Coronary Artery Disease in Peripheral Vascular Patients

A Classification of 1000 Coronary Angiograms and Results of Surgical Management

NORMAN R. HERTZER, M.D., EDWIN G. BEVEN, M.D., JESS R. YOUNG, M.D., PATRICK J. O'HARA, M.D., WILLIAM F. RUSCHHAUPT III, M.D., ROBERT A. GRAOR, M.D., VICTOR G. DEWOLFE, M.D., LINDA C. MALJOVEC, B.A.

From the Cleveland Clinic Foundation, Department of Vascular Surgery and Department of Peripheral Vascular Disease, Cleveland, Ohio

In an attempt to reduce early and late mortality caused by myocardial infarction, coronary angiography was performed in 1000 patients (mean age, 64 years) under consideration for elective peripheral vascular reconstruction since 1978. Those found to have severe, surgically correctable coronary artery disease (CAD) were advised to undergo myocardial revascularization (CABG), usually preceding other vascular procedures. The primary vascular diagnosis was abdominal aortic aneurysm (AAA) in 263 patients (mean age, 67 years), cerebrovascular disease (CVD) in 295 (mean age, 64 years), and lower extremity ischemia (ASO) in 381 (mean age, 61 years). Severe correctable CAD was identified in 25% of the entire series (AAA, 31%; CVD, 26%; and ASO, 21%). Surgical CAD was documented in 34% of patients suspected to have CAD by clinical criteria (AAA, 44%; CVD, 33%; and ASO, 30%) and in 14% of those without previous indications of CAD (AAA, 18%; CVD, 17%; and ASO, 8%). Cardiac procedures (216 CABG) were performed in 226 patients (AAA, 30%; CVD, 22%; and ASO, 19%), with 12 (5.3%) postoperative deaths. A total of 796 patients underwent 1066 peripheral vascular operations with an early mortality of 2.0% (AAA, 3.4%; ASO, 1.9%; and CVD, 0.3%), but only one death (0.8%) occurred in the group of 130 patients having preliminary CABG. The overall operative mortality for 1292 cardiac and peripheral vascular procedures was 2.6%.

BY AN OVERWHELMING MARGIN, coronary artery disease (CAD) is the leading cause of both early and late mortality following peripheral vascular reconstruction. Previous reports from several centers indicate that myocardial infarction is responsible for approximately half of all postoperative deaths occurring after aortic aneurysm resection[1-3] and extracranial[4,5] or lower extremity[3,6] revascularization. Moreover, Cooperman et al.,[7] Goldman et al.,[8] and von Knorring[9] have demonstrated that fatal cardiac complications occur with predictable frequency among patients who have conventional clinical indications of CAD before surgery. Even more importantly, late survival after successful vascular procedures is substantially limited by a high incidence of subsequent cardiac deaths, especially among those with obvious evidence of CAD at the time of their initial evaluations.[2-4,6,10]

Experience at the Cleveland Clinic is entirely consistent with these observations.[11-14] From 1969 through 1978, myocardial infarction accounted for 45% of operative deaths following resection of intact aortic aneurysms and for 67% of those after elective aortic replacement for lower extremity ischemia. The difference in early mortality between patients with no clinical indication of CAD (2.9%) and those suspected to have CAD by standard clinical criteria (9.6%) was statistically significant ($p < 0.01$). Furthermore, a comprehensive survey of 951 patients who required surgical management of aortic aneurysms, extremity ischemia, and cerebrovascular disease clearly demonstrated that late postoperative survival for patients with peripheral atherosclerosis is distinctly worse than that for the normal population of the same age. In this investigation, myocardial infarction caused at least 38% to 55% of all late deaths, representing two to five times the number attributable to the next leading sources of late mortality, and was most common among diabetics as well as among patients with preoperative evidence of CAD.

Throughout the decade comprising these studies, however, abdominal aortic reconstruction was performed

Reprint requests: Norman R. Hertzer, M.D., Department of Vascular Surgery, The Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, OH 44106.

Submitted for publication: June 30, 1983.

TABLE 1. *Composition of Series, According to Primary Peripheral Vascular Diagnosis*

	Abdominal Aortic Aneurysm		Lower Extremity Ischemia		Cerebrovascular Disease		Other		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Patients	263	26	381	38	295	30	61	6	1000	100
Men	221	84	250	66	174	59	40	66	685	68
Women	42	16	131	34	121	41	21	34	315	32
Age										
Range	47–95		29–90		33–88		33–81		29–95	
Mean	67.6		61.8		64.5		59.8		64.0	
Risk factors										
Diabetes	18	7	95	25	50	17	7	11	170	17
Hypertension	142	54	191	50	173	59	42	69	548	55
Both	10	4	53	14	36	12	6	10	105	10
Total vascular diagnosis										
One	173	66	199	52	211	72	22	36	605	61
Two	71	27	158	42	72	24	22	36	323	32
Three	19	7	24	6	12	4	17	28	72	7
Coronary artery disease										
No Indication	127	48	166	44	126	43	27	44	446	45
Suspected	136	52	215	56	169	57	34	56	554	55

without mortality in 87 patients who incidentally had undergone previous myocardial revascularization. In addition, late survival of a contemporary series of 331 patients who required simultaneous carotid endarterectomy and coronary artery bypass was closely comparable to that of the normal population and was far superior ($p < 0.0005$) to that of similar patients who had carotid endarterectomy alone during the same interval.[15] Crawford et al.[16] and McCollum et al.[17] also have noted the protective effect of prior myocardial revascularization during the early postoperative period after peripheral vascular procedures, and a number of reports, including those by Loop et al.[18,19] and Hall,[20] suggest that an overall 5-year actuarial survival of approximately 90% may be anticipated for patients receiving aortocoronary bypass.

