CME CREDIT

Evaluating cardiac risk in noncardiac surgery patients

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SUMMARY The cornerstones of the evaluation of cardiac risk in patients undergoing noncardiac surgery remain a thorough history and physical examination, and a resting electrocardiogram. However, new techniques to assess cardiac function allow more complete evaluation of high-risk patients.

KEY POINTS Patients at high risk include those with myocardial infarctions within the preceding 6 months, unstable angina, congestive heart failure, critical aortic stenosis, severe hypertension (diastolic blood pressure > 110 mm Hg), or peripheral vascular disease. Patients undergoing vascular surgery have a higher risk of cardiac events and require a special approach to risk assessment and intervention. Despite its imperfections, the Goldman index remains a useful tool to assess cardiac risk, because of its ease of use and relative weighting of risk factors. High-risk patients should undergo further risk stratification using noninvasive testing before surgery. Medical management of all treatable conditions should be maximized. All other patients, even those with known cardiovascular disease, can undergo surgery safely without further testing.

INDEX TERMS: SURGERY, OPERATIVE; RISK FACTORS; PREOPERATIVE CARE; CARDIOVASCULAR DISEASES CLEVE CLIN J MED 1995; 62:391–400

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PERIOPERATIVE cardiac events are the most common serious complication of noncardiac surgery. Each year, of the more than 25 million patients who undergo noncardiac surgical procedures, 1 million have known coronary artery disease, 2 to 3 million have multiple cardiac risk factors, and 4 million are older than 65 years. These high-risk patients account for 80% of the 1 million patients who suffer perioperative cardiac morbidity and mortality each year.[1]

The effectiveness of the internal medicine consultation depends on the internist's understanding of the issues faced by anesthesiologists and surgeons in planning and performing a surgical procedure, knowledge of the physiologic stressors associated with the procedure, and ability to communicate strategies that will maximize the patient's medical status.[2]

This paper reviews the current literature on preoperative evaluation of cardiovascular risk, discusses the evaluation of surgical patients who have vascular disease (in whom the risk of cardiac events is higher), and presents an approach to risk assessment and intervention.

HOW SURGERY AFFECTS CARDIAC FUNCTION

The physiologic stress of surgery is related to the direct and indirect effects of anesthetic agents and the body's responses to hypotension, anemia, and postoperative pain. During anesthesia induction, tachycardia and hypertension occur in response to intubation and anxiety. Later, hypotension may occur as a result of vasodilation, myocardial depression associated with anesthetic agents, intermittent positive-pressure ventilation, hemorrhage, or infection. In the early postoperative period, pain, hypertension, and increased catecholamines may increase cardiovascular stress. In addition, hypercoagulability as a result of tissue injury may enhance the risk of coronary occlusion. Limited cardiovascular reserve increases the risk of cardiac events and predisposes the patient to a poorer outcome.

The severity of the physiologic stress is proportional to the risk of the planned procedure. Craniotomies, cardiac procedures, large-bowel surgeries, vascular surgeries, major joint replacements, and exploratory laparotomies pose higher levels of risk than do plastic surgical procedures, tubal ligations, dilatation and currettages, hysterectomies, eye surgery, oral surgery, transurethral resections of the prostate, or herniorrhaphies. Newer anesthetic agents and perioperative care techniques have substantially improved the outcomes of surgical patients with medical problems.[3]

PREOPERATIVE CLINICAL EVALUATION

The internist is commonly consulted to evaluate patients with impaired cardiovascular reserve caused by coronary artery disease, arrhythmias, or poor left ventricular function. The goal is to prevent perioperative complications, including cardiac death, myocardial infarction, transient myocardial ischemia, arrhythmias, and congestive heart failure. At the end of the initial assessment, the physician should decide whether to (1) proceed with surgery without further evaluation, (2) proceed with surgery but take steps to further reduce cardiac risk after surgery, (3) perform further risk stratification, possibly culminating in myocardial revascularization before surgery, or (4) cancel surgery because of unacceptable risk. This last option requires careful discussion with the surgical team to determine other treatment alternatives.

