# Fatal myocardial infarction following peripheral vascular operations

## *A study of 951 patients followed 6 to 11 years postoperatively*

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Coronary artery disease (CAD) is the most common cause of early postoperative mortality and late death among patients who require surgical management of peripheral vascular disease. Several large series[1-10] have indicated that myocardial infarction is responsible for 40% to 70% of all eventual deaths among patients who undergo abdominal aortic aneurysm resection, aortoiliofemoral or femoropopliteal arterial reconstruction, or carotid endarterectomy, and that fatal myocardial infarction occurs with predictably greater frequency among patients who have preoperative evidence of CAD. In such patients, cardiac complications exceed those associated with the underlying peripheral vascular disease that initially required investigation. Szilagyi et al[7] found that 71% of patients with untreated abdominal aortic aneurysms died during observation from either myocardial infarction or aneurysm rupture. Previous reports from the Cleveland Clinic[6] and others[4, 8] have demonstrated that 5- and 10-year mortality rates surpass the incidence of graft occlusion following either aortofemoral or femoropopliteal bypass. DeWeese et al[5] and Thompson et al[9] have shown that myocardial infarction accounts for three to five times the number of late deaths caused by stroke among patients who require carotid endarterectomy.

Several studies suggest that patients who have had previous direct myocardial revascularization sustain fewer cardiac complications after subsequent vascular and other major operations than would be anticipated even in the absence of known CAD.[11, 12] Since cardiac complications appear to be particularly prevalent among patients who have peripheral vascular disease, routine coronary angiography has been recommended to all patients scheduled for elective peripheral vascular operations at the Cleveland Clinic since 1978. As described in a previous report, severe but surgically correctable coronary artery lesions were documented with this format in 55% of patients scheduled for abdominal aortic reconstruction who had preoperative evidence of CAD and in 17% of those with no clinical indication of CAD.[13] Elective myocardial revascularization was performed in 24% of the patients in this investigation, and 96 patients underwent aortic reconstruction which resulted in a single postoperative death unrelated to CAD. During the same study period, 27% of patients who required carotid endarterectomy and 12% of patients scheduled for elective femoropopliteal or distal lower extremity bypass also underwent myocardial revascularization as a staged or combined procedure to correct severe CAD discovered during routine coronary angiography.

Since routine preoperative coronary angiography and, if indicated, elective myocardial revascularization continue to be recommended without prospective randomization to all patients under consideration for elective peripheral vascular operations at this institution, historic standards will be necessary to evaluate the impact of this approach on late survival. Previous publications[14-16] described the influence of CAD upon survival of patients who had had abdominal aortic aneurysm resection, lower extremity revascularization, or carotid endarterectomy at the Cleveland Clinic from 1969 through 1973. This report presents a composite analysis of the 951 consecutive patients who constituted these series. Late follow-up information was obtained during annual examinations or by telephone contact with each patient, a close surviving family member, or the referring physician and is complete for 95% of the patients.

## Patient information

The 951 patients in this investigation consisted of 735 men and 216 women, with an age range of 31 to 81 years (mean, 61 years). Ninety patients (10%) were less than 50 years of age at the time of operation, 318 patients (33%) were 50 to 59 years of age, 381 patients (40%) were 60 to 69 years of age, 147 patients (15%) were 70 to 79 years of age, and 15 patients (2%) were more than 80 years of age.

The surgical procedures included in this report are given in *Table 1*. Three hundred forty-three patients (36%) underwent resection of infrarenal abdominal aortic aneurysms. Of these, elective operations were performed for 251 patients (73%) who had asymptomatic aneurysms; urgent procedures were necessary for 49 patients (14%) who had

**Table 1.** Surgical procedures

| Surgical procedure | Patients Number | | Patients Percent | |
|---|---|---|---|---|
| Abdominal aortic aneurysm resection | 343 | | 36 | |
| Elective | | 251 | | 26 |
| Symptomatic, intact | | 49 | | 5 |
| Ruptured | | 43 | | 5 |
| Carotid endarterectomy | 335 | | 35 | |
| Lower extremity revascularization | 273 | | 29 | |
| Aortoiliac reconstruction | | 186 | | 20 |
| Femoropopliteal or distal bypass | | 87 | | 9 |
| Total | 951 | | 100 | |

