Late results of coronary bypass in patients with peripheral vascular disease

I. Five-year survival according to age and clinical cardiac status[1]

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Coronary angiography was performed in a series of 1000 patients (mean age 64 years) under consideration for elective peripheral vascular reconstruction at the Cleveland Clinic. Of the 251 patients found to have severe, correctable coronary artery disease (CAD), 216 underwent myocardial revascularization as a preliminary procedure. The operative mortality for coronary bypass was 5.5%, but only three early deaths (1.5%) occurred among 200 patients in this subset who subsequently had peripheral vascular operations. In comparison, vascular procedures were undertaken with conventional precautions in 16 of the 35 patients with severe, correctable CAD who declined myocardial revascularization. Two (12%) of these patients had fatal complications ($p = 0.045$). Complete late information was available for over 98% of the study group during follow-up intervals of 3–7 years (mean 4.6 years). Including the operative mortality of coronary bypass, cardiac deaths have been reported in 12% of the 216 patients who received myocardial revascularization, a figure surpassed only by those having normal coronary arteries (1.2%) or mild to moderate angiographic changes (4.4%). Cardiac mortality thus far has occurred in nine (26%) of the 35 unoperated patients with severe correctable CAD ($p = 0.033$). Five-year cumulative survival for the bypass subset currently is 72%, compared with 43% in patients with severe CAD for whom myocardial revascularization was warranted but never performed ($p = 0.001$). At the present time, the operative risk and late survival of selected patients over 70 years of age with peripheral vascular disease appear to be especially enhanced by myocardial revascularization.

Index terms: Aortocoronary bypass • Vascular surgery

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A number of previous reports from the Cleveland Clinic

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Table 1. Results of catheterization*

Stenosis >50%	No.	Percent
Right coronary	456	46
Left coronary		
Main trunk	45	4
Anterior descending	335	34
Circumflex	345	34
No. of vessels		
Single vessel	234	23
Double vessel	201	20
Triple vessel	177	18
Ventricular impairment		
None	683	68
Segmental	207	21
Diffuse	110	11

* Results of cardiac catheterization in 1000 patients with peripheral vascular disease.[8]

have confirmed that coronary artery disease (CAD) is the leading cause of perioperative mortality at the time of peripheral vascular reconstruction and that late survival after vascular procedures is substantially limited by a high incidence of fatal cardiac events, especially among patients with conventional preoperative evidence of ischemic heart disease. From 1969 to 1978, myocardial infarction accounted for 45% of postoperative deaths after resection of intact aortic aneurysms and for 67% of those after elective aortic replacement for lower extremity ischemia.[1–3] Differences in early mortality among patients who had no clinical indication of CAD (2.9%), those suspected to have CAD based on traditional clinical criteria (9.6%), and others who incidentally had received prior myocardial revascularization (0%) were statistically significant ($p < 0.01$, Fisher exact test). Furthermore, a comprehensive survey of 861 patients who had successful surgical treatment of aortic aneurysms, extremity ischemia, or cerebrovascular disease at this center demonstrated that late survival at a mean of eight postoperative years was distinctly worse than the anticipated survival for a normal population of the same age.[4]

During the same decade in which these series were collected, 331 patients required simultaneous carotid endarterectomy and coronary bypass at the Cleveland Clinic, and this group has provided an unusual opportunity to study the results of a planned surgical approach to synchronous peripheral vascular and coronary disease.[5] Although the early mortality for combined operations was 5.7%, five-year actuarial survival following 312 successful procedures was 83%, a figure that is far superior ($p < 0.0005$) to survival among patients of similar age who were suspected to have coronary involvement but received carotid endarterectomy alone during the same era (62%).[6] Since these composite data suggest that timely myocardial revascularization may enhance the operative risk and life expectancy of selected peripheral vascular patients with associated CAD, preoperative coronary angiography was recommended for all of those under serious consideration for elective vascular procedures beginning in 1978.[7]

Of the first 1000 patients entered into this prospective study, 251 were found to have associated CAD of sufficient severity to warrant coronary bypass, including 34% of the group suspected by clinical criteria to have coronary involvement and 14% of those who were not ($p = 2 \times 10^{-13}$).[8] Myocardial revascularization was performed in 216 of these 251 patients, while 35 others either declined cardiac procedures or were excluded from them because of concurrent pulmonary disease or additional considerations. The operative mortality for preliminary coronary bypass was 5.5%, but there were only 21 deaths among 796 patients (2.6%) in this series who underwent a total of 1066 (2.0%) peripheral vascular operations. Most importantly, the early mortality rate for subsequent vascular procedures performed in 130 patients after planned, preliminary myocardial revascularization was limited to 0.8%.

