revascularization prophylaxis trial determined that coronary artery revascularization (with bypass surgery or percutaneous intervention) improves neither long-term survival nor short-term outcomes for


Step 1
Need for emergency noncardiac surgery?
Yes (Class I, LOE C)
Operating room
Perioperative surveillance and postoperative risk stratification and risk factor management
No
Step 2
Active cardiac conditions*
Yes (Class I, LOE B)
Evaluate and treat per ACC/AHA guidelines
Consider operating room
No
Step 3
Low risk surgery
Yes (Class I, LOE B)
Proceed with planned surgery
No
Step 4
Good functional capacity (MET level greater than or equal to 4) without symptoms†
Yes (Class I, LOE B)
Proceed with planned surgery
No or unknown
Step 5
3 or more clinical risk factors ‡
Vascular surgery
Class IIa, LOE B
Consider testing if it will change management§
Intermediate risk surgery
1 or 2 clinical risk factors‡
Vascular surgery
Intermediate risk surgery
Proceed with planned surgery with HR control§ (Class IIa, LOE B) or consider noninvasive testing (Class IIb, LOE B) if it will change management
No clinical risk factors‡
Class I, LOE B
Proceed with planned surgery

elective aortic or infra-inguinal vascular surgery procedures in patients with stable coronary artery disease (however, excluded from this trial were patients with high-risk coronary anatomy, such as left main stenosis of >50%, an ejection fraction of <20%, or severe AS).[17] The protective effect of β-blockade in reducing perioperative cardiovascular events and death from cardiac causes in high-risk patients undergoing major vascular surgery has been well demonstrated in the first Dutch echocardiographic cardiac risk evaluation applying stress echocardiography (DECREASE-I) trial.[18] Lending even more evidence that preoperative revascularization may not be the panacea, the fifth BNP levels have also been DECREASE-V pilot study of 101 patients with extensive stress-induced ischemia on dobutamine stress echocardiography who were randomized to revascularization or no revascularization before elective major vascular surgery also revealed no difference in 30-day or long-term outcome between groups.[19] The results of the DECREASE-V full-scale trial are still pending, but these results will help to further define the best management patients with significant coronary artery disease (CAD) in the perioperative setting. Given this recent evidence regarding the limited value of coronary revascularization before noncardiac surgery, the indication for preoperative coronary revascularization should be limited to the few patients in whom coronary revascularization may be beneficial independent of the surgical setting.

In which patients has coronary revascularization been found to be beneficial? Coronary revascularization is generally recommended in patients with stable angina who have significant left main coronary artery stenosis, 3-vessel disease, 2-vessel disease with significant proximal left anterior descending (LAD) stenosis plus either an ejection fraction of <50% or demonstrable ischemia on noninvasive testing, high-risk unstable angina, non–ST segment elevation MI (NSTEMI), or acute ST-elevation MI (STEMI).[6] Whereas percutaneous coronary intervention (PCI) has been favored more in recent years because it is less invasive, it comes with a significantly increased incidence of repeat revascularization compared with coronary artery bypass grafting (CABG). In certain situations, CABG may be superior to PCI, with potential long-term advantages among the subset of patients with diabetes and multi-vessel disease.[20,21] Whichever mode of revascularization is considered, the cumulative mortality and morbidity of both the coronary revascularization procedure and the noncardiac surgery should be weighed carefully in light of the patient's overall health, functional status, and prognosis.

When considering the type of preoperative revascularization procedure, the urgency of the noncardiac surgical procedure and the mode of revascularization should be kept in mind. Several studies have demonstrated an increased surgical

Fig. 1. Cardiac evaluation and care algorithm for noncardiac surgery. Cardiac evaluation and care algorithm for noncardiac surgery based on active clinical conditions, known cardiovascular disease, or cardiac risk factors for patients 50 years or older. *Unstable coronary syndromes, decompensated heart failure, significant arrhythmias, severe valvular disease. †See text for estimated MET level equivalent. ‡Clinical risk factors include ischemic heart disease, compensated or prior heart failure, diabetes mellitus, renal insufficiency, and cerebrovascular disease. §Consider perioperative β-blockade for populations in which this has been shown to reduce cardiac morbidity/mortality. ACC/AHA, American College of Cardiology/American Heart Association; HR, heart rate; LOE, level of evidence; MET, metabolic equivalent. (*From* L Fleisher, J Beckman, K Brown, et al. ACC/AHA 2007 Guidelines on perioperative cardiovascular evaluation and care for non-cardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2007;50:e169; with permission.)

