Evaluation and Management of Patients With Both Peripheral Vascular and Coronary Artery Disease

BERNARD J. GERSH, MB, CHB, DPhil, FACC, CHARANJIT S. RIHAL, MD, THOM W. ROOKE, MD, DAVID J. BALLARD, MD, PhD

Rochester, Minnesota

The prevalence of serious angiographic coronary artery disease ranges from 37% to 78% in patients undergoing operation for peripheral vascular disease. Clinical studies have demonstrated that cardiac outcome after peripheral vascular surgery is not adequately predicted by the standard criteria of history, physical findings and rest electrocardiogram. An adequate exercise work load, left ventricular function and thallium redistribution have proved important in perioperative risk stratification. The choice of a perioperative functional cardiac test depends on patient-related factors and the nature of the peripheral vascular operation. Although procedures involving aortic cross-clamping exert a greater hemodynamic stress than do carotid endarterectomy and femoral popliteal surgery, late cardiac morbidity and mortality are significant in all patients with atherosclerotic disease.

The management of patients with both coronary and peripheral vascular disease is difficult and raises many controversial issues. What is the prevalence of coronary artery disease in the general population or in patients with occlusive vascular disease? What is the impact of an abnormal cardiac history or a positive stress test on perioperative risk and late outcome? Should stress testing be routinely performed before operation in all patients? To what extent do careful monitoring and intensive medical therapy decrease perioperative morbidity and mortality in high risk patients? What is the role of coronary artery bypass surgery or angioplasty in patients with peripheral vascular disease and when should it be performed? Answers to these important questions are not yet available and in the absence of definitive randomized trials of different management strategies, decisions must be based on extrapolation from data compiled primarily from individual reported series. Such data then need to be interpreted within the framework of the results and experience of a specific physician or in a specific institution.

Recent advances have extended the surgical correction of both coronary and peripheral vascular disease to older patients. Thus, the issue is of increasing importance as the population ages (1). Although old age itself should not be considered synonymous with coronary artery disease, the incidence of the latter increases strikingly in the elderly (2). Inevitably, we will be faced with a rapid expansion of a population in which the combination of advanced age and diffuse atherosclerosis will limit the potential for coronary or peripheral revascularization to alter long-term survival significantly. Paradoxically, the development of newer imaging techniques has enabled the earlier recognition and treatment of peripheral vascular disease in younger patients (3,4). It is in this younger subgroup that the impact of coronary artery disease on late outcome is increasing in importance, as is the potential for coronary revascularization to improve outcome.

Prevalence of Coronary Artery Disease in Patients With Peripheral Vascular Disease

An early Mayo Clinic study (5) in patients <60 years of age with "arteriosclerosis obliterans" seen between 1939 and 1949 drew attention to the association between coronary and peripheral vascular disease. The collective reported
experience was summarized recently by Hertzer (6) in a comprehensive analysis representing >10,000 patients in approximately 50 series. Among patients with abdominal aortic aneurysms, carotid artery disease or lower limb ischemia, clinical evidence of coronary artery disease was present in approximately 50% (range 22% to 70% in individual series) (Fig. 1). The variation is due to multiple factors, including referral bias and changes in medical surveillance techniques for coronary artery disease over time and at different centers.

Significant or "serious" coronary artery disease was present in approximately 60% of the patients undergoing angiography, although the definition of severity varied among the series (6). In a consecutive series (7) of 1,000 patients at the Cleveland Clinic, among those without clinical indications of coronary artery disease, the incidence of significant angiographic coronary disease (stenosis >70%) was as high as 37% compared with 78% in those with coronary artery disease suspected clinically. Moreover, among patients with significant angiographic coronary artery disease, multivessel disease was present in the majority (7–9).

**Impact of Coronary Artery Disease on Outcome After Peripheral Vascular Surgery**

*Perioperative mortality.* Cardiac death (particularly fatal myocardial infarction) accounts for 40% to 60% of early postoperative deaths (6,10–14). The high mortality rate associated with postoperative myocardial infarction after noncardiac surgery was recognized by Master et al. (15) in 1938. In patients with suspected coronary artery disease who undergo peripheral vascular surgery, the perioperative mortality rate is approximately four times higher than in those without coronary artery disease and perioperative morbidity is markedly increased (Table 1). In an analysis (6) of six series totaling approximately 4,500 patients, perioperative cardiac events occurred in 11% (mean) of patients with clinical evidence of coronary artery disease and in only 1.7% of patients without it. In a population-based study (13) of 131 patients undergoing elective abdominal aortic aneurysm repair between 1971 and 1987, perioperative complications occurred in 21% and 7% of patients with and without overt but stable cardiac disease, respectively.