This is the first in a series of reports to present the late clinical course during follow-up intervals of 3–7 years (mean, 4.6 years) for all patients entered into this prospective study. The perspective of the data included in this (age, clinical cardiac status) and a second report (sex, hypertension, and diabetes) will facilitate survival comparisons between the 1000 patients evaluated with coronary angiography and other large groups of peripheral vascular patients who previously were treated at the Cleveland Clinic using conventional preoperative assessment.[4] The concluding report will describe late results in the prospective study group according to specific catheterization features, such as single or multiple-vessel involvement and ventricular function.

Materials and methods

A comprehensive review of our approach has

Table 2. Deaths after vascular reconstruction*

Coronary angiographic classification	No.	Peripheral vascular operative deaths							
		Age <60		Age 60–69		Age >70		Total	
		No.	%	No.	%	No.	%	No.	%
Normal coronary arteries	74	1/44	2.3	0/25	—	0/5	—	1	1.4
Mild to moderate CAD	278	2/109	1.8	1/105	1.0	2/64	3.1	5	1.8
Advanced but compensated CAD	250	0/64	—	4/109	3.7	5/77	6.5	9	3.6
Severe correctable CAD									
With bypass	200	1/59	1.7	2/78	2.6	0/63	—	3	1.5
No bypass	16	0/2	—	1/7	14	1/7	14	2	12
Severe inoperable CAD	28	0/5	—	0/7	—	4/16	25	4	14
Total	846	4/283	1.4	8/331	2.4	12/232	5.2	24	2.8

CAD = Coronary artery disease

* Operative deaths after peripheral vascular reconstruction in 846 patients, according to age and the angiographic classification of associated coronary disease.

been presented elsewhere.[8] In summary, cardiac catheterization was performed in virtually every patient under serious consideration for elective peripheral vascular reconstruction at this center during the study period of 1978–1982. Preliminary or simultaneous coronary bypass was recommended to patients found to have severe, surgically correctable CAD in an attempt to enhance both perioperative risk and subsequent survival. Under urgent circumstances, appropriate vascular procedures were performed prior to coronary angiography in patients presenting with symptomatic aortic aneurysms, impending limb loss, or threatened stroke. 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.

Patient information

Age: The series comprised 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 29–95 years (mean, 64 years). Mean ages were 59 years in 61 patients with miscellaneous peripheral vascular problems, 61 years in 381 with lower extremity ischemia, 64 years in 295 with extracranial cerebrovascular disease, and 67 years in 263 presenting with aortic aneurysms.

Clinical cardiac status: A convincing history of previous myocardial infarction was obtained from 221 patients. A total of 198 patients had symptoms compatible with the diagnosis of angina pectoris, classified as functional (New York) Class II in 156 (79%), Class III in 36 (18%), and Class IV in 6 (3%).

A standard 12-lead electrocardiogram (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, and the ECG demonstrated atrial or ventricular arrhythmias 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 ischemic heart disease. By these criteria, 446 patients had no indication of CAD, while 554 were suspected to have CAD even before coronary angiography.

Coronary angiography: Each patient underwent coronary angiography and left ventriculography, and the results were classified according to the following criteria (N = patients):

1. Normal coronary arteries. ($N = 85$)
2. Mild to moderate CAD, with measurable disease of one or more coronary arteries but no lesion exceeding 70% stenosis. ($N = 317$)
3. Advanced but compensated CAD, with greater than 70% stenosis of one or more

Table 3. Causes of late death*

Primary cause of late death	No.	Fraction of series (%)	Fraction of deaths (%)
Cardiac	102	11	38
Myocardial infarction	68	7.1	26
Congestive failure	26	2.7	9.0
Arrhythmia	8	0.8	3.0
Cancer	34	3.5	13
Stroke	21	2.2	7.9
Ruptured aortic aneurysm	15	1.6	5.6
Renal failure	14	1.5	5.3
Pulmonary failure or embolism	12	1.2	4.5
All other known causes	20	2.1	7.5
Sudden death or unknown	48	5.0	18
Total	266	28	100

