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Each year, more than 36 million surgical procedures are performed in the United States.¹ Approximately one-third are performed in patients older than 65 years.¹ This subset of the population also is the fastest growing, with estimates that by 2030 this population will double from 35 million to 70 million people and will account for 20% of the American population.² A recent prospective cohort study done at a major academic center showed that elderly patients have a higher rate of major perioperative complications and mortality after noncardiac surgery compared to their younger counterparts.³ Complications occur frequently, and cardiovascular events are the leading cause of perioperative death.⁴ The cost of perioperative cardiovascular morbidity alone is approximately \$20 billion in the United States.⁵ Therefore, a preoperative evaluation, especially in the elderly and the young with medical problems, is needed. This evaluation should be geared toward risk assessment and implementation of risk reduction therapies that help decrease perioperative morbidity and mortality, thereby decreasing associated cost. In addition, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) requires all surgical patients to have a history and

physical exam documented in the medical record in the 30 days prior to their surgery.

—The Editor

An Evidence-Based Approach to the Preoperative Evaluation

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Introduction

More and more surgeries are being performed in which patients are admitted and discharged the same day the procedure is completed. For most major elective surgeries, the patient is admitted on the morning of the procedure, allowing minimal time for the anesthesiologists to perform any type of risk assessment. At that point, it may be too late to implement many risk reduction strategies, so they must rely on one of the following models or providers

to perform the preoperative evaluation:

1. Traditional Preoperative Assessment Model. The surgeon, the resident, nurse practitioner (NP), or physician assistant (PA) working on the surgical team performs this assessment. This approach often may rely on multiple consultants, a “shotgun approach to testing,” and sometimes patients may be admitted to the hospital one or more days prior to surgery. In the era of managed care and cost containment, admission to the hospital to conduct preoperative testing has become obsolete.⁶

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2. Preanesthesia Testing (PAT) Clinic Model. Based at the hospital, an NP, PA, or nurse anesthetist sees patients under the supervision of an anesthesia staff. This service is provided at no additional cost to the patient as the preoperative anesthesiology fee is bundled into the diagnosis related group (DRG). These clinics have been shown to decrease costs related to effective use of testing and a decreased cancellation rate but are associated with an initial start-up cost and an annual cost to run.⁶⁻⁸ In addition, these clinics may not be able to handle complex medical and elderly patients.

3. Preoperative Clinic Staffed by Internists. A few institutions across the country have such a model, which is based at the hospital. One such clinic, the Internal Medicine Preoperative Assessment Consultation and Treatment (IMPACT) Center, has been in place since 1997 at the Cleveland Clinic. The IMPACT Center, as part of a unique preoperative evaluation model, has decreased surgical delay rate by 49%, and has decreased significantly the cost of evaluation by the anesthesiologists in their clinic, allowing them to concentrate on anesthesia-related issues such as the choice of anesthetic, airway assessment, prior anesthetic events, patient directives, and postoperative pain control.⁹ During the preoperative evaluation conducted by the internist, the goal is not to clear patients for surgery, but more importantly, to prepare them for surgery. Each patient undergoes a thorough but focused history and physical exam aimed at medical risk assessment, perioperative medication management, implementation of prophylactic therapies such as beta-blockers, optimization of

existing chronic medical conditions, and further testing if necessary. The consultation ends with a typewritten electronic communication that is available to all practitioners involved in the patient's care. Finally, all recommendations are discussed in person with the patient.

4. Primary Care Physician (PCP) Model. This is probably the most commonly used model in which the patient's family physician, internist, or cardiologist performs the preoperative evaluation at the request of the patient's surgeon as a medical consultation. It is, therefore, important for these physicians to be well versed in the nuances in perioperative medicine as well as to understand the issues faced by anesthesiologists and surgeons in planning and performing a surgical procedure. It is key that the evaluating physician communicate with the surgical team and implement clear strategies to maximize the patient's medical status.

The goals of this article are to provide internists and family physicians with a detailed, up-to-date review of this topic with a special emphasis on the various components of a preoperative evaluation.

Goals of the Preoperative Evaluation

The preoperative evaluation serves not to clear patients for surgery but rather to perform a comprehensive evaluation during which the consultant should outline the pertinent risks, medical conditions, and a plan to optimize medical care. The following step-wise approach is recommended for a preoperative evaluation:

1. Conduct a detailed history with a review of systems focused to documenting established disease and uncovering new disease or risk factors that will impact the perioperative complication rate. By incorporating validated risk assessment tools in the evaluation, overall risks for certain complications can be determined. For example, cardiac risk assessment tools, such as the Lee Cardiac Risk Index (see Table 1), may help to assess the overall risk of a cardiac event. Pulmonary risk assessment tools (see Table 2) may help to determine the overall risk of postoperative respiratory failure or pneumonia. The delirium prediction rule (see Table 3) can help to predict the risk of postoperative delirium, and a venous thromboembolism (VTE) risk assessment tool (see Table 4) can help to predict the risk of post-operative VTE with suggested prevention strategies.

2. Assess the patient for signs and symptoms of occult cardiac or pulmonary disease that may impact surgery (e.g., aortic stenosis or asthma).

3. Estimate the patient's functional status using the Duke Activity Status Index. (See Table 5.)

4. Evaluate the surgery-specific risk that is directly related to the type of the procedure. For example, the surgery related risk from the repair of an abdominal aortic aneurysm is high, and the risk related to cataract surgery is minimal. (See Table 6.)

5. Determine if preoperative laboratory or diagnostic tests are needed.

6. Review the patient's medications, including prescribed, over-the-counter, and herbal, and determine their necessity perioperatively.

7. Implement risk reduction therapies or recommendations for

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Table 1. Lee Cardiac Risk Index*

RISK CATEGORY	CARDIAC EVENT RATE (95% CI)
Class I (0 pts)	0.5 (0.2 - 1.1)
Class II (1 pt)	1.3 (0.7 - 2.1)
Class III (2 pts)	3.6 (2.1 - 5.6)
Class IV (> 2 pts)	9.1 (5.5 - 13.8)

* Comprised of 6 factors: High-risk type surgery, ischemic heart disease, h/o CHF, h/o stroke, diabetes on insulin, Cr > 2.0 mg/dl

Adapted with permission from: Lee et al. *Circulation* 1999;100:1043

post-operative use (e.g., beta-blocker therapy, treatment of active bronchitis, VTE prevention strategies, etc.). (See Tables 4 and 7.)

8. Assess if the patient has any special perioperative needs, such as the need for subacute bacterial endocarditis (SBE) prophylaxis (see Table 8) or stress dose steroids. (See Table 9.)

9. Optimize all medical conditions preoperatively.

10. Provide appropriate postoperative medical follow-up.

At the conclusion of this evaluation, it is important for the clinician to communicate his or her recommendations to the patient, surgeon, and anesthesiologist, especially with regard to medication adjustments in preparation for surgery, the perioperative risk, and strategies for risk reduction. Factors that influence or improve compliance with consultant recommendations include: being prompt, limiting the recommendations to fewer than five, identifying crucial and critical recommendations, being specific, providing direct verbal contact, and following up on the patient post-operatively.

Preoperative Laboratory Testing

The goals of preoperative testing are to identify and minimize the risk factors for surgery. Potential reasons for ordering preoperative laboratory tests are:

1. To detect unsuspected abnormalities that might influence the risk of perioperative morbidity or mortality; and

2. To establish a baseline value for a test that will be monitored or altered after the surgery is complete.

Existing literature suggests that 30-60% of abnormalities discovered on routine preoperative tests are ignored.¹¹ Given this fact, routine preoperative testing without documentation of abnormalities actually may lead to more medico-legal risk. In general, it is safe to use test results that were performed and were normal within the previous four months, given that no change has occurred in the patient's clinical status. One study reported that only 0.4% of such tests repeated at the time of surgery were abnormal and could have been predicted by the patient's history.¹²

Complete Blood Count (CBC). Anemia occurs commonly in the postoperative setting, and a measurement of hemoglobin preoperatively in patients undergoing procedures where significant blood loss is expected can be useful. Additionally, in any patient with signs of anemia on physical examination or concerns for

Table 2. Postoperative Pneumonia Risk Index

PREOPERATIVE RISK FACTOR	POINT VALUE
Type of surgery	
Abdominal aortic aneurysm repair	15
Thoracic	14
Upper abdominal	10
Neck	8
Neurosurgery	8
Vascular	3
Age	
> 80 y	17
70-79 y	13
60-69 y	9
50-59y	4
Functional status	
Totally dependent	10
Partially dependent	6
Weight loss > 10% in past 6 months	7
History of chronic obstructive pulmonary disease	5
General anesthesia	4
Impaired sensorium	4
History of cerebrovascular accident	4
Blood urea nitrogen level	
< 2.86 mmol/L (< 8 mg/dL)	4
7.85-10.7 mmol/L (22-30 mg/dL)	2
≥ 10.7 mmol/L (≥ 30 mg/dL)	3
Transfusion > 4 units	3
Emergency surgery	3
Steroid use for chronic condition	3
Current smoker within 1 year	3
Alcohol intake > 2 drinks/day in past 2 weeks	2