symptomatic but intact aneurysms, and emergency intervention with a minimum of preoperative preparation was required for 43 patients (13%) who had ruptured aneurysms. Three hundred thirty-five patients in this series (35%) required carotid endarterectomy. In this group, 252 patients (75%) had previous hemispheric or vertebrobasilar neurologic symptoms, and 83 patients (25%) had asymptomatic carotid stenosis demonstrated by angiography. The remaining 273 patients in this report (29%) had lower extremity revascularization procedures, including reconstruction of aortoiliac occlusive arterial disease in 186 (68%) and femoropopliteal or distal revascularization in 87 (32%). Disabling claudication was the indication for operation in 53% of the patients in this subset whereas 45% of these patients had ischemia manifested by rest pain or tissue necrosis. Six patients (2%) underwent femoropopliteal bypass because of the presence of popliteal artery aneurysms.

*Atherosclerotic risk factors*

Five hundred twenty-six patients (55%) had hypertension under medical management or blood pressure measurements consistently greater than 150/90 mm Hg. Diabetes mellitus under medical treatment, an abnormal glucose tolerance test, or a fasting or 2-hour postprandial blood glucose level greater than 120 mg/dl was present in 284 patients (30%). The serum cholesterol value (range, 50 to 750 mg/dl) was greater than 270 mg/dl in 302 patients (32%). The serum triglyceride value (range, 51 to 3350 mg/dl) was greater than 180 mg/dl in 283 patients (30%). A total of 682 patients (72%) either smoked cigarettes or had discontinued their chronic use of cigarettes less than 5 years before their operations.

*Preoperative cardiac status*

No history of previous symptoms of CAD or known cardiac disease was elicited from 607 patients (63%). Histories obtained from the remaining 344 patients, their families or referring physicians were consistent with previous myocardial infarction in 113 (12%), angina pectoris in 110 (12%), congestive heart failure in 16 (2%), arrhythmias requiring medical treatment in 10 (1%), and two or more of these factors in 95 (10%).

The preoperative electrocardiogram (ECG) was normal in 447 patients (47%). Previous myocardial infarction was documented by ECG evidence in 175 patients (18%) whereas 291 patients (31%) had ischemic myocardial changes within the ST-T segments. Seventeen patients (2%) had arrhythmias on preoperative ECG tracings, and 21 patients (2%) had two or more abnormal ECG findings.

Considering those features most suggestive of CAD by history (previous myocardial infarction, angina pectoris) or by ECG criteria (previous myocardial infarction, ischemic myocardial changes), 367 patients (39%) had no preoperative evidence of CAD, 78 (8%) had CAD by history alone, 237 (25%) had CAD on the basis of ECG information alone, and 247 (26%) had CAD according to both history and ECG results. The remaining 22 patients (2%) had nonspecific ECG changes, such as arrhythmias or isolated conduction defects, and are included among patients with no clinical evidence of CAD in subsequent data in this report.

## Results

*Operative mortality*

The principal causes of early postoperative death are given in *Table 2.* A total of 84 patients (8.8%) in the entire series died within 30 days of operation

**Table 2.** Fatal postoperative complications

| Principal cause of death | Number of patients | Percent of deaths | Percent of series |
|---|---|---|---|
| Myocardial infarction | 36 | 43 | 3.8 |
| Pulmonary failure | 11 | 13 | 1.2 |
| Hemorrhage | 9 | 11 | 0.9 |
| Renal failure | 6 | 7 | 0.6 |
| Pulmonary embolism | 5 | 6 | 0.5 |
| Stroke | 4 | 5 | 0.4 |
| Graft infection | 2 | 2 | 0.2 |
| Other | 11 | 13 | 1.2 |
| Total | 84 | 100 | 8.8 |

or during the same admission to the hospital. The overall operative mortality rate for aortic aneurysm resection in this series, collected nearly a decade ago, was 16.5%. Fatal complications occurred in 9.6% of patients who had elective aneurysmectomy, in 26.5% of those with symptomatic but intact aneurysms, and in 46.5% of those with ruptured aneurysms. The operative mortality rate was 6.2% following lower extremity revascularization and 1.5% after carotid endarterectomy. Myocardial infarction was the leading cause of death in all groups and accounted for 43% of postoperative deaths in the entire series, a figure representing three times as many deaths than were caused by the next most common source of early mortality, pulmonary failure. Fatal postoperative myocardial infarctions occurred in 3.8% of the 951 patients in this study.