* Primary causes of late death in 964 patients with peripheral vascular disease during a follow-up interval of 7 years (mean, 4.6 years).

coronary arteries but no immedicate indication for myocardial revascularization because of adequate intercoronary collateral circulation or because the involved vessel supplied myocardium already replaced by scar. (N = 289)

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. (N = 251)
5. Severe, inoperable CAD, with greater than 70% stenosis of multiple coronary arteries representing inadequate targets for coronary bypass because of diffuse, distal disease or generalized ventricular impairment. (N = 58)

Management

Necessary peripheral vascular reconstruction was routinely performed with customary precautions in patients with normal coronary arteries or mild to moderate CAD. Additional monitoring by pulmonary artery catheterization was commonly employed for those with advanced but compensated CAD. In selected patients with severe CAD, myocardial revascularization usually was performed as a preliminary procedure prior to aortic aneurysm resection or lower extremity revascularization. Whenever feasible, aneurysm resection was scheduled as a second operation during the same hospital admission in order to reduce the risk for rupture during an extended staging interval. Our protocol for patients with severe coronary and carotid disease has already been described.[5]

Patients who declined coronary bypass as well as those found to have severe, inoperable CAD were managed on an individual basis. Semi-elective 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 resection only if they experienced symptoms suggesting aneurysm expansion or if progressive enlargement was documented on serial ultrasound examinations. Conservative treatment usually was continued in patients with extremity ischemia, although those with amenable lesions were informed that compromise procedures, such as axillofemoral or femorofemoral bypass, were available if limb viability became jeopardized by aortoiliac occlusive disease.

Statistical analysis

Paired data were compared using the Fisher exact test. Life table calculations were performed according to Cutler and Ederer[9] and were analyzed for statistical significance using the method described by Lee and Desu.[10] As has been our practice in previous reports, patients who died during the immediate postoperative period following peripheral vascular reconstruction have been omitted from cumulative data in order to permit survival comparisons between this study group and other vascular patients whose operations preceded our current approach to preoperative evaluation. It should be noted, however, that the operative mortality rate of coronary bypass is included in all comparisons involving the subset with severe, correctable CAD. Since myocardial revascularization was a critical feature of the planned approach to associated coronary disease in this series, the importance of its surgical risk is a fundamental consideration.

Results

Coronary disease and ventricular function

Specific results of cardiac catheterization for all 1,000 patients are presented in *Table 1*. Using

Table 4. Total cardiac deaths*

Coronary angiographic classification	No.	Operative and late cardiac deaths							
		Age <60		Age 60–69		Age >70		Total	
		No.	%	No.	%	No.	%	No.	%
Normal coronary arteries	85	1/51	2.0	0/28	—	0/6	—	1	1.2
Mild to moderate CAD	317	4/123	3.3	5/126	4.0	5/68	7.4	14	4.4
Advanced but compensated CAD	289	12/72	17	17/126	13	16/91	18	45	16
Severe correctable CAD									
With bypass	216	9/64	14	10/83	12	6/67	9.0	25	12
No bypass	35	1/7	14	2/14	14	6/16	38	9	26
Severe inoperable CAD	58	4/6	67	9/22	41	9/30	30	22	38
Total	1000	3/323	9.6	43/399	11	42/278	15	116	12

CAD = Coronary artery disease

* Total cardiac deaths in 1000 patients with peripheral vascular disease within 7 years (mean, 4.6 years) of investigation, according to age and the angiographic classification of associated coronary disease.

50% angiographic stenosis as the criterion for potentially serious CAD, the right coronary artery was involved in 46% of patients, the left main trunk in 4%, and the anterior descending and circumflex branches of the left coronary system each in 34%. Coronary involvement was limited to a single vessel in 23% of patients but had a double-vessel or triple-vessel distribution in 20% and 18%, respectively. As determined by left ventriculography, 68% of patients had normal ventricular function. Another 21% had segmental akinesia, and 11% had diffuse ventricular impairment. Measurements of left ventricular end-diastolic pressure, often used as a determinant for perioperative volume management during subsequent peripheral vascular operations, were less than 10 mmHg in 290 patients, 10–20 mmHg in 635, and over 20 mmHg in 75.

