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## *Patterns of Atherosclerosis and their Surgical Significance*

MICHAEL E. DEBAKEY, M.D.,\* GERALD M. LAWRIE, M.D.,† DONALD H. GLAESER, D.Sc.‡

The records of 13,827 patients admitted on one or more occasions to The Methodist Hospital in Houston on the service of the senior author for the treatment of arterial atherosclerotic occlusive disease from 1948 to 1983 were analyzed. The data derived from this analysis are believed to support the concept that atherosclerotic occlusive disease tends to assume characteristic patterns that may be classified, by predominant site or distribution of the disease, into five major categories: (I) the coronary arterial bed, (II) the major branches of the aortic arch, (III) the visceral arterial branches of the abdominal aorta, (IV) the terminal abdominal aorta and its major branches, and (V) a combination of two or more of these categories occurring simultaneously. Category IV had the highest proportion of patients (about two-fifths), Category I the second highest (almost one-third), and Category III had the lowest percentage (3%). Atherosclerotic occlusive disease in all categories tends to be well localized and usually occurs in the proximal or midproximal portions of the arterial bed. Such lesions are amenable to effective surgical treatment directed toward restoration of normal circulation. Less commonly, how-

*From the Cora and Webb Mading Department of Surgery,  
Baylor College of Medicine, Houston, Texas*

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\* Olga Keith Wiess Professor of Surgery, Baylor College of Medicine, Houston, Texas.

† Professor of Surgery, Cora and Webb Mading Department of Surgery, Baylor College of Medicine, Houston, Texas.

‡ Associate Professor, Cora and Webb Mading Department of Surgery, and Director, The Simon and Clara Sakowitz Cardiovascular Computer Monitoring Research Laboratory, Baylor College of Medicine, Houston, Texas.

Reprint requests: Michael E. DeBakey, M.D., Baylor College of Medicine, Texas Medical Center, One Baylor Plaza, Houston, TX 77030.

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ever, the occlusive disease in all categories occurs predominantly in the distal portions of the arterial bed, and such lesions are usually not amenable to effective surgical treatment. Patients in Categories I and III were significantly younger than those in the other categories and, although males predominated in all categories, Categories II and III contained significantly more female patients than did the other categories. In general, however, female patients behaved like male patients in virtually all aspects of the study. The rates of progression of the disease may be classified into: (1) rapid (0 to 36 months), (2) moderate (37 to 120 months), and (3) slow (more than 120 months). The rapid and moderate rates of progression occurred most frequently in Categories II and IV, and the moderate and slow rates occurred most frequently in Category I. The possibility for development of recurrence or progression of disease in the same category and in a new category was significantly greater in younger patients. The patient's sex had no significant influence in this regard. Among the various categories, patients in Category IV had the highest incidence of development of disease in a new category, and Category I had the lowest incidence. Patients originally in Category II had a somewhat greater tendency to development of disease in Category IV, and patients originally in Category IV, for development of disease in Category II. The data presented in this study demonstrate that patients with atherosclerotic occlusive disease are at risk of development of new or recurrent critical lesions, and emphasize the need for careful and continuing follow-up of such patients.

**I**N RECENT YEARS, considerable progress has been made toward a better understanding of the insidious

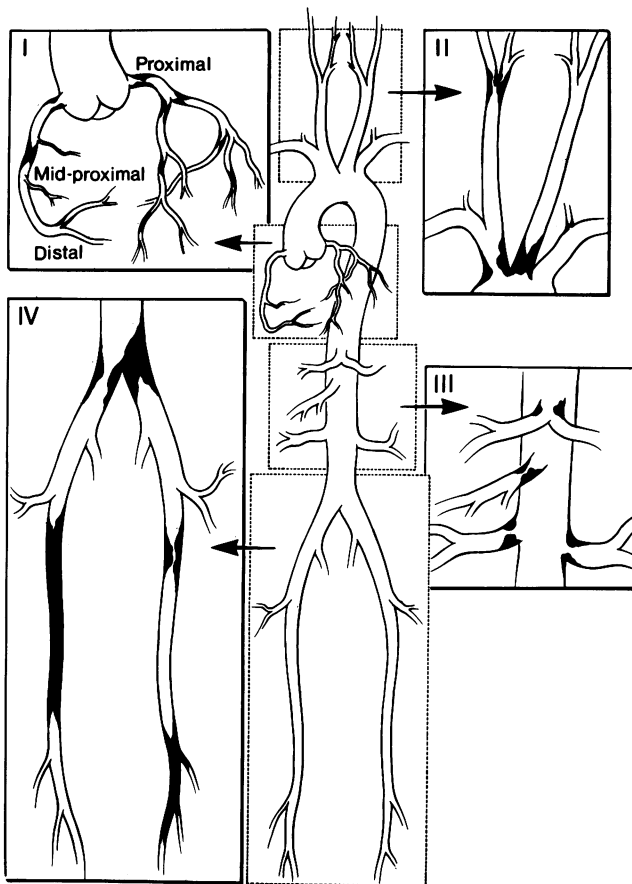


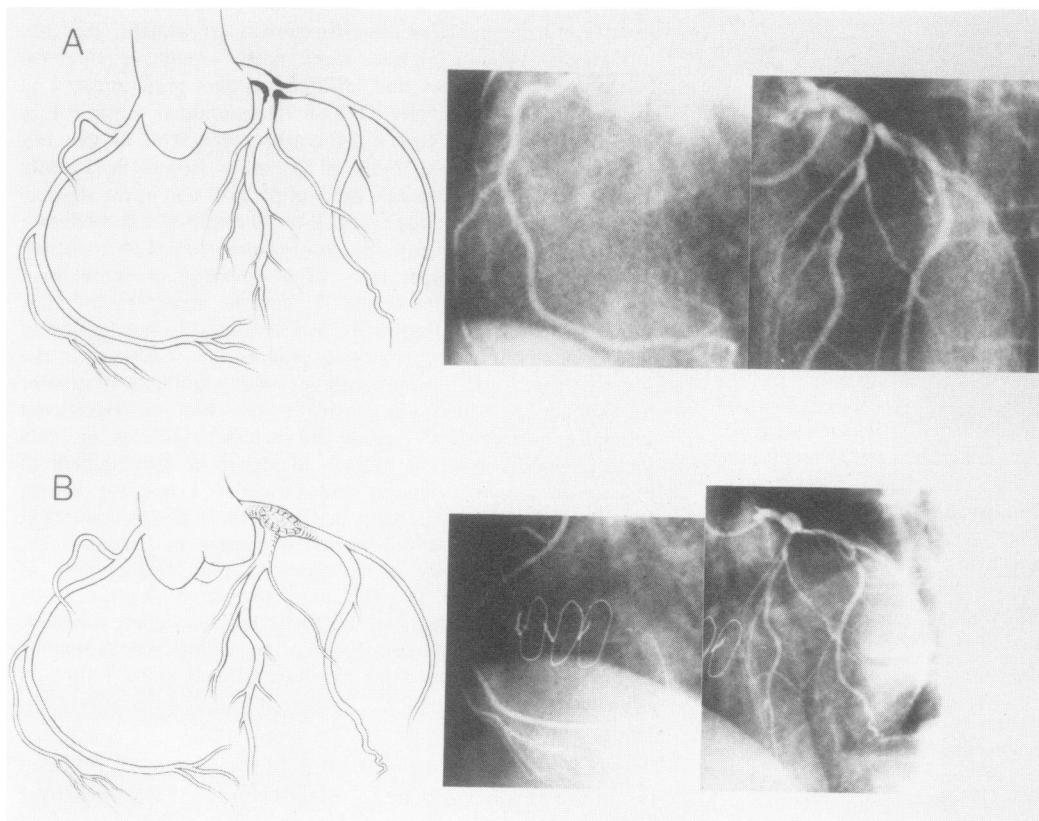
FIG. 1. Diagrammatic representation of predominant anatomic sites (shown in black) and distribution of atherosclerotic occlusive disease in the four major arterial beds of body.



