Patients undergoing surgery experience a well-described stress response of sympathetic nervous system activation, insulin resistance, cytokine production, leukocyte demargination, and pituitary hormone secretion. These physiologic changes, in addition to preexisting patient comorbidities, surgical complexity, and postoperative complications, may contribute to the occurrence of adverse perioperative cardiovascular events in patients undergoing noncardiac surgery. Every patient should undergo an individualized
Keywords

cardiac evaluation
risk assessment
cardiac drugs
coronary stents
anemia
hypertension
risk assessment to delineate the risks, benefits, and alternatives of surgical intervention as part of a perioperative team approach. In the absence of a net benefit, interventions for optimizing cardiovascular health or consideration of alternative approaches should be performed to ensure the maximum potential benefit at a minimum risk to the patient.

This chapter reviews preoperative cardiac evaluation, including a discussion of common risk calculators, to assist perioperative clinicians with risk assessment and surgical planning. The American College of Cardiology (ACC) and American Heart Association (AHA) clinical practice guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery is also reviewed. Recommendations regarding specific and frequently encountered perioperative challenges are discussed, such as medical therapy with β-blockers, angiotensin-converting enzyme (ACE) inhibitors and angiotensin receptor blockers (ARBs), α2-agonists, aspirin (including dual antiplatelet therapy [DAPT]), vitamin K antagonists (VKAs), and new oral anticoagulants (NOACs) are addressed. Perioperative management of anemia, pulmonary vascular disease, and right ventricular (RV) dysfunction is also discussed.

**PREOPERATIVE CARDIAC ASSESSMENT: CATEGORIZING RISK**

Compared with their healthier counterparts, patients with underlying cardiovascular disease have an increased risk of perioperative cardiac complications. This is in part due to the presence of coronary artery disease (CAD), leading to impaired left ventricular ejection fraction (LVEF) and in part due to the physiologic factors associated with surgery that predispose patients to myocardial ischemia. Oxygen supply and demand mismatch may occur secondary to blood loss and hemodynamic changes related to anesthetic administration and surgical stimulation.

Validated algorithms have been developed to determine the cardiovascular risk of mortality and morbidity encountered per patient for each noncardiac operation. Stratification is performed to objectively determine and categorize patients as low, intermediate, or high risk. High-risk patients include those with recent myocardial infarction (MI) or unstable angina, decompensated heart failure (HF), high-grade arrhythmias, or hemodynamically significant valvular heart disease, such as aortic stenosis. These patients are at increased risk for perioperative major adverse cardiac events (MACE), including MI, HF, cardiac arrest, conduction abnormalities, and sudden cardiac death. Certainly, the emergent or urgent status of some surgery plays a large role in estimating risk due to the absence of time for risk assessment and modification. Patients with the high-risk conditions listed are at increased risk of a perioperative cardiovascular event compared with normal, age-matched control participants; however, in most emergent cases, the benefit of proceeding with surgery outweighs the risk of delay to perform additional testing.

The initial preoperative evaluation is typically performed by either a primary care physician or an anesthesiologist, and referral to a cardiologist is warranted if specialized procedures are indicated for life-threatening conditions. Intermediate- or high-risk patients may have angina, dyspnea, syncope, and palpitations, as well as history of heart disease (ischemic, valvular, structural myocardial disease), hypertension, diabetes, chronic kidney disease, and cerebrovascular or peripheral arterial disease. Cardiac functional status may be expressed in metabolic equivalents (METs), as initially determined by the Duke Activity Status Index (Table 1.1). One MET is equivalent to the adult resting oxygen utilization, and an important indicator for MACE after major noncardiac surgery is the preoperative inability to achieve 4 METs or greater, such
as by climbing two flights of stairs or walking four city blocks. The decision to pursue cardiovascular or pulmonary testing should be considered only if the results would impact surgical decision making or would likely identify an immediately life-threatening condition requiring timely management.