**Carotid and peripheral vascular surgery versus abdominal aortic surgery.** There is evidence to suggest that the substantial impact of coronary artery disease on perioperative outcome may not necessarily apply to a similar degree in patients undergoing carotid endarterectomy (a much less formidable surgical procedure) (6,16) or to the more contemporary experience with repair of abdominal aortic aneurysm (4,14,17–20). Similar data are not available for patients undergoing surgery for lower limb ischemia, but it is likely that the adverse effect of preoperative coronary artery disease on early outcome will be less in patients undergoing the more peripheral procedures (such as femoropopliteal reconstruction as opposed to aortoiliac reconstruction). However, in one large series (21), the perioperative event rate in patients undergoing peripheral vascular procedures exceeded that among patients undergoing aortofemoral bypass or abdominal aortic aneurysmectomy.

**Late Outcome**

*Late mortality.* Early natural history studies that antedate direct arterial reconstruction emphasized that the vast majority of deaths in patients with peripheral vascular disease were cardiac related. In the Mayo Clinic study (5) of patients with "arteriosclerosis obliterans" seen between 1939 and 1949, late survival was worse for patients with aortoiliac disease than for those with femoropopliteal disease and the survival in both groups was markedly poorer than in an age- and gender-matched control group. In the longitudinal and prospective Whitehall study (22) of 18,388
civil servants in London, intermittent claudication was independently related to late cardiovascular mortality. In a prospective population-based study (23) from the University of California–San Diego, a history of probable claudication doubled the risk of death. Even isolated small vessel peripheral arterial disease has been shown (24) to be an independent risk factor for future cardiovascular events.

More recent data highlight the important effect of coronary artery disease on late mortality. Irrespective of the underlying peripheral vascular diagnosis, 40% to 60% of late deaths were cardiac related (6,14,25–32). Furthermore, late mortality is approximately twice as high in patients with “suspected” coronary artery disease as in patients without overt coronary artery disease (Table 1). This is reinforced by a Mayo Clinic study (32) of referral patients undergoing repair of abdominal aortic aneurysm. In the absence of hypertension or clinical cardiac disease, the observed 10-year survival rate (54%) among 30-day surgical survivors was almost identical to that in age- and gender-matched control patients.

Abdominal aortic aneurysm. In contrast, population-based data from Olmsted County, Minnesota (13) strongly emphasize the markedly adverse impact of preexisting coronary artery disease on the late outcome after abdominal aortic aneurysm repair. In perioperative survivors, the cumulative incidence of cardiac events at 8 years was 61% and 15% for patients with and without suspected or overt coronary artery disease, respectively. Moreover, the 8-year survival rate (59%) in patients without suspected coronary artery disease was only slightly less than that in an age- and gender-matched control population. This contrasts strikingly with the results in patients with suspected or overt heart disease—the 8-year survival rate was 34%, approximately half of that in age- and gender-matched control subjects (61%). By multivariate analysis, the presence of suspected but uncorrected coronary artery disease was associated with a nearly twofold increase in risk of death and a fourfold increase in risk of late cardiac events. Such data are particularly disturbing given that the symptoms among patients with suspected coronary artery disease were considered to be mild and stable to begin with.

Changing technology has led to the earlier diagnosis of abdominal aortic aneurysm and the median size of clinically recognized aneurysms is decreasing (3). Because it is assumed that rupture is less common with smaller aneurysms, the issue of coronary artery disease is important, particularly in younger patients in whom an abdominal aneurysm may be a marker of aggressive, “premature” vascular and coronary artery disease (3,4). This is relevant to the results of another Mayo Clinic study (14) in which survival after abdominal aortic aneurysm repair in a referral group was compared with survival in age- and gender-matched control subjects; the poorest relative survival (ratio of observed survival to survival in the control group) was in the youngest patients (those <60 years).

Carotid endarterectomy. Late overall mortality appears to be lower in perioperative survivors of carotid endarterectomy than in patients who have undergone abdominal aortic aneurysmectomy or surgery for lower limb ischemia. Nonetheless, a similar pattern is seen—preexisting clinical coronary artery disease has a markedly detrimental influence on late survival (31,33).

The impact of cardiac risk factors on late outcome after endarterectomy in patients without overt clinical heart disease was assessed in a recent large series (31). Over a 15-year period, late mortality and rate of myocardial infarction were markedly less frequent in patients without the cardiac risk factors of diabetes, cigarette use or hyperlipidemia at the time of initial operation. This study emphasized the deleterious impact of overt coronary artery disease on survival and the influence of coronary artery risk factors in patients without “overt” coronary artery disease at presentation.

