

## Perioperative Medicine for the Hospitalized Patient

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In many medical centers, hospitalists have become an important resource for providing inpatient preoperative evaluations. Given the increasing complexity of hospitalized patients and the increasing specialization among surgeons, there is greater reliance on hospitalists for preoperative assessment. Several institutions have developed surgery/medicine comanagement teams that jointly care for patients in the perioperative setting. Despite a growing body of evidence, it is important to recognize there are many gaps in the perioperative literature. This has led to considerable dependence on consensus statements and expert opinion when evaluating patients perioperatively.

This review focuses on the preoperative cardiovascular and pulmonary evaluation of the hospitalized patient: the two systems responsible for the greatest morbidity and mortality. Prevention of postoperative venous thromboembolism and management of perioperative hyperglycemia will also be discussed.

### Clinical vignette

A 70-year-old female presents to the emergency department with a hip fracture after a fall. She has a history of chronic obstructive pulmonary disease (COPD), hypertension, type 2 diabetes treated with insulin, and chronic kidney disease with a baseline creatinine of 2.2 mg/dL. Her medications include aspirin, ramipril, hydrochlorothiazide, 70/30 insulin twice daily, and inhaled ipratropium. She has no complaints except those related to her hip, and denies all cardiopulmonary symptoms on a complete review

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of symptoms. Her functional capacity has been limited to ambulating within her home but avoiding stairs. Her blood pressure is 134/86 and heart rate is 82. The remainder of her physical exam is normal. Should the medical consultant recommend stress testing before surgery for this patient? Are there any interventions that could be employed to reduce the patient's perioperative cardiac or pulmonary risk?

### **Cardiovascular evaluation**

In 2004, there were approximately 35 million noncardiac inpatient surgical procedures performed in the United States [1]. To determine the risk of major perioperative cardiac events for noncardiac surgery, Devereaux and colleagues [2] pooled results from prospective studies that assessed patients who either had or were at risk for cardiac disease. They found that 3.9% of patients experienced a major cardiac event defined as cardiac death, nonfatal myocardial infarction, and nonfatal cardiac arrest. There are many reasons why the perioperative period poses an increased risk for cardiovascular complications. Operative stresses such as anesthesia, intubation/extubation, pain, fasting, stress steroid surges (eg, catecholamines and cortisol), blood loss, thrombophilia, and hypothermia may all increase the risk for a perioperative cardiovascular event [2].

We recommend a step-wise approach to preoperative cardiac assessment and risk reduction (Fig. 1). Although there are many areas of uncertainty within this approach, we feel that it represents a clinically useful synthesis of the available knowledge related to the subject.

#### *Step 1. Determine if the patient has recently undergone a cardiac evaluation or revascularization procedure*

Although limited to retrospective data, studies indicate that a previous revascularization procedure such as coronary artery bypass grafting (CABG) or percutaneous transluminal coronary angioplasty (PTCA) offers a protective benefit with respect to future surgical risk [3–7]. This is best demonstrated in a retrospective analysis of 1600 patients in the Coronary Artery Surgery Study (CASS) registry [3]. The operative mortality for patients without significant coronary artery disease (CAD) undergoing noncardiac surgery (0.5%) was not significantly different from those with CAD having had CABG before surgery (0.9%). However, in patients with considerable CAD without prior CABG, the operative mortality was significantly higher (2.4%). Extrapolating from these data, the American College of Cardiology/American Heart Association (ACC/AHA) guidelines on perioperative cardiovascular evaluation for noncardiac surgery suggest that coronary revascularization within 5 years, and a stable clinical status without signs or symptoms of ischemia, precludes the need for any further

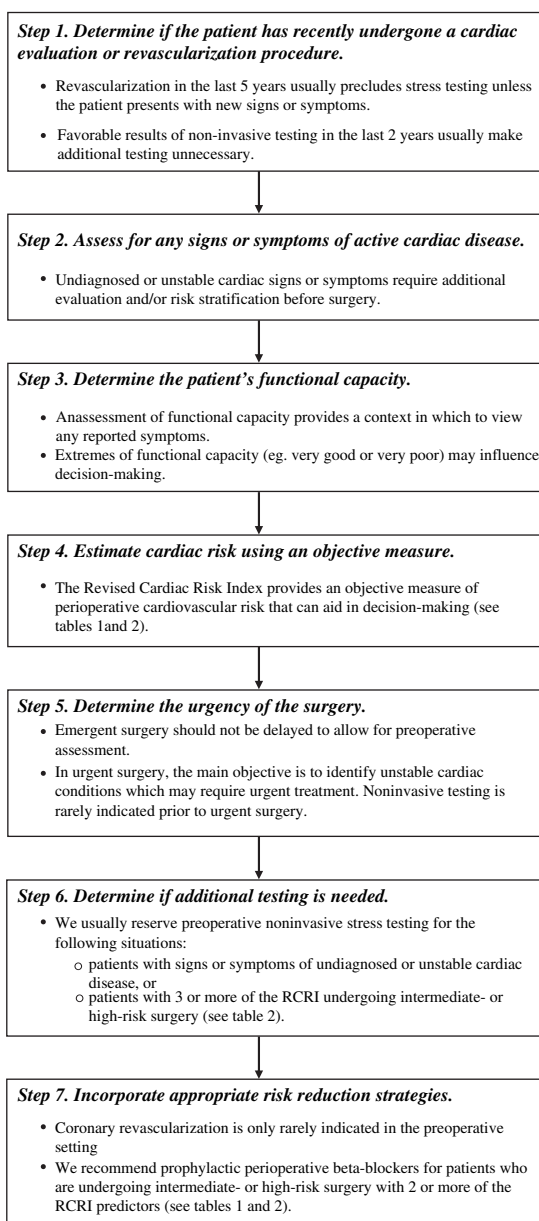


Fig. 1. A stepwise approach to perioperative cardiovascular assessment and risk reduction.

cardiac testing [8]. These guidelines also state that patients who have undergone a coronary evaluation with favorable results within the past 2 years (such as a cardiac stress test or diagnostic cardiac catheterization) do not

require further testing, unless there are new signs or symptoms of ischemic heart disease.