risk if noncardiac surgery is performed within 30 days of CABG. For percutaneous angioplasty without stent placement (percutaneous transluminal coronary angioplasty), delaying noncardiac surgery for at least 2 weeks allows for healing of the vessel injury at the balloon treatment site.[6] Delaying surgery for 4 to 6 weeks after bare-metal stent placement for proper dual antiplatelet therapy (aspirin and clopidogrel) during stent endothelialization will reduce the risk for coronary stent thrombosis.[22] For the drug-eluting stents, because of delayed endothelialization and risk for early and late stent thrombosis with premature discontinuation of dual antiplatelet therapy, it is recommended that elective noncardiac surgery be delayed for at least 12 months, because premature discontinuation of dual antiplatelet therapy markedly increases the risk for catastrophic stent thrombosis, resulting in death or MI.[6,22]

Unscheduled noncardiac surgery in patients who have undergone a prior PCI with stent placement presents special challenges. Approximately 5% of patients who undergo coronary stenting require noncardiac surgery within 1 year of the stent placement.[23] It has been well established in recent literature that patients who have noncardiac surgery soon after stent implantation are at an increased risk for stent thrombosis.[23–25] The reasons for this are likely multifactorial and may include incomplete endothelialization of the stent, premature interruption of dual antiplatelet therapy, and the prothrombotic state associated with surgery. Stent thrombosis, when it does occur, is associated with significant morbidity and mortality. The incidence of death or MI was 64.4% in patients with bare-metal stent thrombosis,[26] and mortality as a result of drug-eluting stent thrombosis ranged from 20% to 45%.[27,28] There is uncertainty as to how much time should elapse after PCI before noncardiac surgery can be safely performed without excess risk for stent thrombosis. Even more uncertainty surrounds the perioperative management of antiplatelet agents in patients who require emergent or urgent surgery during the recommended course of dual antiplatelet therapy.

The authors of the ACC/AHA guideline have proposed an approach to the management of patients with previous PCI who require noncardiac surgery, but clearly state that their recommendations are based on "expert opinion" (**Fig. 2**).[6] For patients who must have surgery within the recommended time frame for dual antiplatelet therapy, it is recommended that serious consideration be given to performing the surgery without interruption of aspirin and clopidogrel administration. Of course, a careful discussion with the patient and the surgeon regarding the risks of perioperative bleeding versus the risk for stent thrombosis needs to take place. There are a few surgical procedures for which the literature indicates that the risk for postoperative bleeding is associated with increased morbidity and mortality, such as intracranial neurosurgical procedures, posterior chamber eye surgery, and prostate surgeries.[29] For these surgical procedures, it is best to recommend discontinuing the antiplatelet agents perioperatively. If clopidogrel must be discontinued before major surgery that is not associated with a major bleeding risk, aspirin should be continued and the clopidogrel restarted as soon as possible postoperatively. Chassot and colleagues[29] from Switzerland have published a proposed approach for the management of patients who are taking antiplatelet therapy and require surgery (**Table 2**). Although some experts have advocated the use of "bridging" therapy with other anticoagulants and short-acting antiplatelet agents, there is no evidence that warfarin, antithrombotics, or glycoprotein IIb/IIIa agents will reduce the risk for stent thrombosis after discontinuation of oral antiplatelet agents.[6,22]

The Role of Perioperative Medical Management

The ACC/AHA guideline[6] tends to favor medical management over revascularization strategies in all but a small subset of the highest-risk patients because the evidence

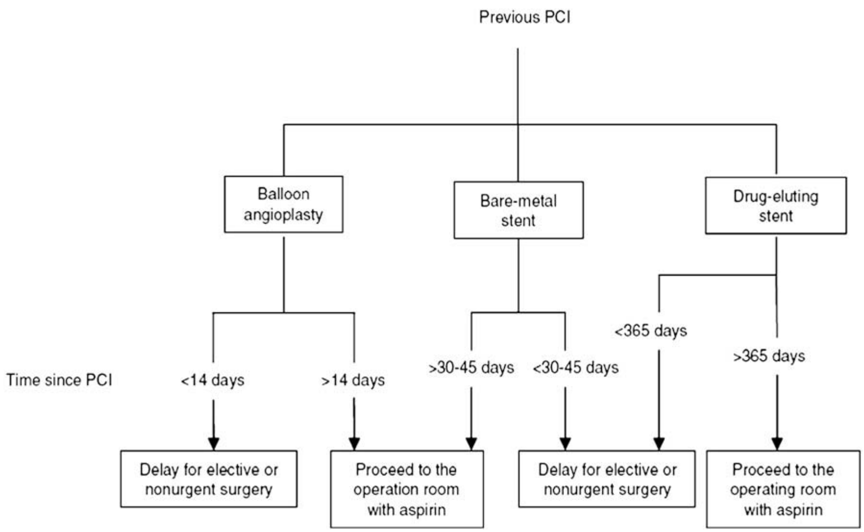


Fig. 2. Proposed approach to the management of patients with previous percutaneous coronary intervention (PCI) who require noncardiac surgery, based on expert opinion. (*From* L Fleisher, J Beckman, K Brown, et al. ACC/AHA 2007 Guidelines on perioperative cardiovascular evaluation and care for non-cardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2007;50:e199; with permission.)