**PREOPERATIVE CARDIAC ASSESSMENT USING RISK MODELING CALCULATORS**

Risk model calculators estimate the probability of a perioperative event based on information obtained from the history, physical examination, and surgery type. These models are more applicable for patients at intermediate or high perioperative cardiac risk during noncardiac surgery. Patients at low risk for MACEs should proceed to surgery without further evaluation.

Specific information pertaining to both the patient and the surgery must be provided to appropriately identify individualized risk using a risk calculator. Perioperative information is entered into one or both of two commonly used perioperative risk indices: the Revised Cardiac Risk Index (RCRI) (Fig. 1.1) (http://www.mdcalc.com/revised-cardiac-risk-index-for-pre-operative-risk) or the American College of Surgeons’ National Surgical Quality Improvement Program (ACS-NSQIP) (Fig. 1.2) surgical risk calculators (http://site.acsnsqip.org). The RCRI determines preoperative risk based on risk of surgery, history of ischemic heart disease, congestive heart failure (CHF), cerebrovascular disease, preoperative use of insulin, and creatinine greater than 2.0 mg/dL. The ACS-NSQIP calculator incorporates 20 patient risk factors in addition to the

<table>
<thead>
<tr>
<th>Can You…</th>
<th>Weight (in METs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Take care of yourself, i.e., eating, dressing, bathing, or using the toilet?</td>
<td>2.75</td>
</tr>
<tr>
<td>2. Walk indoors, such as around your house?</td>
<td>1.75</td>
</tr>
<tr>
<td>3. Walk a block or two on level ground?</td>
<td>2.75</td>
</tr>
<tr>
<td>4. Climb a flight of stairs or walk up a hill?</td>
<td>5.50</td>
</tr>
<tr>
<td>5. Run a short distance?</td>
<td>8.00</td>
</tr>
<tr>
<td>6. Do light work around the house such as dusting or washing dishes?</td>
<td>2.70</td>
</tr>
<tr>
<td>7. Do moderate work around the house such as vacuuming, sweeping floors, or carrying groceries?</td>
<td>3.50</td>
</tr>
<tr>
<td>8. Do heavy work around the house such as scrubbing floors or lifting or moving heavy furniture?</td>
<td>8.00</td>
</tr>
<tr>
<td>9. Do yardwork such as raking leaves, weeding, or pushing a power mower?</td>
<td>4.50</td>
</tr>
<tr>
<td>10. Have sexual relations?</td>
<td>5.25</td>
</tr>
<tr>
<td>11. Participate in moderate recreational activities such as golf, bowling, dancing, doubles tennis, or throwing a baseball or football?</td>
<td>6.00</td>
</tr>
<tr>
<td>12. Participate in strenuous sports such as swimming, singles tennis, football, basketball, or skiing?</td>
<td>7.50</td>
</tr>
</tbody>
</table>

**Fig. 1.1** Revised Cardiac Risk Index calculator depicted for two patients entered into the risk calculator. Patient A has no risk factors and a calculated risk for major cardiac event equal to 0.4%. Patient B has several risk factors and a calculated risk for major cardiac event equal to 11%. (From http://www.mdcalc.com/revised-cardiac-risk-index-for-pre-operative-risk/.)
Fig. 1.2 National Surgical Quality Improvement Program (NSQIP) risk calculator. (A) The online site displays where patient and surgical features may be input into the data calculator. (B) As an example, the surgical risk calculation has been performed for a patient undergoing echocardiography with specific risk factors. The resulting surgical risk calculation, including negative outcomes, percent risk of these outcomes occurring, and the chance of the outcome (e.g., average, above average) are displayed. Note in the lower right corner that the surgeon may adjust this risk calculation. In this example, no adjustment has been made. (From http://site.acsnsqip.org.)
surgical procedure. Surgery-specific risk calculation using RCRI or ACS-NSQIP report the rate of cardiac death or nonfatal MI and are noted to be greater than 5% in high-risk procedures, 1% to 5% in intermediate-risk procedures, and less than 1% in low-risk procedures. Emergency surgery is associated with higher risk of MACEs compared with elective procedures.