Although preoperative atherosclerotic risk factors, such as hypertension and diabetes mellitus, were not associated with statistically significant differences in postoperative mortality, the incidence of fatal complications could be correlated directly with age at the time of operation. Seventeen (4.2%) of 408 patients who were less than 60 years of age died postoperatively, compared to 67 (12.3%) of 543 patients who were more than 60 years of age. Fatal myocardial infarctions accounted for 10 (59%) of the 17 deaths among patients less than 60 years of age, affecting 2.5% of this group, and were responsible for 26 (39%) of the 67 deaths among patients more than 60 years of age, affecting 4.8% of this group. Differences in the operative mortality rate ($p < 0.001$) and the incidence of fatal myocardial infarction ($p < 0.05$) for these two age subsets were statistically significant.

*Late mortality*

Forty-five patients (5%) were lost to follow-up during the maximum observation interval of 11 postoperative years. The principal causes of late mortality among 867 operative survivors in this series are given in *Table 3*. A total of

**Table 3.** Causes of late mortality among 867 operative survivors 1–11 years after operation

| Principal cause of death | Number of patients | Percent of deaths | Percent of operative survivors |
|---|---|---|---|
| Myocardial infarction | 177 | 44 | 20 |
| Stroke | 49 | 12 | 6 |
| Malignant neoplasm | 47 | 12 | 6 |
| Chronic renal disease | 12 | 3 | 1 |
| Chronic pulmonary disease | 11 | 3 | 1 |
| Pulmonary embolism | 9 | 2 | 1 |
| Congestive heart failure | 9 | 2 | 1 |
| Aortic graft complication | 8 | 2 | 1 |
| Ruptured aortic aneurysm | 6 | 1 | 1 |
| Other, or unknown | 78 | 19 | 9 |
| Total | 406 | 100 | 47 |

406 patients (47%) have died, and myocardial infarction was the principal cause of death in 177 (44%). Myocardial infarction has been responsible for more than three times the number of late deaths produced by either of the next leading sources of late mortality, stroke or malignant neoplasm. The actual incidence of fatal myocardial infarction in this investigation undoubtedly is even higher, since the cause of sudden death was considered to be unknown.

Complete life-table data for the 867 patients who survived operation are given in *Table 4.* Two hundred twenty-five patients (26%) died within 5 years of operation. Myocardial infarction was the principal cause of death in 91 patients, accounting for 40% of the 5-year deaths and affecting 10% of the operative survivors. Of the 642 patients who lived at least 5 years after operation, 181 (28%) have subsequently died within 5 to 11 postoperative years. Myocardial infarction was responsible for 86 (48%) of these deaths, affecting 13% of the 5-year survivors. A total of 177 (20%) of the 867 operative survivors have had fatal myocardial infarctions during the maximum follow-up interval of 11 years.

*Figure 1* presents graphic representation of life-table data following each of the operative procedures constituting this series. Although late survival following aortoiliac reconstruction appears to exceed that following femoropopliteal bypass, statistical analysis of survival curves[17] did not confirm significant differences between these groups of patients. Late survival for patients having lower extremity revascularization (mean age, 57 years), carotid endarterectomy (mean age, 60 years), and aortic aneurysm resection (mean age, 66 years) generally corresponded to advancing age. Five- and 10-year survival rates were 79% and 54% after lower extremity revascularization, 73% and 18% after carotid endarterectomy, and 57% and 30% after aortic aneurysmectomy.

Of the 867 operative survivors, 515 had some indication of CAD from cardiac history or preoperative ECG findings, whereas 352 had no clinical evidence of CAD. *Figure 2* presents graphic representation of life-table data for these two groups, together with similar information for a normal 1970 male population of the same age (61 years)[18] and for a group of 601 patients with known

**Table 4.** Complete life-table data for 867 operative survivors

| | Number of patients | | | | | Proportion of patients | | |
|---|---|---|---|---|---|---|---|---|
| Post-operative year | Alive at beginning of year | Lost to follow-up during year | Observed for only part of year | Exposed to risk of dying during year | Died during year | Died during year | Survived the year | Alive to end of each year |
| 1 | 867 | 7 | 0 | 863.5 | 45 | .052 | .948 | .948 |
| 2 | 815 | 15 | 0 | 807.5 | 29 | .036 | .964 | .914 |
| 3 | 771 | 3 | 0 | 769.5 | 47 | .061 | .939 | .858 |
| 4 | 721 | 4 | 0 | 719 | 44 | .061 | .939 | .806 |
| 5 | 673 | 4 | 0 | 671 | 60 | .089 | .911 | .734 |
| 6 | 609 | 4 | 49 | 582.5 | 52 | .089 | .911 | .669 |
| 7 | 504 | 7 | 117 | 442 | 46 | .104 | .896 | .599 |
| 8 | 334 | 0 | 86 | 291 | 36 | .124 | .876 | .525 |
| 9 | 212 | 1 | 73 | 175 | 29 | .166 | .834 | .438 |
| 10 | 109 | 0 | 53 | 82.5 | 9 | .109 | .891 | .390 |
| 11 | 47 | 0 | 38 | 28 | 9 | .321 | .679 | .265 |