supporting an invasive approach has failed to show improved cardiac outcomes in the perioperative setting. Aggressive medical therapy avoids the short-term risk associated with CABG and the dilemma associated with the management of antiplatelet therapy after PCI and the timing of surgery. However, controversy remains, as the studies with β-blockers have yielded conflicting results.

β-Blockers

Perioperative β-blockade first received widespread notice after Mangano and colleagues[30] reported that atenolol given shortly before noncardiac surgery and continued for up to 7 days postoperatively resulted in significantly lower mortality and cardiac morbidity at 2 years. Although atenolol was associated with less perioperative ischemia,[31] there was no difference in short-term event rates (MI or death). However, this study was the impetus for the recommendation of perioperative β-blockers in the American College of Physicians guidelines and by various quality and regulatory agencies. A more convincing study in vascular surgery patients was reported by Poldermans and colleagues[18] using bisoprolol, started at least 7 days before surgery and continued for 30 days postoperatively. These high-risk patients had abnormal dobutamine stress echocardiograms, and the short-term incidence of postoperative MI or death was reduced from 34% in the placebo group to 3.4% in those receiving bisoprolol. Both of these studies involved titration of the β-blocker dose to achieve heart rate control between 55 and 70 beats per minute.

Devereaux and colleagues[32] performed a meta-analysis which confirmed the utility of β-blockers in preventing perioperative ischemia; however, the CIs for MI and death were wide, and crossed the line of unity suggesting that the indiscriminate use of β-blockers in all patients may not be indicated. Lindenauer and colleagues[33]

Table 2
Proposed scheme for management of patients taking antiplatelet therapy and requiring surgery

	Stent Thrombosis Risk		
	Low	**Intermediate**	**High**
Surgical Hemorrhagic Risk	**>6 mo After PCI, BMS**	**6–24 wk After PCI + BMS; >12 mo After DES; High-Risk Stents[a]; low EF, Diabetes**	**<6 wk After PCI, BMS; <12 mo After High-Risk DES**
Low risk Transfusion normally not required: peripheral, plastic, and general surgery, biopsies; minor orthopedic, ENT, and general surgery; endoscopy, eye anterior chamber, dental extraction, or dental surgery	Elective surgery: OK; Maintain aspirin	Elective surgery: OK; maintain aspirin and clopidogrel	Elective surgery: postpone Vital or emergency surgery OK; maintain aspirin and clopidogrel
Intermediate risk Transfusions frequently requires; visceral surgery, cardiovascular surgery; major orthopedic, ENT, reconstructive surgery; endoscopic urologic surgery	Elective surgery: OK; Maintain aspirin	Elective surgery: postpone Vital or emergency surgery: OK; maintain aspirin and clopidogrel	Elective surgery: postpone Vital or emergency surgery: OK; maintain aspirin and clopidogrel
High risk Possible bleeding in a closed space; intracranial neurosurgery; spinal cord surgery; eye posterior chamber surgery	Elective surgery: OK; withdraw aspirin (maximum 7 days)	Elective surgery: postpone Vital or emergency surgery: OK; maintain aspirin (or replace aspirin with ibuprofen), stop clopidogrel	Elective surgery: postpone Vital or emergency surgery: OK; maintain aspirin, bridge with tirofiban/eptifibatide and heparin

Abbreviations: BMS, bare-metal stent; DES, drug-eluting stent; EF, ejection fraction; PCI, percutaneous coronary intervention.

[a] High-risk stents include long, proximal, multiple, overlapping, small vessels, or bifurcation stents.

Adapted from P Chassot, A Delabays, D Spahn. Perioperative antiplatelet therapy: the case for continuing therapy in patients at risk of myocardial infarction. Br J Anaesth 2007;99:322; with permission.

evaluated a large administrative database, and after adjustment for comorbidities using propensity analysis they found that compared with patients who did not receive β-blockers, those with a Lee RCRI score of 3 or more who received a β-blocker within 2 days of surgery had lower hospital mortality, whereas those with a Lee RCRI score of 0 to 1 did worse.