pathologic and anatomic changes that take place in the arterial wall, leading to the development of atherosclerosis, even though the precise cause of the disease remains undetermined. To a large extent, this knowledge has been derived from certain experimental studies, but most important, it has come from surgical experiences that have made it possible to observe the course of the disease based on periodic arteriograms over several decades. As a consequence of our own such studies of our experience during this period, we have made certain significant observations about the distinctive patterns of the disease and their rates of progression.<sup>1-7</sup> A number of other pertinent publications on this subject are cited in the references of these reports<sup>1-7</sup> and are therefore not repeated in this presentation.

These characteristic atherosclerotic patterns may be classified into categories according to the predominant anatomic site or distribution of the disease in the major arterial beds of the body (Fig. 1):

Category I. The coronary arterial bed (Figs. 2 and 3).

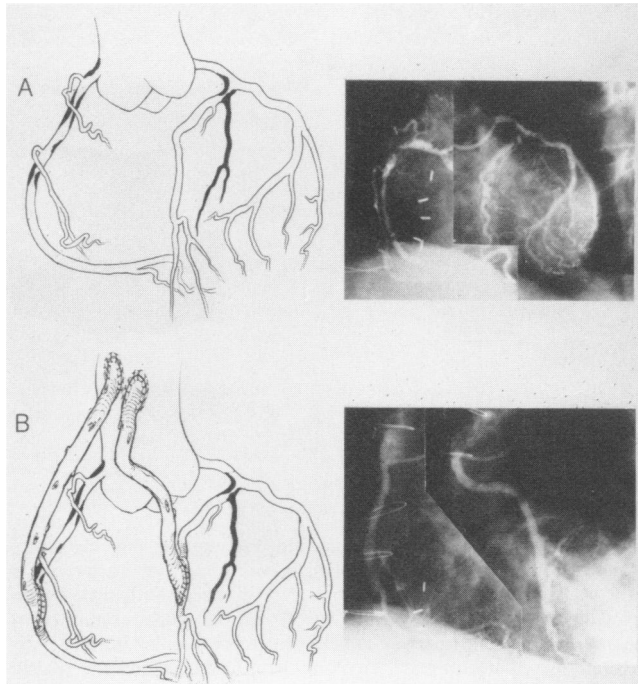


FIGS. 2A and B. A. Drawing and photograph of coronary arteriograms showing severe localizing stenosis of left main coronary artery in a 45-year-old white man with severe angina. Treatment consisted in endarterectomy and patch-graft angioplasty. B. Drawing and photograph of coronary arteriograms 11 years after operation in same patient showing correction of preoperative stenosis with little or no evidence of recurrence or progressive disease in the right and left coronary arterial bed. Patient has remained completely asymptomatic with normal activity during the 18 years since the operation.

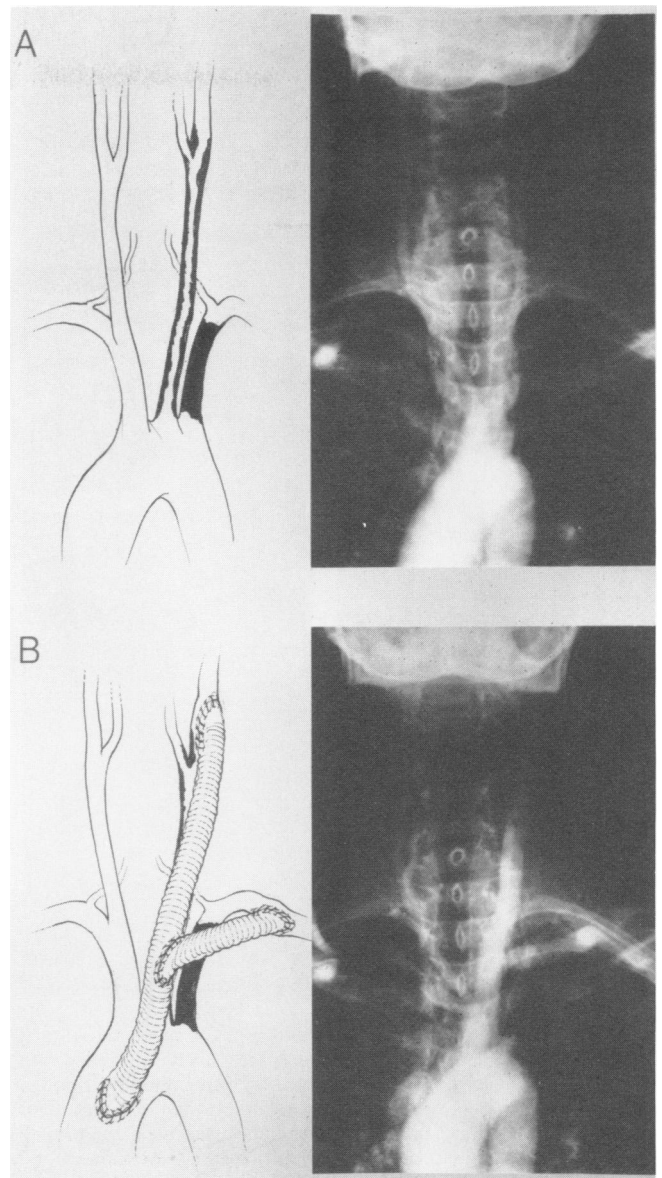
- Category II.** The major branches of the aortic arch (Figs. 4–9).
- Category III.** The visceral branches of the abdominal aorta (celiac, superior mesenteric, and renal arteries, Figs. 10–13).
- Category IV.** The terminal abdominal aorta and its major branches (Figs. 14–18).