Vascular surgical mortality

A total of 846 of the original 1000 patients evaluated by coronary angiography now have undergone peripheral vascular reconstruction. *Table 2* presents a summary of operative deaths according to age and the angiographic classification of associated CAD. Surgical risk generally may be correlated with advancing age and the severity of documented coronary involvement. There have been 24 deaths (2.8%) among the 846 patients, and the difference in operative mortality between those less than 70 years of age (2.0%) and older patients (5.2%) is statistically significant ($p = 0.018$). Early mortality also increased linearly from 1.4% in the group with normal coronary arteries to 14% in a small subset of 28 patients who underwent peripheral vascular operations despite the presence of severe, inoperable CAD.

The operative mortality for vascular procedures following myocardial revascularization in a total of 200 patients currently is 1.5%, a figure that is nearly identical to the surgical risk among patients having normal coronary arteries. In comparison, peripheral vascular operations were performed using conventional precautions in 16 of the 35 patients with severe correctable CAD who did not undergo coronary bypass. Two fatal complications (12%) occurred in this group ($p = 0.045$). It is noteworthy that none of the 63 patients over 70 years of age who had preliminary myocardial revascularization died as the result of subsequent vascular procedures.

Late mortality

Of the 1000 patients studied, 12 died after cardiac procedures and 24 have had fatal complications following peripheral vascular reconstruction. Complete follow-up data have been collected for 945 (98.1%) of the remaining 964 patients during a mean follow-up period of 4.6 years. Within this interval, another 266 deaths (28%) occurred and are summarized in *Table 3*. Fatal cardiac events have accounted for 38% of all late deaths and have been responsible for three times the attrition caused by cancer, as well as for approximately four times the stroke mortality

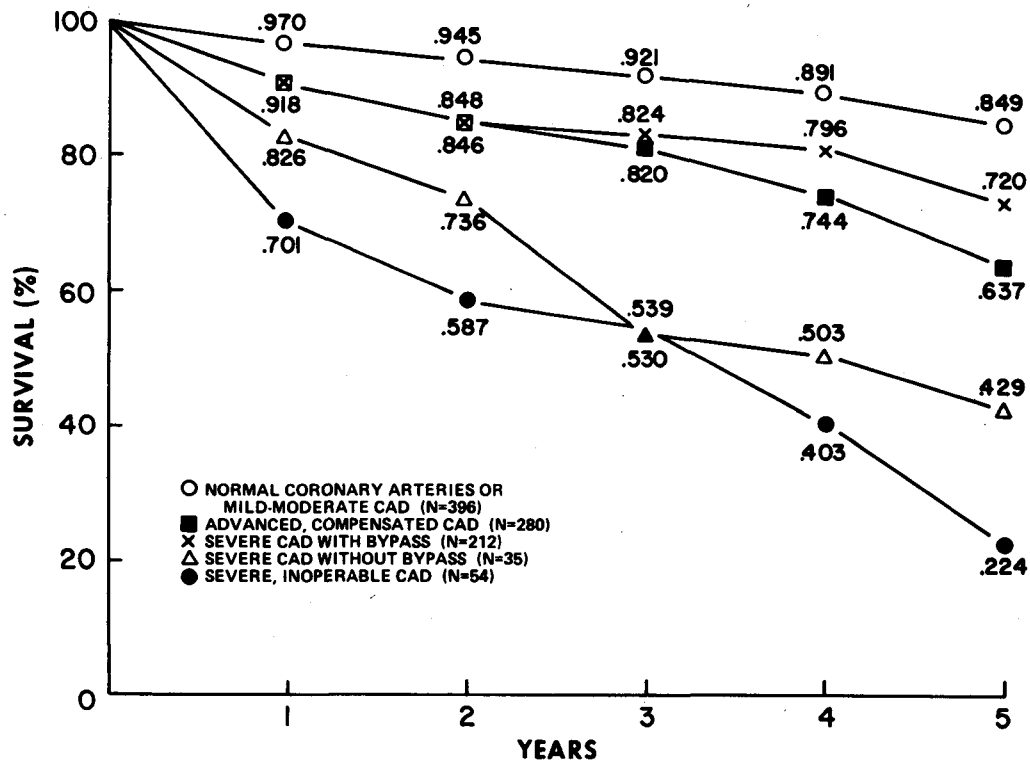

Fig. 1. Cumulative five-year survival of patients with peripheral vascular disease treated at the Cleveland Clinic, according to the angiographic classification of associated coronary artery disease (CAD).

(8%). Ruptured thoracic or abdominal aortic aneurysms occurred in 15 patients, representing 1.6% of the follow-up group and 5.6% of all late deaths.