*Step 2. Assess for any signs or symptoms of active cardiac disease*

The preoperative evaluation also provides an opportunity to unmask any cardiovascular conditions that have gone undiagnosed, or identify worsening of any preexisting conditions. A careful review of systems may reveal concerning signs and/or symptoms, such as chest pain or pressure, shortness of breath, orthopnea, lower extremity edema, unexplained syncope, palpitations, or focal neurologic deficits. The physical exam may also reveal signs that require further evaluation. Patients with clinical signs concerning undiagnosed or unstable cardiac disease (eg, angina, heart failure, valvular heart disease, arrhythmia) often require additional testing for diagnosis and/or risk stratification.

*Step 3. Determine the patient's functional capacity*

An accurate assessment of the patient's functional capacity is an important component of the preoperative evaluation. Patients who are able to achieve a high functional capacity may experience fewer perioperative complications [9,10]. One study included 600 preoperative patients who self-estimated the number of blocks they could walk and flights of stairs they could climb without experiencing symptomatic limitation [9]. Patients who reported poor exercise tolerance (defined as the inability to walk 4 blocks and climb 2 flights of stairs) had significantly more perioperative complications overall (20.4% versus 10.4%,  $P < .001$ ); however, the difference in cardiovascular complications was not significantly different between the groups when adjusted for age.

A physical activity questionnaire can be a useful tool to assess a patient's functional capacity by asking if a patient can perform various tasks or activities [11]. The ACC/AHA perioperative guidelines indicate that the ability to perform four metabolic equivalents (METs) or greater is reflective of at least fair functional capacity [8]. These guidelines also recommend that many patients who are unable to perform four METs should undergo non-invasive cardiac testing, a recommendation that is based on expert opinion. We believe that strict adherence to this recommendation will result in over-testing. While self-reported functional capacity that is either extremely high or low may influence decision making, the existing data suggest that the assessment of functional capacity is most useful in creating a context for understanding a patient's symptoms (or lack thereof). More reliable predictors of risk should form the foundation for perioperative assessment.

*Step 4. Estimate cardiac risk using an objective measure*

For patients who lack signs or symptoms of undiagnosed or unstable cardiac disease, an objective estimate of perioperative cardiovascular risk

can be made by employing a clinical assessment tool. Objectively estimating risk in this manner assists in making decisions about further testing and applying risk reduction interventions. Well-known examples of risk indices include those by Goldman [12], Detsky [13], and Lee [14] in addition to the clinical predictors used in the ACC/AHA perioperative guidelines [8]. Lee's Revised Cardiac Risk Index (RCRI) is a modern, simple, and prospectively validated system that was developed after studying 4315 patients aged 50 years or older undergoing elective major noncardiac surgery [14]. The authors identified six independent predictors of cardiac complications, as shown in Table 1. By simply summing these criteria, patients can be stratified into low (zero to one risk factor), intermediate (two risk factors), or high risk (three or more risk factors). When compared with other risk assessment models using receiver operating characteristic curve analysis, the RCRI proved to be the most accurate [14].

Table 1

The revised cardiac risk index (RCRI) as a predictor of major cardiac event rates<sup>a</sup> for noncardiac surgery

<ul style="list-style-type: none"> <li>• Ischemic heart disease               <ul style="list-style-type: none"> <li>• defined as having any of the following: history of myocardial infarction, history of a positive stress test, current complaint of chest pain considered to be secondary to myocardial ischemia, use of nitrite therapy, or ECG with pathologic Q waves. Note that a history of percutaneous coronary intervention or CABG was not used as criteria for ischemic heart disease unless accompanied by any of the other criteria listed above.</li> </ul> </li> <li>• Congestive heart failure               <ul style="list-style-type: none"> <li>• defined by having any of the following: history of congestive heart failure, pulmonary edema, paroxysmal nocturnal dyspnea, bilateral rales or S3 gallop on physical examination, or chest radiograph showing pulmonary vascular redistribution.</li> </ul> </li> <li>• Cerebrovascular disease               <ul style="list-style-type: none"> <li>• defined as either stroke or transient ischemic attack.</li> </ul> </li> <li>• Diabetes mellitus requiring preoperative treatment with insulin</li> <li>• Serum creatinine &gt; 2.0 mg/dL</li> <li>• High-risk surgery               <ul style="list-style-type: none"> <li>• defined as intraperitoneal, intrathoracic, or suprainguinal vascular.</li> </ul> </li> </ul>		
RCRI classification	Event rate (95% confidence interval)	
	Derivation cohort	Validation cohort
Low risk		
• 0 risk factors	0.5 (0.2–1.1)	0.4 (0.05–1.5)
• 1 risk factor	1.3 (0.7–2.1)	0.9 (0.3–2.1)
Intermediate risk		
• 2 risk factors	3.6 (2.1–5.6)	6.6 (3.9–10.3)
High risk		
• ≥ 3 risk factors	9.1 (5.5–13.8)	11.0 (5.8–18.4)

*Abbreviations:* CABG, coronary artery bypass graft; ECG, electrocardiogram.

<sup>a</sup> Major cardiac events were defined as myocardial infarction, pulmonary edema, ventricular fibrillation or primary cardiac arrest, and complete heart block.

*Data 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;100:1043–9.