Lower limb surgery. In patients undergoing surgery for lower limb ischemia, late outcome is similarly related to the presence of coronary artery disease (11,34,35), diabetes mellitus (34) and diffuse distal occlusive disease (17,36–38). The association between diffuse distal occlusive disease and an adverse outcome suggests that this vascular disease may be a marker for more extensive coronary artery disease.

Effect of Prior Coronary Artery Bypass Surgery on Prognosis

During the last 20 years, several randomized trials and registry and data bank studies (39,40) have provided a wealth of comparative data on the efficacy of coronary artery bypass surgery and medical therapy in multiple subsets of patients with coronary artery disease. The results of these studies are remarkably consistent and the message is clear: the sicker the patient, as judged by severity of ischemia (41–43) or left ventricular dysfunction (39,43–45) and the number of diseased vessels (39–42), the greater the relative benefit of surgery over medical therapy (46). It is evident that many patients with peripheral vascular disease are in a high risk category and, as such, are candidates for coronary revascularization. In the multicenter randomized European Coronary Surgery Study (47), the 8-year survival benefit of surgery over medical therapy was substantially greater in patients in whom peripheral vascular disease was present (85% vs. 52% survival rate) than in patients without vascular disease (90% vs. 81% survival rate). What is noteworthy is the particularly poor 8-year survival rate (only 52%) with medical therapy in patients with peripheral vascular disease.

Risk of Noncardiac Surgery After Coronary Bypass Surgery

Operative mortality. There is evidence from nonrandomized studies (9,11,13,48–54) to suggest that the risk of noncardiac surgery is low after prior coronary artery bypass
surgery. In the Coronary Artery Surgery Study (CASS) Registry (34), the mortality and morbidity rates for noncardiac surgical procedures in patients who had had prior coronary artery bypass surgery were similar to those in patients without significant coronary artery disease on angiography. In patients undergoing vascular surgical procedures, the mean operative mortality rate in seven series (6) totaling 1,237 patients was only 1.5% among patients with prior coronary artery bypass surgery, similar to the 1.3% mortality rate in patients without overt coronary artery disease and substantially lower than the 6.8% mortality rate in patients with suspected but uncorrected coronary artery disease (Table 1).

**Late mortality after vascular surgery.** This also appears to be lower in patients who have undergone prior coronary artery bypass surgery (6,14). The 5-year mortality rate estimated from the overview by Hertz (6) was 21% in patients with prior coronary artery bypass surgery, 20% in patients without "overt" coronary artery disease and 41% in patients with suspected coronary artery disease but no prior revascularization (Table 1). In the Cleveland Clinic experience (25,51) in 216 patients with peripheral vascular disease and "severe, correctable" coronary artery disease, 5-year survival appeared to be substantially enhanced by prior coronary artery bypass surgery, particularly in men and non diabetic patients.

**Effect of peripheral vascular disease on coronary bypass operative mortality.** The protective shield of prior coronary artery bypass surgery has a price. The mean age of patients undergoing vascular surgery is approximately 65 years. In the CASS Registry (55), the operative mortality rate was 5.2% in patients ≥65 years old and 1.9% in patients <65 years old. In the more contemporary Cleveland Clinic experience (56), the operative mortality rate was 0.7%, 2% and 4.7% in patients aged <65, 65 to 74 and ≥75 years, respectively. In a recent Mayo Clinic series (57), after isolated coronary artery bypass surgery in 159 octogenarians, the perioperative mortality rate was 10.7%; it was 4% in patients without other medical conditions and 14.8% and 16.7% in patients with cerebrovascular and peripheral vascular disease, respectively. Furthermore, at the Cleveland Clinic (7) between 1978 and 1983, the operative mortality rate after isolated coronary artery bypass surgery in patients with peripheral vascular disease was 5%. Even among a younger group of patients, approximately 2,500 patients in the CASS Registry with stable angina (of whom many have diffuse multivessel disease, remains to be seen. In a recent Mayo Clinic series (57), after isolated coronary artery bypass surgery in 159 octogenarians, the perioperative mortality rate was 10.7%; it was 4% in patients without other medical conditions and 14.8% and 16.7% in patients with cerebrovascular and peripheral vascular disease, respectively. Furthermore, at the Cleveland Clinic (7) between 1978 and 1983, the operative mortality rate after isolated coronary artery bypass surgery in patients with peripheral vascular disease was 5%. Even among a younger group of patients, approximately 2,500 patients in the CASS Registry with stable angina (of whom many have diffuse multivessel disease, remains to be seen.

**Summary.** The presence of peripheral vascular disease suggests that a patient is in a subset with high risk coronary artery disease. In such patients, the potential benefit from coronary artery bypass surgery (particularly with regard to survival) is enhanced and the desirability of prior revascularization is readily understandable (39,43,44,46,47). Nonetheless, it must also be accepted that perioperative mortality and morbidity after coronary bypass surgery are increased in these patients. Although this is primarily a function of age, the presence of peripheral vascular disease is an important and independent determinant of a poorer late outcome after bypass surgery, even though this outcome may be substantially better than that obtained with medical therapy alone.