For purposes of this presentation, we are adding Category V, which consists of patients in whom two or more of these four categories were diagnosed at the same time (Figs. 19 and 20).

Particularly important is the fact that atherosclerotic lesions often tend to be segmental and fairly well localized, with relatively normal proximal and distal arterial beds. Such atheromas are usually located in the proximal (Figs. 2, 4, 5, 10–16, and 18) or midproximal (Figs. 3, 6–9, and 17) portions of the arterial bed. Their significance lies in the fact that these patterns are almost always amenable to surgical treatment directed toward restoration of normal circulation, consisting essentially

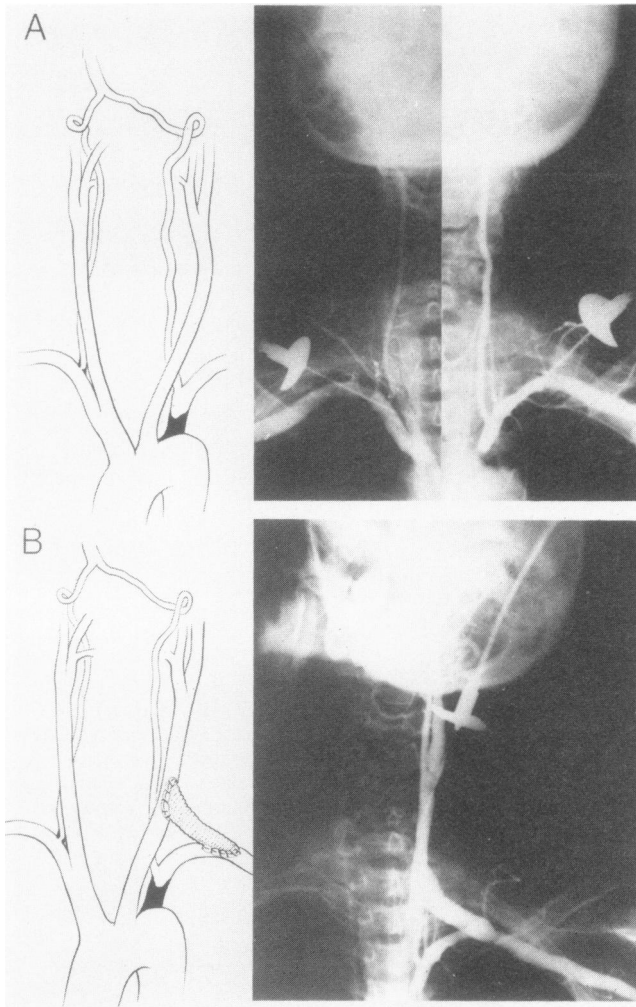


**FIGS. 3A and B.** *A.* Drawing and photograph of coronary arteriograms showing severe localized stenosis in proximal portion of the right and left anterior descending coronary arteries in 51-year-old white man with severe angina. Implantation of left internal mammary artery 2 years previously resulted in little or no improvement. At this time, autogenous saphenous vein bypass was performed from ascending aorta to right and left anterior descending coronary arteries. *B.* Drawing and photograph of coronary arteriograms in same patient 16 years after bypass operation showing patent bypass grafts and little or no progression of disease. Patient remains asymptomatic.



**FIGS. 4A and B.** *A.* Drawing and aortic arch aortogram showing severe occlusive disease in left common carotid and left subclavian arteries in 60-year-old white woman complaining of intermittent attacks of speech difficulties, right-sided hemiparesis, and intermittent claudication of left arm. *B.* Drawing of method of surgical treatment consisting in Dacron bypass graft from ascending aorta to left common carotid artery at bifurcation, after endarterectomy at this site, and to left subclavian artery, and arteriogram 8 years after operation showing well-functioning bypass graft. Patient has remained asymptomatic.

in endarterectomy, patch-graft angioplasty, excision and graft replacement, the bypass graft, and recently, balloon angioplasty. Combined proximal and midproximal disease may also be observed (Figs. 4, 13, 15, and 20). Less commonly, the arteriosclerotic process occurs predominantly in the distal portion of the arterial bed, and this is a pattern that is usually not amenable to effective surgical treatment (Figs. 21 and 22). These characteristic



FIGS. 5A and B. *A.* Drawing and photograph of preoperative arch aortogram showing complete occlusion of left subclavian artery with filling of artery distal to occlusive disease by retrograde flow through vertebral artery in 58-year-old white man complaining of intermittent left-sided weakness and incoordination (subclavian steal syndrome). Treatment consisted in Dacron bypass graft from left common carotid to left subclavian artery. *B.* Drawing and photograph of arch aortogram made 12 years after operation showing patent bypass graft. Patient has remained asymptomatic.

features of atheromas occur in a similar fashion in all categories previously described.

### Material and Methods

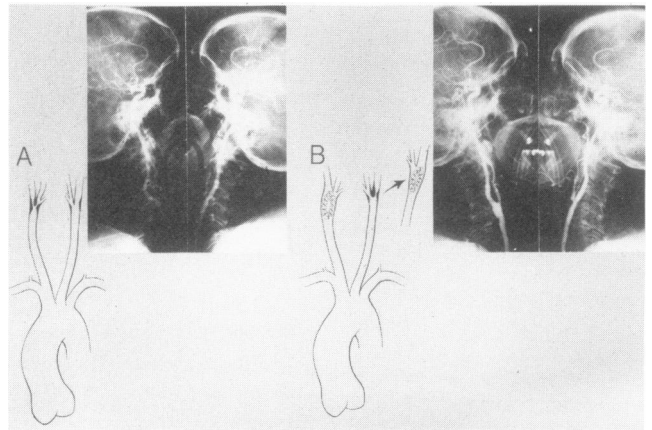
For purposes of this presentation and for maintenance of consistency in surgical treatment and observation, records were analyzed of all 13,827 patients admitted on one or more occasions between 1948 and 1983 to The Methodist Hospital in Houston on the service of

the senior author for treatment of atherosclerotic arterial occlusive disease.

