Myocardial infarction and stroke are the first and third leading causes of death in the United States, and together they affect approximately 20 million Americans between the ages of 65 and 80 years of age. Stroke and myocardial infarction are clearly interrelated events since they share the same risk factors and similar pathogenic mechanisms. The association between carotid and coronary artery disease is well known, and approximately 50% of patients under consideration for peripheral vascular reconstruction have clinical or angiographic manifestations of underlying coronary artery involvement. The leading cause of death in patients with cerebral infarction or transient ischemic attack is myocardial infarction rather than recurrent stroke or other neurological disease. Population surveys conducted to determine the natural history of asymptomatic cervical bruits have shown that even these nonspecific indications of extracranial arterial disease are coincident with a two to three times greater incidence of fatal cardiac complications than would otherwise be anticipated.

Goldman et al and VonKnorrning have demonstrated that fatal myocardial infarction occurs with predictable frequency after virtually any noncardiac operation in patients suspected of having coronary artery disease. Ennix et al have reported an operative mortality of 18% for carotid endarterectomy in patients known to have angina pectoris. The Cleveland Vascular Society reported an early mortality after carotid endarterectomy in northeastern Ohio of 1.2% for all patients. However, increased operative morbidity and mortality have been observed among patients with symptomatic cardiac disease who have required carotid endarterectomy at the Cleveland Clinic. In a report of 390 operations, the early mortality rate was 4% among those who had either angina or prior myocardial infarction compared with only 0.5% in all other patients. Also, in our experience as well as that of others, most late deaths after carotid endarterectomy are caused by myocardial infarction. Furthermore, the number of patients who die from myocardial infarction usually exceeds the total of both fatal and nonfatal strokes. Actuarial survival after carotid endarterectomy is significantly worse among patients with diabetes, angina pectoris, prior myocardial infarction, or ischemic changes on standard electrocardiograms (ECGs).

Despite the importance of myocardial ischemia, evaluation of coronary artery disease is often neglected in the management of patients with stroke or carotid artery disease. We believe that a coronary evaluation is paramount in such patients and that the coexistent nature of carotid and coronary artery disease cannot be ignored. Since a review of the evaluation of extracranial carotid artery disease is beyond the scope of this paper, our preferred approach will be discussed.

Evaluation

Although it is not uniformly accepted, most patients with symptomatic carotid artery disease undergo carotid arteriography. Asymptomatic disease can either be evaluated with a noninvasive study such as carotid duplex scanning or followed clinically without objective evaluation. Our bias is to evaluate most patients with asymptomatic carotid disease noninvasively with carotid ultrasound or, occasionally, intravenous digital subtraction angiography.

If extracranial carotid atherosclerosis has been identified, prospective evaluation of coronary disease is recommended, using guidelines developed by the Vascular Surgery and Vascular Medicine Departments at the Cleveland Clinic. These guidelines were established as a result of evaluating 506 patients with extracranial cerebrovascular disease by coronary angiography between 1978 and 1982. The results of this investigation indicated that approximately 35% of all patients with symptomatic cerebrovascular disease or asymptomatic carotid bruits had severe coronary artery disease that appeared to warrant myocardial revascularization or was already inoperable (Table 1). Severe coronary artery disease was especially common among patients fulfilling conventional clinical criteria for ischemic heart disease. Nearly half (46%) of the patients with a positive cardiac history or an abnormal ECG had severe coronary artery disease on coronary angio-

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raphy. It is perhaps more noteworthy that 18% of patients without clinical suspicion of cardiac disease had severe coronary artery disease. A convincing history of angina pectoris was the most reliable indicator of severe, correctable coronary artery disease since 53% of this subset were eligible for coronary artery bypass. Although the incidence of inoperable coronary artery disease was directly related to advancing age, severe, correctable coronary lesions were documented with comparable frequency in all age groups. Inoperable coronary artery disease was more common in patients with diabetes.