PREDICTION OF POSTOPERATIVE PNEUMONIA 30 DAYS AFTER MAJOR NON-CARDIAC SURGERY

Risk class (point range)	Rate of postoperative pneumonia in derivation cohort (95% CI)
1 (0 to 15)	0.24% (0.24 to 0.25)
2 (16 to 25)	1.20% (1.19 to 1.20)
3 (26 to 40)	4.0% (3.98 to 4.01)
4 (41 to 55)	9.4% (9.34 to 9.42)
5 (>55)	15.3% (15.1 to 15.5)

Adapted from: Arozullah, et al. *Ann Intern Med* 2001;135:847-857.

anemia based on historical information, a hemoglobin test is warranted. There are no data to support the use of a screening CBC in healthy patients undergoing surgery where major blood loss is not anticipated unless dictated by history or physical examination.¹²

Abnormalities in white blood count are rare in healthy patients and do not need to be checked routinely unless the patient's history dictates that there may be an abnormality, such as in individuals with symptoms of infection, patients who have myeloproliferative disorders, or patients who may be on medications causing leukopenia.¹² Management changes on the basis of

Table 3. Risk Factors for the Development of Postoperative Delirium

PREOPERATIVE FACTORS

- Age > 70 y
- Alcohol abuse
- Poor cognitive status
- Markedly abnormal serum sodium, potassium, or glucose level*
- Aortic aneurysm surgery
- Non-cardiac thoracic surgery

POSTOPERATIVE FACTORS

- Use of meperidine or benzodiazepines

*Defined as follows: sodium < 130 or > 150 mEq/L, potassium < 3.0 or > 6.0 mEq/L, glucose < 60 or > 300 mg/dL.

If 3 or more risk factors present, then risk of delirium is ~ 50%.

Adapted with permission from Marcantonio ER, et al. *JAMA* 1994;271:134; and Marcantonio ER, et al. *JAMA* 1994;272:1518.

abnormal platelet counts are rare. Routine platelet counts are not indicated unless directed by history or physical exam findings. In most institutions, however, a CBC commonly is ordered rather than the individual components. If the CBC reveals minor abnormalities in white cell count or platelet count, the test should be repeated. If the abnormalities persist, then a focused search for the abnormality should be initiated.

Coagulation Tests. The partial thromboplastin time (PTT) and prothrombin time (PT) are useful tests for patients on anticoagulants, patients with a history of bleeding, or patients with chronic liver disease or malnutrition, but there are no data to support their use as a screening tool for risk of bleeding in asymptomatic patients. Likewise, the bleeding time is a poor predictor of perioperative bleeding.¹²

Metabolic Panels and Urinalysis

Electrolytes. There is no clear relationship between electrolyte abnormalities and operative morbidity and mortality. The incidence of unexpected electrolyte abnormalities was only 0.6% in one report.¹³ Any historical factors that increase the chance of electrolyte abnormalities, such as medication use, chronic renal insufficiency, congestive heart failure, or diabetes mellitus, may warrant ordering a metabolic profile preoperatively.

Creatinine. Patients with existing renal insufficiency require a recent measurement of serum creatinine, as medication doses may need to be adjusted accordingly. A growing body of literature suggests renal insufficiency to be an important risk factor for postoperative complications. The Lee revised cardiac risk index¹⁴ (see Table 1) and the recently revised American College of Cardiology/American Heart Association (ACC/AHA) guidelines¹⁵ (see Figure 1) have included renal insufficiency (with a Cr > 2.0 mg/dl) as a clinical risk predictor of postoperative cardiac complications. Serum creatinine should be obtained in all individuals

with a likelihood of renal insufficiency and those undergoing major surgery.

Glucose. Established diabetes requiring treatment is a risk factor for postoperative cardiac complications and wound infections. It has been shown that glucose levels above 200 mg/dL result in decreased WBC chemotaxis and phagocytosis, thus increasing the risk of wound infection. In addition, glucose above 250-300 mg/dL is associated with osmotic diuresis and increased vascular instability. However, there are no studies that have identified asymptomatic hyperglycemia as a risk factor for postoperative complications; therefore, routine testing of serum glucose preoperatively is not necessary in healthy patients, but may be necessary in the obese or those with known diabetes.^{12,16}

Liver Function Tests. In the absence of clinically evident liver disease, routine liver function testing is not necessary; however, serum albumin does predict postoperative morbidity. One study prospectively looked at 54,215 veterans undergoing non-cardiac surgery.¹⁷ Mortality was less than 1% for albumin of 4.6 g/dL and 28% for albumin of less than 2.1 g/dL. It is unclear if correcting a low serum albumin improved surgical outcomes. Given this, a recent measurement of serum albumin should be performed preoperatively in patients with known liver disease, patients with multiple chronic illnesses, recent major illnesses, or in patients in whom malnutrition may be an issue. An albumin less than 2.1 g/dL, therefore, may cause the clinician to reconsider the need for surgery in a patient whose post-operative morbidity and mortality may be very high.¹²

Urinalysis. Routine urinalysis has not been shown to be cost-effective, and there is no clear relationship between asymptomatic urinary tract infection and surgical infection. In 1989, one study performed a cost-effectiveness analysis of routine preoperative urinalysis in patients undergoing non-prosthetic knee procedures.¹⁸ Given that the baseline incidence of wound infections is 1% and assuming that 10% of urinalyses would show infection, and that a urinary tract infection would increase risk of wound infection by 1%, doing routine urinalysis potentially could prevent wound infections in 0.001% of the screened patients. The cost per wound infection prevented would be \$1.5 million. Given the high cost and low predictive value of this test, routine preoperative urine analysis is not recommended.¹²

Electrocardiogram

Preoperative electrocardiogram (ECG) may detect abnormalities that would increase the risk of postoperative cardiac complications or serve as a baseline for postoperative ECGs. In the absence of known cardiac disease, routine ECG will have very little impact on the perioperative management of a patient. However, abnormalities on ECG are common and increase with age. In a review of the literature, almost 20% of patients younger than 50 years had abnormalities on ECG but these were of uncertain clinical significance.¹² Although there is no definitive evidence that preoperative ECGs reduce adverse postoperative outcomes, ECGs should be performed in men older than 40 years, women older than 50 years, or in patients with known coronary artery disease, diabetes, or hypertension.¹²

Table 4. Levels of Venous Thromboembolism Risk and Recommendations for Prophylaxis

LEVEL OF RISK	CALF DVT %	PROXIMAL DVT %	CLINICAL PE %	FATAL PE %	PREVENTION STRATEGIES
Low risk	2	0.4	0.2	0.002	No specific measures Aggressive mobilization
Moderate risk	10-20	2-4	1-2	0.1-0.4	LDUH q12h or LMWH, or ES or IPC
High risk	20-40	4-8	2-4	0.4-1.0	LDUH q8h or LMWH or IPC
Highest risk	40-80	10-20	4-10	0.2-5	LMWH or OA or fondaparinux, IPC/ES + LDUH/LMWH, or ADH. Consider pharmacologic prophylaxis for extended duration (i.e., up to 30 days)

Risk Definitions:

Low risk: Minor surgery in patients < 40 years of age with no additional risk factors present*

Moderate risk: Minor surgery in patients with additional risk factor present,* or non-major surgery in patients aged 40-60 with no additional risk factor, or major surgery in patients < 40 with no additional risk factors

High Risk: Non-major surgery in patients > 60 or with additional risk factor present* or major surgery in patients > 40 or with additional risk factor

Highest risk: Major surgery in patients > 40 with additional risk factor present,* or hip or knee arthroplasty, hip fracture surgery, or major trauma, spinal cord injury

*Additional risk factors include one or more of the following: advanced age, prior venous thromboembolism, obesity, heart failure, paralysis, or presence of a molecular hypercoagulable state (e.g., protein C deficiency, factor V Leiden).

Key:

LDUH = low dose unfractionated heparin (e.g., LDUH 5,000 U SQ q12); LMWH = low molecular weight heparin (e.g., enoxaparin 40 mg SQ qd, dalteparin 5000 IU SQ/d); ES = Elastic stocking; IPC = Intermittent pneumatic compression level; OA = Oral anticoagulant (e.g., Warfarin with target INR=2-3); ADH = Adjusted dose heparin.

Adapted from: Geerts, WH, et al. *Chest* 2001;119:132S.