### Preoperative Evaluation

Meticulous preoperative evaluation with attention to concomitant medical conditions is a crucial part of the management of the patient who is to undergo vascular surgery. The immediate objective is to identify high risk patients who will need careful cardiac surveillance and monitoring (before, during and after operation), prior coronary artery revascularization or combined coronary and peripheral vascular procedures. It also is important to identify the factors that determine late prognosis and management.

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**Table 2. Effect of Noncardiac Vascular Disease on Survival After Coronary Artery Bypass Surgery**

<table>
<thead>
<tr>
<th>Vascular disease</th>
<th>Overall</th>
<th>Event-free</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Mild angina</td>
<td>68</td>
<td>86</td>
</tr>
<tr>
<td>Severe angina</td>
<td>71</td>
<td>83</td>
</tr>
<tr>
<td>Duke series</td>
<td>69</td>
<td>82</td>
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*aSix years in the Coronary Artery Surgery Study (CASS) and 8 years in the Duke series. Data from Gersh et al. (39).*
Clinical Evaluation

Preoperative risk factors. In a comprehensive recent review, Mangano (52) discussed the impact of the traditional risk factors on the outcome of noncardiac surgery. Whereas few would dispute that recent prior myocardial infarction (59–62), age (63) and congestive heart failure (63,64) are established preoperative risk factors, the role of other factors such as hypertension, a history of angina pectoris, diabetes, ventricular extrasystoles and an abnormal 12-lead electrocardiogram (ECG) is more controversial (52,65). Differences in the patient groups included in multiple studies that span 35 years, during which there have been profound changes in medical, anesthetic and surgical management, undoubtedly account for many of the discrepancies among the published series (52).

A systematic and laudable approach to the preoperative evaluation of patients undergoing noncardiac surgical procedures was developed by Goldman et al. (63) in 1977. Although their multifactorial cardiac risk index has been validated prospectively (66), it probably underestimates perioperative risk in patients undergoing vascular surgery, who frequently have concomitant coronary artery disease (67,68). Only 16% of the patients studied by Goldman et al. (63) underwent aortic or peripheral vascular surgery, only 27% had clinical evidence of coronary artery disease and only 7% had a history of prior myocardial infarction or angina. Therefore, it is not surprising that Goldman et al. did not find stable angina to be a significant predictor of outcome. Consequently, neither the presence nor the severity of angina pectoris is taken into account in their calculation of the risk score, although these factors were incorporated into a modified cardiac risk index by Detsky et al. (69,70).

Left ventricular function. The lack of quantitative measurements of left ventricular function is another limitation of the preoperative cardiac risk indexes developed in the 1970s. Clinical evidence of prior congestive heart failure undeniably identifies patients at very high risk (64), but interobserver agreement over the presence or absence of the standard clinical signs of heart failure (S3 gallop, distended neck veins and pulmonary rales) is disappointingly poor, as is the correlation between clinical signs and measurement of ejection fraction (Fig. 2) (71). In another prospective study (72) of patients with chronic heart failure, the combination of rales, edema and distended neck veins was highly specific for pulmonary capillary wedge pressure ≥22 mm Hg, but the sensitivity was only 58%.

These data do not diminish the importance of a careful initial clinical evaluation in addition to routine laboratory testing. However, in high risk patients such as those undergoing vascular surgery, in whom underlying cardiac disease has a substantial impact on both early and late outcome, the additional prognostic information provided by stress testing is needed.

Figure 2. Correlation between physical signs of congestive heart failure and left ventricular ejection fraction (LVEF) in patients with myocardial infarction. Relatively few patients had two or more physical signs of cardiac failure. In the majority who had no or one physical finding, the correlation with ejection fraction was poor. The shaded area represents the normal range of ejection fraction. (From Gadsbøll et al. [71], with permission of the European Society of Cardiology.)

Laboratory Evaluation

Rest and exercise electrocardiography. In adult patients, the 12-lead ECG is almost universally recorded during the preoperative period. Despite its common use, few prospective studies evaluating either the efficacy or the cost-effectiveness of a routine preoperative ECG have been reported. In a strict multivariate analysis of 200 patients undergoing elective noncardiac surgery, Carlener et al. (73) found an abnormal rest ECG (defined as ST-T wave abnormalities, left ventricular hypertrophy or the presence of Q waves) to be the only independent predictor of postoperative cardiac events. However, others (64,74) have not reproduced these results.