*Step 5. Determine the urgency of the surgery*

When a hospitalized patient is to undergo surgery, it is usually emergent or urgent in nature. A formal preoperative evaluation before emergent surgery is unnecessary since there is no time for additional testing or therapeutic interventions. Urgent surgery can be described as surgery that needs to be performed during the same hospitalization, although a delay of a few days may be appropriate. In urgent surgical cases, identification of unstable cardiac conditions may influence management, but there is no role for testing to identify occult cardiac disease even when patients have significant risk factors. This is because there is neither time for, nor data to support, more extensive interventions (such as coronary revascularization) for stable patients in this setting. Hip fracture repair, as in our vignette, is a good example of an urgent procedure as studies have shown optimal outcomes when performed within 24 to 72 hours [15,16].

For elective procedures, the preoperative evaluation is usually performed under lesser time constraints. This allows for consideration of revascularization strategies if indicated for long-term benefit.

*Step 6. Determine if additional testing is needed*

The vast majority of pertinent clinical information will be acquired from the history and physical examination. Although an electrocardiogram (ECG) is usually obtained preoperatively, data to support this practice are limited [17]. An ECG is recommended for patients with known cardiac disease or significant risk factors, and the presence of pathologic Q-waves represents ischemic heart disease according to the RCRI.

The utility of noninvasive cardiac stress testing preoperatively is debated. Given recent evidence, there has been a trend toward less preoperative stress testing in favor of increased use of prophylactic pharmacologic interventions to decrease cardiovascular risk. It should also be emphasized that no testing should be performed if the results will not alter patient management. For example, a preoperative stress test would be inappropriate for patients who are poor candidates for coronary revascularization.

The ACC/AHA perioperative guidelines nicely summarize the trials that used stress testing for preoperative cardiac risk assessment [8]. Stress myocardial perfusion testing demonstrated a positive predictive value of 4% to 20% for cardiac ischemia, while the negative predictive value of a normal scan was approximately 99% for myocardial infarction and/or cardiac death. Similarly, trials employing dobutamine stress echocardiography (DSE) for preoperative risk assessment established a positive predictive value of myocardial infarction or death of 7% to 25%, with a negative predictive value ranging from 93% to 100%. These numbers illustrate that, although a negative stress test result can be reassuring, a positive test is poorly predictive of perioperative cardiovascular events and thus unhelpful in the large majority of patients.

There are circumstances, however, when the results of a preoperative stress test may provide useful risk-stratification. Among high-risk patients, noninvasive testing may help distinguish those whose perioperative risk might be acceptable from those whose risk will remain very high, even if treated with perioperative beta-blockers. This was demonstrated in a study by Boersma and colleagues [18], who examined the cardiac event rate in patients undergoing major vascular surgery in relation to clinical risk factors, DSE results, and beta-blocker therapy. The clinical risk factors used in this study were very similar to Lee's RCRI. The authors found that in patients with less than three risk factors, DSE offered minimal prognostic benefit. This was particularly true in patients receiving beta-blocker therapy. However, in patients with three or more risk factors, DSE did provide prognostic value. A normal DSE in this group was predictive of a relatively low post-operative event rate, while extensive reversible ischemia detected on DSE correlated with a high rate of cardiac death or nonfatal myocardial infarction, even for patients treated with beta-blockers. A more recent trial demonstrated that preoperative cardiac testing did not alter outcomes in intermediate-risk patients undergoing vascular surgery with tight heart rate control using beta-blockers [19].

Some authors have published preoperative approaches using the RCRI as the primary decision tool for determining if noninvasive cardiac testing is indicated [20–22]. Following these strategies, in contrast to the 2002 ACC/AHA perioperative guidelines, would lead to a significant reduction in the number of noninvasive cardiac stress tests performed. We generally reserve preoperative noninvasive testing for patients with signs or symptoms of undiagnosed or unstable cardiac disease, or patients with an RCRI score of three or more (Table 2). One might have a lower threshold for noninvasive testing in cases where the surgical risk is very high, the functional capacity is very low, or the patient is unable to tolerate beta-blocker medications.

### *Step 7. Incorporate appropriate risk-reduction strategies*

#### *Revascularization*

The literature has consistently shown that coronary revascularization should almost never be performed simply to improve the odds of a favorable surgical outcome. The Coronary Artery Revascularization Prophylaxis (CARP) trial is the only prospective study to date that has assessed long-term mortality in high-risk patients who were randomized to either revascularization (percutaneous coronary intervention or CABG) or no revascularization before elective major vascular surgery [23]. Patients were included if they had significant but stable coronary artery disease (at least one coronary artery with a stenosis of 70% or more by angiogram). Exclusion criteria consisted of a stenosis of 50% or more in the left main coronary artery, left ventricular ejection fraction of less than 20%, and severe aortic stenosis. The results revealed no significant difference between the two

Table 2

A preoperative approach using the RCRI for determining when to use beta-blockers and/or noninvasive cardiac testing

RCRI score	Recommendations
0	Neither prophylactic beta-blockers nor noninvasive cardiac testing are recommended for these patients.
1	Prophylactic beta-blockers are generally not recommended but may be considered if surgery type is high-risk and/or functional capacity is very poor. Noninvasive stress testing is not recommended.
2	Prophylactic beta-blockers are recommended for these patients. Noninvasive stress testing is not recommended but may be considered if surgery type is high risk and/or functional capacity is very poor.
3 or more	Prophylactic beta-blockers are highly recommended for these patients. Noninvasive stress testing is reasonable for most of these patients but may be omitted if surgery type is low risk, functional capacity is very good, or surgery is urgent.

*Abbreviation:* RCRI, revised cardiac risk index.

*Data from* Wesorick DH, Eagle KA. The preoperative cardiovascular evaluation of the intermediate-risk patient: new data, changing strategies. *Am J Med* 2005;118:1413.

groups with respect to mortality at 2.7 years, or postoperative myocardial infarction at 30 days. Not surprisingly, there was a significant delay in surgery for the revascularization group. The authors concluded that preoperative revascularization before elective vascular surgery should not be recommended in this patient population.