Chest Radiographs

Of all preoperative tests, routine chest radiographs are the most likely to be abnormal, but a normal chest radiograph does not make postoperative pulmonary complications less likely (*see the section under Preoperative Pulmonary evaluation for a discussion of risk factors increasing pulmonary complications postoperatively*). Most abnormal films could have been predicted based on clinical risk factors. A protocol for ordering preoperative chest radiographs was developed by Charpak, et al.¹⁹ They recommended preoperative chest radiographs for patients with existing lung disease, cardiovascular disease, cancer, emergent surgery, current smoking history in patients older than 50 years of age, immune suppression, or immigrants with no prior chest radiograph. They found 52% of all radiographs to be abnormal, but only 1.5% of screening radiographs impacted on patient management. A comprehensive review found only 3% of preoperative chest radiographs, among more than 20,000 patients, impacted management of the patient.¹² Based on this data, it is best to perform preoperative chest radiographs in patients with known cardiopulmonary disease or in whom physical exam findings suggest a likelihood of finding disease that will impact perioperative morbidity and mortality.

Evaluation of Coronary Artery Disease

Overall risk of postoperative cardiac death or major cardiac complications is less than 6% in patients older than 40 years

undergoing major noncardiac surgeries.²⁰ However, approximately 8 million individuals undergoing surgical procedures each year have known coronary artery disease or coronary risk factors,²¹ and approximately 1 million individuals will have some perioperative cardiac complication.

The critical **first step** in the cardiac evaluation of the patient undergoing non-cardiac surgery is identifying the patient's clinical features, including the presence of unstable symptoms. There is evidence that decompensated congestive heart failure (CHF), significant arrhythmia, severe valvular disease, or unstable angina (USA) are associated with increased perioperative cardiac morbidity. A high index of suspicion also may identify individuals with occult symptoms. For example, dyspnea may be the only manifestation of underlying coronary artery disease (CAD). Identification and management of uncontrolled symptoms greatly will reduce postoperative cardiac morbidity.

In an attempt to quantify the preoperative risk in patients with known or suspected cardiac disease, several multivariate indices of risk have been developed. Some of the more well-known and studied indices include Goldman cardiac risk index (*see Table 10*), the revised Goldman cardiac risk index called the Lee Risk Index (*see Table 1*), and the Detsky modified risk index.²² The role of the risk indices is to assist physicians in identifying low, intermediate, and high-risk patients for post-operative cardiac complications. Indices developed by Eagle²³ (*see Table 7*) and

Table 5. Evaluation of Functional Status Using Specific Activities: The Duke Activity Status Index

ACTIVITY	ESTIMATED METABOLIC COST OF EACH ACTIVITY (MET UNITS)
Can you	
• Walk indoors, such as around your house?	1.75
• Do light work around the house, such as dusting or washing dishes?	2.70
• Take care of yourself, that is, eating, dressing, bathing, using the toilet?	2.75
• Walk a block or 2 on level ground?	2.75
• Do moderate work around the house such as vacuuming, sweeping floors, or carrying in groceries?	3.50
• Do yard work such as raking leaves, weeding, or pushing a power mower?	4.50
• Have sexual relations?	5.25
• Climb a flight of stairs or walk up a hill?	5.50
• Participate in moderate recreational activities, such as golf, bowling, dancing, doubles tennis, or throwing a baseball or football?	6.00
• Participate in strenuous sports, such as swimming, singles tennis, football, basketball, or skiing?	7.50
• Do heavy work around the house, such as scrubbing floors or lifting or moving heavy furniture?	8.00
• Run a short distance?	8.00

Reprinted with permission from: Hlatky MA, et al. *Am J Cardiol* 1989;64:651-654.

Vanzetto²⁴ each determined the usefulness of doing dipyridamole-thallium imaging in addition to using clinical variables in predicting ischemic events after vascular surgery.

The Goldman Cardiac Risk Index (CRI). In 1977, Goldman and his colleagues published a landmark article evaluating 1,001 patients undergoing noncardiac surgery.²⁰ Nine independent correlates of perioperative fatal or major nonfatal cardiac events were identified and were assigned a certain number of points. Patients then were placed in four classes depending on the total number of points. In Class 4 (highest risk category), 78% of patients had a major cardiac event, compared to fewer than 1% of patient in Class 1 (lowest risk category) group. The Goldman index (see Table 10) divides patients into high- and low-risk categories, but a large group of patients are in the intermediate risk category where there still is a 9% chance of a major cardiac event. Other limitations of this index include the fact that relatively few vascular surgery patients were included in the

Table 6. Cardiac Risk (Nonfatal Myocardial Infarction or Death) Stratification for Noncardiac Surgical Procedures

HIGH (REPORTED CARDIAC RISK OFTEN > 5%)
<ul style="list-style-type: none"> • Emergent major operations, particularly in the elderly • Aortic and other major vascular surgery • Peripheral vascular surgery • Anticipated prolonged surgical procedures with associated with large fluid shifts or blood loss
INTERMEDIATE (REPORTED CARDIAC RISK GENERALLY 1-5%)
<ul style="list-style-type: none"> • Carotid endarterectomy • Head and neck surgery • Intraperitoneal and intrathoracic surgery • Orthopedic surgery • Prostate surgery
LOW (REPORTED CARDIAC RISK GENERALLY < 1%)
<ul style="list-style-type: none"> • Endoscopic procedures • Superficial procedure • Cataract surgery • Breast surgery

Reprinted with permission from: Eagle, et al. *Circulation* 2002; 105:1257-1267.

study; it was developed in the mid-1970s and does not take into account advances in medical, anesthetic, or surgical care; and the data were collected only at one institution.

The Modified Multifactorial Index by Detsky and coworkers²² modified the CRI by assigning a higher score to emergency surgery, and recent MI (fewer than 6 months) and included angina and pulmonary edema in the index. However, like the Goldman index, Detsky also may underestimate the cardiac risk in vascular patients. The Detsky modification of the Goldman index is the starting point of the American College of Physicians (ACP) guidelines for preoperative testing for coronary artery disease.²⁵

The Lee Revised Cardiac Risk Index. The revised Goldman cardiac risk index¹⁴ (see Table 1) seeks to simplify the original criteria. In a prospective study of 4315 patients 50 years and older undergoing elective major noncardiac surgeries, Lee et al¹⁴ identified six independent predictors of perioperative complications, namely high-risk type of surgery, history of ischemic heart disease, history of congestive heart failure (CHF), history of stroke or transient ischemic attack (TIA), diabetes requiring insulin therapy, and a preoperative serum creatinine of more than 2 mg/dl and assigned them one point each. Table 1 shows the rate of complication in each risk category during this study. This index appears to be more accurate than older indices in predicting major postoperative cardiac complications.²⁶

The **second step** is to determine the patient's functional class during the interview. Self-reported exercise tolerance is the key for cardiovascular risk stratification and is an independent predictor for postoperative cardiovascular complications.²⁷ The Duke activity status index²⁸ (see Table 5) is one way of dividing

Table 7. Eligibility Criteria for Use of Perioperative Beta-Blockers

MINOR CLINICAL CRITERIA (ADAPTED FROM MANGANO ET AL.⁶²)

Use beta-blockers in patients meeting any 2 of the following criteria:

- Aged 65 years or older
- Hypertension
- Current smoker
- Serum cholesterol concentration at least 240 mg/dL
- Diabetes mellitus not requiring insulin therapy

OR

MAJOR CLINICAL CRITERIA (ADAPTED FROM LEE ET AL.¹⁹)

Use beta-blockers in patients meeting any 1 of the following criteria:

- High-risk surgery
- Ischemic heart disease
- Cerebrovascular disease
- Diabetes mellitus on insulin therapy
- Chronic renal insufficiency with Cr > 2.0 mg/dL

Adapted from: Auerbach, et al., *JAMA*. 2002 Mar 20;287:1435-1444.

patients into four functional classes (I-IV) based on their activity level that can help generate an estimate of their metabolic equivalents (METs). The ability to perform more than 4 METs has been associated with a lower cardiovascular risk.²⁷

The **third step** is to determine the patient's surgery-specific risk, and Table 6 categorizes different surgical procedures into three categories labeled as high (reported cardiac risk greater than 5%), intermediate (reported cardiac risk 1-5%) and low (cardiac risk less than 1%).

The assessment of the first three steps is essential to determine the **fourth step**, which is to determine the need for noninvasive testing. Patients who are at low risk based on clinical features, functional status, and proposed low-risk surgery generally do not require any further evaluation. On the other hand, patients who are deemed high risk using clinical features developed by Lee¹⁴ (see Table 1) and often termed as the "intermediate clinical predictors" per the ACC/AHA guidelines (see Figure 1) may benefit from further non-invasive evaluation if they have either a poor functional class or are undergoing a high risk procedure. In addition, patients with unreliable histories and poor functional status from vascular or orthopedic disease may make the assessment of angina difficult. In such patients, noninvasive cardiac testing also may be useful. In patients who can exercise, exercise stress testing accurately can stratify risk inpatients undergoing vascular or general surgery. Patients who achieve 75% of maximally predicted heart rate (HR) without ECG changes are low risk for cardiac complications.²¹ Dipyridamole-thallium imaging (DTI) accurately can predict cardiac complications in selected patients undergoing vascular surgery. In patients with one or two risk factors (intermediate risk), a positive test is associated with a high cardiac complication rate, and a negative test is associated

with a substantially lower rate (see Table 11).²³ Data are limited in nonvascular surgery patients, but it is likely that DTI may be useful in the intermediate risk patients as defined by the AHA/ACC guidelines.