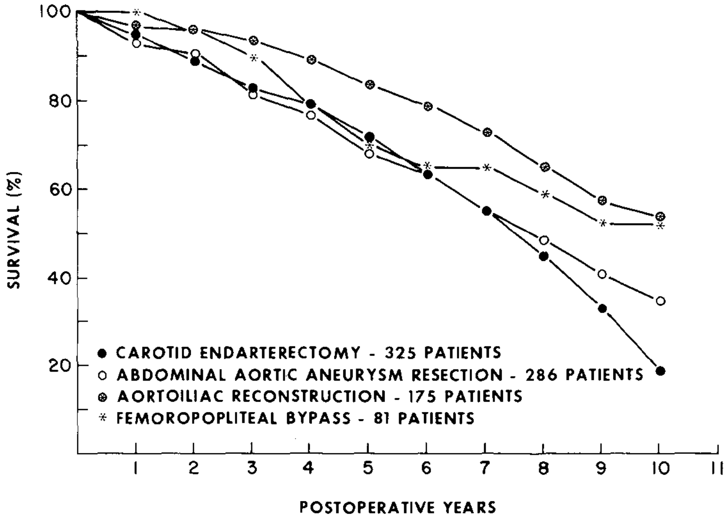


**Fig. 1.** Life-table survival curves for 867 operative survivors according to peripheral vascular operation performed.

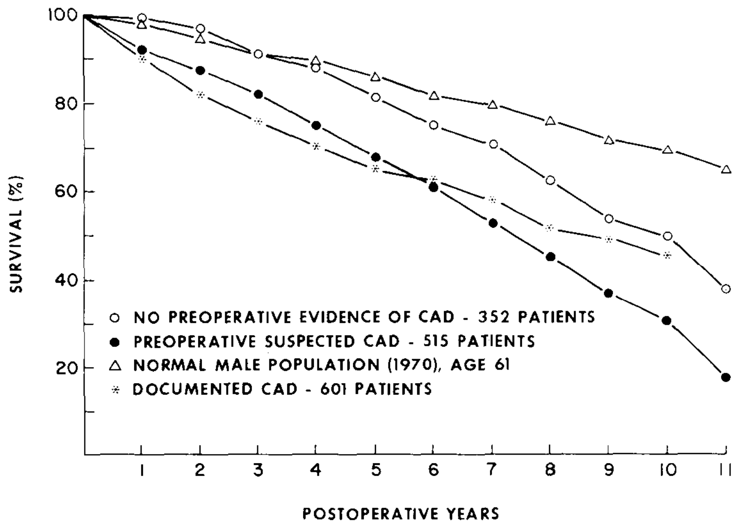


**Fig. 2.** Life-table survival curves for 867 operative survivors according to preoperative cardiac status, compared to a normal male population of the same age[18] and to a group of 601 patients with CAD documented by coronary angiography.[19]

CAD documented by coronary angiography at the Cleveland Clinic previously reported by Proudfit et al.[19] The 5- and 10-year survival rates following peripheral vascular operations were 82% and 49% for patients without evidence of CAD, and 67% and 31% for patients with suspected CAD. These differences were statistically significant ($p < 0.05$). Late survival of patients with suspected CAD in this series was significantly lower ($p < 0.05$) than that of the normal male population beyond the third postoperative year. Moreover, there was no statistically significant difference in survival rates during the first 8 postopera-