Similar to operative risk, cardiac mortality may be stratified according to age and the angiographic classification of associated CAD. In *Table 4*, these two factors are correlated with all recognized cardiac deaths that have occurred during the perioperative period or the late follow-up interval. A total of 116 deaths (12%) has been attributed to cardiac causes, ranging from 1.2% of patients documented by angiography to have normal coronary arteries to 38% of those found to have severe, inoperable CAD. Cardiac mortality has occurred in 12% of the 216 patients who received myocardial revascularization, a figure surpassed only by those with either normal coronary arteries or mild to moderate angiographic changes (4.4%). In comparison with the coronary bypass subset, cardiac deaths thus far have occurred in nine (26%) of the 35 unoperated patients known to have severe, correctable coronary lesions ($p = 0.033$). The overall incidence of fatal cardiac complications rose from 9.6% in younger patients to 15% of those over 70 years of age. Nevertheless, only 6 (9.0%) of 67 patients over 70 years of age who received myocardial revascularization have experienced fatal cardiac events, compared with 38% of others in the same age group for whom coronary bypass was warranted but never performed.

Cumulative survival

Cumulative survival for all angiographic subsets is depicted in *Figure 1*. Five-year survival ranged from only 22% among patients found to have severe, inoperable lesions to 85% for those having normal coronary arteries or mild to moderate CAD. Five-year survival presently is 72% in patients with severe, correctable CAD who underwent myocardial revascularization. This figure exceeds the late results (64%) in patients with advanced but compensated coronary lesions for which bypass was not considered necessary, and it is surpassed only by survival in those with

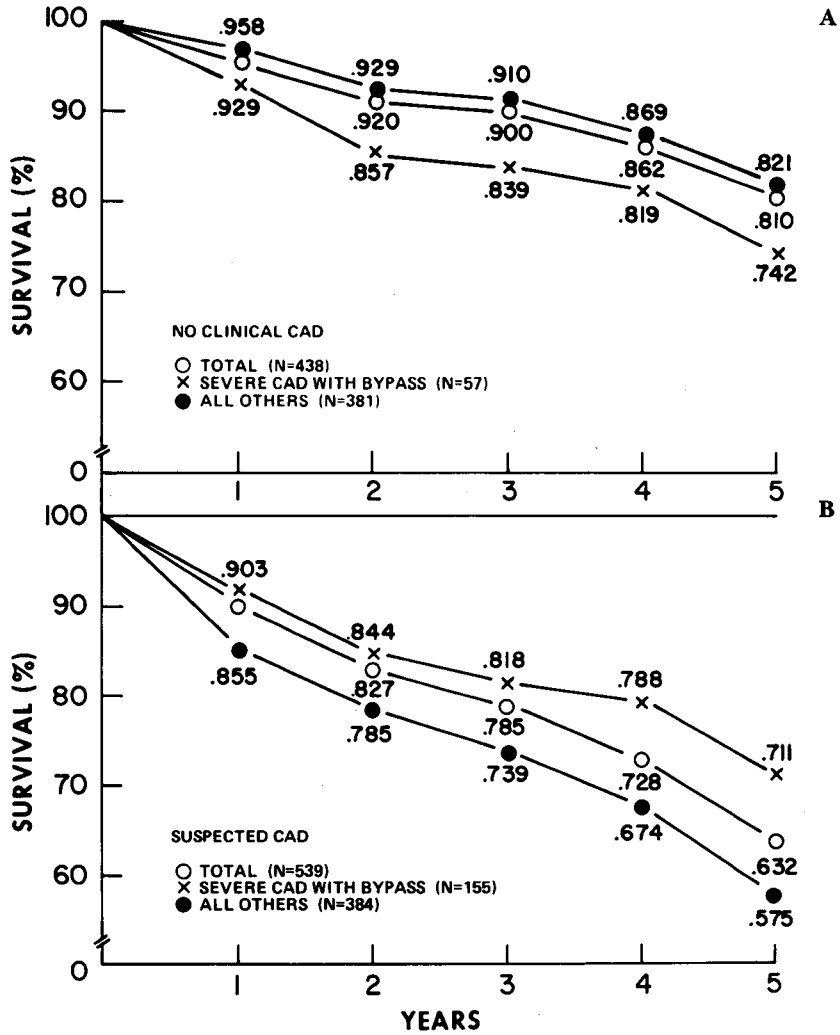

Fig. 2. Cumulative five-year survival according to the clinical cardiac status for patients with no indications of associated coronary artery disease (CAD) (**A**) and suspected CAD (**B**).

normal coronary arteries or mild to moderate CAD. In comparison with the bypass group, 43% of 35 nonoperated patients known to have severe, correctable CAD have survived five years since they entered this study ($p = 0.001$).