However, subsequently, 3 studies were published reporting no benefit of perioperative metoprolol in vascular surgery (Yang and colleagues[34] and Brady and colleagues[35]) and in diabetic patients undergoing noncardiac surgery (Juul and colleagues[36]). Suggested reasons for this lack of benefit were the absence of β-blocker titration and the lower risk patient population in these studies compared with the initial β-blocker studies, which demonstrated benefit.

Additional evidence supporting tight heart rate control came from Feringa and colleagues[37] who reported significantly reduced perioperative ischemia and troponin T release as mean heart rate decreased from more than 80 to less than 70 beats per minute. Poldermans and colleagues[38] went a step further noting that in the DECREASE-II study group, vascular surgery need not be delayed for preoperative cardiac testing in intermediate-risk patients receiving β-blockers with tight heart rate control (≤65 beats per minute) as outcomes were no different with or without noninvasive testing.

Preliminary results from the largest clinical trial of perioperative β-blockers, the Peri-Operative ISchemic Evaluation (POISE)[39] trial, were reported at the 2007 American Heart Association annual meeting. Devereaux and colleagues[40] found that β-blockers were associated with reduced perioperative MI and cardiac death (the primary outcome), but this benefit was offset by an increase in total mortality and stroke. β-blockers also resulted in lower rates of atrial fibrillation and need for revascularization but were associated with significantly more hypotension and bradycardia requiring treatment. There were more deaths related to sepsis in the β-blocker group, and the investigators urged caution in broad use of perioperative β-blockers. One of the criticisms of the study has been the high, unadjusted dose of metoprolol used (100 mg 2-4 hours preoperatively, followed by 100 mg 6 hours postoperatively, followed by 200 mg daily 12 hours after the postoperative dose for 30 days). The published results and subgroup analyses are anxiously awaited as the preliminary results raise concerns about current guidelines and performance measures.

Although the controversy continues, it is best to reserve β-blockers for patients in the highest-risk groups as outlined in the ACC/AHA guideline.[6] β-Blockers

- should be continued in patients already taking them
- should be given to vascular surgery patients with ischemia on preoperative testing
- are probably recommended for patients with CAD or high cardiac risk who are undergoing vascular or intermediate-to-high risk surgery
- may be considered for any patients undergoing vascular surgery or those at intermediate-to-high cardiac risk [who are] undergoing intermediate- to high-risk surgery
- should not be given to patients with contraindications to β-blockers.

α-2 Agonists

If β-blockers cannot be used, what alternatives are there for the high-risk patient? A meta-analysis of limited data on α-2 agonists showed some benefit in vascular surgery patients, however, there was no benefit in nonvascular surgery patients.[41] Furthermore, the results were based mainly on mivazerol which is not available in the United States. Small studies using clonidine demonstrated reduced perioperative ischemia but not MI, and in 1 study, improved 30-day and 2-year survival.[42] The evaluating perioperative ischemia reduction by clonidine (EPIC) trial is currently underway in Toronto which will determine if the addition of clonidine to chronic β-blockade will reduce mortality and cardiac morbidity among intermediate- to high-risk patients undergoing noncardiac surgery.

Statins

Recently, attention has been focused on the role of perioperative statins in potentially reducing adverse cardiac events. Statins have been shown to have beneficial effects in the nonsurgical setting because of both lipid lowering effects and pleiotropic effects. It is believed that the anti-inflammatory and plaque-stabilizing effects of statins may prevent perioperative MIs. Several observational studies have reported that patients receiving statins perioperatively had fewer cardiac events and deaths compared with patients who did not receive statins. A systematic review[43] demonstrated a treatment benefit of statins for postoperative mortality (OR, 0.58) and a benefit for combined outcome of death or acute coronary syndrome (OR, 0.78). There has only been 1 small randomized controlled trial which showed a benefit of atorvastatin on a composite outcome.[44] A recent study in elderly patients undergoing vascular surgery showed that statins, β-blockers, aspirin, and angiotensin-converting enzyme inhibitors were associated with decreased hospital stay and long-term mortality, and even the very elderly may benefit from statin therapy.[14] Hopefully, the DECREASE-IV trial evaluating fluvastatin and bisoprolol in high-risk patients undergoing noncardiac surgery will shed more light on these issues.[45]

The ACC/AHA guideline recommends continuing statins perioperatively in patients already taking them (based on observational evidence) because of the potential benefit and concerns that the withdrawal of statins in the perioperative period may be associated with an increased risk for adverse cardiac outcomes. Pharmaceutical companies still recommend, however, that statins be discontinued before surgery. Yet unresolved questions concerning statins include which patients or subgroups benefit, whether or not there is a class effect, what is the optimal dose, whether statins should be started prophylactically, and if so, how far in advance of surgery.