Dobutamine stress echocardiography (DSE) may be useful in both intermediate and high-risk patients as defined by the AHA/ACC guidelines. In the largest study of preoperative DSE undergoing vascular surgery, a normal test was associated with a very low cardiac complication rate.²⁹ In a meta-analysis of six non-invasive tests, DSE showed a positive trend toward better diagnostic performance than the other tests, but this was only significant in the comparison with myocardial perfusion scinti-graph.³⁰ DSE should be avoided in patients with significant arrhythmias, very high or low blood pressure, and critical aortic stenosis.

The **fifth step** is to decide when to refer patients for coronary angiography preoperatively. In general, the indications are similar for to those for non-operative settings, i.e., those who are high risk based on findings from a non-invasive test, angina unresponsive to medical therapy, unstable angina, and those scheduled for intermediate or high risk surgery after an equivocal noninvasive study.³¹

The **sixth step** is to optimize medical therapy preoperatively, and this includes, but is not limited to, titrating medications to better control blood pressure and initiating beta-blocker therapy in those patients who would benefit from it. Details regarding beta-blocker therapy are discussed in the section on this topic.

The overall approach to assessing preoperative cardiac risk is best done by incorporating guidelines into one's own practice. There are two well-written and often cited guidelines, one developed by the ACC/AHA (see Figure 1) and the other by the American College of Physicians.^{15,32}

The ACC/AHA guidelines outlined in Figure 1 were first published in 1996 and updated in 2002.³³ This guideline integrates clinical risk factors, exercise capacity, and type of surgery into the preoperative decision process. The ACC/AHA guidelines are based on both evidence and expert opinion and suggest that first the urgency of the surgery be evaluated, then the physician should determine if the patient has had previous coronary revascularization or coronary evaluation. Next, any patient with unstable coronary syndromes should be stabilized prior to surgery, and the decision for further testing should be based on a combination of clinical risk factors, surgery-specific risk, and functional capacity. Patients with minor or no clinical predictors generally require no further testing unless they have poor functional capacity and are undergoing high-risk procedures. Importantly, no preoperative testing should be performed if the results will not change perioperative management.¹⁵

Beta-Blockers and Reduction of Cardiac Events

There is heterogeneity of trials looking at the use of beta-blockers to reduce perioperative cardiac morbidity and mortality. One study³⁴ reviewed six publications, including five randomized trials studying the effectiveness of beta-blockade in reducing perioperative myocardial ischemia, cardiac, or all-cause mortality. The studies used different agents and dosing schedules, but they all administered a beta-blocker before the induction of anesthesia and con-

Table 8. Recommended Prophylactic Antibiotic Regimens

PATIENT	REGIMEN
Standard	Amoxicillin 2.0 g orally 1 h before procedure <i>OR</i> Ampicillin 2.0 g IM or IV within 30 min of procedure
Patients allergic to penicillin	Clindamycin 600 mg orally 1 h before procedure <i>OR</i> Cephalexin or cefadroxil 2.0 g orally 1 h before procedure <i>OR</i> Azithromycin or clarithromycin 500 mg orally 1 h before procedure <i>OR</i> Clindamycin 600 mg IV within 30 min before procedure <i>OR</i> Cefazolin 1.0 g within 30 min of procedure
High-risk patients	Ampicillin 2.0 g IM or IV plus gentamicin 1.5 mg/kg IV or IM (not to exceed 120 mg) within 30 min of starting procedure <i>AND</i> Ampicillin 1.0 g IM or IV or amoxicillin 1 g orally 6 h later
High-risk patients allergic to penicillin	Vancomycin 1.0 g IV over 1-2 h plus gentamicin 1.5 mg/kg (not to exceed 120 mg) IV or IM; complete injection/infusion within 30 min of starting procedure
Moderate-risk patients	Amoxicillin 2.0 g orally 1 h before procedure <i>OR</i> Ampicillin 2.0 g IM or IV within 30 min of starting procedure
Moderate-risk patients allergic to penicillin	Vancomycin 1.0 g IV over 1-2 h; complete infusion within 30 min of starting procedure

CARDIAC CONDITIONS AND SURGICAL PROCEDURES IN WHICH ENDOCARDITIS PROPHYLAXIS IS RECOMMENDED

CARDIAC CONDITIONS	SURGICAL PROCEDURES
High risk	Respiratory tract
Prosthetic heart valves	Tonsillectomy or adenoidectomy
Previous bacterial endocarditis	Rigid bronchoscopy
Complex cyanotic congenital heart disease	Surgical operations involving the respiratory mucosa
Surgically constructed pulmonary shunts or conduits	Gastrointestinal tract
	Sclerotherapy
Moderate risk	Esophageal stricture dilation
Other congenital heart lesions	Endoscopic retrograde cholangiography with biliary obstruction
Acquired valvular dysfunction	Surgical operations involving the intestinal mucosa
Hypertrophic cardiomyopathy	Biliary-tract surgery
Mitral-valve prolapse with regurgitation or thickened leaflets	Genitourinary tract
	Prostate surgery
	Cystoscopy
	Urethral dilation

Adapted from: Dajani AS, et al. *JAMA* 1997;277:1797.

tinued beta-blockade throughout the operative and post-operative period. All studies except one titrated the dose to a target heart rate of less than 80. The number needed to treat to prevent cardiac death or nonfatal MI with beta-blocker therapy were very favorable, ranging from 2.5 to 8.3 patients for up to two years of follow-up.³⁴ Despite the evidence supporting the beneficial effects, some physicians are afraid of the side-effects of beta-blockers, and underuse these drugs in the perioperative setting.^{35,36} All the studies used beta-1 selective agents. There is no evidence that shows advantage of one selective agent over another, thereby suggesting

that the efficacy of beta-blockade is a class effect and not drug-dependent. Table 7 shows which patients are candidates for beta-blockade. All patients who fit these criteria should receive them perioperatively unless they have an absolute contraindication.

The approach to using beta-blockers perioperatively is as follows:

1. Identify patients who are candidates for beta-blocker therapy (*see Table 7*).
2. Start with metoprolol (Lopressor) 25 mg po bid or atenolol (Tenormin) 50 mg po qd or bisoprolol (Zebeta) 5 mg po qd. A

Table 9. Recommended Perioperative Hydrocortisone Dosage for Patients on Long-term Steroid Therapy

SURGERY TYPE	STRESS DOSE	DURATION*
Minor (e.g., inguinal herniorrhaphy)	25 mg/day	1 day
Moderate (e.g., total joint replacement)	50-75 mg/day	1-2 days
Major (e.g., cardiopulmonary bypass)	100-150 mg/day	2-3 days

*In the absence of complications.

Reprinted with permission from: Shaw M. *Cleve Clin J Med* 2002;69:9-11.

lower starting dose may be used if patient already has a heart rate less than 70 or BP is less than 120/70.

3. Start beta-blockers up to 30 days prior to surgery and titrate the dose to goal HR approximately 60 beats/min.

4. Patients receiving long-term beta-blockers should have their dose adjusted as needed.

5. Use intravenous beta-blockers (atenolol, metoprolol, or esmolol) intraoperatively to maintain a HR approximately 60 beats/min if BP allows.

6. Postoperatively, start intravenous beta-blockers as soon as possible if patient cannot take oral medication and titrate to a HR of approximately 60. Once oral intake is adequate, switch to an equivalent oral dose of beta-blocker.

7. Continue oral beta-blocker through the hospital stay and for one month postoperatively with gradual titration off the beta-blocker if there is no indication for long-term treatment.

8. Hold beta-blockers only in patients with absolute contraindications, i.e., patients with:

- major atrioventricular nodal conduction disease in the absence of a pacemaker; or
- severe asthma; or
- significant reactive airway disease; or
- history of presyncope or syncope of unknown cause.

Preoperative Evaluation of Non-Ischemic Cardiac Disease

Hypertension. Patients with hypertension have a higher incidence of silent CAD and previous MI than the general population. Traditionally, surgery was delayed for patients presenting with diastolic blood pressure (DBP) greater than 110 mmHg, but review of the literature shows that these patients may be at increased risk for hemodynamic lability but not necessarily for MI. Chronic anti-hypertensive medications can be continued in the perioperative period with some exceptions for the morning of surgery, which will be discussed in the section on medication management. Preoperatively, a systolic blood pressure (SBP) greater than 180 mmHg and DBP greater than 110 mmHg are definite indications for preoperative intervention.