Figure 2 illustrates actuarial data according to the clinical cardiac status at the time of coronary angiography. Five-year survival currently is 63% in patients suspected to have coronary disease and is 81% among those who were not, but the late results after myocardial revascularization in both groups are closely comparable (71% and 74% respectively). Although 63% of the patients who had no clinical evidence of coronary disease were documented to have normal coronary arteries or only mild to moderate CAD, the difference in cumulative survival between those who required coronary bypass and all others in this group (82%) did not approach statistical significance ($p = 0.16$). In comparison, five-year survival among patients who received myocardial revascularization thus far has exceeded the figure (57%) for all other patients with traditional indications of associated CAD by approximately 15% actuarial ($p = 0.06$).

Less than severe coronary involvement (normal coronary arteries, mild to moderate CAD, or advanced but compensated CAD) was identified by angiography in 61% of patients under 60 years of age, in 59% of those aged 60–69, and in

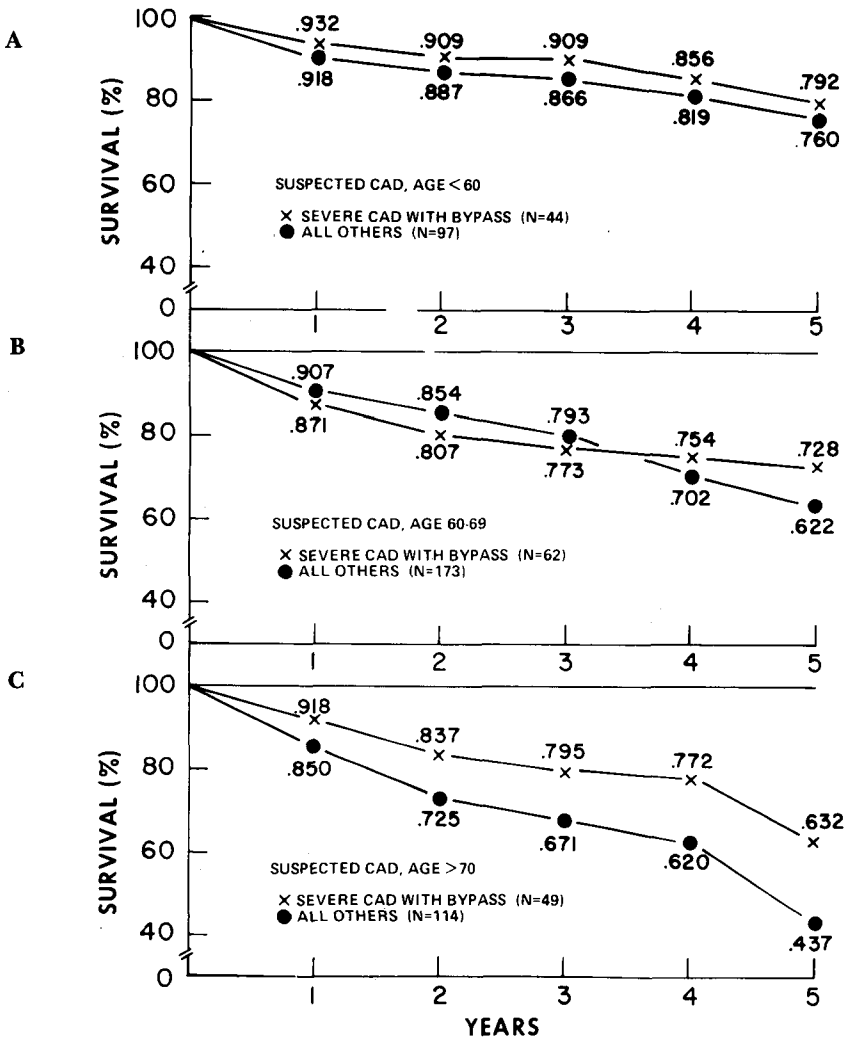

Fig. 3. Cumulative five-year survival for patients suspected to have coronary artery disease (CAD), according to age at the time of coronary angiography: Less than 60 years of age (**A**); age 60–69 (**B**); over 70 years of age (**C**).