POSTOPERATIVE CARDIAC COMPLICATION MANAGEMENT

Myocardial Infarction

The mechanisms underlying perioperative MI are poorly understood. In the nonoperative patient, plaque rupture is an important mechanism. However, in the perioperative setting, other mechanisms seem to play a role in the mismatch between myocardial oxygen supply and demand, including (1) mobilization of fluids perioperatively, which increases the strain on the susceptible myocardium with decreased reserve, (2) increased thrombotic risk, which is associated with surgery, (3) catecholamine surges, which cause arrhythmias, and (4) postoperative pain, which causes increased tachycardias and blood pressure.

Eagle and colleagues[46] have identified vascular surgical procedures and major abdominal, thoracic, and head and neck surgeries as having the highest risk for cardiovascular complications. Poor preoperative cardiac status (coronary artery disease and history of congestive heart failure [CHF]), postoperative hypotension, new intraoperative ST-T changes of long duration, and increased intraoperative blood loss with transfusion have also been associated with postoperative MI.[47]

Perioperative MIs most often occur in the first 48 hours after surgery, with most occurring on the evening of surgery. Unlike the usual symptoms that occur with myocardial ischemia, this is often a chest pain–free event in the postoperative patient that begins with an increase in heart rate to 90 to 100 beats per minute followed by ST segment depression on ECG and elevation of cardiac enzymes. Common findings that occur with postoperative MI are heart failure, arrhythmia, hypotension, and confusion. Badner and colleagues[48] studied 323 patients with coronary disease undergoing noncardiac surgery and found postoperative MI in 18 of 323 patients (5.6%) screened with daily cardiac enzymes and ECGs for 7 days. Forty percent of the MIs were asymptomatic and 56% were non-Q wave MIs. Most MIs (44%) occurred on the day of surgery, whereas 34% occurred on postoperative day 1, 16% on postoperative day 2, and only 6% on postoperative day 4.

What is the role of perioperative surveillance for myocardial ischemia and/or infarction? The data supporting an optimal strategy for surveillance of perioperative MI are limited. The ACC/AHA guideline recommends, on the basis of limited evidence, that surveillance in patients without documented CAD should be restricted to those who develop perioperative signs of cardiovascular dysfunction. For patients with high or intermediate clinical risk who have known or suspected CAD and who are undergoing high- or intermediate-risk surgical procedures, obtaining an ECG at baseline, immediately after the surgical procedure, and daily on the first 2 days after surgery seems to be the most cost-effective strategy. Measurement of cardiac-specific troponins should be limited to patients with ECG changes or symptoms suggestive of acute coronary syndrome. Although some experts advocate the postoperative measurement of troponins as a surveillance measure in asymptomatic patients who are at high risk for postoperative cardiac events (ie, vascular surgery patients), the usefulness and cost-effectiveness of this practice are not well established.

How should patients who have postoperative myocardial ischemia/infarction be managed? There are no randomized controlled trials addressing the medical management of postoperative MI. Postoperative MIs are classified as either NSTEMI or STEMI. The management of perioperative MIs is complicated by the increased risk for bleeding in the postoperative patient, especially when thrombolytic drugs, antiplatelet agents, and antithrombotic agents are considered. Possible algorithms to help direct the management of NSTEMI and STEMI in the perioperative period are illustrated in **Figs. 3** and **4**.[47] The hospital mortality rate for patients who have a postoperative MI is 15% to 25%,[48] and patients who survive the hospitalization have an increased risk for cardiovascular death and nonfatal MI during the 6 months after surgery.[49] Patients who have a symptomatic MI after surgery have an increased risk for death (as high as 40% to 70%),[50] so it is imperative that they receive close management and follow-up for risk reduction well beyond the perioperative period.

Congestive Heart Failure

CHF is not only a significant risk factor for perioperative morbidity and mortality in noncardiac surgery, but it is also one of the postoperative outcomes that are measured. Mangano and colleagues[51] identified a history of arrhythmia, diabetes, vascular surgery, duration of anesthesia, and narcotic anesthesia as risk factors for postoperative CHF, however, postoperative ischemia was not found to be a risk factor.