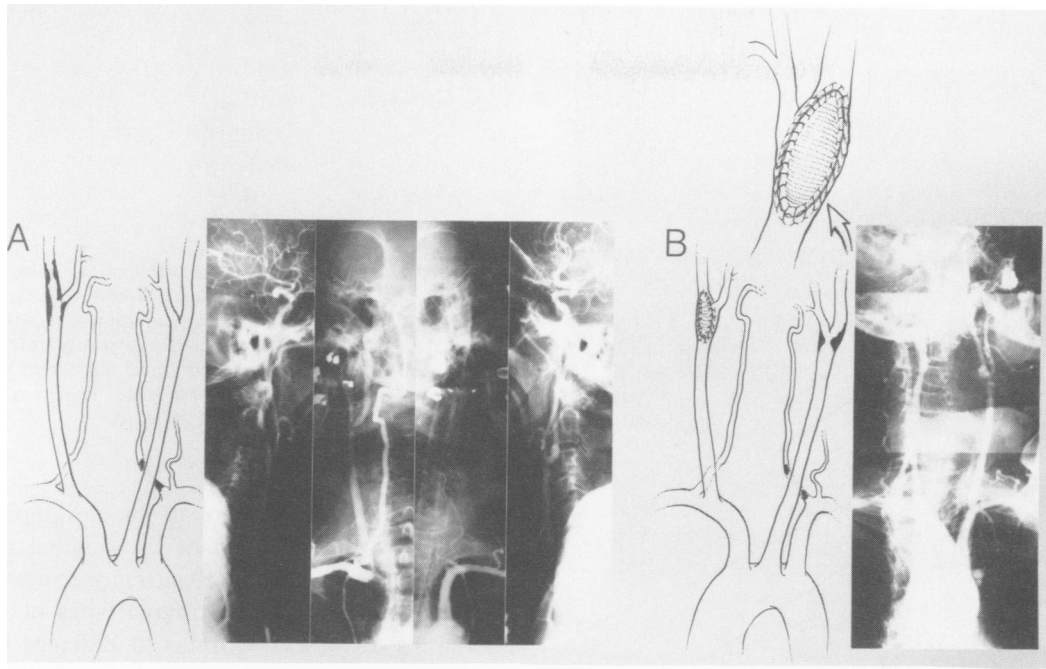
We made a retrospective survey of the records of these patients to determine the principal vascular diagnosis for each admission and any site or sites in the arterial tree that were operated on. This and other information was recorded on data sheets designed for this purpose. For each admission or readmission, a new data sheet was completed. These data on the diagnosis and surgical treatment received for atherosclerotic occlusive disease during each admission were entered into a custom database system implemented in the InterSystems Inc. dialect of Standard MUMPS (ANSI X11.1-1977).<sup>8</sup>

The patients were classified into the five categories of atherosclerotic patterns described earlier, according to the site or sites of atherosclerosis identified at the time of initial admission. The data were analyzed for determination of the age at initial admission and sex distribution among categories, and of the incidence, time, and patterns of occurrence of a new category or recurrence within the same category.

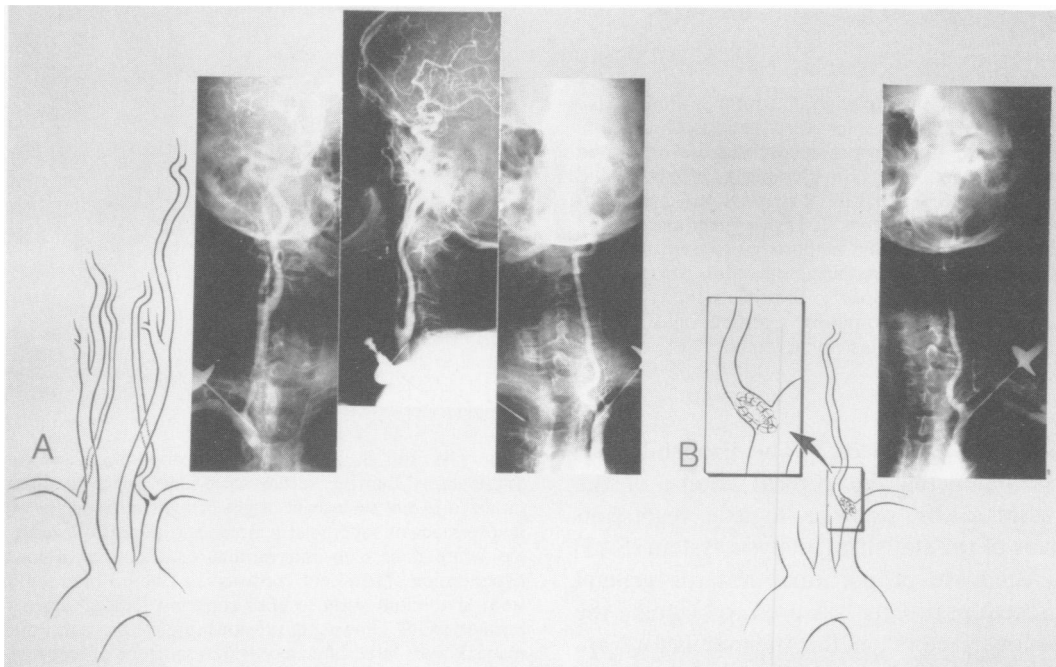
The significance of associations among variables was analyzed by two-way contingency table analyses. The differences among groups according to individual variables were determined by analysis of variance according