Considering the ominous implications of uncorrected CAD in patients with advanced peripheral vascular disease, the authors concluded in 1978 that cardiac catheterization was a logical extension of the preoperative evaluation for those scheduled for aortic aneurysm resection, lower extremity or extracranial revascularization, and other major vascular procedures. In an effort to improve operative risk and late survival, virtually all patients under serious consideration for elective vascular reconstruction at the Cleveland Clinic have since been advised to have coronary angiography and, when indicated by the presence of severe, surgically correctable CAD, coronary artery bypass which usually preceded any other operation.[21,22] Although "routine" coronary angiography was not the permanent objective of this investigation, it appeared necessary to include all patients in an initial study group in order to identify each subset having a substantial incidence of CAD. This report presents the results of cardiac catheterization and surgical management for the first 1000 patients evaluated using this approach.

Material and Methods

During the study period, a considerable number of patients who incidentally had undergone previous coronary angiography or direct myocardial revascularization had peripheral vascular reconstruction at the Cleveland Clinic without further investigation and are not included in this series. In addition, appropriate surgical intervention was performed prior to cardiac catheterization in occasional patients who are included in this series but presented with urgent vascular problems, such as symptomatic aneurysms, impending limb loss, frequent neurologic symptoms, or high-grade asymptomatic carotid stenosis already documented by angiography. Since its inception, however, this study has excluded only a few patients with stable peripheral vascular disease because they declined catheterization, were too senile to grant informed consent, or had incurable malignancies. Advanced age alone was never the basis for exception, and many patients in the study had multisystem vascular and general medical disease.

Peripheral Vascular Diagnosis

Table 1 contains information concerning the primary peripheral vascular diagnosis at the time of the original

examination, as well as the composition of this series according to sex, age, atherosclerotic risk factors (diabetes mellitus and hypertension), and the clinical cardiac status determined by the previous history and a standard 12-lead electrocardiogram (ECG). A total of 395 patients had more than a single vascular diagnosis identified during their initial evaluations, including 323 with two distinct diagnoses and 72 with three or more. All references to site of peripheral vascular disease throughout this report, however, apply to the *primary* diagnosis with which each patient originally presented.

The primary diagnosis was abdominal aortic aneurysm (AAA) in 263 patients, involving the infrarenal aorta and common iliac arteries in 250 (95%) and the suprarenal or thoracoabdominal aortic segment in only 13 (5%). Lower extremity ischemia (ASO) was the principal vascular problem in 381 patients, comprising 230 whose symptoms were limited to claudication and 151 requiring limb salvage because of rest pain or tissue necrosis. A total of 295 patients had cerebrovascular disease (CVD) as their primary diagnosis, including 232 (79%) with previous hemispheric or vertebrobasilar neurologic symptoms and 63 (21%) who had asymptomatic carotid bruits. Finally, 61 patients had a variety of principal diagnoses which could be classified into several small subsets, such as renal or mesenteric artery stenosis (26), extremity aneurysms (5), and miscellaneous problems (30) generally related to false aneurysms or other complications of prior vascular reconstruction.

Sex and Age

The series consists of 685 men and 315 women and includes 71 patients less than 50 years of age, 252 aged 50–59, 399 aged 60–69, 245 aged 70–79, and 33 over 80 years of age. The age range for all 1000 patients was 29 through 95 years (mean, 64 years). Mean ages were 59 years among patients with miscellaneous vascular diagnoses, 61 years in the ASO group, 64 years in the CVD group, and 67 years in the AAA group (Table 1).

Atherosclerotic Risk Factors

Diabetes mellitus. Diabetes mellitus was defined as consistent elevation of the fasting or 2-hour postprandial blood sugar level above 140 mg/dl, or abnormal glucose tolerance testing, either of which required formal management by insulin or oral hypoglycemic agents. Patients having abnormal glucose values that were inconsistent or corrected by dietary measure alone were considered to have simple glucose intolerance. Glucose intolerance was discovered in 107 patients, while established diabetes was present in 170 (Table 1).

Hypertension. The diagnosis of hypertension was restricted to patients with reproducible elevation of systolic or diastolic blood pressure above 180 or 90 mmHg, respectively, as well as to those who required antihypertensive management to maintain normal blood pressure at the time they entered this study. A total of 548 patients were considered to be hypertensive (Table 1).

Clinical Cardiac Status

A convincing history of previous myocardial infarction was obtained from 221 patients. A total of 198 patients in this series had symptoms compatible with the diagnosis of angina pectoris, classified as functional Class II in 156 (79%), Class III in 36 (18%), and Class IV in six (3%).

A standard ECG was normal in 500 patients. The ECG indicated previous myocardial infarctions in 143 patients, nonspecific ST-T segment changes in 212, and both of these findings in 52 others. A left bundle-branch block obscured any diagnosis of myocardial ischemia in 10 patients. The ECG demonstrated atrial or ventricular arrhythmias and miscellaneous conduction defects in the remaining 83 patients.

Certain features of the cardiac history (previous myocardial infarction, angina pectoris) and ECG (previous infarction, ST-T changes, left bundle-branch block) were considered most suggestive of CAD. By these criteria, 446 patients had no indication of CAD, while 554 were suspected to have CAD on clinical grounds preceding coronary angiography (Table 1).

Cardiac Catheterization

Each patient underwent coronary angiography and left ventriculography using the transbrachial technique. The results of coronary angiography and ventriculography were classified according to the following established guidelines:

(1) *Normal coronary arteries.*

(2) *Mild to moderate CAD,* with measurable disease of one or more coronary arteries but no lesion exceeding 70% stenosis.

(3) *Advanced but compensated CAD,* with greater than 70% stenosis of one or more coronary arteries but no immediate indication for myocardial revascularization using coronary artery bypass grafting (CABG) because of adequate intercoronary collateral circulation or because the involved vessel supplied myocardium already replaced by scar.

(4) *Severe, correctable CAD,* with greater than 70% stenosis of one or more coronary arteries serving unimpaired myocardium and representing immediate or foreseeable risk for myocardial infarction.

(5) *Severe, inoperable CAD,* with greater than 70% stenosis of multiple coronary arteries representing inadequate targets for CABG because of diffuse, distal disease or generalized ventricular impairment.