Heart failure often manifests or worsens during 2 periods in the postoperative setting: immediately after surgery (because of length of surgery, myocardial ischemia, or large fluid shifts) or on the second to third postoperative day when third spaced fluids begin to be reabsorbed. There is a paucity of data to direct an optimal approach to managing heart failure before, during, or after noncardiac surgery. Further studies

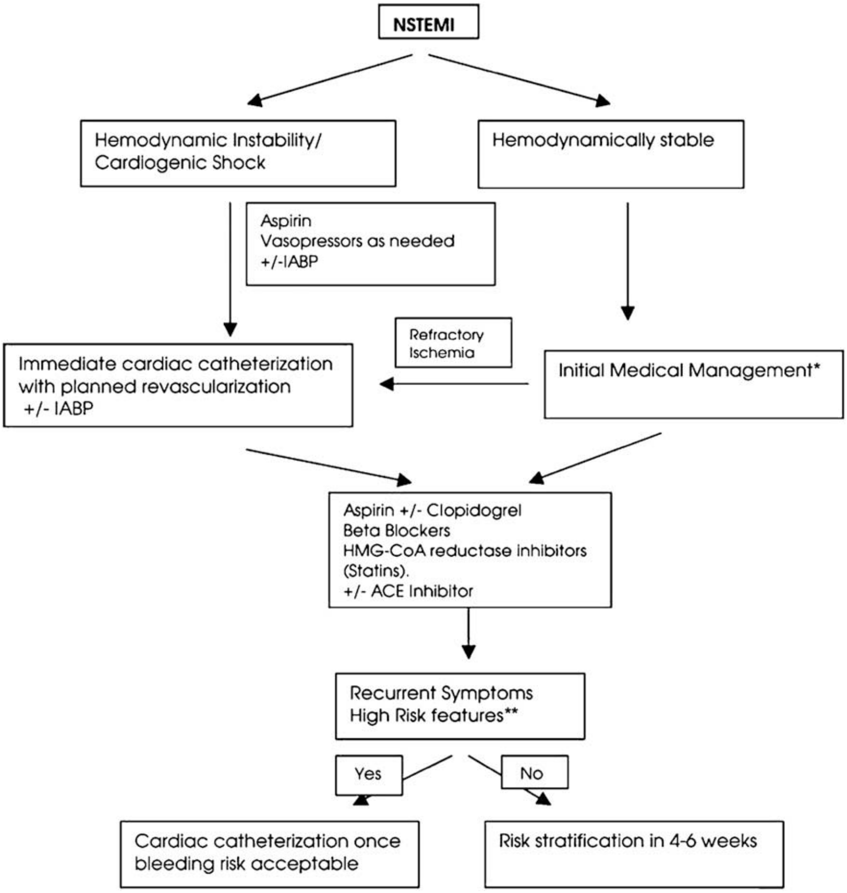


Fig. 3. Suggested algorithm for management of perioperative NSTEMI. *Initial medical management includes morphine sulfate, oxygen, nitroglycerin, and aspirin with or without unfractionated heparin if bleeding risk is acceptable. **High-risk features include major arrhythmias (ventricular tachycardia, ventricular fibrillation), dynamic ST segment depression in multiple leads, an ECG pattern that precludes assessment of ST segment changes, evidence of severe CHF, or left ventricular dysfunction. Refractory ischemia is ischemia unresponsive to medical management. (*From* A. Adesanya, J deLemos, N Greilich, et al. Management of perioperative myocardial infarction in non-cardiac surgical patients. Chest 2006; 130:589; with permission.)

are needed to help guide the management of patients with CHF perioperatively. Medical optimization of CHF preoperatively is crucial; however, overdiuresis should be avoided as it may exacerbate intraoperative hypotension.[52] Right heart catheterization is not recommended perioperatively in the management of these patients as it often results in as much harm as benefit.[52] In general, perioperative management of CHF should be directed by the presumed cause of the CHF (eg volume overload, significant valvular disease, diastolic dysfunction, ischemia). Recent studies have shown that patients with clinically stable heart failure did not have increased perioperative mortality rates in association with elective major noncardiac surgery compared with control subjects, but they were more likely than patients without heart failure to have longer