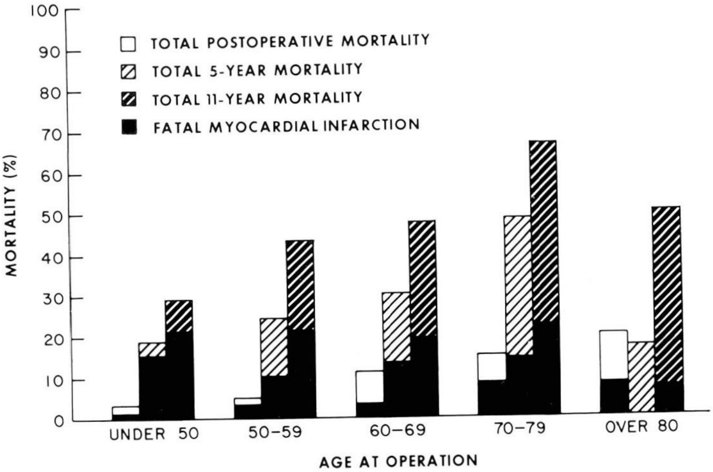


**Fig. 3.** Comparison of postoperative and late mortality for 951 patients according to age at the time of operation.

tive years between patients with suspected CAD in this investigation and those with proved CAD described by Proudfit et al.

The influence of age at the time of operation on early postoperative mortality rates, 5-year and total late mortality rates, and the incidence of fatal myocardial infarction is presented in *Figure 3.* As might be anticipated, advancing age was associated with an increase in late mortality from all causes. Fatal myocardial infarction accounted for 52% of all late deaths affecting 21% of the group of patients less than 60 years of age, and caused 38% of all late deaths affecting 20% of the group of patients over 60 years of age. Myocardial infarction was especially prevalent as a source of premature late death within a group of 87 patients who were less than 50 years of age at the time of operation. In this subset, fatal myocardial infarction was responsible for 81% of deaths within 5 postoperative years and for 72% of all deaths within the maximum follow-up interval of 11 years.

The preoperative cardiac status is correlated with the incidence of fatal myocardial infarction during the early postoperative and late follow-up periods in *Table 5.* Chi-square analysis demonstrated highly significant differences (p

**Table 5.** Total incidence of fatal myocardial infarction according to preoperative cardiac status*

| Preoperative cardiac status | Patients | Postoperative Patients No. | Postoperative Patients % | Late (1–11 yr) Patients No. | Late (1–11 yr) Patients % |
|---|---|---|---|---|---|
| Negative cardiac history and normal ECG | 389 | 4 | 1.0 | 55 | 14.3* |
| Previous myocardial infarction or angina by history alone | 78 | 3 | 3.8 | 22 | 29.3 |
| Previous myocardial infarction or myocardial changes by ECG alone | 237 | 10 | 4.2 | 37 | 16.3 |
| Positive cardiac history and abnormal ECG | 247 | 19 | 7.7 | 63 | 27.6 |

* Late incidence calculated on the basis of operative survivors.

$< 0.001$) in the incidence of fatal myocardial infarction during the immediate postoperative period and during the late follow-up interval between patients with no preoperative evidence of CAD and those who had both a positive cardiac history as well as abnormal ECG findings. Statistical testing also indicated ($p < 0.01$) that late death from myocardial infarction was more likely to occur among patients who had a convincing history of angina pectoris with a normal ECG than among asymptomatic patients with incidental ECG abnormalities.

**Comment**

The results of this study suggest that the late survival among patients who have preoperative indications of CAD on the basis of previous cardiac symptoms or abnormal ECG findings at the time they require surgical management of peripheral vascular disease is more closely comparable to survival demonstrated by patients with significant CAD documented by coronary angiography than to that of the normal population of the same age. Patients who had preoperative evidence of CAD sustained a statistically significant number of fatal myocardial infarctions throughout the 11-year follow-up interval, and late death from complications of CAD appeared to be especially prevalent among patients less than 60 years of age at the time of peripheral vascular reconstruction. Myocardial infarction was the most common cause of mortality in this series by severalfold, accounting for three times the number of early postoperative deaths caused by pulmonary failure as well as for three times the number of late deaths caused by either stroke or malignant neoplasm.