Management

When indicated, peripheral vascular reconstruction was electively performed with customary precautions in patients with normal coronary arteries or mild or moderate CAD. Additional monitoring by pulmonary artery catheterization was commonly employed among those with advanced but compensated CAD. Myocardial revascularization prior to aortic aneurysm resection or lower extremity revascularization was recommended to patients with severe CAD, which was correctable by CABG. Most patients with aortic aneurysms who required CABG underwent elective resection within 10 days to 6 weeks after their cardiac procedures, a shorter staging interval than often was chosen for lower extremity revascularization since occlusive arterial disease does not represent the unpredictable threat to life that is the case with aneurysm rupture.

Appropriate surgical management of patients with simultaneous severe CAD and extracranial disease is controversial, and a number of options were pursued for the CVD group in this series, depending upon the relative severity of CAD. Staged extracranial repair prior to CABG was preferred for those with stable cardiac symptoms, intermediate coronary stenosis, and satisfactory ventricular function. Most patients with unstable angina, preocclusive CAD, or advanced ventricular impairment underwent combined coronary and carotid procedures because of the perceived risk of any operation preceding myocardial revascularization.[15]

Patients who declined CABG as well as those found to have severe, inoperable CAD were managed on an individual basis. Semielective aneurysm resection with Swan-Ganz monitoring was performed for patients having extremely large aneurysms because the risk of imminent rupture appeared to exceed that of operation. Others with smaller aneurysms were advised to undergo aneurysm resection only if they experienced symptoms suggesting aneurysm expansion or if progressive enlargement was documented on serial ultrasound examinations. Conservative management was usually continued in patients in the ASO group, although those with amenable lesions were informed that compromise procedures, such as axillofemoral or femorofemoral bypass under local or regional anesthesia, were available if limb viability was jeopardized.

Finally, it should be noted that peripheral vascular reconstruction did not always prove to be feasible or necessary even among patients in this series who had less than severe CAD. A few patients with small aneurysms were found to have other relative surgical contraindications, including chronic obstructive pulmonary disease or renal insufficiency. More commonly, patients in the ASO and CVD groups were occasionally excluded as operative candidates on the basis of angiograms obtained during or after cardiac catheterization. Patients with diffuse, unreconstructable tibioperoneal disease or remote internal carotid occlusions are only two such examples.

Statistical Analysis

Statistical analysis was performed using Fisher's exact test of the null hypothesis and PROPHET, a national computer resource supported in part by the Biotechnology Resources Program, Division of Research Resources, National Institutes of Health.

Results

Coronary Artery Disease (CAD)

Specific results of cardiac catheterization for all 1000 patients are presented according to primary peripheral vascular diagnosis in Table 2, using 50% angiographic stenosis as a standard criterion for potentially significant CAD. Measurable reduction in lumen diameter involved the right coronary artery in 42–49% of diagnosis subsets, the left main trunk in 2–5%, the left anterior descending branch in 30–38%, and the circumflex branch in 28–37%. In comparison, lumen stenosis of 70% or more was identified in 40%, 2%, 27%, and 27% of these vessels, respectively.

The incidence of single- and multiple-vessel CAD was remarkably similar, irrespective of the principal vascular diagnosis. Single-vessel CAD was demonstrated in 21% to 28% of subsets, while multiple-vessel involvement was found in 32–41%. Employing greater than 70% stenosis as the criterion, significant CAD involved a single coronary artery in 27%, two vessels in 19%, and three vessels in 11%.

Ventricular Function

As determined by left ventriculography, 68% of patients had normal ventricular function, 21% had segmental akinesia in the distribution of previous infarctions, and 11% had diffuse ventricular impairment (Table 2). Measurements of left ventricular end-diastolic pressure, often used as a benchmark for perioperative volume management in those undergoing subsequent peripheral vascular operations, were less than 10 mmHg in 290 patients, 10 to 20 mmHg in 635, and over 20 mmHg in 75.

Disparity between the objective results of ventriculography and the precatheterization assessment of cardiac status was not uncommon. Ventricular impairment was demonstrated only in 149 (67%) of 221 patients with a history compatible with previous myocardial infarction, and in 142 (73%) of 195 interpreted to have had prior infarctions by ECG. Conversely, and of more concern from a clinical perspective, ventricular impairment was

TABLE 2. *Results of Cardiac Catheterization*

Results	Abdominal Aortic Aneurysm		Lower Extremity Ischemia		Cerebrovascular Disease		Other		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Stenosis > 50%										
Right coronary	130	49	177	46	123	42	26	43	456	46
Left coronary										
Main trunk	13	5	15	4	16	5	1	2	45	4
Anterior descending	101	38	115	30	101	34	18	30	335	34
Circumflex	97	37	134	35	97	33	17	28	245	34
Single vessel	69	26	79	21	69	23	17	28	234	23
Double vessel	53	20	77	20	59	20	12	20	201	20
Triple vessel	54	21	67	18	49	17	7	12	177	18
Ventricular impairment										
None	179	68	251	66	211	71	42	69	683	68
Segmental	63	24	80	21	52	18	12	20	207	21
Diffuse	21	8	50	13	32	11	7	11	110	11

documented in 168 (22%) of 779 patients with no previous symptoms of myocardial infarction, and in 175 (22%) of 805 having no evidence of infarction by ECG.

Angiographic Classification of CAD

The presence of isolated coronary stenosis does not necessarily imply that myocardial infarction is a foreseeable risk nor that CABG is indicated. As a basis for management, an angiographic classification of CAD is presented according to primary peripheral vascular diagnosis in Table 3. Only 8% of the patients in this series had normal coronary arteries, but CAD was limited to a mild to moderate degree in another 32%. Advanced but compensated CAD was identified in 29% of patients.

Severe, surgically correctable CAD was documented in 25% of the entire series, and 6% had severe CAD that already was inoperable. Severe CAD was discovered in a total of 36% of patients with AAA, 32% of those with CVD, and 28% of those with ASO. A number of factors other than the primary vascular diagnosis influenced the distribution of severe CAD, most notably the clinical cardiac status, sex and age, and diabetes mellitus.