Congestive Heart Failure. CHF patients with compensated congestive heart failure have a 5-7 % incidence of perioperative cardiac complications in comparison to 20-30% in patients with decompensated CHF.³³ In addition to stabilizing CHF prior to surgery and delaying surgery if necessary, the etiology of CHF needs to be determined, if not known, as perioperative monitoring will differ depending on the etiology. Optimizing medical management of patients with CHF is critical prior to elective surgeries and, if the surgery is emergent, invasive monitoring may be useful.

Cardiac Murmurs. When a murmur is detected on physical examination as part of the preoperative evaluation, one should try to ascertain the chronicity of the murmur and determine whether the murmur is functional or structural. If the murmur is felt to be functional, then a search for anemia, thyroid disorders, and other causes should be initiated. Evaluation by echocardiography is recommended for all diagnosed murmurs if none has been performed previously. Echocardiography can help determine the severity of the lesion and appropriate medical management as needed. Aortic stenosis increases the risk of perioperative mortality³⁷ and nonfatal myocardial infarction by five-fold regardless of the presence of the other revised cardiac risk index criteria. The need for bacterial endocarditis prophylaxis should be kept in mind for individuals undergoing most major procedures. Cardiac conditions and surgical procedures along with recommended prophylactic antibiotic regimens are outlined in Table 10.³⁸

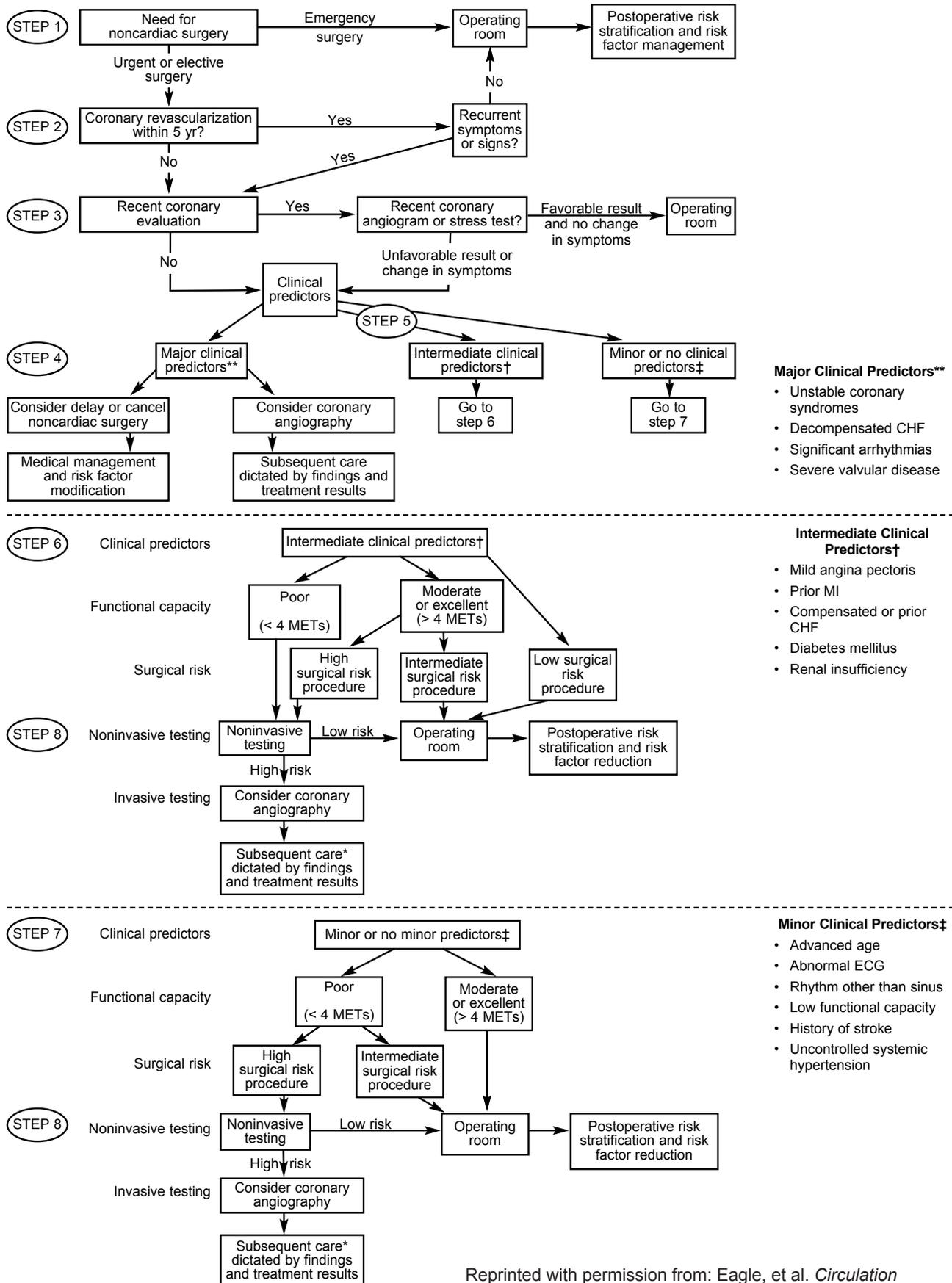
Preoperative Pulmonary Evaluation

Postoperative pulmonary complications (PPC) include atelectasis, infection (tracheobronchitis or pneumonia), acute respiratory failure requiring mechanical ventilation, acute exacerbation of underlying lung disease, and bronchospasm. The frequency of these complications is higher than cardiovascular complications.³⁹ Risk factors for PPC include smoking, poor exercise tolerance, chronic obstructive pulmonary disease (COPD), surgical site (the risk of PPC increases as the incision approaches the diaphragm), surgery duration more than three hours, general anesthesia, and intraoperative pancuronium use.⁴⁰ Most pulmonary complications are the result of alteration of normal pulmonary physiology. Postoperative pain may cause splinting, and the residual effects of anesthesia and narcotics may impair cough and mucociliary clearance of respiratory secretions. In addition, altered pulmonary mechanics and altered pattern of breathing postoperative may lead to a PPC.

Preoperative pulmonary risk-reduction strategies⁴⁰ include:

- Encouraging patients to stop smoking for at least eight weeks before surgery. Practically, this may never be possible because often the patients may not undergo a preoperative evaluation until a few weeks prior to surgery.
- Treating airflow obstruction with beta-agonists and steroids in patients with COPD or asthma.
- Using antibiotics and delaying surgery for about six weeks if upper respiratory or pulmonary infection is present.⁴⁰
- Educating patients preoperatively regarding lung-expansion exercises and the techniques and the use of incentive spirometry postoperatively.

Figure 1. Step-wise Approach to Preoperative Cardiac Assessment



Reprinted with permission from: Eagle, et al. *Circulation* 2002;105:1257-1267.

Table 10. Cardiac Risk Index

CARDIAC RISK INDEX	POINTS
Age > 70 years	5
MI < six months	10
S3 gallop or JVD	11
Important valvular aortic stenosis	3
Non-sinus rhythm, PACs or > 5 PVCs/min	7
PO ₂ < 60 or pCO ₂ > 50 mmHg	3
K < 3.0 or HCO ₃ < 20 mEq/L	3
BUN > 50 or Cr > 3.0 mg/dl	3
Chronic liver disease, or patients bedridden from non cardiac cause	3
Intraperitoneal, intrathoracic, or aortic operation	3
Emergency operation	4

RISK ASSESSMENT

CLASS	POINTS	RISK
I	0-5	0.7% Complication 0.2% Death
II	6-12	5.0% Complication 2.0% Death
III	13-25	11% Complication 2.0% Death
IV	26+	22% Complication 56% Death

Adapted from: Goldman, et al. *N Engl J Med* 1977; 297:845-850.

Preoperative Pulmonary Testing

In general, there is no single test or combination of tests that reliably will predict pulmonary complications. Preoperative history should focus on exercise tolerance, chronic cough, or unexplained dyspnea. All candidates having lung resection should undergo preoperative pulmonary function testing.

Preoperative pulmonary function tests (PFTs) are not useful for non-pulmonary surgery except in cases where there is a significant smoking history, unexplained dyspnea, or uncharacterized lung disease, in which case preoperative PFTs may help provide a diagnosis or evaluate the degree of impairment.