The cornerstones of the preoperative evaluation are the history, physical examination, and resting electrocardiogram. It is essential to find out whether there is any history of MI (especially recent), stable or unstable angina, coronary artery disease, heart failure, valvular heart disease, or multiple risk factors, as these help determine risk. The physical examination should include a detailed cardiovascular examination.

FREQUENT CLINICAL SCENARIOS

No known coronary artery disease

Patients younger than age 45 with no history or symptoms of cardiovascular disease need only a history and physical examination before proceeding with surgery. Patients older than 45 years should also have an electrocardiogram.

Known coronary artery disease

Perioperative MIs occur in 3% to 18% of patients who have a history of MI, compared with only 0.15% of patients without previous clinical evidence of heart disease.[4] Patients with a history of coronary artery disease have a mortality rate 25% to 50% higher than those without coronary artery disease,[5] although the absolute event rate is low. In emergency surgery, this risk is four times as high as in those without coronary artery disease.

A 1993 study[6] divided 1487 consecutive patients (all men older than age 40 undergoing major elective or urgent noncardiac surgery) into four groups according to their cardiac history. Of the high-risk patients (those with known coronary disease as shown by a history of MI, evidence of an old MI on electrocardiography, typical angina, a history of coronary artery bypass grafting, or angiographic coronary artery disease with stenoses > 70%), 4.1% suffered MIs and 2.3% died of cardiac causes. In intermediate-risk patients (those with other vascular disease or atypical chest pain syndromes, but without known coronary artery disease), the incidence of MI was 0.8% and the incidence of cardiac death was 0.4%. Low-risk patients (those with no known atherosclerosis, but who were older than 75 years or at high risk by the Framingham criteria, that is, who had a 15% or greater risk of coronary artery disease in 6 years) experienced no MIs and a 0.4% incidence of cardiac death. The negligible-risk group (patients with no atherosclerosis and a low-risk profile) experienced no cardiac deaths. These data indicate that, even in the presence of known coronary artery disease, the risk of a cardiac event during noncardiac surgery is relatively low in the absence of recent MI or unstable angina.

Recent MI

An MI within the previous 6 months imposes a high risk of perioperative infarction, although modern anesthetic techniques that emphasize careful monitoring and hemodynamic intervention have lowered this risk. In elective surgery, the perioperative reinfarction rate is 5.8% for patients who have had an MI within 3 months, decreasing to 2.3% between 3 to 6 months and 1.3% thereafter.[7] In urgent or emergent surgery, patients who have had an MI within 3 months face a 16.7% rate of reinfarction or cardiac death.[8] Therefore, elective procedures should be delayed until 6 months after an MI. If surgery cannot be delayed, perfusion imaging or stress ventriculographic assessment using radionuclide or echocardiographic techniques should be performed.[9,10]

At greatest risk are patients with postinfarction angina, severe left ventricular dysfunction, or extensive inducible ischemia. For these patients, revascularization should be considered to minimize cardiovascular instability, depending on the balance between the risks associated with revascularization and those of surgery without prior intervention. Patients undergoing high-risk procedures who have had a recent MI or who have ischemia on preoperative testing (without prior myocardial revascularization) or poor left ventricular function (ejection fraction < 30%) might benefit from invasive monitoring during anesthesia.

Angina

Chronic stable angina can be managed safely without further investigation. A patient who can climb two flights without angina or significant dyspnea has adequate cardiopulmonary reserve and usually does not need additional testing. Perioperative administration of nitrates and beta-blockers should be considered. Patients with unstable angina require further investigation before surgery.

Heart failure

A third heart sound denotes left ventricular failure severe enough to increase the risk of cardiac death or complications.[11] Echocardiographic assessment of active left ventricular failure can further define the risk, and hemodynamic monitoring with aggressive management may lead to improved outcomes. Every effort should be made to maximize left ventricular function before surgery. In all circumstances, the anesthesiologist needs to be aware of any left ventricular dysfunction to choose anesthetics and manage fluids appropriately.

Aortic-valve stenosis

Aortic-valve stenosis increases the risk of endocarditis, embolization, and congestive heart failure.[12,13] Severe aortic stenosis precludes most high-risk elective surgical procedures; evaluation for valvuloplasty or valve replacement should therefore be done first. In a series at the Mayo Clinic,[13] patients with recognized, carefully managed aortic stenosis had a 10% incidence of intraoperative hypotension but no cardiac deaths or MIs. Hypotension responded promptly to treatment.