Clinical Cardiac Status

The clear distinction between the results of coronary angiography among patients with no clinical indication of CAD and those suspected to have CAD is shown in Table 4. A normal coronary system or mild to moderate CAD was demonstrated in 63% and 22% of these groups, respectively. More importantly, differences in the incidence of severe CAD were statistically meaningful. Severe, surgically correctable CAD was found in 34% of patients

TABLE 3. *Angiographic Classification of Coronary Artery Disease, According to Primary Peripheral Vascular Diagnosis*

	Abdominal Aortic Aneurysm		Lower Extremity Ischemia		Cerebrovascular Disease		Other		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Normal Coronary Arteries	16	6	38	10	27	9	4	7	85	8
Mild to moderate CAD*	77	29	125	33	94	32	21	34	317	32
Advanced but compensated CAD	77	29	111	29	80	27	21	34	289	29
Severe, correctable CAD	81	31	79	21	77	26	14	23	251	25
Severe, inoperable CAD	12	5	28	7	17	6	1	2	58	6

* CAD = Coronary artery disease.

TABLE 4. *Angiographic Classification of Coronary Artery Disease, According to Clinical Indications*

	Clinical Coronary Disease			
	No indication		Suspected	
	No.	%	No.	%
Normal Coronary Arteries	64	14	21	4
Mild to moderate CAD*	218	49	99	18
Advanced but compensated CAD	97	22	192	34
Severe, correctable CAD	63	14	188	34
Severe, inoperable CAD	4	1	54	10

* CAD = Coronary artery disease.

suspected by traditional means to have CAD and in 14% of those who were not ($p < 0.001$), while inoperable CAD already was present in 10% *vs.* 1% of these groups, respectively ($p < 0.001$). Of the 554 patients in this investigation suspected by standard criteria to have CAD, therefore, coronary angiography confirmed that nearly half (44%) either deserved myocardial revascularization or had such severe CAD that CABG no longer was feasible.

Each of the individual features determining the clinical cardiac status had a significant correlation with the results of coronary angiography. Severe, surgically correctable CAD was present in 51% of patients who had angina pectoris compared to 19% of those who did not ($p < 0.001$), while inoperable CAD was found in 15% and 3.5% of these groups, respectively ($p < 0.001$). A convincing history of previous myocardial infarction was associated with severe, correctable CAD in 32% of patients and with inoperable CAD in 14%. Severe, correctable CAD was found in 23% ($p < 0.01$) of those without prior infarction symptoms, and inoperable CAD in 3.3% ($p < 0.001$).

Severe correctable CAD was identified in 19% of patients with normal ECG patterns, and inoperable CAD in 2.2%. In comparison, severe, correctable CAD was documented in 32% of patients with ECG evidence of previous myocardial infarction ($p < 0.001$) and in 33% of those with nonspecific ST-T changes ($p < 0.001$). Severe, inoperable CAD was present in 12% ($p < 0.001$) and 7.5% ($p < 0.01$) of these subsets, respectively.

A total of 295 patients had clinical evidence of prior myocardial infarction on the basis of their history, ECG findings, or both. Of these, 101 continued to have angina pectoris, while 194 had no subsequent cardiac symptoms. Severe, correctable CAD was demonstrated by angiography in 44% and 28% of these subsets, respectively ($p < 0.01$). Moreover, severe, inoperable CAD was identified in 22% of those who had angina in contrast to only 7.2% of those who did not ($p < 0.001$).

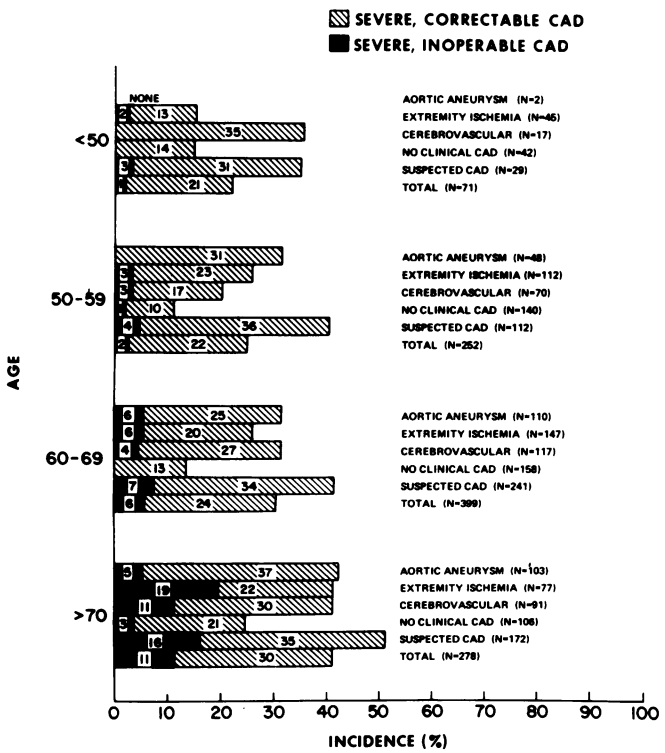

FIG. 1. Graphic representation of the incidence of severe CAD in 1000 patients according to age.

Sex and Age

Severe, correctable CAD was found in 198 (29%) of the 685 men and in 53 (17%) of the 315 women in this series ($p < 0.001$), but a slight difference in the incidence of inoperable CAD (6.0% and 5.4%, respectively) was not significant. A total of 323 patients were less than 60 years of age at the time of coronary angiography, while 677 were age 60 or older. Although the incidence of severe, correctable CAD in these subsets was similar (22% and 27%, respectively), inoperable CAD was identified in only 1.9% of younger patients compared to 7.7% of those over 60 years of age ($p < 0.001$).