In patients requiring vascular surgery, up to 35% of patients with a normal rest 12-lead ECG will have an abnormal exercise ECG and some will have postoperative cardiac ischemic events (75,76). These data support the view that although the 12-lead ECG may be useful for screening general surgery patients, functional cardiac testing is necessary for adequate risk stratification in higher risk patients with peripheral vascular disease.

Treadmill exercise test. The feasibility of treadmill exercise testing has been examined in patients undergoing general (73) and vascular (75,77,78) surgery. Clearly, treadmill exercise testing will not be suitable in patients who have severe claudication or rest ischemia or an amputated limb. In patients with a lesser degree of claudication who undergo treadmill exercise testing, careful attention to target achievement (percent functional aerobic capacity or maximal heart rate) is needed. In one study (75), 45 of 130 patients undergoing peripheral revascularization were unable to achieve a target heart rate for noncardiac reasons. Such patients continued to have an undefined risk of perioperative myocardial infarction and remained susceptible to perioperative ischemic episodes (75).
Both the ability to reach an adequate exercise work load and the ECG response to treadmill exercise testing have been important in identifying patients at high or low risk of perioperative cardiac events (75,77,78). Thirty-five patients who achieved >75% of maximal predicted heart rate and had a normal exercise ECG had no perioperative myocardial infarction (75). However, patients with clearly abnormal treadmill exercise test results had a 16% incidence of perioperative myocardial infarction. Furthermore, among 27 high risk patients (positive ECG at low work load), 7 had a perioperative myocardial infarction, which was fatal in 5. Similar successful risk stratification in patients undergoing vascular surgery was reported in a European series (77), but these results have not been generalizable to patients undergoing general surgery, which may reflect a lesser prevalence of severe coronary artery disease in the latter patients (73).

**Radionuclide angiography: role of left ventricular function.**

In a retrospective review (79) of 100 patients undergoing lower limb revascularization, radionuclide angiography at rest was found to accurately predict the risk of perioperative myocardial infarction. On the basis of ejection fraction criteria, incremental increases in the incidence of perioperative myocardial infarction were noted: 0% if ejection fraction was >56%, 19% if it was 36% to 55% and 75% if it was <36%. Additionally, radionuclide angiography has been useful in making the decision to perform preoperative coronary angiography and coronary artery bypass surgery (53). Nonetheless, others (68,74,80-82) have not confirmed the predictive utility of the preoperative left ventricular ejection fraction at rest in patients undergoing abdominal aortic aneurysm repair. In one study (80) despite an overall perioperative myocardial infarction rate of 7%, stratification of patients on the basis of ejection fraction alone also failed to identify patients with perioperative infarction, although an ejection fraction of <35% was associated with a significantly poorer long-term outcome.

In a Mayo Clinic study (81) of the clinical utility of supine exercise radionuclide angiography in 114 patients undergoing peripheral vascular surgery, eight perioperative cardiac events occurred in the subgroup of 63 patients unable to achieve a work load of 400 kg·m/min (4.5 METs for a 70 kg person). Multiple other variables including rest ejection fraction and ejection fraction response to exercise failed to predict perioperative events independently. Similar findings were noted in another study (74) of patients >65 years old undergoing noncardiac (although not necessarily vascular) surgery, emphasizing the importance of a functional limitation due to ischemia as opposed to rest left ventricular function alone in the prediction of perioperative events (68,82).

**Dipyridamole thallium-201 scintigraphy.**

Intravenous dipyridamole thallium-201 scintigraphy has provided an important addition to the prognostic capability of nuclear imaging. In patients unable to exercise adequately, intravenous infusion of dipyridamole at 0.56 mg/kg (the usual dose in clinical studies) causes a significant increase in coronary blood flow in regions perfused by normal coronary arteries but only a minimal increase in zones subtended by a stenotic vessel (83,84). The ability to detect regions of abnormal coronary flow reserve in patients unable to exercise has focused considerable attention on the technique and the risk stratification of patients undergoing peripheral vascular surgery (85-89). The technique is safe; there were only 10 major adverse events (including 2 fatal and 2 nonfatal myocardial infarctions) in a recent series of 3,911 cases (90). Side effects, including bronchospasm, chest pain and dizziness, are frequent and the 4.6% incidence of hypotension mandates caution, particularly in patients with carotid artery disease. It was reassuring, however, that in nearly all patients, intravenous administration of aminophylline promptly relieved symptoms (90).

In 1985, Boucher et al. (91) reported on 48 patients who underwent dipyridamole thallium-201 imaging before peripheral vascular surgery. Eight of the 16 patients with thallium redistribution (indicative of underperfused but viable myocardium on planar imaging) had significant perioperative cardiac ischemic events (Table 3) (91-96). In contrast, none of the 32 patients with either a normal scan or a fixed perfusion deficit (generally indicating prior myocardial infarction but no concomitant active ischemia) had a cardiac event in the postoperative period. Six other patients who had a thallium-201 redistribution defect underwent coronary...