Hypertension

Patients with severe hypertension (diastolic blood pressure > 110 mm Hg) have higher morbidity and mortality rates than do patients with controlled hypertension or normotension. They also have a larger absolute decrease in systolic blood pressure during surgery, more operative blood pressure lability, and greater incidences of arrhythmias, myocardial ischemia or infarction, neurologic complications, renal failure, congestive heart failure, and postoperative hypertension.[14] In contrast, patients with mild-to-moderate diastolic hypertension (90 to 109 mm Hg) do not have increased rates of operative mortality or complications.[15] There are no differences between patients with controlled or uncontrolled hypertension in nadir of intraoperative blood pressure, use of vasopressors or intravenous fluids during surgery, or incidence of postoperative hypertension. Data are inadequate to assess the risk in patients with isolated systolic hypertension.

Peripheral vascular disease

Peripheral vascular disease adds to the risk of cardiovascular complications during noncardiac surgery. More than 30% of patients with peripheral vascular disease have coexistent coronary artery disease.[16] Further, peripheral vascular disease may limit activity and thus mask angina pectoris and significant coronary artery disease. The hemodynamic stress of aortic cross-clamping used during many vascular procedures places these patients at added risk of cardiac and other major complications. A consid-

TABLE 1
THE GOLDMAN MULTIFACTORIAL INDEX

Finding	Points
Myocardial infarction within 6 months	10
Age > 70 years	5
S_3 gallop or jugular venous distension	11
Important aortic-valve stenosis	3
Rhythm other than sinus, or sinus rhythm and atrial premature contractions on last preoperative electrocardiogram	7
More than five premature ventricular contractions per minute anytime before surgery	7
Poor general medical status†	3
Intraperitoneal, intrathoracic, or aortic operation	3
Emergency operation	4

Class	Points	Life-threatening complications (%)	Cardiac deaths (%)
I	0–5	0.7	0.2
II	6–12	5	2
III	13–25	11	2
IV	≥26	22	56

*From Goldman et al, reference 11
†PaO_2< 60 mm Hg, $PaCO_2$ > 50 mm Hg, serum potassium < 3.0 mEq/L, serum bicarbonate < 20 mEq/L, blood urea nitrogen > 50 mg/dL, serum creatinine > 3.0 mg/dL, abnormal aspartate aminotransferase, signs of chronic liver disease, bedridden from noncardiac causes

erable body of literature has enhanced our understanding of how best to evaluate these patients and is discussed below.

ESTIMATING CARDIAC RISK USING CLINICAL CRITERIA

The Goldman index

Goldman et al[11] assigned a point value to each of nine clinical risk factors and divided surgical patients into four risk classes on the basis of their total point scores, creating an assessment tool known as the "Goldman index" (*Table 1*). The Goldman index remains the most useful multivariate instrument to assess cardiac risk, primarily because of its ease of use and relative weighting of risk factors. However, it has limitations. It was developed from a data set in the mid-1970s, and hence does not reflect modern practice in anesthesia, medicine, or surgery. It may not fairly represent the pretest probabilities of events for every institution, surgical team, or surgical procedure. The incidence of complications among patients in class IV cited in the series of Goldman et al (78%)[11] was higher than has been found at other institutions.[17] The data set included relatively few vascular surgical patients.[18] Although this index is useful in predicting risk, its sensitivity is relatively low, and it may miss important coronary artery disease, especially in elderly patients.

Nevertheless, the Goldman index can be combined with other factors, such as the nature of the surgical procedure, the extent to which risk factors are reversible, and the benefits of the proposed surgery. Pooled data from three studies show a rate of death or major complications of 1.3% in class I, 4.7% in class II, 15.3% in class III, and 56% in class IV (*Table 2*).[11,12,17]

One of the most important effects of the Goldman index has been to alert physicians to the major risk factors in noncardiac surgery. This has probably led to improvements in outcomes as physicians have identified patients at risk, aggressively intervened to correct risk factors, and applied closer perioperative monitoring.