After patient risk has been estimated, perioperative physicians and the patient can use the information to proceed with the planned operation, postpone, or modify the treatment plan. Options include proceeding directly with the operative plan, delaying surgery pending further diagnostic evaluation, or changing the planned surgery. This last option may involve altering the surgical plan to a lesser risk procedure, a nonsurgical alternative, or cancelling the operation so that cardiac interventions (e.g., coronary revascularization) can be performed. The risk calculation models are discussed individually in the following section.

Revised Cardiac Risk Index

In the derivation of the RCRI, 2893 patients undergoing elective major noncardiac operations were monitored for major cardiac complications (death, acute MI, pulmonary edema, ventricular fibrillation or cardiac arrest, and complete heart block) (see Fig. 1.1). The index was validated in a cohort of 1422 similar individuals. The predictive value was significant in all types of major noncardiac surgery except for abdominal aortic aneurysm surgery. The RCRI performs well in distinguishing patients at low compared with high risk for all types of noncardiac surgery but is less accurate in patients undergoing vascular, noncardiac surgery. In addition, the RCRI does not predict all-cause mortality well, which is inherent to a risk predictor that does not capture risk factors for noncardiac causes of perioperative mortality.

ACS-NSQIP Universal Surgical Risk Calculator

A universal surgical risk calculator model was developed using a web-based tool consisting of 20 patient factors plus the surgical procedure (see Fig. 1.2) and has excellent performance for predicting mortality and morbidity. The ACS-NSQIP has not been validated through external studies, but it remains more comprehensive than the other risk calculators.

After a patient is deemed as being at intermediate or high risk, the ACC/AHA guidelines may then be used to guide further preoperative optimization and perioperative management.

ALGORITHMIC APPROACH TO PERIOPERATIVE CARDIAC ASSESSMENT

The 2014 ACC/AHA Perioperative Guideline proposed a stepwise approach to perioperative cardiac assessment, incorporating both the physician’s role in managing risk and providing informed consent while also involving the patient’s perspective in weighing risk, benefit, and alternatives to invasive testing or preventive therapies. The emphasis on sharing information contextually with other perioperative physicians and the patient highlights the importance of patient-centered care while minimizing risk for each intervention. The algorithmic flow chart begins with determination of surgical urgency followed by assessment of the presence or absence of a preoperative unstable cardiac condition (Box 1.1) and concludes with a perioperative risk calculation.
BOX 1.1 Unstable Cardiac Conditions

- Acute coronary event
- Recent myocardial infarction with residual myocardial ischemia
- Acute heart failure
- Significant cardiac arrhythmias
- Symptomatic valvular heart disease

for MACEs (Fig. 1.3). For patients at low risk of MACE, no further testing is needed, and the patient may proceed to surgery without further evaluation. For patients at high risk for MACE, an objective determination of the functional capacity of the patient is recommended. If a patient at high risk for MACE has 4 METs or greater as determined by objective testing, no further evaluation is required (Fig. 1.3). For high-risk patients who exert less than 4 METs without symptoms or have an indeterminate functional capacity, the perioperative clinician should consult with the perioperative team to determine whether or not further testing will impact the decision to undergo the current surgery or delay surgery for cardiac evaluation and possible intervention (e.g., pharmacologic stress testing, coronary revascularization). If further testing will not impact the surgical plan or perioperative care, then the high-risk patient should either proceed directly to surgery or noninvasive treatment, and palliation strategies should be considered.