Although the CARP trial was an intervention trial, it does raise questions about the utility of using noninvasive cardiac testing for the purpose of identifying asymptomatic coronary disease in preoperative patients. This is particularly true for situations involving urgent surgeries, such as those most commonly encountered in the hospitalized patient.

#### *Antiplatelet management for patients with a recent coronary artery stent*

Although preoperative coronary revascularization is very rarely indicated, it is not uncommon for patients to develop a need for surgery after having a coronary stent placed. This scenario warrants special attention from the evaluating clinician. The placement of a stent in a coronary artery increases the likelihood of a coronary thrombotic event. The duration of that increased risk remains uncertain, and probably correlates with the period of time before the stent is endothelialized. This increased thrombotic risk is generally combated with dual antiplatelet therapy (aspirin and clopidogrel), which effectively reduces this risk. Therefore, in patients with recent coronary stents who are to undergo surgery, the decision to discontinue this therapy must be made with careful consideration of the risks and benefits to the patient.

Bare-metal stents endothelialize more rapidly than drug-eluting stents and thus require a shorter course of dual antiplatelet therapy. Current data indicate that patients who discontinue antiplatelet therapy soon after

stent placement may be at increased risk of stent thrombosis [24–27]. The American College of Cardiology, the American Heart Association, and the Society for Cardiovascular Angiography and Interventions (ACC/AHA/SCAI) suggest that patients with bare-metal stents be treated with dual antiplatelet therapy with aspirin and clopidogrel for at least 1 month after stent implantation [28].

Dual antiplatelet therapy is required for a longer period after the implantation of drug-eluting stents. The ACC/AHA/SCAI guidelines recommend that dual antiplatelet therapy be continued for 1 year after implantation of drug-eluting stents in patients who are not at high risk for bleeding (and, at minimum, 3 months for sirolimus-eluting stents, and 6 months for paclitaxel-eluting stents) [28]. In studies examining stent thrombosis, the most powerful predictor of this often-catastrophic event is the discontinuation of antiplatelet therapy. One study examining 2229 patients after stent implantation found that 5 of 17 patients who prematurely discontinued antiplatelet therapy suffered this complication [29]. Furthermore, the extended use of clopidogrel in patients with drug-eluting stents appears to be protective [30].

An advisory document, written by a multidisciplinary panel (including the ACC/AHA/SCAI, American College of Surgeons, and American Dental Society), provides specific recommendations about how to proceed when a patient with a recently placed coronary stent faces surgery [31]. These recommendations include the following:

- Elective procedures with significant perioperative bleeding risk should be delayed until patients have completed an appropriate course of thienopyridine (ie, clopidogrel) therapy.
- For patients treated with drug-eluting stents who are to undergo subsequent procedures that require discontinuation of thienopyridine therapy, aspirin should be continued if at all possible and the thienopyridine restarted as soon as possible postoperatively.
- For patients undergoing percutaneous coronary intervention who are likely to have a surgical procedure within the next 12 months, balloon angioplasty or implantation of a bare metal stent should be considered instead of a drug-eluting stent.

The true balance between risk and benefit of continuing antiplatelet therapy perioperatively remains uncertain. Although antiplatelet therapy is routinely held in this setting, there are many surgeries that can be safely completed while the patient is taking these medications [32]. Any recommendations to continue antiplatelet therapy through the perioperative period should be discussed directly with the referring surgeon. These discussions usually result in an acceptable plan for managing the antiplatelet agents.

### *Beta-blockers*

The decision about which patients should receive perioperative beta-blocker therapy is not straightforward. The theory that beta-blockers can

reduce demand ischemia and lower perioperative risk has not been consistently shown in the published literature. Study results have greatly varied demonstrating (1) extraordinary benefit in high-risk vascular surgery patients [33], (2) no significant benefit for low-risk diabetic patients [34], (3) delayed 2-year postoperative mortality reduction [35], and (4) no benefit in lower-risk vascular surgery patients [36]. Key factors that appear to influence trial outcomes include the degree of patient risk, type of surgery, duration of beta-blocker therapy, and whether the drug was titrated to a target heart rate.

More recent publications have attempted to clarify the role of perioperative beta-blockers. A meta-analysis of all randomized trials found that, although beta-blockers may reduce cardiac events, this benefit has only been demonstrated in a small number of trials encompassing few cardiac events [37]. Also, treatment with beta-blockers is associated with an increased risk of perioperative bradycardia and hypotension requiring treatment [37,38]. Another study used an administrative database of almost 800,000 patients to assess the effect of perioperative beta-blockers on in-hospital mortality [39]. Using propensity-score matching, a direct relationship was found corresponding to the patient's cardiac risk. In patients with an RCRI score of 0 or 1, beta-blocker use was associated with no benefit and possible harm. In patients with an RCRI score of 2 or more, the use of beta-blockers was associated with decreased in-hospital mortality. The ACC/AHA published a focused update on perioperative beta-blocker therapy in 2006 [40] that describes certain patient populations that may benefit from this therapy. According to these guidelines, beta-blockers are recommended for the following: patients already taking beta-blockers for a valid indication (eg, ischemic heart disease or hypertension), patients with coronary artery disease or findings of ischemia undergoing vascular surgery, and patients with multiple clinical risk factors undergoing intermediate- or high-risk procedures.

As described above, there is now evidence to suggest that beta-blockers may reduce perioperative cardiac risk in a subset of patients who are at higher baseline cardiac risk. However, more research is needed to more clearly delineate which patients will benefit from perioperative beta-blockade. The ongoing PeriOperative Ischemic Evaluation (POISE) trial plans to randomize 10,000 patients to metoprolol versus placebo before noncardiac surgery [41]. In the meantime, we believe there is sufficient evidence to recommend prophylactic perioperative beta-blockers to patients who are undergoing intermediate- or high-risk surgery with two or more of the RCRI predictors (see Table 2). Initiating beta-blockers should also be considered for patients who have a preexisting indication such as uncontrolled hypertension, congestive heart failure, or history of myocardial infarction. It should be noted that cardioselective beta-blockers are considered a safe intervention for patients with mild to moderate reactive airway disease or COPD as demonstrated in a meta-analysis [42] and Cochrane review [43].