The Eagle factors

Eagle and colleagues[19] found five clinical factors that identify patients at greatest risk of cardiac events during vascular surgery: age greater than 70 years, a history of angina, significant Q waves, congestive heart failure, and diabetes requiring treatment. In a series of 200 patients referred for dipyridamole-thallium stress testing before vascular surgery, patients with none of these factors had a 3.1% rate of ischemic events (unstable angina, ischemic pulmonary edema, myocardial infarction, or cardiac death). The rate was 15.5% in patients with one or two factors, and 50% with three or more factors. These clinical factors alone correctly classified these patients into risk categories 71% of the time, compared with 69% for thallium imaging alone and 81% for combined thallium and clinical variables. The role of dipyridamole-thallium stress testing in unselected patients remains uncertain, and recent studies question its value in these circumstances (see below).

NONINVASIVE TESTS TO EVALUATE CORONARY ARTERY DISEASE

Exercise electrocardiography is widely used to diagnose coronary artery disease and assess prognosis in the general population. However, for exercise elec-

TABLE 2
RATES OF DEATH AND MAJOR COMPLICATIONS
ACCORDING TO GOLDMAN MULTIFACTORIAL CARDIAC RISK INDEX

Authors	Year	Type of patient	Class I			Class II			Class III			Class IV		
			Events	Patients	%	Events	Patients	%	Events	Patients	%	Events	Patients	%
Goldman et al[11]	1977	> 40 years	5	537	1	21	316	7	18	130	14	14	18	78
Zeldin[17]	1984	> 40 years	4	590	1	13	453	3	11	74	15	7	23	30
Detsky et al[12]	1986	Preoperative consults	8	134	6	6	85	7	9	45	20	4	4	100
Pooled data			17	1261	1.3	40	854	4.7	38	249	15.3	25	45	56

trocardiography or exercise imaging to be accurate, the patient must exercise maximally, which most patients with vascular disease or undergoing major noncardiac surgery cannot do. Therefore, most patients who need preoperative stress testing before major surgery undergo pharmacologic stress (dipyridamole, adenosine, or dobutamine), not exercise.

Myocardial perfusion imaging

Stress myocardial perfusion scintigraphy is usually reported to have a sensitivity of more than 90% for detecting significant coronary artery disease. The specificity of thallium single-proton emission computed tomography (SPECT) in recent large studies has been in the range of 70% to 80%, although this range may have been influenced by posttest referral bias. False-positive results may be caused by soft tissue attenuation, left ventricular hypertrophy, and left bundle branch block, all of which are relevant in the patient population undergoing risk stratification, especially before vascular surgery.

Table 3 summarizes the results of dipyridamole-thallium perfusion imaging for predicting cardiac events.[19–29] In pooled data, dipyridamole-thallium imaging has a positive predictive value of 22% and a negative predictive value of 94%. The high negative predictive value is consistent with a high sensitivity for coronary disease. The studies that showed a lower negative predictive value[20,21,25,27] most likely reflect the effect of population selection on the predictive value of a test. According to Bayes' theorem, the posttest probability of an event pertains to both the accuracy of the result and the pretest probability of an event. If a patient with a high probability of disease has a negative perfusion image, the patient continues to have high probability of disease. It is important therefore that perfusion imaging be used on patients at intermediate risk, rather than in all patients.

Some perioperative cardiac events are unpredictable, no matter how accurate the test. The most common cardiac event in the absence of preoperative ischemia is MI. Presumably, MIs occur when a thrombus forms on a ruptured plaque, and in many instances the severity of stenosis is only mild. Stenoses of less than 50% diameter do not significantly limit maximal hyperemic flow, and consequently do not produce perfusion defects detectable by even the most accurate techniques such as positron emission tomography.

A positive scan does not necessarily mean the patient will suffer a cardiac event either, even if it truly reflects coronary disease. This is because artifacts introduce false-positive results, and also because a positive scan may indicate mild coronary artery disease, which is generally benign.

To circumvent this problem, several investigators have examined the criteria for a positive test result. Because severe ischemia is difficult to distinguish from scar tissue using standard thallium protocols, fixed (stress and redistribution) redistribution defects are ambiguous, although some studies suggest that such defects do predict events. Further, larger perfusion defects are more strongly associated with subsequent events than are smaller defects. Thus, the nature and size of the perfusion defect may be used to enhance the predictive value of a positive test.