The 2014 ACC/AHA guideline update features important information extracted from the critical analysis of nearly 500 referenced articles, which are summarized and appended to the document. Important updates in the evaluation of myocardial ischemia, perioperative management of medical therapy in patients with risk factors for cardiovascular disease, and management of established disease after percutaneous coronary intervention (PCI) and stent implantation are discussed in the subsequent sections. Perioperative medical therapy recommendations have undergone major changes, and management of β-blockers, ACE inhibitors, and α2-agonists (e.g., clonidine) are discussed. Many patients with established cardiovascular disease and a history of coronary stents are on antiplatelet therapy, and management of antiplatelet therapy and timing of surgery are addressed.

**CLASSIFICATION OF RECOMMENDATIONS**

The development of recommendations occurs as a result of literature searches that focus on randomized controlled trials, registries, nonrandomized comparative, and descriptive studies, case series, cohort studies, systematic reviews, and expert opinion. Each recommendation is assigned a class, and level of evidence (LOE) is determined by the guideline writing committee to provide information to the clinician regarding the likelihood that the recommendations are well-supported by the evidence (Fig. 1.4). Understanding the classification and LOE of a particular recommendation is important when considering implementing or foregoing a particular treatment intervention. Class I suggests that benefit clearly outweigh the risks of a particular intervention and that the particular procedure or treatment should be performed or administered. Class IIa suggests that it is reasonable to perform a particular intervention, class IIb
Step 1: Is noncardiac surgery emergent?

No → Step 2: Is there any significant/unstable cardiac condition?

No → Step 3: Estimate perioperative risk of MACE

Low risk (<1%) → Step 4: No further testing, Proceed to surgery

Elevated risk (>1%) → Step 5: No further testing, Proceed to surgery

Yes → Moderate or greater (>4 METs) functional capacity?

No or unknown → Will further testing affect surgical decision making or perioperative care?

Yes → Step 6: Pharmacologic (or exercise) stress testing

Normal/mildly abnormal → Proceed to surgery, according to the existing practice guidelines or alternative strategies (e.g., noninvasive treatment, palliation)

Significantly abnormal → Coronary revascularization according to the existing practice guidelines

No → Step 7: Proceed to surgery, according to the existing practice guidelines or alternative strategies (e.g., noninvasive treatment, palliation)

**SIZE OF TREATMENT EFFECT**

<table>
<thead>
<tr>
<th>CLASS</th>
<th>Benefit</th>
<th>Risk</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLASS I</strong></td>
<td>Benefit &gt;&gt; Risk</td>
<td>Procedure/Treatment SHOULD be performed/administered</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
</tr>
<tr>
<td><strong>LEVEL A</strong></td>
<td>Multiple populations evaluated</td>
<td>Data derived from multiple randomized clinical trials or meta-analyses</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
</tr>
<tr>
<td><strong>LEVEL B</strong></td>
<td>Limited populations evaluated</td>
<td>Data derived from a single randomized trial or nonrandomized studies</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
</tr>
<tr>
<td><strong>LEVEL C</strong></td>
<td>Very limited populations evaluated</td>
<td>Only consensus opinion of experts, case studies, or standard of care</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
</tr>
</tbody>
</table>

**ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT**

| CLASS la | Benefit >> Risk | Additional studies with focused objectives needed; it is reasonable to perform procedure/administer treatment | Recommendation in favor of treatment or procedure being useful/effective |
| CLASS Ib | Benefit > Risk | Additional studies with broad objectives needed; additional registry data would be helpful | Recommendation’s usefulness/efficacy less well established |
| **CLASS IIa** | Benefit > Risk | Additional studies with focused objectives needed | Recommendation’s usefulness/efficacy less well established |
| **CLASS IIb** | Risk >> Benefit | Procedure/Treatment should NOT be performed/administered since it is not helpful and may be harmful | Recommendation that procedure or treatment is not useful/effective and may be harmful |
| **CLASS III** | Benefit >> Risk | Procedure/Treatment SHOULD be performed/administered | Recommendation that procedure or treatment is useful/effective |

**ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT**

| CLASS IIa | Benefit >> Risk | Additional studies with focused objectives needed; it is reasonable to perform procedure/administer treatment | Recommendation in favor of treatment or procedure being useful/effective |
| CLASS IIb | Benefit > Risk | Additional studies with broad objectives needed; additional registry data would be helpful | Recommendation’s usefulness/efficacy less well established |
| **CLASS IIa** | Benefit > Risk | Additional studies with focused objectives needed | Recommendation’s usefulness/efficacy less well established |
| **CLASS IIb** | Risk >> Benefit | Procedure/Treatment should NOT be performed/administered since it is not helpful and may be harmful | Recommendation that procedure or treatment is not useful/effective and may be harmful |
| **CLASS III** | Benefit >> Risk | Procedure/Treatment SHOULD be performed/administered | Recommendation that procedure or treatment is useful/effective |

**Fig. 1.4** Classification of recommendations and level of evidence (LOE). HR, Heart rate; MET, metabolic equivalent. (From Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). Circulation. 2007;116:e418–e499.)
indicates that an intervention may be considered, and class III indicates that the intervention will be of no benefit and may even be harmful. The LOE encompasses the extent to which populations have been evaluated regarding a certain intervention. For example, LOE A implies that multiple populations have been evaluated and that data have been derived from multiple randomized clinical trials or meta-analyses. On the other hand, LOE C suggests that a very limited population of patients have been evaluated regarding a particular intervention and may include expert opinion or case studies (Fig. 1.4).

PRINCIPLES OF MANAGEMENT AND CARDIAC MEDICATIONS

Electrocardiograms

The 2014 ACC/AHA guideline on preoperative evaluation and management of the cardiac patient undergoing noncardiac surgery recommends a 12-lead electrocardiogram (ECG) for patients with CAD, arrhythmias, peripheral artery disease, cerebrovascular disease, and structural cardiac disease unless they are undergoing low-risk procedures (class IIa recommendation, LOE B). Routine preoperative ECG is not helpful in managing patients undergoing low-risk surgery regardless of cardiovascular disease burden or risk factors. Postoperative ECG is recommended for patients with a clinical suspicion for myocardial ischemia, infarction, or arrhythmia after noncardiac surgery; however, routine postoperative ECGs in asymptomatic patients is not useful regardless of the presence of patient risk factors. The decision to perform a postoperative ECG should be guided based on patient symptoms and clinical evaluation.

Cardiac Enzymes

The measurement of laboratory markers of myocardial injury (e.g., troponins) is recommended in patients at high risk for MACE who may benefit from an intervention (class II, LOE B). Routine measurement is not recommended without patient selection (class II, LOE B). The usefulness of postoperative screening with troponin levels for perioperative MI in patients without signs or symptoms suggestive of myocardial ischemia or infarction is uncertain in the absence of established risks and benefits of a defined management strategy. Furthermore, routine screening with troponin provides a nonspecific assessment of risk, does not specify a particular course of therapy, and is not clinically useful outside of the patient with signs or symptoms of myocardial ischemia or MI.

β-Receptor Antagonists

The 2014 ACC/AHA guideline provides recommendations for perioperative β-blockade based on multiple research articles, including a recent meta-analysis by Wijeysundera and colleagues. There are two recommendations of particular interest. First, β-blockade should be continued in patients undergoing noncardiac surgery who have been prescribed these medications chronically (class I, LOE B). This recommendation emphasizes the importance of continuing chronic β-blockade in patients with certain conditions, such as myocardial ischemia or infarction or CHF, in whom long-term survival benefit from β-blockade administration has been demonstrated. Second, it is recommended that β-blockers not be initiated within 1 day of noncardiac surgery. The benefit of MI prevention is offset by the increase in stroke, hypertension, and
death, although β-blocker immediately before surgery may prevent nonfatal MI (class III, LOE B).