A comprehensive analysis of the influence of age on the incidence of severe, correctable, and inoperable CAD is presented in figure 1. While the overall incidence of severe CAD is substantial in all age groups, coronary angiography produced a higher yield of severe CAD in each decade of advancing age. Severe CAD was present in 22% of patients less than 50 years of age, 24% of those aged 50–59, 30% of those aged 60–69, and 41% of those over 70 years of age. These data also suggest that the primary vascular diagnosis did not measurably affect the probability of severe CAD among patients of similar age.

The clinical cardiac status was the most important factor with respect to the incidence of both correctable and inoperable CAD in each age subset. When suspected by conventional criteria, severe CAD was documented in

34% of patients less than 50 years of age, 40% of those aged 50–59, 41% of those aged 60–69, and 51% of those over 70 years of age. Severe CAD was correctable by CABG in 31% to 36% of patients suspected to have CAD, but myocardial revascularization also was warranted in 10% to 21% of the respective age groups even when the clinical cardiac status was unremarkable.

Atherosclerotic Risk Factors

Neither hypertension nor diabetes mellitus had a significant influence upon the incidence of severe, correctable CAD. Myocardial revascularization was indicated in 22% of diabetics and 26% of nondiabetics, as well as in 26% of hypertensive patients and 24% of those who were normotensive. The incidence of severe, inoperable CAD also was comparable between those with and those without hypertension (6.6% and 4.9%, respectively). However, inoperable CAD was discovered in 12% of diabetics, in comparison to only 4.5% or nondiabetics. This difference was statistically significant ($p < 0.001$).

The incidence of severe CAD in patients having diabetes, hypertension, and both of these risk factors is depicted graphically in figure 2. Irrespective of the risk factor, severe CAD was still far more common among patients already suspected to have it (41%, 46%, and 41%, respectively) than among those who were not (17%, 13%, and 19%). The deleterious effect of diabetes upon the distal branches of the coronary circulation is clearly shown by the impressive incidence of severe, inoperable CAD in this group, especially among patients over 70 years of age.

Surgically Correctable CAD

The cardinal objective of this study was to identify patients with common peripheral vascular disease considered for surgical management whose operative risk and late survival might be enhanced by myocardial revascularization. Figure 3 presents the incidence of severe, surgically correctable CAD in a total of 926 patients primarily presenting with infrarenal aortic aneurysms, lower extremity ischemia, and cerebrovascular disease. Additional comparisons are given according to clinical cardiac status, age, glucose intolerance (established diabetes as well as diet-controlled hyperglycemia), and hypertension.

Irrespective of age or associated risk factors, coronary angiography had twice to three times the yield of surgically correctable CAD among patients with traditional indications of CAD than was found among those having a normal cardiac history and ECG. This distribution was strongly suggested even among subsets that were too small to permit statistical confirmation. In the future, information contained in figures 1–3 will be used to determine those patients scheduled for peripheral vascular reconstruction at the Cleveland Clinic who require preoperative coronary angiography. Cardiac catheterization will continue to be requisite for those suspected to have CAD on clinical grounds, but such screening measures as stress electrocardiography or radionuclide myocardial scanning appear appropriate for subsets found in this investigation to have an incidence of severe CAD of approximately 15% or less.

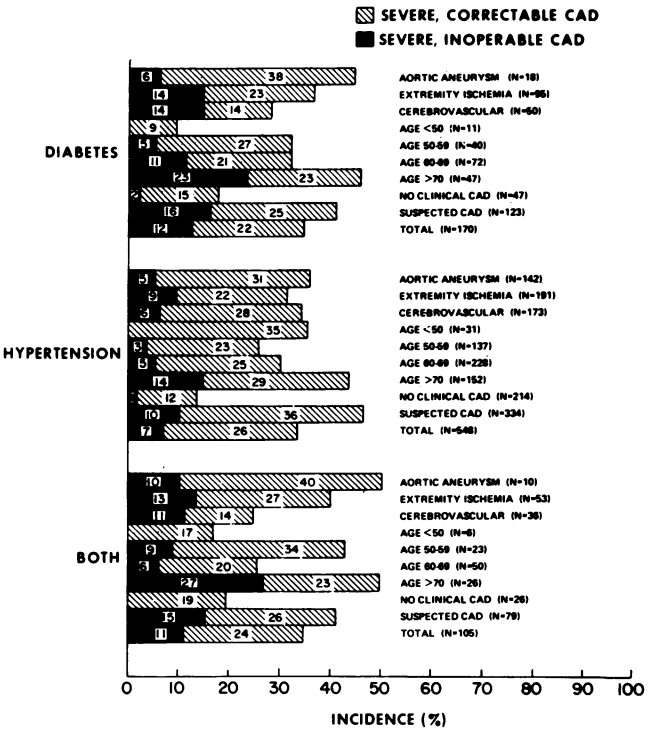

FIG. 2. Graphic representation of the incidence of severe CAD in all subsets with diabetes mellitus and hypertension.

No Clinical Indication Of CAD	Total (N = 415)		Atherosclerotic Risk Factors: Glucose Intolerance (N = 87)		Hypertension (N = 214)		Both (N = 52)	
	No.	%	No.	%	No.	%	No.	%
Age < 60	20/162	12	2/33	6	10/77	13	2/17	12
Age > 60	38/253	15	7/54	13	15/137	11	4/35	11

Suspected CAD	Total (N = 511)		Atherosclerotic Risk Factors: Glucose Intolerance (N = 171)		Hypertension (N = 327)		Both (N = 114)	
	No.	%	No.	%	No.	%	No.	%
Age < 60	45/128	35 p < .001	13/42	31 p < .02	34/82	41 p < .001	10/29	34 p = NS
Age > 60	131/383	34 p < .001	34/129	26 p = NS	84/243	34 p < .001	23/85	27 p = NS

FIG. 3. Incidence of severe, surgically correctable coronary artery disease (CAD) in all patients with infrarenal aortic aneurysms, lower extremity ischemia, or cerebrovascular disease as the primary vascular diagnosis.