Pharmacologic stress echocardiography

In experienced hands, stress echocardiography has been as accurate as myocardial perfusion imaging in identifying coronary artery disease. It is somewhat less sensitive than perfusion imaging, with most of the discrepancies being caused by single-vessel coronary disease. On the other hand, it has higher specificity, because artifacts are less frequent. At least in theory, these findings should translate to a slightly lower negative predictive but a somewhat

TABLE 3
PREDICTIVE VALUES OF DIPYRIDAMOLE THALLIUM IMAGING FOR PREDICTING POSTOPERATIVE CARDIAC EVENTS

Investigators	Year	n	True positive tests	Total positive tests	Positive predictive value (%)	True negative tests	Total negative tests	Negative predictive value (%)
Boucher[22]	1985	48	8	16	50	32	32	100
Eagle[19]	1987	111	16	42	38	—	—	—
Lette[28]	1989	66	9	27	33	39	39	100
Younis[29]	1990	111	6	50	12	61	61	100
Marwick[27]	1990	86	3	9	33	70	77	90
Mangano[20]	1991	60	6	22	27	35	38	92
Hendel[23]	1992	327	26	186	14	140	141	99
Cambria[24]	1992	58	2	26	8	—	—	—
Takase[25]*	1993	53	8	15	53	35	38	92
Younis[26]	1994	161	15	50	30	106	111	95
Baron[21]	1994	457	31	160	19	265	297	89
Pooled data		1538	130	603	22	783	834	94

*Included major nonvascular surgery

higher positive predictive value, both because of fewer false-positive results and (paradoxically) because of its lower sensitivity for prognostically benign, single-vessel coronary disease.

The limited data using stress echocardiography for risk stratification in patients undergoing vascular surgery are shown in *Table 4*.[10,30–35] The wide range of reported positive predictive values probably reflects diversity of the studied patients more than differences in pharmacologic techniques. When pooled, the data for pharmacologic stress echocardiography showed a positive predictive value of 45% and a negative predictive value of 98%. On multivariate testing, the risk of an event was over 40 times higher in patients in whom ischemia could be provoked by dobutamine.

It should be noted that the data pooling we have done in *Table 4* (and in *Tables 2* and *3*) does not constitute a statistically valid meta-analysis. This approach is especially risky in *Table 4*, in which the patients in the cited studies were treated differently, with a fairly wide range of resulting positive predictive values. Nonetheless, we believe that the studies support the conclusion that abnormal results of pharmacologic stress echocardiography in vascular surgery patients signify increased risk of serious cardiac events.

Dobutamine stress echocardiography may have some advantages over dipyridamole thallium testing.[30] First, it measures both left ventricular function and the potential for ischemia, the major determinants of cardiac risk. Second, dobutamine is more physiologic than dipyridamole is in mimicking the circumstances of perioperative ischemia. Additionally, it can detect unsuspected or underappreciated valvular disease. However, ischemic changes during stress echocardiography are less quantifiable and probably more dependent on operator interpretation and experience than are the changes seen during perfusion imaging. Few data are available to compare the predictive values of scintigraphy and stress echocardiography in the same patients. The results summarized in *Tables 3* and *4* suggest that the techniques are comparable, and therefore the choice should be made according to local experience and availability.

APPROACH TO PATIENTS UNDERGOING VASCULAR SURGERY

In patients undergoing major vascular surgery, preoperative ischemia during ambulatory monitoring, dipyridamole-thallium stress testing, or stress echocardiography indicates a risk of cardiac events of 24% to 45% and a risk of death of 3% to 7%, levels generally thought to justify preoperative interventions to minimize ischemia.[9,16,36] However, the best approach to the vascular surgery patient with a positive test for ischemia has yet to be determined.