**Angiotensin-Converting Enzyme Inhibitors or Angiotensin Receptor Blockers**

Angiotensin-converting enzyme inhibitors and ARBs are among the most commonly prescribed antihypertensives. Both ACE inhibitors and ARBs have cardiovascular and metabolic effects beyond their antihypertensive properties, and their prescription frequency partially relates to their demonstrated outcome and mortality benefit in patients with MI with residual left ventricular dysfunction, HF, and diabetic kidney disease with respect to prevention of the progression to end-stage renal disease. There is increased transient intraoperative hypotension among patients taking ACE inhibitors, but no differences in outcomes have been illustrated in patients receiving ACE inhibitors compared with those who did not. Of note, clinical practice guidelines recommend continuing ACE inhibitors in the setting of acute HF treatment or hypertension, and it is reasonable to continue ACE inhibitors or ARBs perioperatively (class IIa, LOE B). Nevertheless, some practitioners prefer to hold these drugs for 24 hours before surgery to reduce the incidence of intraoperative hypotension. However, if ACE inhibitors or ARBs are held before surgery, it is recommended that they be restarted as soon as clinically feasible in the postoperative period (class IIa, LOE C).

**Aspirin Therapy in Patients Without Coronary Stent Implantation**

The 2014 ACC/AHA guidelines strongly recommend against routine aspirin therapy without previous coronary stent implantation (class III, LOE B). The effects of aspirin have also been evaluated by the PeriOperative Ischemia Evaluation (POISE-2) investigators in patients undergoing noncardiac surgery without recent history of coronary stent placement. Patients at risk for MACE were separated into whether or not they were taking preoperative aspirin. Patients who were not previously taking aspirin (n = 5628) were randomized to receive aspirin (initial dose 200 mg followed by 100 mg/day) or placebo on day of surgery for 30 days after surgery. Patients previously on aspirin (n = 4382) were also randomized to receive aspirin (similar dosing as above) or placebo beginning on day of surgery for 7 days postoperatively and then asked to resume preoperative dosing regimen. Aspirin administration did not decrease the incidence of death or nonfatal MI at 30 days after surgery (hazards ratio, 0.99; 95% confidence interval, 0.86–1.15; P = .92), but exposure to aspirin resulted in increased risk of clinically significant bleeding.

Aspirin administration, however, is recommended when risks of myocardial ischemia exceed the risk of surgical bleeding (class III recommendation, LOE C). The guidelines, therefore, recommend only that consideration be given to the administration of aspirin for elective noncardiac surgery in patients with CAD without history of PCI and stenting (class IIb, LOE B).

**Dual Antiplatelet Therapy After Coronary Stent Implantation**

Patients with a history of coronary stent implantation require special attention to management of DAPT with aspirin and a P2Y₁₂ inhibitor (e.g., clopidogrel, prasugrel,
ticagrelor) to maximize the chances of maintaining stent patency and minimize the risk of perioperative stent thrombosis. In a recent 2016 ACC/AHA guideline–focused update on duration of DAPT in patients with CAD, the acceptable interval from drug-eluting stent (DES) implantation to surgery requiring discontinuation of DAPT has been shortened from 12 months to 6 months (class I, LOE B) for most patients with stable ischemic heart disease. In patients with variable disease, prior STEMI, or a coronary scaffold, the recommendation is still 12 months. If the risk of further delay of surgery is greater than the expected risks of stent thrombosis, discontinuation of DAPT for surgery may be considered 3 months after DES placement (class IIb, LOE C). Surgery should be delayed and DAPT continued for at least 30 days after bare-metal stent placement (class I, LOE B). Perioperatively, aspirin should be continued if possible, and P2Y₁₂ inhibitor therapy should be restarted as soon as possible after surgery.

A summary of the recommendations related to the timing of elective noncardiac surgery after PCI are provided in Table 1.2 and Chapter 3.