49% of those over 70 years of age who had conventional clinical indications of ischemic heart disease. Cumulative survival for these three age groups is presented in *Figure 3*. Despite the fact that the majority of patients in the younger subsets had only a mild to intermediate degree of CAD, five-year survival in those who underwent bypass for severe coronary lesions currently is 3–10% better than the results in all others of similar age. The most impressive differences in five-year survival thus far have involved patients over 70 years of age. In this group, five-year survival was 63% after coronary bypass, compared with 44% for all other comparable patients ($p = 0.04$).

A previous report from the Cleveland Clinic described actuarial survival after successful peripheral vascular reconstruction in 867 patients who were treated prior to the introduction of preoperative coronary angiography.[4] In that series, 419 patients were suspected to have associated coronary disease by clinical criteria. *Figure 4* illustrates five-year survival and the cumulative cardiac mortality for that particular group in comparison with similar data for patients with documented CAD who received myocardial revascularization in the current study. Although patients in the historic subset generally were younger (mean age, 61 years), five-year survival

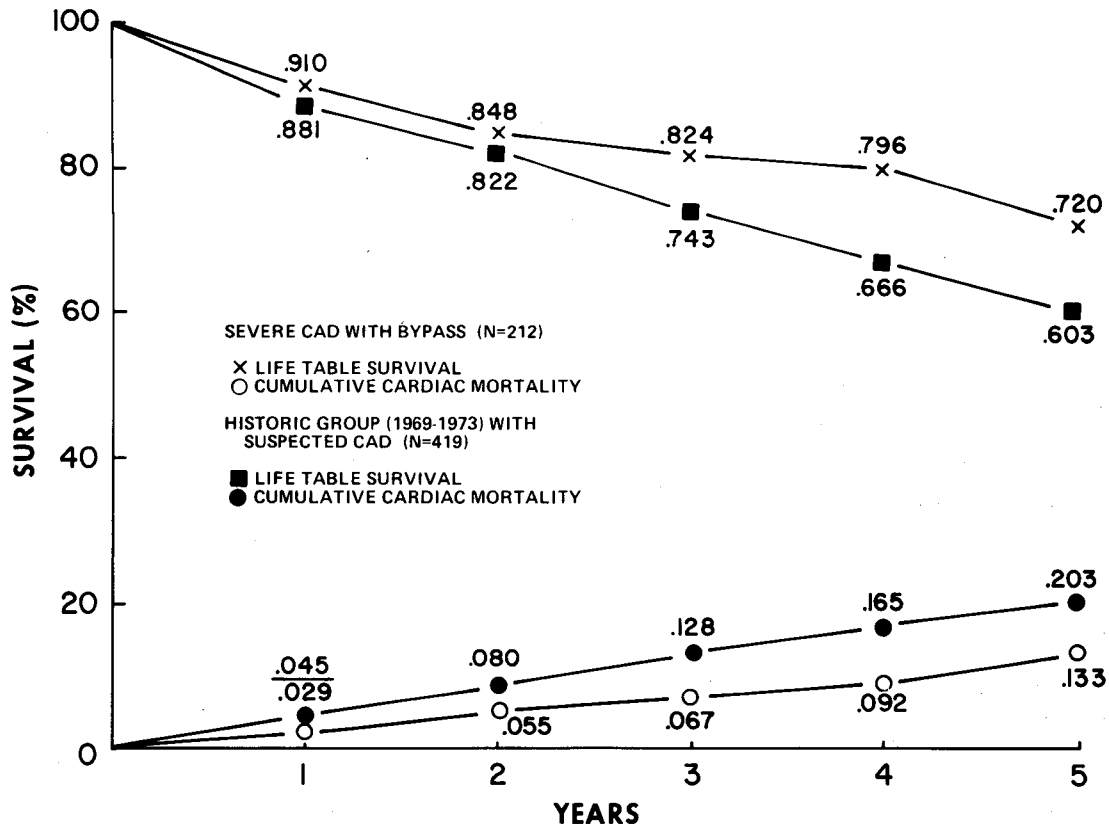

Fig. 4. Cumulative five-year survival and cardiac mortality in selected patients whose associated coronary artery disease (CAD) was managed by coronary bypass, compared with historic group of patients with peripheral vascular disease who had suspected but uninvestigated CAD.[4]

for contemporary patients with severe CAD treated by coronary bypass (72%) is statistically superior ($p = 0.003$) to the survival (60%) of similar patients who previously underwent major vascular procedures without further investigation of suspected coronary disease.