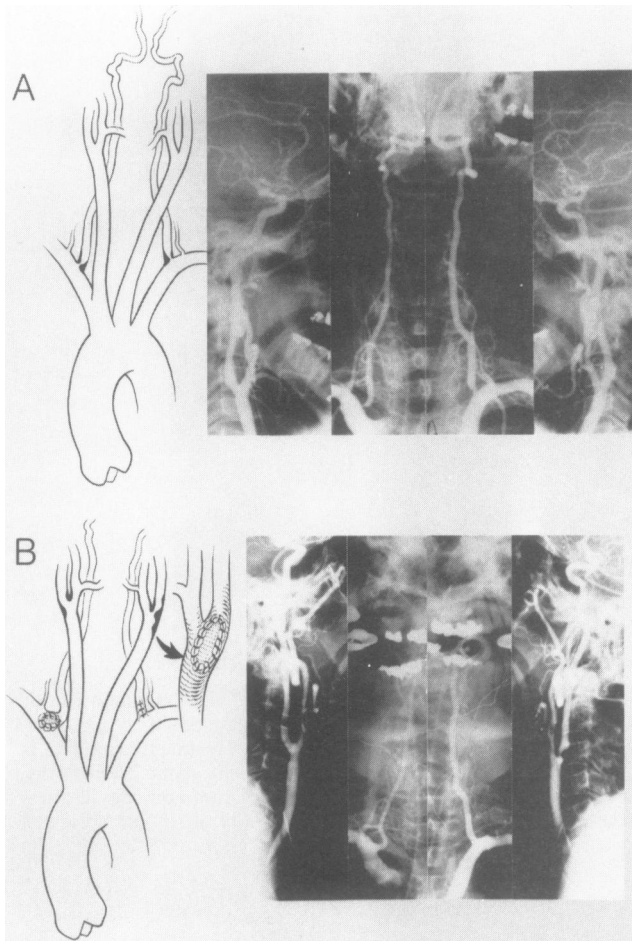
FIGS. 6A and B. *A.* Drawing and carotid arteriograms showing severe atherosclerotic occlusive disease of right common carotid artery at its bifurcation and at origin of internal carotid artery with little or no involvement of left carotid artery in 59-year-old white woman complaining of transient ischemic attacks of cerebrovascular insufficiency. Treatment consisted in endarterectomy with Dacron patch angioplasty of right carotid artery. *B.* Drawing and carotid arteriograms in same patient made 14 years later showing correction of previous occlusive disease of right carotid artery and development of severe stenosis of left carotid artery. Treatment consisted in endarterectomy and Dacron patch angioplasty of left carotid artery. Patient has remained well during past 6 years since this operation and 20 years since first operation.



FIGS. 7A and B. *A.* Drawing and carotid and vertebral arteriograms showing severe atherosclerotic occlusive disease of right common carotid artery at bifurcation and origin of internal carotid artery, complete occlusion of left vertebral artery, and little or no disease of left carotid artery in 62-year-old white man complaining of symptoms of transient ischemic attacks of cerebrovascular insufficiency. Treatment consisted in endarterectomy and patch-graft angioplasty of right carotid artery. *B.* Drawing and carotid arteriograms in same patient about 2 years later, showing correction of previous occlusive disease of right carotid artery and development of severe stenotic lesion of left common carotid artery at bifurcation and origin of internal carotid artery. Treatment consisted in endarterectomy and Dacron patch angioplasty of left carotid artery. Patient has remained well during 10 years since this operation.

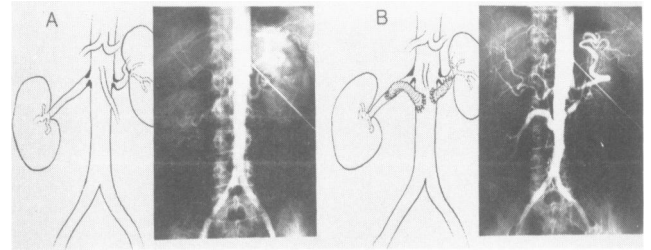


FIGS. 8A and B. *A.* Drawing and carotid and vertebral arteriograms showing well-localized severe stenosis at origin of left vertebral artery in a 71-year-old white man with manifestations of vertebral basilar artery insufficiency. *B.* Drawing showing method of surgical treatment, consisting in endarterectomy and patch-graft angioplasty of left vertebral artery at its origin from left subclavian artery and left subclavian, and vertebral arteriogram made 13 years after operation showing correction of stenotic lesion.



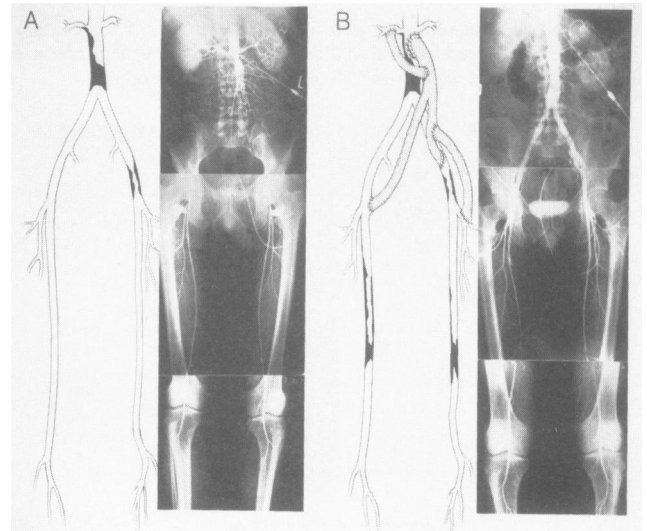
FIGS. 9A and B. *A.* Drawing and photograph of carotid and subclavian arteriograms showing bilateral, severe, localized stenosis of vertebral arteries at their origin with little or no stenotic disease of carotid arteries in a 63-year-old white man complaining of dizziness and blurring of vision. Treatment consisted in endarterectomy and patch-graft angioplasty of both vertebral arteries. *B.* Drawing and photograph of carotid and subclavian arteriograms made 6 years later, showing severe stenosis of left carotid artery requiring operation consisting in endarterectomy and patch-graft angioplasty. Previous stenosis of both vertebral arteries has been corrected, resulting in restoration of normal lumen and circulation. Patient remains asymptomatic 10 years after this operation.

to Duncan's multiple range test.<sup>9</sup> The probability of various factors influencing the clinical course of the patients was assessed by stepwise logistic regression analysis by means of the statistical analysis system (SAS) package.<sup>10</sup> The stepwise proportional hazards general linear model procedure of Cox was used to evaluate the influence of various factors on the interval before appearance of new disease;<sup>10</sup> these analyses were based on the assumption that most patients with new disease requiring treatment had returned to the service of the senior author for its treatment.