<table>
<thead>
<tr>
<th>Source</th>
<th>With Redistribution</th>
<th>With Normal Scans or Fixed Defects</th>
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<tbody>
<tr>
<td></td>
<td>Events</td>
<td>No. of Pts</td>
</tr>
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<td>Boucher et al. (91)</td>
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<td>Leppo et al. (94)</td>
<td>14</td>
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<td>Eagle et al. (95)</td>
<td>25</td>
<td>82</td>
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<tr>
<td>Lapeyre et al. (96)</td>
<td>9</td>
<td>46</td>
</tr>
<tr>
<td>Total*</td>
<td>61</td>
<td>214</td>
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*Predictive values: positive 28%; negative 98%. MI = myocardial infarction; Pts = patients.
angiography, which confirmed severe multivessel disease in all patients. In this study, the only clinical or scintigraphic independent predictor of postoperative cardiac events was the presence of a thallium-201 redistribution defect.

The prognostic capability of dipyridamole thallium-201 scintigraphy can be extended to many different subsets of patients with coronary artery disease (Table 3) (97). Pooled data from several studies (76,91–96) illustrate that the technique is highly sensitive (90% [61 of 68 patients]) but only moderately specific (59% [305 of 519 patients]) in the preoperative evaluation of vascular surgery patients (Table 3). The positive predictive accuracy of dipyridamole thallium-201 scanning is enhanced by semiquantitative techniques aimed at assessing the extent of thallium redistribution (98,99).

In an attempt to place the dipyridamole thallium study into clinical perspective, Eagle et al. (95) combined the prognostic information from scintigraphy with important clinical predictors of events—namely, Q waves on the ECG, history of premature ventricular extrasystoles, diabetes, advanced age and angina pectoris. Preoperative imaging was most useful in predicting outcome in those patients considered to be at intermediate risk on the basis of one or two clinical predictors, whereas among those with no risk factors, the event rate was extremely low (3.1%) irrespective of the scintigraphic findings. In contrast, the 20 patients at high risk (three or more risk factors) had an event rate of 50%, and this rate did not differ significantly between those with or without a redistribution defect. Two other studies (100,101) in which a fixed defect was considered to be synonymous with a reversible defect also implied that dipyridamole thallium-201 imaging was less useful in patients considered to be at low risk. However, other investigators (94,102–104) noted that scintigraphic variables were superior to clinical factors in predicting events in their entire patient groups.

Despite the data presented in Table 3, the presence of a fixed defect at 4-h imaging should not necessarily lull one into a false sense of security. McEnroe et al. (68) reported a high (47%) perioperative cardiac event rate among 15 patients undergoing vascular surgery who had a fixed defect at 4-h imaging. This finding is not surprising. There is an accumulating body of evidence (105–111) that 15% to 20% of apparently fixed defects on thallium scans at 4 h may represent viable myocardium as determined by more sensitive imaging techniques. However, despite these disparities in segmental analyses, the great majority of individual patients are correctly categorized as having ischemic myocardium in one or more other areas. All of these imaging techniques are promising and include computed poston emission tomography (105), late redistribution imaging within 18 to 72 h (106), single photon emission computed tomography (107–109), quantitative analysis of thallium kinetics (112) and imaging with a second injection of thallium-201 given after the initial redistribution images are recorded (110,111). It is likely that the use of these methods will enhance the predictive ability of stress testing in patients being considered for vascular surgery, but this remains to be determined in studies in larger numbers of patients.

Recent evidence has drawn attention to the value of dipyridamole thallium-201 scintigraphy for late prognosis. In a large series (99) in which survivors of elective vascular surgery were followed up for a mean of 32.5 months, the strongest factor predicting late cardiac death or events was the presence of a fixed defect on dipyridamole thallium scintigraphy.

Ambulatory ECG monitoring. Raby et al. (113) use 24- to 48-h Holter ECG monitoring to evaluate prospectively 176 consecutive patients undergoing vascular surgery. ST segment depression of 1 mm occurring 60 ms after the J point and persisting for ≥60 s was considered to be evidence of preoperative myocardial ischemia. Of the 32 patients with such ischemic episodes, 12 had significant postoperative cardiac events. In contrast, only 1 of the 144 patients with no preoperative ischemia had a postoperative cardiac event. In a multivariate analysis (113), preoperative ischemia was the most powerful predictor of postoperative ischemia (relative risk 24.4; 95% confidence interval 6.8 to 88; sensitivity 92%; specificity 88%). A much smaller study (114) using shorter periods of preoperative monitoring produced similar findings. These preliminary but promising data warrant further evaluation, but the technique is limited to patients without repolarization abnormalities on the rest ECG.