Arterial blood gases generally are not indicated preoperatively except perhaps in patients undergoing lung resection, in patients with underlying lung disease, or to quantify lung disease in patients who have dyspnea. Small case series have asserted that a partial pressure of carbon dioxide (PaCO₂) greater than 45 mmHg suggests limited pulmonary reserve and increased risk for postoperative pulmonary complications. However, clinicians generally should not use arterial blood gas analyses to delay surgery unless the patient's lung disease is not fully optimized preoperatively.⁴⁰

Pulmonary Risk Indices. The cardiopulmonary risk index (CPRI) was established in a group of patients undergoing pulmonary resection and has not been validated in individuals undergoing abdominal surgery.⁴¹ This index uses some of the Goldman criteria and adds pulmonary risk factors. Studies to validate this index have yielded mixed results, and the CPRI

Table 11. Dipyridamole-Thallium Imaging to Predict Postoperative Cardiac Ischemia

CLINICAL GROUP*	POSTOPERATIVE EVENT**
0 Factors	2 / 64 (3%)
1-2 factors and - thallium	2 / 62 (3%)
1-2 factors and + thallium	16/ 54 (30%)
3+ factors	10/ 24 (50%)

*Factors including: age > 70, history of angina, history of ventricular ectopic activity (VEA) requiring treatment, DM on therapy, Q-wave on ECG

**Cardiac death, MI, ischemic pulmonary edema, unstable angina

Adapted from: Eagle, et al. *Ann Intern Med* 1989;110:859.

requires that all patients undergo PFTs and arterial blood gases. The Lawrence risk index and the Brooks-Brunn risk index are other indices that have been validated.

Perhaps the most comprehensive risk index is the one developed by Arozullah et al.⁴² This is a multifactorial risk index for postoperative respiratory failure and was derived and validated from a large Veterans Administration database. In addition to developing an index to assess risk of postoperative respiratory failure, Arozullah also has developed an index to assess the risk for postoperative pneumonia outlined in Table 2. Type of surgery, age, and functional status appear to be the most predictive factors for postoperative pneumonia.

In general, a careful history and physical exam are key in identifying potential postoperative pulmonary complications. Lung expansion maneuvers, including deep breathing and incentive spirometry are the mainstays in postoperative prevention of pulmonary complications. Medical optimization of COPD and asthma will reduce the risk of postoperative complications significantly.

Management of the Surgical Patient with Endocrinologic Issues

Diabetes Mellitus. Patients with diabetes should be questioned about symptoms of cerebrovascular, cardiovascular (CV), and peripheral vascular disease (PVD) as well as glycemic control. Diabetes is a risk factor for developing CV disease, and patients may have silent myocardial ischemia. Patients should be advised not to take their oral hypoglycemic agents on the morning of surgery. In general, short-acting insulin should be held on the morning of surgery, but one-third to one-half of long-acting insulin may be administered. Patients reporting to the surgical area should have a glucose check on arrival. In patients taking evening insulin, generally it is recommended that patients take one-half the usual evening dose of long-acting and a full-dose of short-acting insulin. Further management of glycemic control is based on a glucose measurement perioperatively. Intraoperative management of diabetics on insulin is managed with IV insulin drips; a continuous drip of IV glucose also should be given to prevent hypoglycemia and prevent ketosis and acidosis. More recent-

ly, studies in critically ill patients in the surgical intensive care unit (ICU) suggest that tight control with intensive insulin therapy reduced mortality from 8.0% to 4.6% ($P < 0.04$) and morbidity with conventional therapy.⁴³ Therefore, tight control of sugars postoperatively is indicated and should be managed with insulin until adequate oral intake resumes. For patients on oral diabetic agents, these can be resumed once oral intake is at baseline.

Thyroid Disorders. Patients with pre-existing hypothyroidism should be questioned as to recent changes in therapy, symptoms of hypo- or hyperthyroidism, and results of any recent thyroid tests. Newly diagnosed hypothyroid patients do not need to be treated before surgery unless signs or symptoms of hypothyroidism or myxedema are present. It is not essential for patients to take their thyroid replacement on the morning of surgery since the half-life of levothyroxine is approximately seven days.

Patients currently under treatment for hyperthyroidism should take their antithyroid drugs on the day of surgery and resume therapy as soon as possible because these drugs have a short half-life. Elective surgery should be postponed until hyperthyroid patients become euthyroid because of the mortality associated with thyroid storm. Patients with hyperthyroidism or severe hypothyroidism should be managed in conjunction with an endocrinologist preoperatively and perhaps perioperatively.¹⁶

Chronic Steroid Usage. It is controversial as to exactly how much steroid exposure will result in adrenal suppression. In general, patients receiving 5 mg or more of prednisone or its equivalent daily for more than two weeks within the last 9-12 months may be at risk for adrenal insufficiency during stress. Given the degree of morbidity and mortality associated with adrenal insufficiency, prophylactic glucocorticoid therapy is indicated when adrenal suppression is likely. Recommendations for stress doses of perioperative hydrocortisone are outlined in Table 9.

Management of the Surgical Patient with Hematologic Issues

Anemia. Anemia is probably the most commonly encountered hematologic abnormality in patients and often is an objective sign of disease. There are no data to define minimum preoperative hemoglobin and, certainly, chronic anemia is much better tolerated than acute. A systematic, practical, and cost-effective method should be used to diagnose the cause of the anemia if not already known. The decision to transfuse preoperatively must take into account several factors, including type of surgery, expected blood loss, coexisting diseases, and duration of anemia. In general, there are few data to support blood transfusion at hemoglobin concentrations greater than 10 g/dL.

Assessing for Coagulopathies or Bleeding Risk. In the absence of historical information to suggest an existing coagulopathy, there are no data that show any benefit from ordering preoperative coagulation profiles or bleeding times.¹² The risk of bleeding can be assessed best by a directed preoperative bleeding history. Questions should include assessment of prolonged bleeding after surgery, dental extractions, or lacerations. Patients should also be questioned about excessive bleeding events in relatives and any excessive bruising without explanation.

Management of the Surgical Patient with Renal Disease

Complications in patients with end stage renal disease (ESRD) or chronic renal insufficiency primarily are due to infection, bleeding, postoperative hypotension, or electrolyte abnormalities. Patients with ESRD are at increased risk for cardiac complications, but the indications for non-invasive testing are the same as those for patients without renal disease. It is important in patients with underlying renal dysfunction to maintain euvolemia, and dose adjust medications as needed for the underlying level of renal function. Uremia-induced platelet dysfunction may be a cause of excessive bleeding in patients with ESRD; therefore, they may benefit from dialysis within 24 hours of the surgical procedure. The administration of desmopressin acetate (DDAVP) or cryoprecipitate also may be useful in patients with significant underlying renal dysfunction⁴⁴ for optimizing platelet function.

Management of the Surgical Patient with Liver Disease

Hepatitis is a non-specific inflammation of the liver resulting from viral infection or exposure to toxins such as alcohol and certain hepatotoxic drugs. Cirrhosis is a chronic process resulting in fibrous tissue and scarring in the liver. Cirrhosis can lead to portal hypertension with subsequent esophageal variceal bleeding, splenic sequestration of platelets, ascites, and spontaneous bacterial peritonitis. Patients with cirrhosis also are at risk for renal insufficiency from pre-renal or intrinsic renal etiologies. The liver metabolizes many drugs and thus careful dose adjustment needs to be kept in mind. Cirrhosis also can lead to coagulopathies from deficiencies in vitamin K dependent clotting factors with concomitant elevation in PT and international normalized ratio (INR). Patients with advanced disease and cirrhosis do have a marked increased risk of postoperative complications and death. Patients who are Child-Pugh class C cirrhosis have a 76% mortality rate when undergoing abdominal surgery compared to 10% for class A.⁴⁵

Liver function tests should be ordered preoperatively in any patient suspected of having acute or chronic hepatitis. If acute hepatitis is suspected, serologic testing for hepatitis A, B, and C should be undertaken. Clotting function should be assessed by a measurement of PT and PTT and, given the propensity for bleeding in patients with liver disease, a CBC also should be ordered. If a procedure with significant blood loss is anticipated, then a type and screen also should be ordered. Given the potential for electrolyte abnormalities due to sodium retention in ascites or diuretic use, a metabolic panel to assess sodium, potassium, chloride and glucose should be ordered preoperatively as well. Since some patients can develop postoperative hepatic encephalopathy due to worsened ammonia levels, consider checking a baseline serum ammonia level preoperatively.

In patients with acute viral hepatitis, surgery should be postponed until blood tests have normalized, given the high morbidity and mortality. Patients with acute exacerbation of alco-

holic hepatitis also should have their surgical procedures delayed if possible. Asymptomatic patients with chronic hepatitis generally can proceed with surgery. Coagulopathies should be corrected preoperatively and, in general, most medications with the exception of diuretics should be continued preoperatively. Patients on interferon alpha therapy for chronic hepatitis B or C should have their interferon continued perioperatively with special attention noted to the side effects of the drug, including possible bone marrow suppression with resultant leukopenia and thrombocytopenia.⁴⁵

Management of the Patient with Substance Abuse Issues

The three most commonly abused drugs are alcohol, cocaine, and opioids. Diagnosis of excessive alcohol intake can be difficult to determine during a preoperative evaluation, but patients should be questioned about their use of alcohol and other drugs. Since alcohol affects every organ system, preoperatively the patient with a history of excessive alcohol consumption should be evaluated with a CBC to look for anemia and thrombocytopenia, liver function tests, tests of coagulation, electrolytes, magnesium, and phosphorous. The possibility of withdrawal or delirium tremens should be anticipated and perhaps even prevented with the administration of benzodiazepines.