**Anticoagulants: Vitamin K Antagonists and New Oral Anticoagulants**

Vitamin K antagonists, such as warfarin (Coumadin), are prescribed for stroke prevention in patients with atrial fibrillation, prevention of thrombotic or thromboembolic complications in patients with prosthetic valves, and in patients requiring deep venous thrombosis prophylaxis and treatment. Dabigatran and factor Xa inhibitors are prescribed for prevention of stroke in the management of atrial fibrillation, but are not recommended for long-term anticoagulation of prosthetic valves because of an increased risk of thrombosis compared with warfarin. The risk of bleeding for any
surgical procedure must be weighed against the benefit of remaining on anticoagulants. For example, an office-based procedure for minor dermatologic surgery may not require cessation or reversal of the anticoagulant. Prothrombin complex concentrates (PCCs) have been used in the acute reversal of patients taking VKAs requiring surgery. Discontinuation of NOACs for 48 hours or longer is recommended for elective surgery. New reversal agents are now available for urgent surgery with extensive bleeding for patients taking dabigatran (Idarucizumab) or factor Xa inhibitors (e.g., andexanet alfa).

**Perioperative Anemia Management**

Anemia is an important topic of discussion, especially because it may contribute to myocardial ischemia. Hemoglobin is a potent oxygen carrier, and ischemia may be triggered by both lack of oxygen delivery to poststenotic myocardium and a demand for increased cardiac output to supply oxygen to other vascular beds. Although blood transfusion may improve anemia, there is association with increased morbidity and mortality in addition to increased healthcare costs. Therefore hemoglobin transfusion thresholds remain a moving target to appropriately balance risk and benefit. Patients undergoing hip surgery with either CAD or known risk factors for CAD with hemoglobin of less than 10 g/dL treated with either a liberal transfusion strategy or a conservative transfusion strategy less than 8 g/dL have been studied. There were no differences in the 60-day endpoints of death or inability to walk between groups but that the study was not sufficiently powered to show a difference in the aforementioned areas if a difference did indeed exist. The 2012 American Association of Blood Banks recommended a restricted transfusion strategy (hemoglobin <7–8 g/dL) in asymptomatic, hemodynamically stable patients without CAD, a relative restricted transfusion strategy in hospitalized patients with cardiovascular disease, and consideration of transfusion for patients with symptoms or hemoglobin less than 8 g/dL. In postoperative patients, the recommended maintenance hemoglobin concentration is 8 g/dL or greater unless the patient is symptomatic (e.g., angina pectoris, orthostasis, CHF). There are no specific recommendations for hemodynamically stable patients with acute coronary syndrome because of the lack of high-quality evidence for either liberal or a restrictive transfusion strategy in these patients. The consensus of experts recommended a symptom-guided approach to evaluating hemoglobin level to determine whether to transfuse an anemic patient.

**Pulmonary Vascular Disease and Right Ventricular Dysfunction**

The evidence for management of patients with pulmonary hypertension is limited to those with pulmonary arterial hypertension. Perioperative events including, but not limited to hypoxia, hypercarbia, hypertension or hypotension, and positive-pressure ventilation may worsen pulmonary hypertension and RV systolic function. In addition to the urgency of the surgery and the surgical risk category, risk factors for perioperative adverse events in patients with pulmonary hypertension include the severity of symptoms related to pulmonary hypertension, the degree of RV dysfunction, and the absence of a specialized center in the treatment of patients with pulmonary hypertension. Patients with pulmonary arterial hypertension, particularly with features of increased perioperative risk, should undergo a thorough preoperative risk assessment including determination of functional capacity, hemodynamics, and echocardiography that includes evaluation of RV function. Right heart catheterization may be particularly useful to confirm the severity of illness and determine secondary causes of elevated pulmonary arterial pressures (e.g., pulmonary venous hypertension
secondary to reduced LVEF, mitral regurgitation, mitral stenosis). Optimization of pulmonary hypertension and RV function are necessary to minimize perioperative cardiovascular risk.

SUGGESTED READING