A recent important study (115) of 474 patients with or at high risk of coronary artery disease undergoing noncardiac surgery assessed the importance of myocardial ischemia by continuous ECG monitoring, beginning 2 days before surgery and continuing for 2 days thereafter. The greatest frequency of myocardial ischemia occurred during the postoperative period (41% of episodes) compared with 20% preoperatively and 25% intraoperatively. In a multivariate analysis (115), early postoperative ischemia was the most important correlate of all adverse cardiac outcomes (2.8-fold increase) and of a cardiac ischemic event (9.2-fold increase). Moreover, in another large study (116), ambulatory ECG monitoring for myocardial ischemia was shown to be a significant independent predictor of 1- to 2-year prognosis as opposed to perioperative outcome alone.

Other techniques under development that have potential applicability include thallium scintigraphy with atrial pacing (117), dobutamine echocardiography (118) and the use of adenosine in place of dipyridamole in thallium scintigraphy.

Comment. The choice of a functional cardiac test in patients undergoing vascular surgery may be very complex. Test applicability for an individual patient will be contingent on the severity of cardiac symptoms, ability to ambulate, associated medical and surgical conditions, baseline ECG abnormalities and institutional expertise with specific diagnostic techniques. Knowledge of the test's positive and negative predictive values in patients selected to undergo vascular surgery is crucial. Ideally, the perfect test would include an assessment of both myocardial perfusion and left ventricular function, but the appropriate test or tests actually
favorable and several series (18,19,62) have documented low
dynamic fluctuations during aortic cross-clamping, aortic
en...

Figure 3. Preoperative hemodynamics in 130 patients undergoing
elective abdominal aortic surgery. "High risk" refers to patients
with a preoperative history of cardiac disease or hypertension. The
shaded area represents the normal range of left ventricular function.
Only 20% of high risk patients (solid circles) were within the normal
limits of the curve compared with 70% of low risk patients (open
circles). LVSWI = left ventricular stroke work index; PAo =
pulmonary artery occluded pressure. (From Cohen et al. [18], with
permission of Reed Publishing USA.)

Management Strategies

A standardized approach to the high risk patient cannot
be advocated at this time. Moreover, the absence of defini-
tive data from randomized trials must be emphasized.
Clearly, a policy of routine prophylactic coronary revascular-
ization before vascular surgery is impractical and could be
dangerous. Moreover, in the current era, it is evident that
patients with serious cardiac disease can undergo extensive
vascular procedures with relative safety, albeit at an in-
creased risk. The preoperative identification of high risk
patients is crucial. Intensive medical therapy with monitor-
ing can stabilize the patient preoperatively, potential intra-
operative problems can be anticipated and during the post-
operative period, careful hemodynamic monitoring and
continued cardiac surveillance are mandatory.

Perioperative hemodynamic monitoring. Although there
are no definitive data to substantiate the role of hemody-
namic monitoring, its use is logical, clinical impressions are
favorable and several series (18,19,62) have documented low
morbidity and mortality in high risk patient subsets. Preoper-
ative invasive monitoring has revealed that some patients
have significant hemodynamic derangements; in these, cor-
rection of hypovolemia or cardiac failure is likely to be
beneficial (Fig. 3) (18,19,119,120). Moreover, major vascular
procedures are associated with extensive and labile hemo-
dynamic fluctuations during aortic cross-clamping, aortic
declamping, hemorrhage, transfusion, fluid shifts due to
sequestration and mobilization. Most would agree that in
this setting, the careful use of invasive monitoring outweighs
the potential risks (18,19,121). Of emerging interest are
technologies aimed at the detection of transient myocardial
ischemia during the perioperative period. These include ST
segment monitoring (122,123), transesophageal echocardiog-
raphy (122,124) and radionuclide monitoring of left ventricu-
lar function (125). In patients undergoing coronary artery
bypass surgery, the development of wall motion abnormali-
ties on transesophageal echocardiography is more sensitive
than the ECG as an indicator of ischemia (122).

Indications for Coronary
Artery Revascularization

The decision as to which patient should undergo coronary
revascularization in addition to vascular surgery depends on
many factors, including age, the presence and severity of
other medical conditions, the severity of ischemia, the
number of diseased coronary arteries and the degree of left
ventricular dysfunction. Consideration for vascular surgery
alone is not an indication for coronary revascularization, but
its timing may be influenced by the nature of the intended
vascular procedure. More limited procedures—for example,
carotid endarterectomy and femoropopliteal reconstruction—
can be accomplished with minimal morbidity in the
stable cardiac patient, provided that careful attention is
given during the preoperative and perioperative periods.
Consequently, if clinically indicated, coronary revascular-
ization can be performed later after vascular surgery.