The chronic use of intravenous opiates can have systemic effects such as cellulitis, thrombophlebitis, endocarditis, HIV, and hepatitis. Patients who chronically use synthetic opiates for pain control may have a high pain threshold and may require additional pain medication postoperatively.

Management of the Elderly Patient Undergoing Surgery

Many physiologic changes occur that make surgery for geriatric patients riskier than surgery in younger individuals. The cardiovascular system is less sensitive to baroreceptor activity, and anatomic changes in the conduction system can lead to arrhythmias. The incidence of silent ischemia also increases with age. The pulmonary system takes on a more restrictive picture, and there is a change in the ventilation and perfusion ratio. Renal function declines by approximately 1% per year, and creatinine clearance decreases despite normal levels of serum creatinine. Hepatocellular function generally is well preserved. Drug clearance is reduced, thus geriatric patients need lower doses of drugs compared to younger patients.⁴⁶

The elderly are at increased risk for delirium. Delirium is a multifactorial disorder, and risk factors for delirium can be classified into those that increase baseline risk and those that will precipitate delirium. Factors that increase an individual's baseline risk for delirium include underlying organic diseases such as stroke, dementia, and Parkinson's disease and advanced age or sensory impairment. Factors that may precipitate delirium include polypharmacy, infection, dehydration, immobility (including the use of restraints), and bladder catheterization. The route of anesthesia does not seem to affect the risk for delirium. The clinical predication rule^{47,48} in Table 3 can be used to identify

those patients who are at increased risk for post-operative delirium.

In elderly patients, cardiopulmonary, metabolic, and nervous system functional reserves appear to be the most important predictors of ability to undergo surgery without adverse outcomes. The risks for adverse drug reactions also are high, and a thorough review of indications and dosages of the current medication list of the elderly patient is an important part of the preoperative evaluation.

Management of Medications

There are few controlled trials on the safety of drugs in the perioperative period. Therefore, the recommendations on which medications to stop or continue during this time are based on expert consensus, case reports, in-vitro studies, manufacturer's recommendations in the package insert, and known information such as the drug's pharmacokinetics, known effects, perioperative risks, and possible interactions with anesthetic agents.⁴⁹ In addition, it is key to take a detailed history to include not only prescribed medications but over-the-counter medications, vitamins, and herbal supplements. A recent review found that one-third of the pre-surgical population was taking an herbal medication; it concluded that physicians explicitly should elicit and document a history of herbal medication and be aware of the potentially serious perioperative problems associated with their continued use.⁵⁰ Potentially harmful perioperative effects of some herbs include excessive bleeding, sedation, and even hypoglycemia. As a general rule, it is recommended that all herbal remedies and vitamins be stopped 14-days prior to surgery.

Aspirin irreversibly inhibits platelet cyclooxygenase and should be discontinued 7-10 days before surgery to allow replacement of the circulating platelet pool. In patients undergoing coronary artery bypass surgery, a prospective study showed that continuing aspirin leads to increased post-operative bleeding.⁵¹

Nonsteroidal anti-inflammatory (NSAIDs) drugs reversibly inhibit the platelet cyclooxygenase. Most NSAIDs can be stopped 3-5 days before surgery, except for some long-acting drugs such as piroxicam and oxaprozin that must be stopped 14 days prior to surgery. In vitro-studies show no increased risk of bleeding with cyclooxygenase-2 inhibitors (COX-2); therefore, theoretically, these can be continued perioperatively.⁴⁹ However, since all NSAIDs can inhibit renal prostaglandin synthesis, they can induce renal failure in combination with other drugs as well as hypotension. Therefore, it may be best to stop all NSAIDs in patients with underlying renal insufficiency.

Clopidogrel causes irreversible antiplatelet effect by inhibiting adenosine diphosphate induced stimulation of platelets. Therefore, it should be discontinued at least seven days before surgery.⁴⁹

Hormone replacement therapy (HRT) use is associated with a 2.7-fold increased risk of venous thromboembolism compared to non-users.⁵² The perioperative management of HRT still is controversial. Some still recommend stopping HRT about four weeks before surgery;⁴⁹ however, a recently completed case-control study found no association between perioperative HRT use and post-operative VTE in patients undergoing major orthopedic

surgery as long as they were receiving pharmacological prophylaxis with either enoxaparin or warfarin post-operatively.⁵³

Among cardiovascular medications, all forms of nitrates, digoxin, beta-blockers, calcium channel blockers, statins, and anti-arrhythmics can be continued safely, including in the morning of surgery.⁴⁹ However diuretics, angiotensin converting enzyme inhibitors (ACE-Is) and angiotensin receptor antagonists (ARBs) should not be taken the morning of surgery^{54,55} due to reports of refractory hypotension.

Pulmonary medications such as theophylline, inhaled beta-agonists, ipratropium, and corticosteroids can be continued safely perioperatively.⁴⁹ In addition, all anti-seizure medications, H₂-blockers, and proton pump inhibitors also should be continued perioperatively.⁴⁹

Among the antidepressants, selective serotonin reuptake inhibitors are safe perioperatively. Monoamine oxidase inhibitors (MAO-I) have a large number of drug interactions and potential for hypertensive crisis. Tricyclic (TCAs) antidepressants may enhance the action of sympathomimetics.⁴⁹ Patients on these last two classes of medications usually have more severe depression, and there is the potential for these patients to have a severe recurrence of depressive symptoms postoperatively with increased risk for suicide. Therefore, some physicians tend to continue all antidepressants but alert anesthesia to these medications so that potentially interacting sedatives and or anesthetics can be avoided.

Warfarin is a commonly used anticoagulant. Most patients needing major surgery or invasive procedures will require discontinuation of warfarin. It takes approximately five days for the anti-thrombotic effect of warfarin to wear off.⁵⁶ In most patients with preoperative INRs between 2-3, warfarin can be discontinued five days before surgery. During this time, patients may be at increased risk of thromboembolism. In addition, discontinuation of oral anticoagulation may be associated with a rebound hypercoagulable state, which has been described but not validated in clinical practice.^{57,58} Surgery also poses an increased risk for the development of venous thromboembolism (VTE). To minimize the risk of thromboembolism, some higher risk patients may require treatment with intravenous (IV) unfractionated heparin (UFH) in the hospital, or as outpatients with subcutaneous (SQ) low-molecular-weight-heparin (LMWH) as a bridge to surgery. Patients undergoing minor surgery can be managed using a nomogram that adjusts the perioperative dose of warfarin and minimizes the time the patient has a sub-therapeutic INR. Certain procedures such as cataract surgery, or minor dermatologic and dental procedures can be performed without stopping or adjusting the warfarin dose. This topic is beyond the scope of this article, but readers are referred to a recent comprehensive review on this topic by Jaffer et al.⁵⁹

Venous Thromboembolism Prevention (VTE)

The risk of VTE is determined by several factors: the type of surgery, the patient's clinical risk factors for VTE, and the period of perioperative immobilization. The clinical risk factors for VTE include: increasing age, prior VTE, obesity, stroke, immobility, paralysis, congestive heart failure, cancer, trauma, varicose veins,

pregnancy, estrogen use, and a hypercoagulable state (e.g., protein C or S deficiency, Factor V Leiden mutation). Table 4 outlines a risk stratification scheme put forth for surgical patients by the American College of Chest Physicians (ACCP). The risk categories range from low risk to highest risk. The approximate prevalence of calf deep vein thrombosis (DVT), proximal DVT, and clinical pulmonary embolism (PE) in the absence of prophylaxis is listed for each category of risk in Table 4 along with the suggested prevention strategies. A more detailed discussion is covered in a recent review by Kaboli et al.⁶⁰

Conclusion

There are many medical considerations in the preoperative evaluation and management of patients about to undergo a major noncardiac surgery, as outlined above. By providing careful attention to optimizing the various preoperative medical conditions, initiating specific risk reduction therapies, and communicating the details to the anesthesiologist and surgeon, the primary care physician in his or her role as the medical consultant can assist in delivering the best care quality care to the patient.