TABLE 5. *Surgical Procedures and Operative Mortality for Entire Series*

	Patients		Procedures		Mortality			
					Patient		Procedure	
	No.	%	No.	%	No.	%	No.	%
Cardiac	226	23	226	100	12	5.3	12	5.3
CABG* only	212	21	212	94	11	5.2	11	5.2
CABG plus other	4	0.4	4	4	1	25	1	25
Other only	10	1	10	2	0	—	0	—
Peripheral vascular	796	80	1066	100	21	2.6	21	2.0
Infrarenal aortic aneurysm resection	206	26	206	19	7	3.4	7	3.4
Lower extremity revascularization	256	32	335	32	6	2.3	6	1.8
Extracranial reconstruction	231	29	319	30	1	0.4	1	0.3
Other	103	13	206	19	7	6.8	7	3.4
Total	1022	—	1292	—	33	3.2	33	2.6

* CABG = Coronary artery bypass grafting.

Surgical Management

As indicated in Table 5, a total of 1292 cardiac (226) and peripheral vascular (1066) surgical procedures were performed in this series. Thirty-three postoperative deaths occurred, for an overall patient mortality of 3.2% and a procedure mortality of 2.6%.

Cardiac Procedures

Because of information obtained by cardiac catheterization, 226 patients initially evaluated because of peripheral vascular disease underwent cardiac surgical procedures (Table 5). CABG alone was necessary in 212 patients and was done in conjunction with another procedure in four others. Ten patients required cardiac operations not involving CABG, such as valve replacement, ventricular aneurysm resection, or repair of idiopathic hypertrophic subaortic stenosis.

CABG was performed in 70 (28%) of 250 patients with infrarenal AAA, in 63 (21%) of 295 with CVD, and in 70 (18%) of 381 with ASO as the primary vascular diagnosis. Another 31 patients in this study were advised to have CABG on the basis of coronary angiographic findings, but declined.

Operative Mortality

Twelve patients (5.3%) died following cardiac operations, with an operative mortality for CABG alone of 5.2%. The principal cause of postoperative death was myocardial infarction or arrhythmia in five (2.2%), stroke in two (0.9%), and renal failure, sepsis, and hemorrhage each in one (0.4%). Another two patients (0.9%), representing 0.8% of all patients in this series having infrarenal aneurysms and 2.9% of those in this subset who underwent CABG, sustained aneurysm rupture after cardiac operations and died despite emergency resection.

Simultaneous extracranial reconstruction was performed as a combined operation during 47 of the 226 cardiac procedures, usually because of incidental subtotal stenosis of one or both internal carotid arteries. Six (13%) of these patients had fatal complications, accounting for 50% of all postoperative deaths. In comparison, the overall operative mortality for a total of 331 combined carotid and coronary operations reported from the Cleveland Clinic is 5.7%.[15] Data in Table 6 indicate that patients in the present series who died following CABG had multiple risk factors. They generally were older (mean age, 65 years) than most patients undergoing myocardial revascularization, and several had multisegmental vascular disease. All had severe coronary lesions that tended to involve multiple vessels and appeared to limit life expectancy as well as to preclude major, elective peripheral vascular reconstruction unless CABG were first performed.

Peripheral Vascular Procedures

As presented in Table 5, 796 patients in this study underwent a total of 1066 operations for correction of the primary peripheral vascular diagnosis, including 130 patients who required myocardial revascularization as a preliminary procedure. Resection of infrarenal aortic aneurysms was performed in 206, lower extremity revascularization in 256 (335 operations), and extracranial reconstruction in 231 (282 operations). Extremity revascularization was accomplished by a direct aortoiliofemoral approach in 177 procedures, by axillofemoral or femorofemoral bypass in 33, by femoral endarterectomy and profundaplasty in 37, and by femoropopliteal (49) or distal (39) bypass in 88. Extracranial lesions were corrected by carotid bifurcation endarterectomy in 293 procedures and by extrathoracic (18) or transthoracic (8) brachiocephalic bypass in 26. Preliminary CABG was necessary for 61 patients in the AAA group, for 45 with ASO, and for 71 with CVD (including 47 combined carotid and coronary operations).

Operative Mortality

Twenty-one deaths occurred after peripheral vascular operations for a patient mortality of 2.6% and a procedure mortality of 2.0%. Procedure mortalities were 3.4% for aneurysm resection, 1.8% for lower extremity revascularization (aortoiliofemoral, 0%; extra-anatomic, 3.3%; profundaplasty, 2.7%; and femoropoliteal or distal, 4.5%), and 0.3% for extracranial reconstruction (carotid endarterectomy, 0.3% and brachiocephalic, 0%) not performed

TABLE 6. *Summary of Mortality Following Cardiac Surgical Procedures*

Peripheral Vascular Diagnosis	Age	Clinical Indications of Coronary Disease	Coronary Artery Stenosis by Angiography (%)				Cardiac Surgical Procedure	Cause of Death
			Right	Left Main	Anterior Descending	Circumflex		
CVD	70	Suspected	100	80	50	—	Single CABG	Arrhythmia
VISC-CVD	61	Suspected	99	—	50	30	Double CABG	Hemorrhage
AAA-ASO	58	Suspected	100	10	90	80	Triple CABG	Stroke
ASO-CVD	72	Suspected	100	—	100	80	Double CABG carotid endarterectomy	Sepsis
AAA-ASO CVD	66	Suspected	100	—	75	80	Double CABG	Myocardial infarction
ASO	65	Suspected	99	—	30	99	Double CABG	Stroke
CVD	59	Suspected	100	—	50	90	Double CABG carotid endarterectomy	Myocardial infarction
VISC-AAA CVD	60	Suspected	90	—	—	—	Single CABG aortic valve replacement carotid endarterectomy	Renal failure
AAA-CVD ASO	68	Suspected	100	20	90	100	Triple CABG	AAA rupture
CVD	53	None	80	80	90	80	Triple CABG carotosubclavian bypass	Myocardial infarction
CVD	74	None	70	70	90	100	Triple CABG carotid endarterectomy	Arrhythmia
AAA-CVD	74	None	100	80	50	100	Triple CABG carotid endarterectomy	AAA rupture

AAA = abdominal aortic aneurysm; CABG = Coronary artery bypass grafting; ASO = lower extremity ischemia; VISC = visceral artery disease; and CVD = cerebrovascular disease.

in conjunction with myocardial revascularization. An additional 206 miscellaneous procedures consisted of renal and mesenteric revascularization, replacement of femoral or popliteal aneurysms, an occasional thoracoabdominal aneurysm resection, and remedial procedures for complications of previous vascular reconstruction, such as false aneurysms and infected grafts. The mortality for all operations in this group was 3.4%.