Conversely, although more extensive procedures—for ex-
ample, abdominal aortic aneurysm repair or aortoiliac reconstruc-
tion—can be performed with relative safety in a
cardiac patient, perioperative morbidity is increased com-
pared with that associated with minor procedures. With this
in mind, if it has already been decided that a patient is a
candidate for coronary revascularization, it appears to be
reasonable to perform this first and to perform the elective
vascular procedure at a later date.

Approaches

Patient without overt heart disease. In the ambulatory
patient without overt heart disease, perioperative morbidity
and mortality are very low, particularly in nondiabetic
patients <70 years old (95). The bulk of the available data
(82,95,100,101) suggest that preoperative stress testing is not
necessary in all patients (specifically not in those at low risk)
if the sole objective of the test is to evaluate perioperative
risk. Nonetheless, the powerful impact of coronary artery
disease on late prognosis and its close association with
peripheral vascular disease (even among patients without
clinically suspected coronary artery disease) reinforce the
role of stress testing at some time in the patient's course,
even if during the period of convalescence (82). In this
setting, the stress test provides important prognostic infor-
mation in addition to serving as a baseline for comparisons at
regular intervals during follow-up study (82).
Many patients with peripheral vascular disease are relatively inactive, which may mask the presence of symptomatic coronary artery disease. Despite the apparent absence of overt heart disease in these patients, preoperative stress testing using dipyridamole thallium-201 or Holter ECG monitoring is indicated. Subsequent management should be dictated by the results of the stress test and will involve the decision to perform angiography with a view toward coronary revascularization as opposed to proceeding directly to vascular surgery with or without intensive pre- and perioperative monitoring.

**Patients with overt “stable” coronary artery disease.** A strong case can be made for preoperative stress testing in all patients with stable coronary artery disease and abdominal aortic aneurysm or lower limb ischemia. In patients with a significantly positive test, preoperative coronary angiography and, if necessary, coronary revascularization are indicated. Both stress testing and coronary angiography may identify subsets of patients in whom coronary revascularization is not needed, but in whom potential perioperative problems can be anticipated and perhaps prevented by optimization of medical therapy and intensive monitoring.

**Patients with carotid artery disease** should be approached differently because the development of exercise-induced hypotension (which may be particularly dangerous in the presence of a severe carotid stenosis) is increased in patients with significant coronary artery disease. Furthermore, perioperative morbidity and mortality after coronary endarterectomy appear to be lower in patients with stable coronary artery disease than after more extensive procedures on the abdominal aorta. Consequently, in patients who have coronary artery disease considered to be stable and who are to undergo carotid endarterectomy, preoperative stress testing can be avoided but should be performed before hospital discharge because the impact of coronary artery disease on the long-term outcome after carotid endarterectomy is substantial.

**Patient with unstable or severely symptomatic coronary artery disease.** Patients with an unstable coronary artery syndrome or those with severe ischemic and peripheral vascular disease can be categorized into two subgroups according to the stability or instability of the peripheral vascular disease. In those being considered for an “elective” vascular procedure, the first step is to stabilize the cardiac symptoms. This is followed by angiography with a view toward coronary revascularization. In some patients, the approach is dependent in part on the clinical indications for vascular surgery, and the most prudent option may be to defer or cancel the vascular procedure entirely. In others in whom coronary revascularization is performed, this should be followed by a “staged” vascular repair, either during the same hospitalization or at a later date, dependent in part on the underlying vascular diagnosis (126). In the relatively few patients with both unstable coronary and peripheral vascular disease, a combined procedure will be necessary.

**Conclusions**

There is a close association between coronary and peripheral vascular disease and the evaluation and management of such patients are complex. Undoubtedly, the presence of coronary artery disease in patients undergoing peripheral vascular surgery identifies those at high risk with regard to both early and late outcome. In certain subgroups of patients, coronary revascularization is likely to improve the outcome, but the mortality rate after coronary artery bypass surgery is increased and the long-term outcome is not as good as in patients without peripheral vascular disease. Definitive guidelines for the management of patients with combined coronary and vascular disease are not available, but it is becoming increasingly apparent that stress testing plays an important role in most subsets of patients.

The key to successful peripheral vascular surgery is a close collaboration among the cardiologist, vascular surgeon, anesthesiologist and, for many patients, the cardiac surgeon. Because atherosclerosis is a progressive disease and the association between coronary and peripheral vascular disease is strong, the interaction between the cardiologist and the vascular surgeon should continue after the patient is discharged from the hospital and during subsequent postoperative evaluations.

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