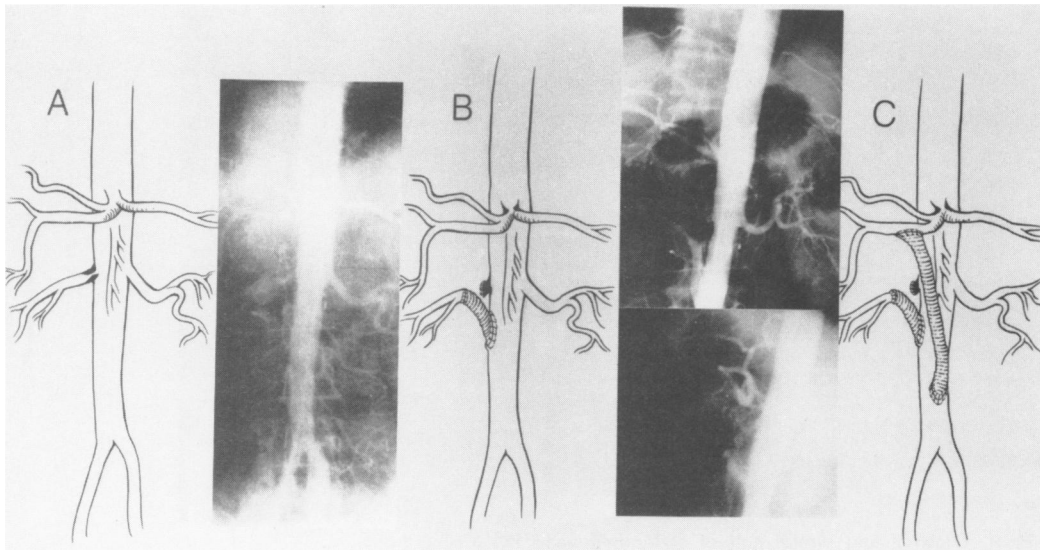


FIGS. 10A and B. *A.* Drawing and abdominal aortogram showing severe proximal renal occlusive disease of both renal arteries in a 45-year-old white woman with severe hypertension. *B.* Drawing of method of surgical treatment consisting in Dacron bypass graft from abdominal aorta to both renal arteries and abdominal aortogram made 20 years later showing well-functioning bypass grafts. Patient remains asymptomatic with good control of blood pressure.

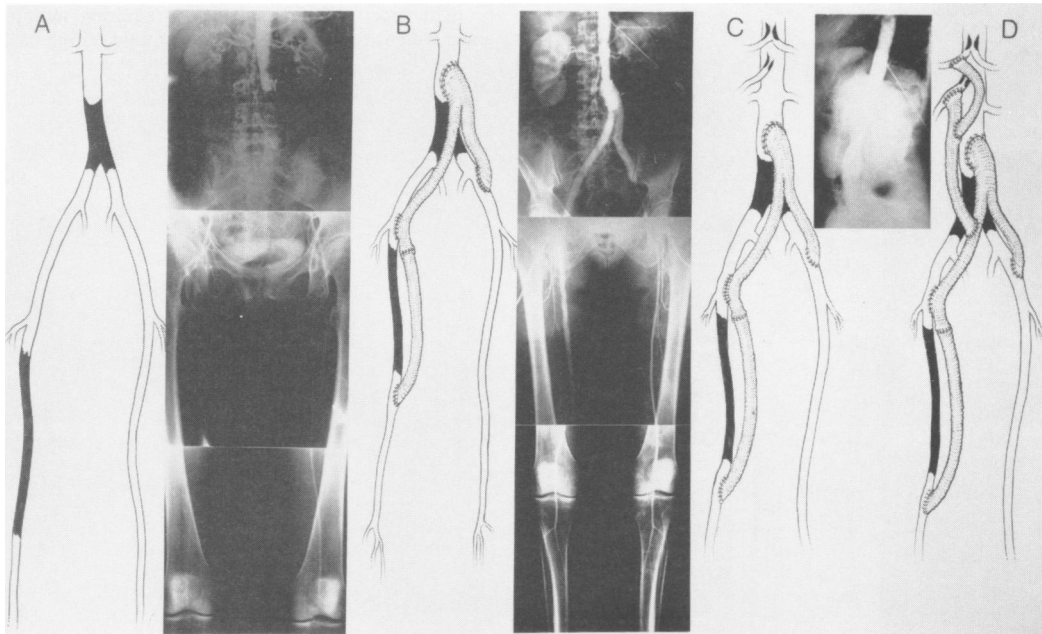
Recurrence was defined as the development of an atheroma within the field of the original category requiring another operation. Recurrence therefore included both reoperations on the original sites of disease and operations on new atheromas in different branches of the same region of the arterial tree included in the



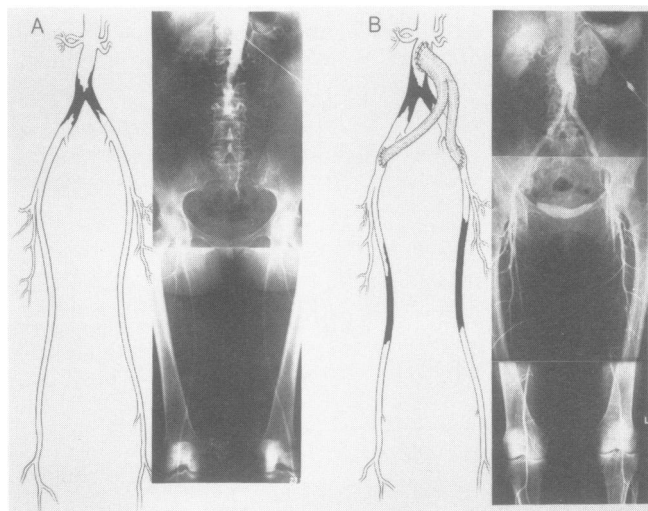
FIGS. 11A and B. *A.* Drawing and abdominal and femoropopliteal arteriograms showing severe aorto-iliac occlusive disease with well-localized severe stenosis at origin of right renal artery with little or no involvement of superficial femoral and popliteal arteries in a 44-year-old white man with intermittent claudication of lower limbs and hypertension. Treatment consisted in Dacron bifurcation bypass graft from abdominal aorta to both common femoral arteries and to right renal artery. *B.* Drawing of previous surgical procedure and arteriograms made 3 years later, after recent development of recurrent intermittent claudication, showing well-functioning aorto-femoral and right renal artery bypass graft with development of localized, complete occlusive disease of both superficial femoral arteries. Treatment consisted in bilateral Dacron femoropopliteal bypass grafts with relief of symptoms during past 5 years.



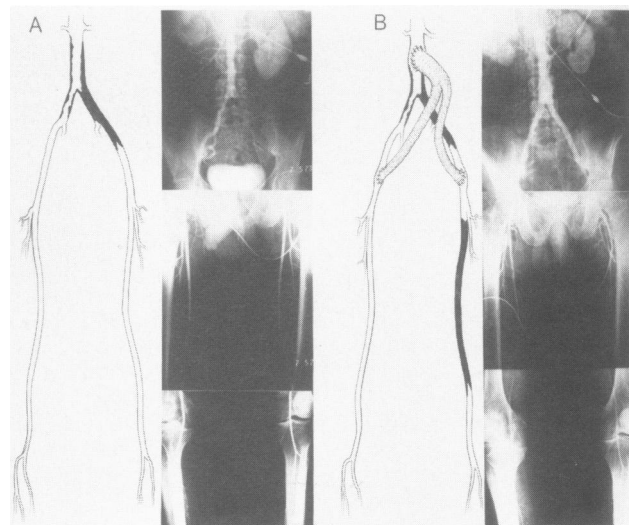
FIGS. 12A-C. *A.* Drawing and abdominal aortogram showing well-localized occlusive disease near origin of right renal artery in a 64-year-old white man complaining of severe hypertension. *B.* Drawing of method of surgical treatment consisting in Dacron graft from abdominal aorta to right renal artery and abdominal aortogram made 2 years later showing well-functioning graft to right renal artery and development of well-localized stenotic disease at origin of celiac artery in same patient with recent development of postprandial pain and loss of weight. *C.* Drawing of method of surgical treatment consisting in Dacron bypass graft to right hepatic artery. Patient has remained asymptomatic during past 6 years since this operation.