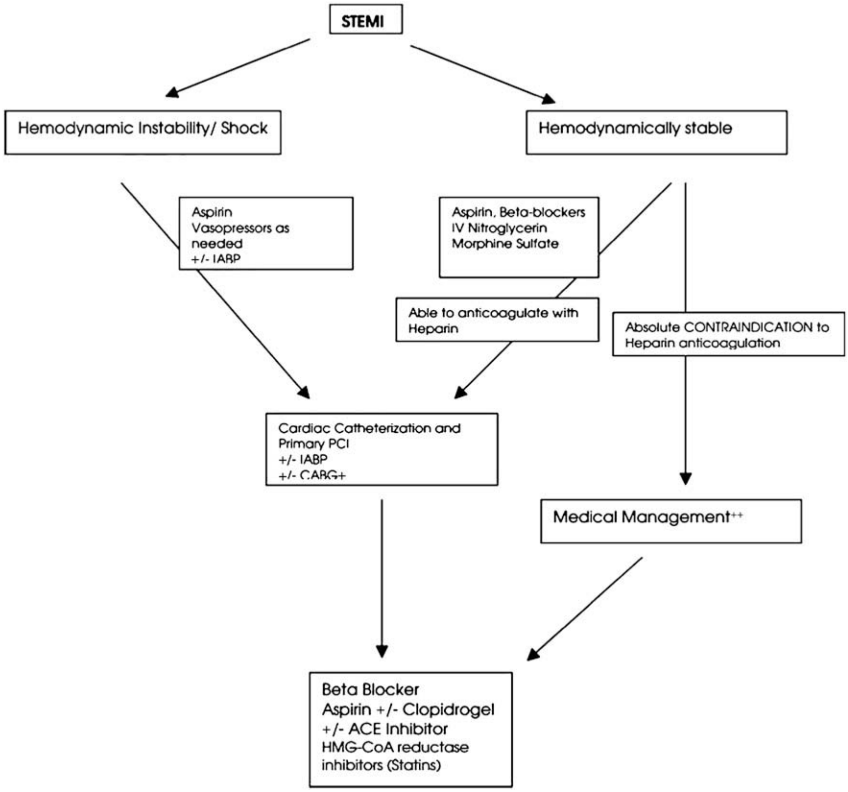


Fig. 4. Suggested algorithm for management of perioperative STEMI. +Clopidogrel should not be administered if CABG is planned within 5 days. ++Medical management includes morphine sulfate, oxygen, nitroglycerin, and aspirin. (*From* A. Adesanya, J deLemos, N Greilich, et al. Management of perioperative myocardial infarction in non-cardiac surgical patients. Chest 2006;130:589; with permission.)

hospital stays and were more likely to require hospital readmission,[53] thus emphasizing the importance of preoperative optimization and close postoperative surveillance in these patients.

B-type natriuretic peptide (BNP) measurement may be of value for perioperative risk stratification and predicting postoperative cardiac outcomes,[15,16] however, until further large prospective trials data are available, it is not current standard of care to measure BNP for perioperative risk stratification purposes.

Valvular Heart Disease

Valvular heart disease can increase risk for perioperative cardiac complications in the elderly because of the anatomic challenges posed by the valvulopathy in conjunction with associated comorbidities. Strategies to optimize outcomes in patients with valvular heart disease include knowledge of the criteria for surgical management for valvular heart disease before noncardiac surgery, recommending the appropriate endocarditis prophylaxis, using perioperative bridge therapy for high-risk patients on therapeutic anticoagulation due to mechanical heart valves, and optimizing medical therapy perioperatively.

There are few data available to help direct the decision regarding valvular repair or replacement before noncardiac surgery. Experts suggest that serious consideration should be given to surgical treatment of patients with severe symptomatic valvular disease before proceeding with elective noncardiac surgery. Severe aortic or mitral stenosis or severe aortic or mitral regurgitation should be recognized preoperatively so that appropriate measures can be taken to help decrease the perioperative risk for cardiac complications.

AS is the most common and serious perioperative valvulopathy for noncardiac surgery. The severity of AS has been shown to be highly predictive of perioperative mortality and nonfatal MI. Perioperative medical management for mild to moderate AS involves heart rate control to minimize tachycardia and close volume management to avoid volume depletion. However, for severe or symptomatic AS, the ACC/AHA guideline recommends postponing or canceling elective noncardiac surgery until after aortic valve replacement. In patients who refuse or have contraindications to AVR, percutaneous balloon valvuloplasty may be considered before noncardiac surgery, or if the patient and surgeon agree, surgery can proceed at an approximate perioperative mortality risk of 10%.[6]

Mitral stenosis is uncommon. Perioperative tachycardia can reduce the diastolic filling period leading to severe pulmonary congestion and heart failure, so rate control should be optimized.[6] Patients with severe mitral stenosis will benefit from either balloon mitral valvuloplasty or open surgical valve repair before elective noncardiac surgery.[54]