The principal cause of death was pulmonary insufficiency in four patients (0.5%), renal failure in four (0.5%), myocardial infarction or arrhythmia each in three (0.4%), stroke in one (0.1%), and all other causes in a total of six (0.7%). Only one death (0.8%) occurred following peripheral vascular reconstruction in the group of 130 patients who had preliminary myocardial revascularization. One (1.6%) of 61 such patients died after infrarenal aortic aneurysm resection. No mortality occurred among 45 patients who subsequently had lower extremity procedures, nor in the subset of 24 others who underwent staged extracranial operations following CABG.

The mortality for the principal groups in this series may be assessed from a final perspective. Of 250 patients entering this study with a primary vascular diagnosis of infrarenal aortic aneurysm, 76 underwent preliminary cardiac procedures with four postoperative deaths and 206 had elective aneurysm resection with seven postoperative deaths. Thus, 11 deaths occurred in a total of 282 operations, for an overall mortality of 3.9%. Comparable mortality for the ASO and CVD groups was 2.4% and 1.8%, respectively. These figures represent the sum of mortality that was exchanged for correction of the presenting vascular problem as well as for protection against early and late myocardial infarction in each patient subset.

Discussion

Since preliminary results of this study were presented in 1979,[22] the use of routine coronary angiography in the evaluation of patients under consideration for peripheral vascular reconstruction has generated considerable controversy. The issue of whether it is reasonable to investigate and correct associated CAD which may adversely influence late survival as well as postoperative mortality has been addressed in previous publications and discussions.[1,22] The authors are convinced that it is. The present report of 1000 patients is an attempt to classify the incidence of severe CAD so that coronary angiography may be employed selectively in the future.

The results of this investigation indicate that approximately 30% of all patients scheduled for aortic aneurysm resection, lower extremity revascularization, or extracranial reconstruction have severe CAD which warrants myocardial revascularization or already is inoperable. Severe CAD is concentrated among patients with conventional criteria for ischemic heart disease that may be detected without sophisticated equipment at any hospital.

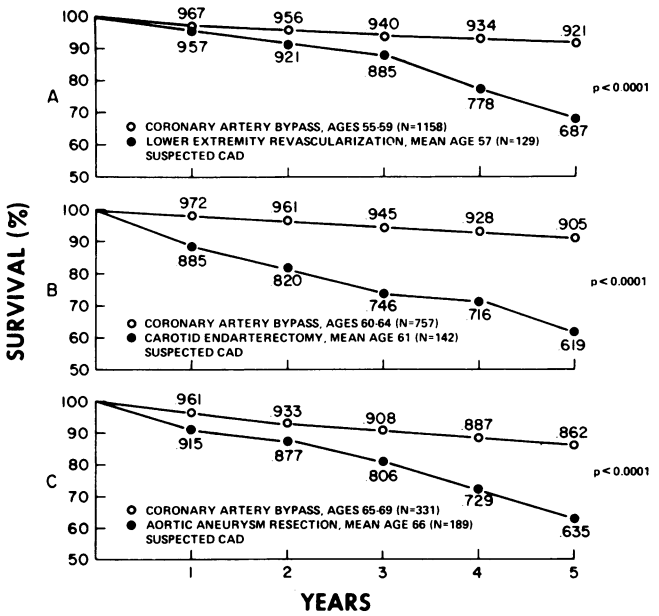

FIG. 4. Actuarial 5-year survival for patients of comparable ages who underwent either myocardial revascularization or peripheral vascular reconstruction during previous studies (see text).

In this series, nearly half (44%) of the group of patients with a positive cardiac history or an abnormal electrocardiogram had severe CAD, in comparison to only 15% of those with normal cardiac parameters.

Although advancing age was associated with an increase in the incidence of inoperable CAD, surgically correctable coronary lesions were documented with similar frequency in all age subsets, irrespective of the principal peripheral vascular diagnosis. Hypertension had no meaningful influence on the incidence of severe CAD, but inoperable CAD was significantly more common among diabetics (12%) than among nondiabetics (4.5%). This finding is consistent with the prevalence of fatal cardiac events which eventually occur in diabetics according to the Framingham study.[23] Nevertheless, many of these complications may be avoidable, since myocardial revascularization was indicated and feasible in 25% of all diabetics with clinical evidence of CAD in this series.

Nearly one of every four patients in this study (23%) underwent cardiac procedures as the direct result of survey coronary angiography, the vast majority of these operations being limited to myocardial revascularization. The cardiac surgical mortality was 5.3%, a figure higher than expected for all patients undergoing CABG but comparable to previous experience at the Cleveland Clinic[15] and elsewhere[24] with older patients having multiple risk factors. Considering that only one death (0.8%) occurred after elective vascular operations in a group of 130 patients who had previously undergone CABG, however, the immediate protection provided by myocardial revascularization in those with documented severe CAD is unmistakable. Moreover, the operative mortality for all cardiac and vascular procedures was only 3.9% in the aneurysm group, 2.4% for those with lower extremity ischemia, and 1.7% among patients with cerebrovascular disease. Assuming that late survival as well as operative risk will be enhanced by CABG among patients with severe CAD, these figures hardly seem excessive.