The actual incidence of fatal myocardial infarction in the historic group is speculative and almost certainly is underestimated, since sudden unexplained deaths were not classified as cardiac events even though many probably were. Nevertheless, the difference in cumulative cardiac mortality between patients who appeared to have associated coronary disease in the historic group (20%) and those with documented CAD who presently are managed by coronary bypass (13%) is statistically significant ($p = 0.02$).

Discussion

With the introduction of contemporary anesthetic techniques, Swan-Ganz pulmonary artery catheterization, and pharmacologic advances, countless reports have suggested that the perioperative morbidity of major vascular reconstruction may be reduced to an acceptable level even in the presence of multiple risk factors. Since fatal complications are most likely to occur among patients who require transabdominal aortic replacement, improvement in the safety of elective aortic aneurysm resection often has been cited as an indication of progress in the field of vascular surgery. In this limited context, reports from prominent referral centers have demonstrated that aneurysm resection presently may be performed with an operative mortality of less than 3% under the best of circumstances.[11,12] There is no compelling reason to believe, however, that such exemplary results may be duplicated in the thousands of other hospitals at which most peripheral vascular operations in the United States actually are performed. According to information from the computer registry of the

Cleveland Vascular Society, perhaps the most reliable contemporary survey of vascular surgical risk because of its metropolitan data base, the average operative mortality for elective aneurysm resection recently was 6.5% at 27 hospitals throughout northeastern Ohio.[13] Most of these deaths were related in some way to ischemic cardiac events.

Several retrospective studies have indicated that virtually any noncardiac operation may be performed with exceedingly low risk after previous coronary bypass.[14–17] Crawford et al[16] described a series of 358 patients who underwent 484 additional operations at various intervals following myocardial revascularization, including 308 peripheral vascular procedures in 232 patients. Only four operative deaths (0.8%) occurred, and only 12 patients (3%) had fatal cardiac complications within five postoperative years. In another large series of 1093 patients who eventually required peripheral vascular procedures at some time after coronary bypass, Reul et al[17] found that the operative mortality for subsequent vascular reconstruction was only 2% and reported no deaths in a subset of 120 patients who underwent staged aortic aneurysm resection. Moreover, five-year survival in this investigation ranged from 82–87%, a figure that is consistent with five-year survival of 83% following simultaneous myocardial revascularization and carotid endarterectomy at the Cleveland Clinic.[5]

None of these retrospective studies included the intrinsic risk of coronary bypass in their calculations of operative mortality or late survival. Although myocardial revascularization as presently performed at this center has an immediate mortality approaching 1% and an anticipated 10-year survival of 79%, it is unrealistic to expect comparable results in older patients with multisegmental peripheral vascular disease, no matter how carefully they are selected for coronary bypass.[18,19] Nevertheless, several preliminary conclusions are suggested by this initial review of late results in our prospective study of 1000 patients. First, the operative mortality of coronary bypass is higher in those with systemic vascular disease (5%) than in younger patients whose indication for surgical treatment is limited to isolated coronary involvement. Second, the risk of subsequent vascular procedures is so low (1.5%) that the composite mortality rate for the combination of cardiac and vascular operations hardly exceeds the mortality of myocardial revascularization alone. The vascular surgical risk was 12% ($p = 0.045$) in this study among patients with severe, uncorrected CAD and was 10% in our earlier experience in a heterogeneous group having clinical indications of ischemic heart disease.[1] Accordingly, preliminary coronary bypass appears to reduce the overall surgical mortality in selected vascular patients by approximately half.

Finally, it seems important to recognize that any approach that does not directly influence the eventual course of incidental coronary disease may be expected to have little influence on late survival after successful peripheral vascular operations. Our current data indicate that five-year survival in selected patients undergoing peripheral reconstruction and receiving coronary bypass (72%) is superior to the cumulative figures of 43% for a smaller cohort with comparable angiographic findings ($p = 0.001$) and 60% for a historic group with suspected but undocumented coronary disease ($p = 0.003$).[4] In both comparisons, the reduction in long-term cardiac mortality within the bypass subset also is statistically significant. During the current follow-up period (mean, 4.6 years), patients over 70 years of age seem to be the principal beneficiaries of the protection offered by myocardial revascularization.

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