Advances in the technology of preoperative preparation and postoperative surgical care have enhanced the safety of elective operations for peripheral vascular disease during the past 15 years, but the impact of fatal myocardial infarction upon late survival of such patients has remained remarkably constant. Five- and 10-year survival rates in this report were 57% and 30% for patients with aortic aneurysms, 79% and 54% for those with lower extremity ischemia, and 73% and 18% for those with extracranial cerebrovascular disease. Fatal myocardial infarctions caused 40% of deaths within 5 years of operation and 44% of deaths within the maximum follow-up interval of 11 years. During the past 2 decades, a number of reports presenting comparable data in large series have concluded that certain preoperative atherosclerotic risk factors imposed predictable limitations upon late survival.[1-9] De Bakey et al[1] documented a substantial reduction in late survival following aortic aneurysm resection among patients with hypertension or clinical evidence of CAD, and DeWeese and Rob[4] clearly demonstrated that patients who had preoperative evidence of CAD, diabetes mellitus, or multisegmental atherosclerotic lesions in the lower extremities had twice the late mortality rate following femoropopliteal bypass than did patients without these risk factors.

The operative risk of selected patients with peripheral vascular disease and obvious, severe CAD may be reduced by compromise surgical procedures, such as axillofemoral or femorofemoral bypass for those with aortoiliac atherosclerosis, or may be entirely avoided by nonoperative management. However, such precautions alone do not influence the late incidence of fatal cardiac complications. Thompson et al[9, 20] and Toole et al[10] observed that myocardial infarction accounted for approximately three times the number of late deaths in patients with carotid atherosclerosis than did stroke, irrespective of whether the extracranial disease received surgical correction, medical management, or no treatment at all. Furthermore, Szilagyi et al[7] described 156 patients who were not considered to be suitable candidates for elective aortic aneurysm resection, including 59 patients in whom suspected cardiac disease was cited as the contraindication to operation. Of 127 patients who never underwent aneurysm resection in this study, 71% died during observation, and 69% of all deaths were caused by either myocardial infarction or aneurysm rupture. Flanigan et al[21] subsequently reported a mortality rate of 48% for a similar series of 153 patients with known abdominal aortic aneurysms who did not undergo elective operation. Myocardial infarction or aneurysm rupture caused 59% of all deaths in this series including 80% of deaths among patients who had been denied elective aneurysm resection because of suspected CAD. Elective aneurysm resection clearly is the most logical form of management for such patients if it can be performed with a reasonable margin of safety.

Patients with documented CAD who undergo direct myocardial revascularization have been reported to sustain fewer cardiac complications after subsequent vascular and other major operations than otherwise would be expected. Ennix et al[22] determined that perioperative myocardial infarctions at the time of carotid endarterectomy occurred in 13% of patients who had angina pectoris and in only 0.8% of patients who had no clinical evidence of CAD. In this series of 1238 patients who underwent 1546 carotid procedures, the operative mortalities were 1.5% for patients without CAD, 18% for patients with angina pectoris who underwent carotid endarterectomy alone, and 3% for patients with angina pectoris who underwent simultaneous carotid endarterectomy and myocardial revascularization. Crawford et al[11] presented a series of 358 patients who underwent 484 subsequent operations at various intervals following direct myocardial revascularization, including 308 peripheral vascular procedures in 232 patients. Only four operative deaths (0.8%) occurred following these subsequent operations, and only 12 patients (3%) have died from cardiac causes within a 5-year follow-up period. Other reports from medical centers with extensive experience with coronary artery bypass indicate that 5-year survival rates of 90% or greater may be anticipated following direct myocardial revascularization even in patients who previously had multiple-vessel CAD, and that the prospects for extended survival are conspicuously enhanced if coronary bypass is performed before extensive myocardial damage has occurred.[23, 24]

The results of this report of 951 patients reveal that earlier recognition and, if indicated, appropriate surgical management of severe CAD might be expected to have a substantial influence upon late survival in patients who have peripheral vascular disease. Although radionuclide myocardial scanning may eventually provide a reliable screening mechanism to determine those patients for whom coronary angiography is necessary, noninvasive assessment of patients with peripheral vascular disease via stress electrocardiography presently has distinct limitations. Gage et al[25] found that 24% of such patients were unable to comply with the requirements of stress electrocardiography because of claudication or dyspnea. In addition, Weiner et al[26] determined that the incidence of false-negative stress ECG results is unacceptable when the test is conducted in a group of patients in which the prevalence of severe CAD is high. Considering the prevalence and ominous implications of CAD in patients with peripheral vascular disease, coronary angiography has been recommended to all patients under consideration for elective peripheral vascular operations at the Cleveland Clinic since 1978. Although late follow-up information is not yet available for patients whose management presently includes coronary angiography and, if indicated, elective myocardial revascularization, this report presents an historic control group with which such patients will eventually be compared in an effort to define those for whom preoperative coronary angiography is advisable for improved postoperative results and late survival.

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