Cardiac Assessment

The initial approach for the investigation of coronary disease includes the history, physical examination, and ECG. In the presence of an abnormal ECG or angina pectoris, coronary angiography is recommended. Patients with stable mild angina pectoris or asymptomatic patients undergo stress electrocardiography with thallium-201 perfusion scintigraphy. Using noninvasive methods, Charuzi et al. confirmed the presence of coronary artery involvement among all patients undergoing stress electrocardiography.

At least two other investigations have assessed the predictive value of a positive stress test in patients scheduled for peripheral vascular procedures. Gage et al. evaluated 22 patients who required lower extremity revascularization: 11 had abnormal stress tests, and six others (27%) were unable to achieve maximum exercise because of claudication or other factors. Weiner et al. found that conventional stress testing has limited value among patients with other convincing indications of coronary artery disease. In 2,045 participants in the Coronary Artery Surgery Study protocol, angiography confirmed the presence of coronary artery disease in 44% of men and 22% of women with angina pectoris who had normal stress tests. Moreover, 37% of anginal men with negative stress tests had multivessel coronary involvement. On the basis of these data, the usefulness of a normal stress test is speculative when obtained in a population having a high likelihood of coronary artery disease. Many patients known to have extracranial atherosclerosis undoubtedly fall into this category.

In comparison with standard stress electrocardiography, either thallium-201 scintigraphy or gated pool angiography provides a better assessment of myocardial performance. Rokey et al. performed thallium-201 scintigraphy and exercise angiography in 30 consecutive patients with cerebrovascular symptoms. Abnormal nuclear scans were obtained in 14 of 15 patients with clinical evidence of coronary artery disease as well as in 41% of patients in whom myocardial ischemia was not otherwise anticipated. Twenty of the 22 patients with abnormal scans who underwent cardiac catheterization were found to have either significant coronary artery disease or cardiomyopathy. Overall, 58% of patients with cerebrovascular disease in this investigation had some objective indication of associated coronary atherosclerosis.

Although radionuclide imaging is not an efficient screening method for the normal population, it may have predictive value in patients with cerebrovascular disease without cardiac symptoms. Limited angiographic data suggest that serious, unsuspected coronary involvement is present in 15–20% of this group. Okada et al. calculated that the sensitivity of either exercise thallium-201 scintigraphy (82%) or gated pool angiography (87%) is superior to standard stress electrocardiography (60–64%) and that the specificity for each of these tests exceeds 90%. The accuracy of nuclear scanning has been well demonstrated among patients who have conventional indications of coronary artery disease.

Unfortunately, there is often a need to circumvent exercise during cardiac stress testing in patients with multisystem atherosclerotic disease. Boucher et al. evaluated intravenous dipyridamole thallium-201 myocardial imaging in 54 patients with other evidence of associated coronary artery disease who were scheduled for major arterial reconstruction. Of 16 patients with delayed thallium-201 redistribution, 50% had postoperative myocardial ischemia manifested by angina at rest, acute myocardial infarction, or death. Another six of the 16 patients with positive tests underwent preoperative coronary angiography. Each was found to have significant multivessel coronary artery disease, and four required myocardial revascularization prior to uncomplicated peripheral vascular operations. Di-

### TABLE I: Correlation of Clinical Cardiac Status With Results of Coronary Angiography in 506 Patients Presenting With Extracranial Cerebrovascular Disease

<table>
<thead>
<tr>
<th>Angiographic classification</th>
<th>Clinical indications of coronary disease</th>
<th>No.</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
<td>45</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Suspected</td>
<td>Suspected</td>
<td>93</td>
<td>46</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>141</td>
<td>16</td>
<td>32</td>
</tr>
</tbody>
</table>

CAD, coronary artery disease.
Pyridamole nuclear scanning is only the most recent example of the evolution in noninvasive cardiac assessment, which promises to influence profoundly the management of patients with extracranial and other forms of peripheral vascular disease.