### *Alpha-2 adrenergic agonists*

Another class of medication that has been evaluated for perioperative cardiovascular risk reduction is the alpha-2 adrenergic agonists. A meta-analysis including 23 trials and 3395 patients demonstrated a significant reduction in mortality and ischemia in those receiving alpha-2 agonist therapy [44]. Among those undergoing vascular surgery, these agents achieved a significant reduction in mortality and myocardial infarction. A systematic review involving fewer trials established a significant reduction in cardiac mortality in patients with alpha-2 agonist exposure during noncardiac surgery [38]. It should be noted, however, that the benefits of alpha-2 agonists in these trials appeared to be influenced by a single large trial that used intravenous mivazerol—an alpha-2 agonist not available in the United States.

A large randomized trial of prophylactic alpha-2 agonists is needed to better determine the role of these agents in perioperative cardiovascular risk reduction. A head-to-head trial of perioperative alpha-2 agonists and beta-blockers is also required. For now, alpha-2 agonists should be considered for higher risk patients who have a contraindication to beta-blockers.

### *HMG-CoA reductase inhibitors (statins)*

Recent observational trials have demonstrated reduced perioperative cardiovascular event rates in patients on statin therapy [45–49]. Despite this suggestive evidence, there has only been one randomized controlled trial assessing the effect of statin exposure on perioperative cardiovascular events in noncardiac surgery [50]. At present, we recommend that patients who are taking statins continue them in the perioperative period, although we currently do not initiate statins specifically for perioperative risk reduction. The ongoing Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echo-IV (DECREASE-IV) trial [51] should clarify the role of perioperative statins.

### **Clinical vignette continued**

This 70-year-old hip fracture patient has multiple cardiovascular risk factors and has not had a recent cardiac evaluation. She does not have any signs or symptoms suggestive of active cardiac disease, albeit in the setting of a poor functional capacity. Using the RCRI to estimate cardiac risk, this patient would score 2, indicating intermediate risk. This surgery would be classified as intermediate risk and urgent, ideally performed within 24 to 72 hours for optimal surgical outcome. Additional cardiac testing would not be recommended for this patient given her intermediate risk profile, the lack of undiagnosed or unstable cardiac symptoms, and the urgency of surgery. With respect to perioperative beta-blockers, the RCRI score of 2 suggests this patient is a reasonable candidate. A beta-blocker should be initiated, titrated to a goal heart rate of 50 to 65 beats per minute, and continued for at least 7 but up to 30 days postoperatively.

## **Pulmonary evaluation**

Perioperative pulmonary complications are similar in prevalence to cardiac complications. In a prospective study of 3970 patients undergoing major noncardiac surgery, the frequency of cardiac complications was 1% for myocardial infarction and 1% for pulmonary edema, while pulmonary complications had a frequency of 2% for respiratory failure and 1% for bacterial pneumonia [52]. Furthermore, it has been shown that perioperative pulmonary complications lead to longer hospital lengths of stay when compared with cardiac complications [53]. Given these findings, it is important to fully assess a patient's pulmonary status during the preoperative evaluation (Fig. 2).

### *Step 1. Determine if the patient has known pulmonary disease*

For patients with existing lung disease, it is important to determine the severity of the disease and the effectiveness of current management. Reports of recent pulmonary evaluations or testing may be helpful. Also, having the patient describe their perceived satisfaction of disease management is often useful in determining whether further evaluation or intervention is indicated.

### *Step 2. Assess for any signs or symptoms of active lung disease*

Similar to the cardiovascular evaluation, the preoperative encounter is an opportunity to discover undiagnosed conditions. With appropriate questioning, the patient may report symptoms such as breathlessness, wheezing, cough, or sputum production. The patient's smoking history is also important to ascertain. If an undiagnosed pulmonary disease is suspected, additional evaluation may be appropriate.

### *Step 3. Recognize markers of increased perioperative pulmonary risk*

Perioperative pulmonary complications are typically defined as any of the following: atelectasis, pneumonia, respiratory failure, exacerbation of a chronic lung disease, and bronchospasm. Pulmonary edema and pulmonary embolism are not considered pulmonary complications. To estimate the likelihood of developing a perioperative pulmonary complication, risk factors are categorized as patient-related and surgery-related.

Evidence-based guidelines for perioperative pulmonary evaluation were recently published [54] and accompanied by a systematic review on pulmonary risk stratification for noncardiothoracic surgery [55]. This analysis concluded that advanced age, an American Society of Anesthesiologists (ASA) class of greater than or equal to 2, congestive heart failure, functional dependence, and COPD were all strong indicators of patient-related risk for developing a perioperative pulmonary complication. Cigarette use is associated with a modest increase in risk, while obesity and asthma are