TABLE 4
VALUE OF PHARMACOLOGIC STRESS ECHOCARDIOGRAPHY IN PREDICTING SERIOUS CARDIAC EVENTS IN VASCULAR SURGICAL PATIENTS

Investigators	n	Agent	True positive tests	Total positive tests	Positive predictive value (%)	True negative tests	Total negative tests	Negative predictive value (%)
Tischler[10]	109	Dipyridamole	7	9	78	99	100	99
Vincent[31]	67	Dipyridamole	12	18	67	46	49	94
Lane[32]	57	Dobutamine	4	19	21	19	19	100
Lalka[33]	60	Dobutamine	10	30	33	28	30	93
Davila-Roman[34]	91	Dobutamine + atropine	17	23	74	68	68	100
Poldermans[30]	131	Dobutamine + atropine	15	35	43	96	96	100
Langan[35]	81	Dobutamine	3	16	19	31	31	100
Pooled data	596		68	150	45	387	393	98

Consideration should be given to reducing cardiac risk both perioperatively and long-term.

Mason et al[37] recently examined the risks and benefits of preoperative coronary angiography and coronary revascularization in vascular surgery patients with positive dipyridamole-thallium scans. Surprisingly, proceeding directly to vascular surgery led to lower morbidity and cost; preoperative coronary angiography led to better outcomes only if inoperable coronary artery disease was found and the surgery was cancelled. The reason seems to be that exposing the patient to the risk of three procedures (coronary angiography, coronary revascularization, and vascular surgery) leads to event rates that are close to that of proceeding directly to vascular surgery (and the three procedures cost more). An alternative approach might be to reduce postoperative event rates by intensifying medical therapy.[38]

Although there may be grounds to question the efficacy of preoperative revascularization for risk reduction, it is important to remember that late cardiac events are highly prevalent in patients with vascular disease. In a group of patients followed after elective aortic aneurysmectomy, the cardiac event rate at 8 years was 61% among those with suspected or overt coronary disease before surgery, and 15% in those without disease.[39] Similarly, Younis[29] has shown that patients with preoperative evidence of ischemia on thallium imaging have an event rate of about 50% over 2 years after vascular surgery if they do not undergo myocardial revascularization. More research is needed to explore the optimal selection and timing of revascularization in these patients.

Vascular surgical patients: recommendations

The *Figure* shows an algorithm for evaluating patients scheduled for vascular surgery. Low-risk patients (less than 70 years old, class I or II New York Heart Association activity level), may proceed with surgery without further evaluation. Patients at intermediate risk should complete noninvasive testing. If there is inducible ischemia, coronary angiography should be performed. High-risk patients should also undergo coronary angiography.

Recommendations depend on the severity of disease found during coronary angiography. Left main coronary artery disease, left main equivalent disease, poorly controlled angina, and left ventricular dysfunction due to ischemia are indications for coronary artery surgery or percutaneous transluminal coronary angioplasty (PTCA), regardless of the planned vascular surgery procedure. In a patient with no current indication for coronary artery surgery or PTCA, the decision to intervene should weigh the combined risk of a staged procedure and the patient's longer-term risk of a coronary event. In the study by Mason cited above,[37] proceeding directly with surgery was the preferred course, but it did not consider long-term outcomes that might be improved by revascularization. If a patient has severe inoperable disease or anatomy otherwise unsuitable for intervention, the decision to proceed with surgery should be done with full understanding of the risk and the likelihood of adverse events if the planned procedure is not undertaken. Patient preference is critical in these decisions.

If surgery is essential, medical therapy should be maximized and the patient should have hemody-