In the presence of significant neurological symptoms or high-grade extracranial lesions, good judgment may dictate that sophisticated cardiac studies be postponed until carotid endarterectomy has been performed. Nevertheless, there is abundant evidence that close, objective surveillance is necessary to protect those with concurrent carotid and coronary disease from the long-term risk of myocardial infarction as well as stroke.

Surgical Management

Several studies have demonstrated that stroke as a complication following coronary artery bypass surgery occurs in <5% of cases.23-26 The experience at the Cleveland Clinic indicates that the risk of major stroke during direct myocardial revascularization is <2% among all cases.23 Candidates for coronary artery bypass at the Cleveland Clinic who have specific stroke risk factors, including those with a history of transient ischemic attacks (TIAs) or previous stroke and those with high-grade asymptomatic carotid stenosis, have been treated with staged or simultaneous carotid endarterectomy and myocardial revascularization. Few would disagree that carotid reconstruction is a reasonable option for patients with focal neurological symptoms and appropriate bifurcation lesions. However, the treatment of asymptomatic carotid stenosis is controversial under any circumstance, especially at the time of coronary artery bypass or other major surgical procedures. Whereas the risk of perioperative stroke associated with asymptomatic carotid stenosis is still uncertain, the most important determinant in the selection of cardiac patients for either staged or combined carotid endarterectomy at the Cleveland Clinic is whether extracranial reconstruction would be justified on its own merit, even in the absence of coronary disease.

The choice between staged or combined operation can be resolved by assessment of the relative severity of the carotid and cardiac risk factors. Staged operations are preferred at the Cleveland Clinic because of the lower incidence of iatrogenic stroke with this approach (<1.5%). Carotid reconstruction preceding coronary artery bypass surgery should be restricted to patients who are free of cardiac symptoms or who are limited only by chronic stable angina.

Because of the substantial risk of cardiac complications during any staging interval following carotid reconstruction, combined procedures should be considered for patients with left main coronary artery disease or severe multivessel lesions with inadequate collateral development, as well as for any patient with unstable angina. Impaired left ventricular function that is sufficiently severe to represent an additional risk during staged carotid endarterectomy may also be a relative indication for simultaneous operations.

The early results of simultaneous management of coexistent carotid and coronary artery disease at the Cleveland Clinic were satisfactory but, nonetheless, were associated with a higher morbidity and mortality than staged reconstruction.25 Perhaps these results were due to more severe and diffuse disease in the patients selected for combined reconstruction. By the nature of their selection, the first 331 patients who received combined operations at this center were older (mean age 61 years) and had a higher incidence of left main coronary stenosis (21%), multiple vessel coronary involvement (63%), and left ventricular impairment (56%) than did 22,100 other patients who underwent coronary artery bypass surgery alone during this same period. All of these distinctions were statistically significant (p<0.01).

In the combined group there was a total of 19 deaths, giving an operative mortality of 5.7%. Perioperative myocardial infarctions occurred in 6.3% of the combined procedures compared with 2.7% of all bypass procedures performed during this study interval. Ventricular impairment was found to be the only independent factor that influenced early mortality (p<0.05). Postoperative neurological complications were identified in 30 patients (9%), but only half of these involved the hemisphere ipsilateral to the simultaneous carotid reconstruction or were permanent deficits.28

Summary

At the present time staged carotid reconstruction several days before elective coronary artery bypass surgery seems to be the safest and most logical approach for patients with neurological symptoms, stable cardiac symptoms, and acceptable coronary anatomy. Combined procedures may well be necessary for those who have active neurological symptoms or bilateral carotid lesions in conjunction with diffuse or unstable coronary artery disease, but the incidence of neurological complications at the time of simultaneous operations could exceed the stroke risk for either carotid endarterectomy or coronary bypass alone. The asymptomatic patient with unilateral carotid stenosis who presents for coronary artery bypass might be best managed by myocardial revascularization followed by medical or surgical management of the carotid disease. In order to obtain optimal long-term results, both coronary disease and associated carotid disease require appropriate evaluation and medical and surgical management.

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R A Graor and N R Hetzer

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