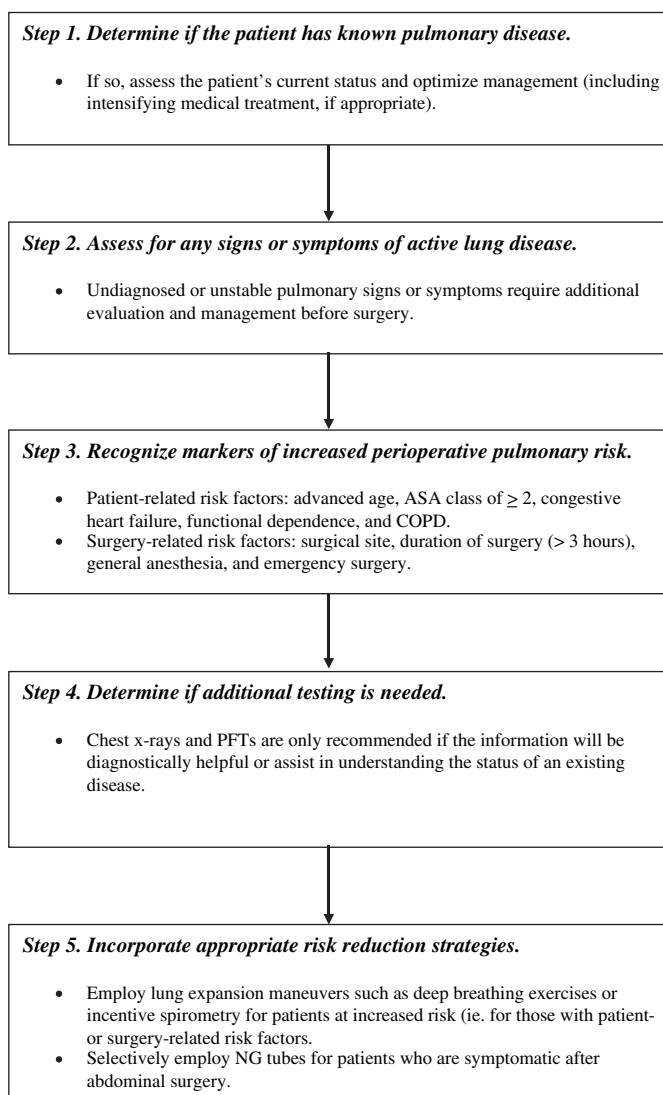


Fig. 2. A stepwise approach to perioperative pulmonary assessment and risk reduction.

not associated with increased risk. There was insufficient evidence to determine if obstructive sleep apnea is a risk factor.

Surgery-related risk factors are likely more important than patient-related risk factors for predicting perioperative pulmonary complications. The surgery-related risk factors include surgical site, duration of surgery (> 3 hours), type of anesthesia (general), and emergency surgery [55]. The surgical site is by far the most significant risk, with aortic aneurysm repair, thoracic, and abdominal surgery posing the greatest risk [56,57]. The higher risk surgical

sites can be remembered by the “closest to the diaphragm” rule, as diaphragmatic dysfunction and splinting secondary to pain can lower vital capacity and functional reserve capacity, increasing the risk for pulmonary complications.

*Step 4. Determine if additional testing is needed*

The history and physical examination will usually provide all of the information needed to complete the preoperative pulmonary evaluation. On occasion, additional testing may be indicated, most commonly when new symptoms are reported, a previous diagnosis is unclear, or the patient’s presentation suggests worsening clinical status.

A preoperative chest radiograph is commonly ordered despite insufficient data showing clinical utility. Although an abnormal chest radiograph has been shown to be predictive of postoperative pulmonary complications [58], it is felt this imaging rarely provides any additional information beyond what can be determined by the history and physical examination. This was shown in a meta-analysis of 21 studies involving 14,390 patients where abnormalities were present in 10% of preoperative chest radiographs, but only 1.3% showed unexpected abnormalities and only 0.1% influenced management [59]. A more recent review demonstrated similar findings [60]; however, neither of these studies assessed for postoperative pulmonary complications. Despite the limited evidence, the recent guidelines from the American College of Physicians state that a preoperative chest radiograph may be helpful for patients older than 50 with known cardiopulmonary disease who are undergoing upper abdominal, thoracic, or abdominal aortic aneurysm surgery [54]. In our practice, we order chest radiographs for diagnostic indications or to better understand the status of an existing disease. We do not order this test for the purpose of preoperative “screening.”

Pulmonary function tests (PFTs) are rarely indicated before surgery. PFTs have not been shown to predict perioperative risk more accurately than clinical assessment alone. A nested case-control trial of 2291 patients undergoing abdominal surgery sought to identify risk indicators for perioperative pulmonary complications [58]. Although variables including an abnormal chest radiograph and abnormal findings on lung physical examination were found to be independent risk factors, no components of PFTs were predictive of perioperative pulmonary complications. Furthermore, there is no established spirometry value cutoff for which noncardiac surgery should be denied [61].

Alternatively, preoperative PFTs can be diagnostically useful in the assessment of unexplained symptoms. In addition, they are sometimes helpful in assessing the status of known lung disease, especially when the history and physical exam do not lead to a firm conclusion. Last, PFTs are always obtained for patients scheduled for lung reduction surgery.

*Step 5. Incorporate appropriate risk-reduction strategies*

Despite fairly robust risk stratification data, strategies to reduce risk for perioperative pulmonary complications are limited. The initial approach for

patients with chronic lung disease is to optimize their management. For example, in patients with respiratory symptoms such as chest tightness or wheezing, aggressive bronchodilator therapy with the option of preoperative systemic steroid therapy is recommended. Although physicians may fear that steroid exposure will increase perioperative infection risk and hinder wound healing, the limited evidence available suggests this is not the case [62].

The type of anesthesia is another potentially modifiable factor that may influence perioperative pulmonary complication risk. A large meta-analysis showed a significant reduction in pneumonia, respiratory depression, and overall mortality in patients allocated to neuraxial blockade, compared to those receiving general anesthesia [63]. However, this topic remains controversial and decisions about the specific type of anesthesia to be employed are usually made in consultation with an anesthesiologist.

The greatest reduction in postoperative pulmonary complications can be achieved by implementing lung expansion modalities. These include deep-breathing exercises, incentive spirometry, intermittent positive-pressure breathing, and continuous positive airway pressure. A meta-analysis of 14 randomized controlled trials of patients undergoing upper abdominal surgery demonstrated a significant reduction in postoperative pulmonary complications of approximately 50% among patients treated with these modalities [64]. Other strategies that have been shown to reduce the risk of pulmonary complications include postoperative epidural pain control [65] and selective use of nasogastric decompression for symptomatic patients following abdominal surgery [66].