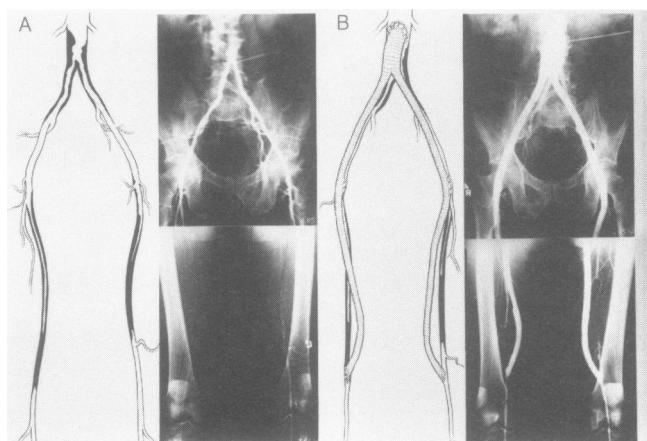
FIGS. 13A-D. *A.* Drawing and abdominal aortogram showing complete occlusion of terminal abdominal aorta and right superficial femoral artery in a 52-year-old white woman with intermittent claudication of legs. *B.* Drawing of method of surgical treatment consisting in Dacron bypass graft from abdominal aorta to left external iliac and right common femoral and popliteal arteries and abdominofemoral arteriogram made 2 years later showing well-functioning grafts. *C.* Drawing and abdominal aortogram showing severe stenotic disease of origin of celiac and superior mesenteric arteries in same patient made 2 years later after patient complained of postprandial abdominal pain and loss of weight. *D.* Drawing of method of surgical treatment consisting in Dacron bypass graft from right limb of previous Dacron abdominal bifurcation graft to superior mesenteric and right hepatic artery. Patient has been asymptomatic for the past 5 years.



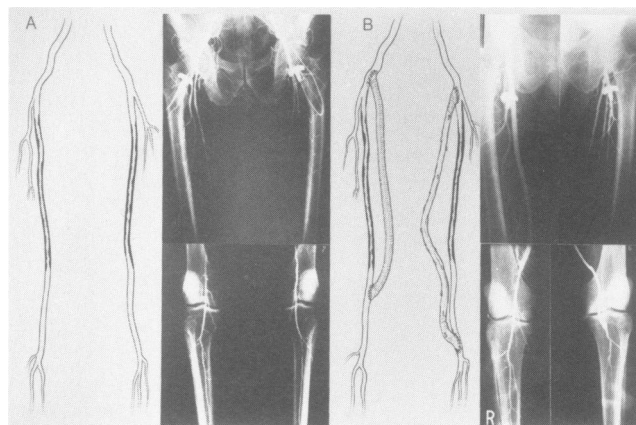
FIGS. 14A and B. *A.* Drawing and photograph of abdominal and femoropopliteal arteriograms showing well-localized aorto-iliac occlusive disease with little or no disease of superficial femoral arteries in a 57-year-old white woman with intermittent claudication of legs. Treatment consisted in Dacron bifurcation bypass graft from abdominal aorta to both external iliac arteries. *B.* Drawing showing previous surgical procedure and abdominal and femoropopliteal arteriograms, made in same patient 12 years later because of recent recurrence of intermittent claudication, showing development of localized complete occlusion in both superficial femoral arteries. Treatment, consisting in Dacron femoropopliteal bypass grafts, resulted in relief of symptoms for past 6 years.



FIGS. 16A and B. *A.* Drawing and abdominal aortic and femoropopliteal arteriogram showing severe aorto-iliac atherosclerotic occlusive disease with little or no involvement of superficial femoral and popliteal arteries in a 49-year-old white man with intermittent claudication of legs. Treatment consisted in Dacron bifurcation bypass graft from abdominal aorta to both external iliac arteries. *B.* Drawing showing previous surgical procedure and arteriograms, made 5 years later in same patient because of recent development of intermittent claudication of left lower extremity, showing development of complete occlusion of left superficial femoral artery. Treatment consisted in Dacron femoropopliteal bypass graft. Three years later, patient returned with same symptoms in right leg; arteriogram showed complete occlusion of right superficial femoral artery requiring femoropopliteal bypass graft. Patient has remained asymptomatic during past 3 years.

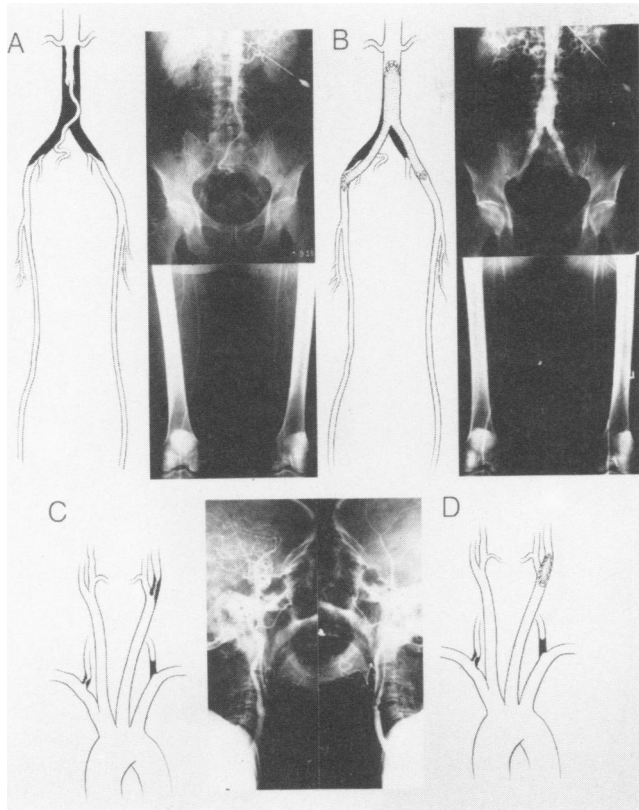


FIGS. 15A and B. *A.* Drawing and photograph of abdominal, aortic, femoral, and popliteal arteriogram showing extensive aorto-iliac and superficial femoral atherosclerotic occlusive disease in a 59-year-old white man with intermittent claudication. *B.* Drawing showing method of surgical treatment consisting in Dacron aorto-femoral-popliteal bypass graft and arteriogram made 7 years after operation showing well-functioning bypass graft. Patient remains asymptomatic.