Late mortality for this series will be presented in future reports, but related data already are available to suggest that survival will be superior to that which would have been anticipated if severe CAD had been disregarded. Figure 4 graphically depicts actuarial 5-year survival for a total of 460 patients with clinically suspected but uncorrected CAD who underwent lower extremity revascularization,[13] carotid endarterectomy,[14] or aortic aneurysm resection[12] at the Cleveland Clinic from 1969 through 1973, together with similar information for 2246 patients of comparable ages who received myocardial revascularization at the Cleveland Clinic from 1974 through 1978.[25] Life-table survival was superior by 23% to 29% among patients who had severe CAD corrected by CABG in comparison to peripheral vascular patients whose cardiac status was not investigated by coronary angiography.[26] In each age group, these differences were statistically significant ($p < 0.001$). Absolutely firm conclusions may not be drawn from even such convincing historic data, but late results from the present study of 1000 patients should provide additional insight concerning the role of myocardial revascularization in those with peripheral vascular disease.

In the future, preoperative cardiac catheterization will continue to be recommended to all patients with clinical indications of CAD who are scheduled for peripheral vascular reconstruction at the Cleveland Clinic. Noninvasive screening measures, such as stress electrocardiography or radionuclide myocardial scanning, will be employed to determine the necessity for coronary angiography among those having no cardiac symptoms and normal conventional electrocardiograms. The results of this study of routine cardiac catheterization in peripheral vascular patients strongly suggest that these precautions will extend the benefit of modern myocardial revascularization to those who need it most.

Acknowledgments

The authors acknowledge the invaluable contributions of John R. Kramer, M.D., Daniel F. Phillips, M.D., and their associates in the Department of Cardiology and the Department of Thoracic and Cardiovascular Surgery. Joe H. Gallagher, Ph.D., Department of Scientific Computing, was responsible for the design of the Peripheral Vascular Information Registry. Miss Geri Locker, Research Division, performed the statistical analysis and Mrs. Frances Federico assisted in preparation of the manuscript.

References

1. Brown OW, Hollier LH, Pairolero PC, et al. Abdominal aortic aneurysm and coronary artery disease. Arch Surg 1981; 116:1484–1488.
2. Crawford ES, Salwa AS, Babb JW, et al. Infrarenal abdominal aortic aneurysm. Ann Surg 1981; 193:699–709.
3. Jamieson WRE, Janusz MT, Miyagishima RT, Gerein AN. Influence of ischemic heart disease on early and late mortality after surgery for peripheral occlusive vascular disease. Circulation 1982; 66:92–97.
4. DeBakey ME, Crawford ES, Cooley DA, et al. Cerebral arterial insufficiency: one to 11-year results following arterial reconstructive operation. Ann Surg 1965; 161:921–945.
5. Ennix CL, Lawrie GM, Morris GC Jr, et al. Improved results of carotid endarterectomy in patients with symptomatic coronary disease: an analysis of 1546 consecutive carotid operations. Stroke 1979; 10:122–125.
6. Crawford ES, Bomberger RA, Glaeser DH, et al. Aortoiliac occlusive disease: factors influencing survival and function following reconstructive operation over a twenty-five-year period. Surgery 1981; 90:1055–1066.
7. Cooperman M, Pflug B, Martin EW Jr, Evans WE. Cardiovascular risk factors in patients with peripheral vascular disease. Surgery 1978; 84:505–509.
8. Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. N Engl J Med 1977; 297:845–853.
9. von Knorring J. Postoperative myocardial infarction: a prospective study in risk group of surgical patients. Surgery 1981; 90:55–60.
10. Burnham SJ, Johnson G, Gurri JA. Mortality risks for survivors of vascular reconstructive procedures. Surgery 1982; 92:1072–1076.
11. Diehl JT, Cali RF, Hertzer NR, Beven EG. Complications of abdominal aortic reconstruction. Ann Surg 1983; 197:49–56.
12. Hertzer NR. Fatal myocardial infarction following abdominal aortic aneurysm resection. Three hundred forty-three patients followed 6–11 years postoperatively. Ann Surg 1980; 192:667–673.
13. Hertzer NR. Fatal myocardial infarction following lower extremity revascularization. Two hundred seventy-three patients followed six to eleven postoperative years. Ann Surg 1981; 193:492–498.
14. Hertzer NR, Lees CD. Fatal myocardial infarction following carotid endarterectomy. Three hundred thirty-five patients followed 6–11 years after operation. Ann Surg 1981; 194:212–218.
15. Hertzer NR, Loop FD, Taylor PC, Beven EG. Combined myocardial revascularization and carotid endarterectomy. J Thorac Cardiovasc Surg 1983; 85:577–589.
16. Crawford ES, Morris GC Jr, Howell JF, et al. Operative risk in patients with previous coronary artery bypass. Ann Thorac Surg 1978; 26:215–221.
17. McCollum CH, Garcia Rinaldi R, Graham JM, DeBakey ME. Myocardial revascularization prior to subsequent major surgery in patients with coronary artery disease. Surgery 1977; 81:302–304.
18. Loop FD, Cosgrove DM, Lytle BW, Golding LR. Life expectancy after coronary artery surgery. Am J Surg 1981; 141:665–671.
19. Loop FD, Cosgrove DM, Lytle BW, et al. An 11-year evolution of coronary arterial surgery (1967–1978). Ann Surg 1979; 190:444–455.
20. Hall RJ. Coronary artery bypass: facts and figures. Texas Heart Inst J 1982; 9:478–482.
21. Hertzer NR. Myocardial ischemia. Surgery 1983; 93:97–101.
22. Hertzer NR, Young JR, Kramer JR, et al. Routine coronary angiography prior to elective aortic reconstruction. Arch Surg 1979; 114:1336–1344.
23. Kannel WG, McGee DL. Diabetes and cardiovascular disease. The Framingham study. JAMA 1979; 241:2035–2038.
24. Hibler BA, Wright JO, Wright CB, et al. Coronary artery bypass surgery in the elderly. Arch Surg 1983; 118:402–404.
25. Cleveland Clinic Cardiovascular Information Registry, unpublished data.
26. Cutler SJ, Ederer F. Maximum utilization of the life-table method in analyzing survival. J Chronic Dis 1958; 8:699–712.