### **Clinical vignette continued**

Our patient has a history of COPD, but is not exhibiting any signs or symptoms related to this disease. Despite her perioperative pulmonary risk factors of advanced age, ASA class  $\geq 2$ , and history of COPD, she does not require any preoperative testing such as chest radiography or PFTs. Postoperative lung expansion maneuvers are highly recommended for this patient.

### **Venous thromboembolism (VTE) prevention**

The need for VTE prophylaxis in the surgical patient is undisputed. Given the high incidence of VTE, its significant morbidity and mortality, and the effective prevention strategies available, VTE prophylaxis must be a priority when managing patients in the postoperative setting [67]. The risk of developing DVT among surgical patients without prophylaxis is striking, with estimates of 15% to 30% in general surgery patients [68], 40% to 60% in lower extremity orthopedic patients [67], and greater than

60% in trauma patients [69]. Although mechanical forms of VTE prevention such as intermittent pneumatic compression devices and graduated compression stockings are available, the vast majority of hospitalized surgical patients will require pharmacologic prevention. Internists who manage perioperative patients should feel comfortable with the timing and duration of prophylactic anticoagulation. Low-dose unfractionated heparin (LDUH), low molecular weight heparin (LMWH), fondaparinux, and warfarin have all been shown to be efficacious for VTE prevention in surgical patients. The preferred agent and dosing regimen often depend on the level of VTE risk and the type of surgery (Table 3). The American College of Chest Physicians (ACCP) has published detailed guidelines for perioperative VTE prophylaxis [67].

Lower extremity orthopedic surgery is associated with a very high risk of VTE. In hip fracture patients, the risk for VTE starts at the time of injury as opposed to the time of surgery [70,71]. Therefore, prophylaxis should be initiated as soon as possible in the preoperative period and continued until 12 to 24 hours before surgery. For hip fracture and total hip replacement surgery, extended VTE prophylaxis is recommended for a total of 28 to 35 days, while total knee replacement surgery should receive prophylaxis for at least 10 days postoperatively [67].

The timing of prophylactic anticoagulation is further complicated when neuraxial anesthesia is employed. The delivery of anesthetic to the neuraxis requires insertion of a needle or catheter into the epidural space, and the concomitant use of prophylactic anticoagulation may increase the risk of paraspinal hematomas. Both the ACCP and the American Society of Regional Anesthesiology (ASRA) agree that pharmacologic VTE prophylaxis can still be used concomitant with neuraxial anesthesia, as long as precautions are taken to reduce bleeding risk [67,72]. These precautions are outlined in Table 4.

Since most hospitalized surgical patients are candidates for VTE prophylaxis, we believe that the approach should be standardized. Hospitals should have written protocols for VTE prophylaxis, and these protocols should be incorporated into order sets.

### **Clinical vignette continued**

Hip fracture patients are at very high risk for VTE. Given our patient's chronic kidney disease, the choices for VTE prophylaxis become limited. Enoxaparin has an approved renal dosing of 30 mg subcutaneously daily, and should be started shortly after the patient's arrival to the hospital. The last dose should be given 24 hours before surgery, then restarted 12 to 24 hours postoperatively. Pharmacologic VTE prophylaxis should be continued for 4 weeks postoperatively, which can be achieved with enoxaparin or warfarin for this patient.

Table 3  
Recommended VTE prophylaxis strategies for the surgical patient

Type of surgery	VTE prophylaxis options
Minor general, gynecologic, urologic, vascular, and arthroscopic surgical procedures without additional VTE risk factors <sup>a</sup>	<ul style="list-style-type: none"> <li>• No routine pharmacologic prophylaxis recommended</li> <li>• Early mobilization</li> </ul>
Minor general surgery with additional risk factors <sup>a</sup>	<ul style="list-style-type: none"> <li>• LDUH 5000 U SC bid</li> </ul>
Major general and gynecologic surgical procedures without additional risk factors <sup>a</sup>	<ul style="list-style-type: none"> <li>• LMWH:               <ul style="list-style-type: none"> <li>• enoxaparin 40 mg SC daily</li> <li>• dalteparin 2500 U SC daily</li> </ul> </li> </ul>
Major gynecologic, vascular, urologic, and general surgical procedures with additional risk factors <sup>a</sup>	<ul style="list-style-type: none"> <li>• LDUH 5000 U SC tid</li> <li>• LMWH:               <ul style="list-style-type: none"> <li>• enoxaparin 40 mg SC daily</li> <li>• dalteparin 5000 U SC daily</li> </ul> </li> </ul>
Lower extremity orthopedic surgery: <ul style="list-style-type: none"> <li>• total hip arthroplasty</li> <li>• total knee arthroplasty</li> <li>• hip fracture surgery</li> </ul>	<ul style="list-style-type: none"> <li>• LMWH:               <ul style="list-style-type: none"> <li>• enoxaparin 40 mg SC daily or 30 mg SC bid starting 12–24 h postoperatively</li> <li>• dalteparin 5000 U SC daily starting 12 h before surgery, or</li> <li>• 2500 U SC starting 4–6 h postoperatively, then 5000 U SC daily</li> <li>• fondaparinux 2.5 mg SC daily starting 6–8 h postoperatively</li> <li>• warfarin starting the night before surgery or the evening after surgery adjusting to an INR goal of 2–3</li> </ul> </li> </ul>

*Abbreviations:* INR, international normalized ratio; LDUH, low dose unfractionated heparin; LMWH, low molecular weight heparin; SC, subcutaneous; VTE, venous thromboembolism.

<sup>a</sup> VTE risk factors include prior VTE, advancing age, malignancy, trauma, immobility, inherited or acquired thrombophilia, pregnancy, estrogen therapy, obesity, smoking, and varicose veins.