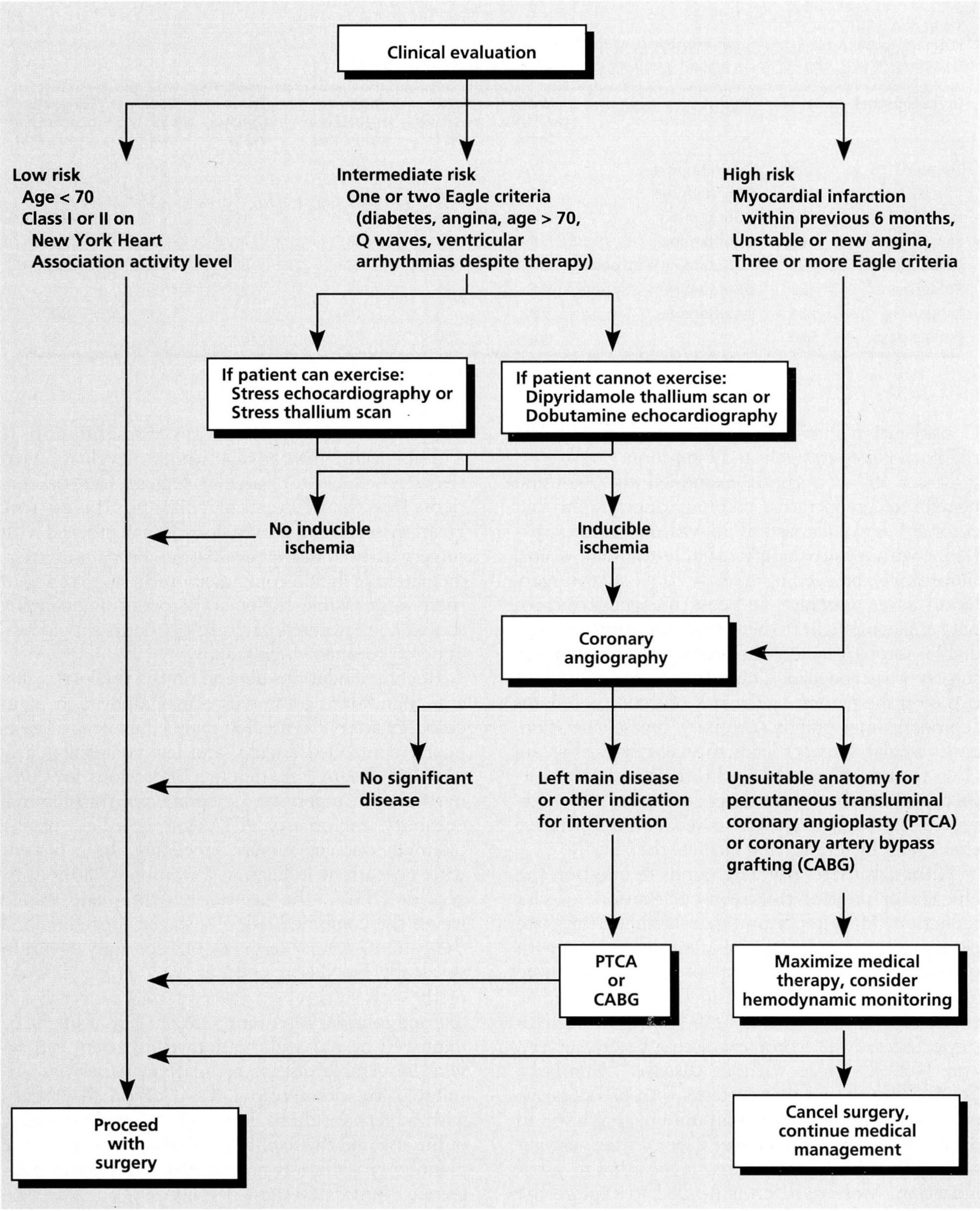

FIGURE. Algorithm for evaluating cardiac risk in vascular surgical patients.

namic monitoring. Although the algorithm in the *Figure* is for vascular surgical patients (in whom the data are most compelling), it can be applied to any high-risk patient undergoing an extensive surgical procedure. Risk stratification by stress testing should be considered for any patient with more than three Eagle criteria who is scheduled for major surgery.

APPROACH TO PATIENTS UNDERGOING MINOR SURGERY

Most patients at low or intermediate risk can safely undergo minor surgical procedures without an extensive evaluation. Patients with unstable angina or MI within 6 months should have elective surgery delayed until they are stable. As in all cases, clinical judgement is necessary in deciding the proper preoperative evaluation for patients undergoing minor surgical procedures.

SUMMARY

Perioperative cardiac events remain the most common serious complications of noncardiac surgery. The internist plays an important role in assessing and managing this risk. The preoperative evaluation of cardiac risk is a science that continues to evolve, but it is based on a thorough history, physical examination, and resting electrocardiogram. In high-risk patients, further risk stratification with noninvasive testing can be useful to define the long-term risk of a cardiac event and to optimize medical management.

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