Aortic regurgitation is not as well tolerated by the elderly as younger patients because elderly patients often have associated AS and/or coronary artery disease. Perioperatively, medical management revolves around volume control and afterload reduction. Slow heart rates result in a net increase in volume of regurgitation, so some permissive tachycardia would reduce aortic regurgitation,[6] however, this will need to be balanced with the potential risk for increased myocardial demand and ischemia in patients with coexisting coronary artery disease. Preoperative risk assessment and criteria for AVR or repair relate to severity of disease based on echocardiography and clinical symptoms. AVR or repair should be performed inpatients with severe symptomatic aortic regurgitation regardless of ejection fraction, asymptomatic patients with chronic severe aortic regurgitation and ejection fraction less than 50%, or chronic severe aortic regurgitation while undergoing CABG surgery, aortic surgery, or surgery on other valves. The data are less clear for other indications.[55]

Mitral regurgitation presents unique management options perioperatively, especially if it is severe. The goal of medical therapy is to improve forward output and eliminate pulmonary congestion. Afterload reduction and diuretics preoperatively may produce maximum hemodynamic stability before high surgical risk procedures.[6] In patients with mitral regurgitation, it is important to know the ejection fraction, keeping in mind that if the ejection fraction is not supra-normal, it indicates that the patient also has associated left ventricular dysfunction. Even in asymptomatic individuals, severe mitral regurgitation with decreased ejection fraction meets criteria for valve replacement. The challenge with elderly patients is the decision whether to surgically correct severe mitral regurgitation.

In summary, because there is limited evidence regarding the repair or replacement of heart valves before noncardiac surgery, clinical experience and patient preference will dictate whether surgical management or medical therapy is best for an individual patient. A detailed review of the general indications for valve replacement can be found in the 2006 American College of Cardiology Guidelines for the Management of Patients with Valvular Heart Disease.[55]

Prosthetic Heart Valves

Patients with mechanical prosthetic valves present a unique management situation perioperatively because of the potential need for antibiotic prophylaxis against infectious endocarditis and the need for perioperative anticoagulation management to decrease the risk for a potentially catastrophic perioperative thromboembolic event. The American Heart Association recently updated its recommendations for prevention of infectious endocarditis.[56] Regarding the type of procedure, the guidelines suggest that (1) antibiotic prophylaxis is reasonable for dental procedures involving gingival or the periapical region of the teeth or perforation of nasal septum but only for cardiac conditions associated with the highest risk and (2) it is not necessary to give antibiotic prophylaxis for gastrointestinal and genitourinary procedures solely for prevention of endocarditis.

The cardiac conditions most likely to be adversely affected by endocarditis and therefore warranting prophylaxis for the above procedures include a prior history of infective endocarditis, a prior history of cardiac valve replacement, a surgically constructed pulmonary shunt or conduit, an unrepaired cyanotic congenital heart defect or repaired congenital heart defects with residual defects or prosthetic materials, and valvuloplasty following cardiac transplant. The recommended antibiotic regimens vary based on the location of the surgical procedure (gastrointestinal, genitourinary, respiratory tract, skin/soft tissue/musculoskeletal), the patient's ability to take medication orally, and whether the patient is allergic to penicillin. Antibiotics should be administered between 30 and 60 minutes before the surgical procedure. More specific recommendations can be found in the 2007 AHA guidelines for the Prevention of Infective Endocarditis.[56]

Patients with mechanical valves may also require perioperative anticoagulation management. Bridge therapy with heparinoids is recommended in patients in whom the risk for a thromboembolic event is high when the international normalized ratio drops below the therapeutic level. Jaffer and colleagues[57] suggest an anticoagulation strategy for patients to be bridged with intravenous heparin infusion or low molecular weight heparin based on their risk for thromboembolism without anticoagulation and the risk for perioperative bleeding with continued anticoagulation. Further recommendations can be found in the American College of Chest Physicians (ACCP) Conference on Antithrombotic and Thrombolytic Therapy Evidence-Based Guidelines[58] (these are scheduled to be revised in 2008).

SUMMARY

Surgical and anesthetic practices have made remarkable strides in the last 25 years. As surgery has become safer for most patients, older and sicker patients have been undergoing surgery with remarkably few perioperative complications. However, perioperative cardiac complications remain the major source of perioperative morbidity and mortality. With the rapidly growing population of elderly patients who are living longer and often considering surgery well into the ninth decade of life, it is important for clinicians to be able to provide the patient and surgeon with a perioperative cardiac risk assessment so that risks and benefits can be carefully weighed before proceeding. Clinicians are called on to stratify risk and medically optimize patients who often present with significant cardiac comorbidities. Hopefully, this clinically focused review of perioperative cardiac evaluation in the elderly patient will help facilitate this process.

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