*Data from* Geerts WH, Pineo GF, Heit JA, et al. Prevention of venous thromboembolism: the seventh ACCP conference on antithrombotic and thrombolytic therapy. *Chest* 2004;126(suppl 3):338S–400S.

## Glycemic management

Optimal glycemic control in the perioperative period can be challenging for many reasons. Hyperglycemia often results from physiologic stress, infection, reduced activity, total parenteral nutrition, and the modification of the patient's usual diabetes medications. Hypoglycemia is also common, largely due to patient anorexia or fasting (NPO) status.

Achievement of euglycemia in the postoperative setting appears to be beneficial. Basic science research has shown that hyperglycemia is associated with an increased risk of thrombosis, reversible immune dysfunction, inflammatory marker elevation, and dysfunction of vascular endothelium

Table 4  
VTE prophylaxis management for patients receiving neuraxial anesthesia/analgesia

	Before neuraxial technique	Before catheter removal	After catheter removal
LDUH	No contraindication	No contraindication	No contraindication
LMWH			
• single daily dosing	Wait 10–12 hours after last dose	Wait 10–12 hours after last dose	Wait 2 hours before resuming
• twice daily dosing	Wait 10–12 hours after last dose	Not recommended for use while catheter in place	Wait 2 hours before resuming
Warfarin	INR < 1.5	INR ≤ 1.5	Resume therapy to INR goal
Fondaparinux	Currently not recommended in conjunction with neuraxial anesthesia/analgesia		

*Abbreviations:* INR, international normalized ratio; LDUH, low-dose unfractionated heparin; LMWH, low molecular-weight heparin; VTE, venous thromboembolism.

*Data from* Horlocker TT, Wedel DJ, Benzon H, et al. Regional anesthesia in the anticoagulated patient: defining the risks (the second ASRA consensus conference on neuraxial anesthesia and anticoagulation). *Reg Anesth Pain Med* 2003;28:172–97.

[73]. Moreover, the benefits of euglycemia in surgical patients have been recently demonstrated in clinical trials. The strongest evidence comes from a prospective trial involving 1548 patients admitted to a surgical intensive care unit who were randomized to intensive (intravenous) insulin therapy versus conventional treatment [74]. Intensive care unit mortality was reduced by 42% and overall in-hospital mortality was reduced by 34% in the group receiving intensive insulin treatment. In addition, postoperative hyperglycemia is associated with increased infection rates [75] and studies have shown that aggressive blood sugar control decreases the risk of deep sternal wound infections [76] and mortality [77] in diabetic patients undergoing cardiac surgical procedures.

Guidelines set forth by the American Diabetes Association [78] recommend a glycemic target for hospitalized patients in the intensive care unit between 80 and 110 mg/dL. For non-critical care patients, the preprandial goal is 90 to 130 mg/dL and the postprandial or random blood glucose target is less than 180 mg/dL.

Scientific evidence supports using intravenous insulin to control hyperglycemia in critically ill postoperative patients. However, the current best practice for insulin in the non-critically ill postoperative patient is based primarily on expert opinion. Oral antidiabetic agents are sometimes contraindicated in the perioperative patient, and these agents are difficult to rapidly titrate to effect. In addition, using “sliding-scale insulin” as the sole means of glycemic control is ineffective for most patients, and potentially harmful [79,80]. Therefore, to achieve optimal glycemic targets, hospitalists must become comfortable using subcutaneous insulin in an anticipatory and physiologic manner [73].

The best practice for glycemic control in non-critically ill hospitalized patients is sometimes referred to as “basal-bolus” subcutaneous insulin delivery [73,81], with insulin divided into its physiologic components: basal insulin (longer-acting, nonpeaking insulin), nutritional insulin (short- or rapid-acting insulin provided as boluses with meals), and correctional insulin (additional boluses of short- or rapid-acting insulin given to correct hyperglycemia). This approach allows clinicians to provide basal insulin to patients continuously, and to provide nutritional insulin that best matches the patient’s actual nutritional intake.

To effectively use insulin regimens in perioperative patients, hospitalists must be able to estimate a patient’s total daily dose of insulin (TDD), and understand how that dose should be divided into the physiologic components. There are several ways to estimate the TDD. For patients on insulin, the easiest way is to simply add up how much insulin the patient takes at home. However, for patients who are not on full insulin regimens at home, the TDD can be estimated based on the patient’s weight. A total daily dose of 0.4 units/kg is a reasonable starting place for most patients. One half of this dose can be provided to cover basal insulin needs, and continued even when the patient is fasting perioperatively. Basal insulin is best supplied as a low- or nonpeaking insulin, such as glargine or detemir. The other half of the TDD can be given as divided doses to cover the patient’s nutritional needs, once nutrition is resumed. Nutritional insulin is usually provided as rapid-acting or regular insulin, and must be matched, in real time, to the patient’s nutritional intake. When the patient is fasting perioperatively, the nutritional insulin is held. A small amount of correctional insulin should be given in addition to the basal and nutritional insulin, if hyperglycemia occurs. Many institutions are now using standardized subcutaneous insulin order sets to promote this physiologic use of insulin. Although a complete discussion of insulin management in the hospital is outside the scope of this article, there are several resources available to help clinicians learn and employ these principles [82].

### **Clinical vignette continued**

This patient has type 2 diabetes mellitus and uses 60 units/day of mixed insulin at home. To facilitate perioperative management, we would recommend changing to an insulin regimen that provides separate basal and nutritional insulin for this patient. For basal insulin coverage, we would initiate glargine insulin 30 units subcutaneously daily, which can be given even if the patient is NPO (nothing by mouth) for surgery. We would recommend 10 units of rapid-acting insulin to be given with each of her three daily meals, and held when the patient is fasting. A small amount of correctional insulin can be given in addition to the basal and nutritional components if the patient experiences hyperglycemia.

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