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PHARMACOLOGY WATCH

Supplement to *Clinical Cardiology Alert, Clinical Oncology Alert, Critical Care Alert, Infectious Disease Alert, Internal Medicine Alert, Neurology Alert, OB/GYN Clinical Alert, Primary Care Reports, Travel Medicine Advisor.*

Linking COX-2 Inhibitors and Cardiovascular Event Risk

A new, and as of yet unpublished study, has raised increased concern about the relationship between rofecoxib (Vioxx), Merck's blockbuster COX-2 inhibitor, and cardiovascular events. The study, which was presented at a meeting in Bordeaux France, was financed by the FDA in collaboration with California's HMO giant Kaiser Permanente. The study was designed to determine if celecoxib, rofecoxib, ibuprofen, naproxen, or other NSAIDs increase the risk of acute myocardial infarction (AMI) or sudden cardiac death (SCD). Utilizing the 6-million member California database for Kaiser Permanente, all patients ages 18-84 who had taken a COX-2 inhibitor or nonselective NSAIDs between January 1999 and December 2001 were entered into the cohort. Controls were a risk-set match 4:1 on event date, birth year, gender, and health plan region. There were 8199 acute cardiac events within the study cohort (6675 AMI, 1524 SCD). The data revealed that rofecoxib use at > 25 mg per day increased the risk of acute cardiac events 3.15 fold (OR, 3.15 [1.14-8.75]). Rofecoxib at a dose < 25 mg resulted in an odds ratio of 1.29 (0.93-1.79), which was not statistically significant. When comparing low-dose rofecoxib to celecoxib (Celebrex), the risk of AMI and SCD was higher with rofecoxib ($P= 0.04$). Other NSAIDs, including naproxen, indomethacin, and possibly diclofenac, also increased the risk of AMI and SCD. These data will be presented in this country in October at the American College of Rheumatology. Concern about the relationship between rofecoxib and cardiac events was first raised with the publication of the VIGOR trial (*N Engl J Med.* 2000;343:1520-1528) which showed a relative risk

of cardiac events associated with rofecoxib of 2.38 (95% CI, 1.39-4.00; $P= .002$). Dr. Eric Topol and colleagues from the Cleveland clinic subsequently reevaluated these data along with data from other studies and raised the concern of prothrombotic potential of COX-2 inhibitors, especially rofecoxib (*JAMA.* 2001;286:954-959). Their concern centered on the tendency for COX-2 inhibitors to block production of prostacyclin—thus blocking antiaggregatory and vasodilatory effects, while having no effect on thromboxane, which is responsible for platelet aggregation. Blockage of thromboxane is a COX-1 effect and accounts for the majority of the cardioprotective effects of aspirin and other NSAIDs. Rofecoxib, the most COX-2 specific of the drugs tested, may unbalance thromboxane and prostacycline accounting for the cardiovascular risk.

Some have considered a strategy of adding aspirin to a COX-2 inhibitor, but a new study suggests that aspirin negates the GI benefits of the COX-2 inhibitor, the primary benefit of COX-2 inhibitors over nonselective NSAIDs.

Researchers from USC performed a double-blind trial of rofecoxib, rofecoxib plus low-dose

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aspirin, ibuprofen, or placebo in patients without ulcers or erosive esophagitis. Endoscopies were performed at baseline, 6 weeks, and 12 weeks. At 12 weeks, the cumulative index of ulcers was placebo 5.8%, aspirin 7.3%, rofecoxib plus aspirin 16.1%, and ibuprofen 17.1% ($P < 0.001$ for rofecoxib plus aspirin and for ibuprofen vs each of placebo and aspirin). Over the same time, rofecoxib plus aspirin and ibuprofen both significantly increased the number of erosions (both $P < 0.001$ vs aspirin and placebo). The authors conclude that low-dose aspirin does not significantly increase ulcer recurrence, but that the addition of a COX-2 inhibitor with aspirin increases the rate of ulceration to a rate that is similar to a nonselective NSAIDs (*Gastroenterology*. 2004;127:395-402).

Viagra: Maximum Capacity at High-Altitudes?

High-altitude hikers may soon be requesting sildenafil (Viagra) prescriptions based on the results of a new study. The drug, which is a phosphodiesterase-5 inhibitor, is known to cause pulmonary vasodilation. German researchers postulated that such an effect may increase exercise capacity during induced hypoxemia at low altitudes and at Mount Everest base camp. Fourteen healthy mountaineers and trekkers were assessed with measurements of systolic pulmonary artery pressure, cardiac output, and peripheral arterial oxygen saturation at rest and during assessment of maximal exercise capacity on cycle ergometry while breathing a hypoxic gas mixture at low altitude, and retested at high-altitude at the Mount Everest base camp. Sildenafil 50 mg significantly increased arterial oxygen saturation during exercise ($P = 0.005$), reduced systolic pulmonary artery pressure at rest ($P < 0.001$), and during exercise ($P = 0.031$). Sildenafil also increased maximum workload and maximum cardiac output compared with placebo. At high-altitude, the drug had no effect on arterial oxygen saturation at rest nor during exercise compared with placebo, however, the sildenafil reduced systolic pulmonary artery pressure at rest ($P = 0.003$), during exercise ($P = 0.021$), increased maximum workload ($P = 0.002$), and cardiac output ($P = 0.015$). Two patients noted worsening headache at high-altitude with the drug. The authors conclude that sildenafil is the

first drug to increase exercise capacity during severe hypoxia both at sea level and at high-altitude (*Ann Intern Med*. 2004;141:169-177). An accompanying editorial suggests that sildenafil is not a substitute for acclimatization to high-altitude and suggests that the findings of the study are compelling and that further research into a phosphodiesterase inhibitors in the treatment of pulmonary vascular disease is needed (*Ann Intern Med*. 2004;141:233-235).

FDA Actions

Eli Lilly has received FDA approval to market duloxetine (Cymbalta) for the treatment of major depression. The drug is a serotonin and norepinephrine reuptake inhibitor (SNRI), similar to venlafaxine (Effexor-Wyeth). The drug is also being studied for the treatment of stress urinary incontinence and diabetic neuropathic pain. Lilly, and the drug approval process for duloxetine, came under scrutiny earlier this year when a 19-year-old female volunteer committed suicide after discontinuing the drug during clinical trials. The patient had no history of depression prior to the study.

Shire Pharmaceuticals has received expanded indication for its mixed amphetamine product Adderall XR for the treatment of adults with attention deficit hyperactivity disorder (ADHD). The drug is a one-a-day preparation that has been widely used in children since 2001.

The FDA and Genentech have issued a warning to physicians regarding the risk of serious arterial thromboembolic events associated with bevacizumab (Avastin). The drug is an angiogenesis inhibitor, a novel antineoplastic used to treat metastatic colon cancer and other solid tumors. Reports of cerebral infarctions, myocardial infarctions, transient ischemic attacks, and angina have all been associated with use of the drug.

The FDA has approved an orally disintegrating form of carbidopa/levodopa for the treatment of Parkinson's disease. The preparation dissolves rapidly in the mouth without the need for water, allowing for dosing even when patients are rigid or suffering from "off periods," when producing can be problematic. It will be marketed under the trade name Parcopa and will be available in 10/100 tabs, 25/100 tabs, and 25/250 tabs, similar to brand name Sinemet levodopa/carbadopa.

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Physician CME Questions

21. The goal of the preoperative evaluation is to clear patients for surgery.
 - a. True
 - b. False
22. All of the following factors improve compliance with the consultant recommendations *except*:
 - a. promptness.
 - b. limiting recommendations to fewer than five.
 - c. being specific.
 - d. verbal contact.
 - e. providing no follow-up.

23. Which of the following is *not* a criteria contained in the Lee revised cardiac risk index?
 - a. High-risk surgery
 - b. History of ischemic heart disease
 - c. History of CHF
 - d. Age older than 70 years
 - e. Preoperative creatinine greater than 2 mg/dL
24. A 65-year-old woman with history of three-vessel CABG two years ago, Type 2 diabetes mellitus on insulin, and prior stroke is scheduled for elective total hip replacement surgery. What drug would you consider starting preoperatively if she was not already taking it?
 - a. Nitrate
 - b. Diuretic
 - c. Calcium channel blocker
 - d. ACE inhibitor
 - e. Beta-blocker
25. Which of the following risk reduction strategies is *not* proven to decrease postoperative pulmonary complications?
 - a. Smoking cessation at least four weeks before surgery
 - b. Treating air flow obstruction in COPD or asthma
 - c. Educating patients preoperatively on incentive spirometry
 - d. Delaying surgery for six weeks if upper respiratory or pulmonary infection is present

CME Answer Key

21. b. ; 22. e. ; 23. d. ; 24. e. ; 25. a.

In Future Issues:

DVT

Primary Care Reports

CME Objectives

To help physicians:

- summarize the most recent significant primary care medicine-related studies;
- discuss up-to-date information on all aspects of primary care, including new drugs, techniques, equipment, trials, studies, books, teaching aids, and other information pertinent to primary care;
- evaluate the credibility of published data and recommendations; and
- describe the pros and cons of new testing procedures.

CME Instructions

Physicians participate in this continuing medical education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to evaluate their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. *After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a certificate of completion.* When your evaluation is received, a certificate will be mailed to you.