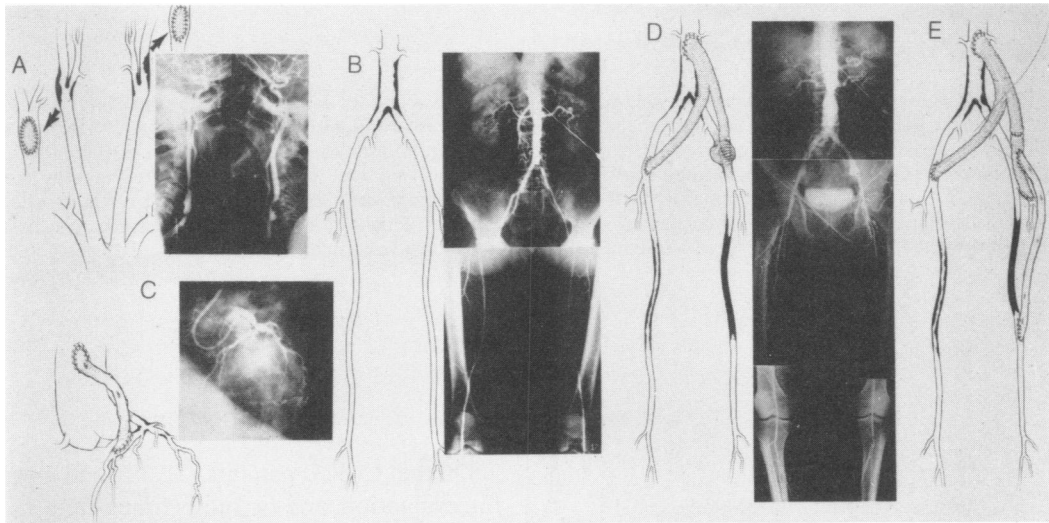
FIGS. 17A and B. *A.* Drawing and femoropopliteal arteriograms showing extensive occlusive disease of both superficial femoral arteries in a 72-year-old white man with intermittent claudication of both legs. *B.* Drawing showing method of surgical treatment, consisting in Dacron femoropopliteal bypass graft above knee on right side and autogenous saphenous vein femoropopliteal bypass graft below knee on left side, and arteriograms made 11 years after operation showing both grafts functioning well.



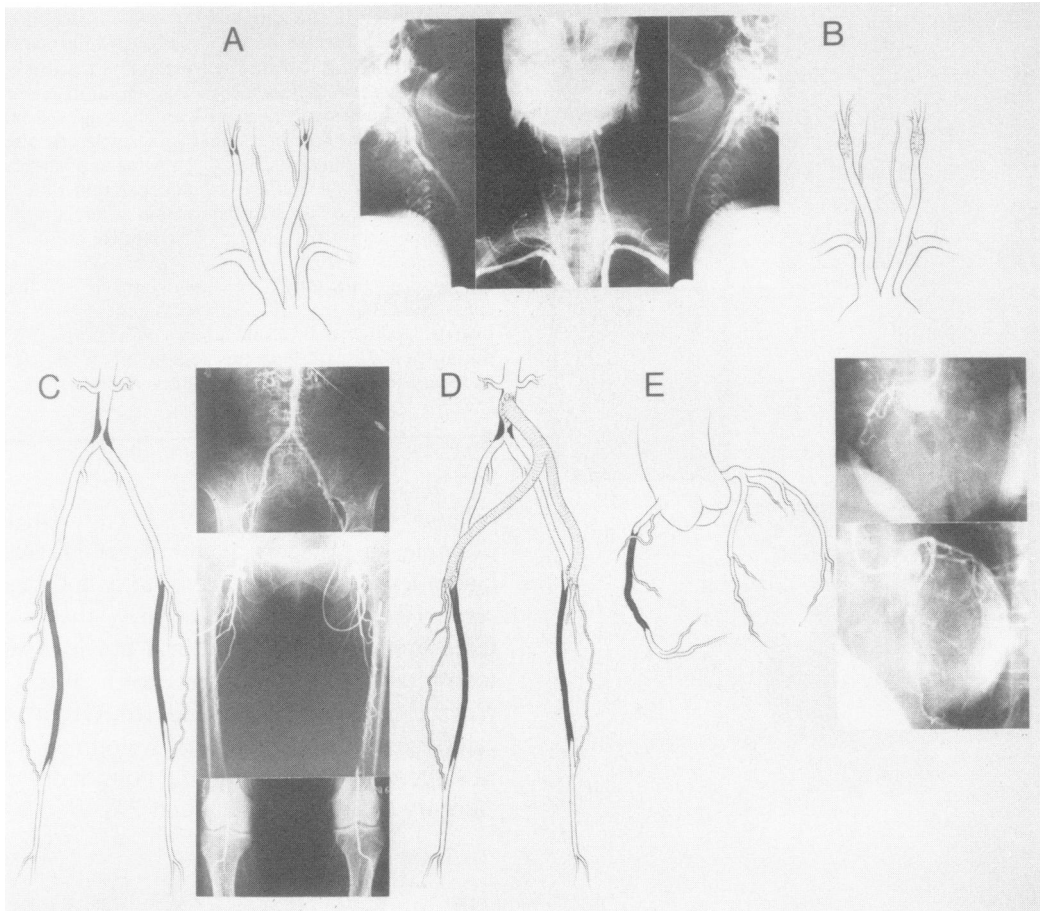


**FIGS. 18A-D.** *A.* Drawing and arteriogram showing complete aorto-iliac occlusive disease in a 59-year-old white man with intermittent claudication of legs. Treatment consisted in Dacron bifurcation bypass graft from abdominal aorta to both external iliac arteries. *B.* Drawing and arteriogram made 15 years later showing well-functioning bypass graft with little or no progression of atherosclerotic disease in superficial femoral and popliteal arteries. *C.* Drawing and bilateral carotid arteriograms made 15 years after previous operation showing severe atherosclerotic occlusive disease of bifurcation of left common carotid artery. As drawing shows, patient also had complete occlusion of left vertebral and stenosis of right vertebral arteries. Patient had recently had transient ischemic attacks of cerebrovascular insufficiency. Treatment consisted in endarterectomy with patch-graft angioplasty of left common, internal, and external carotid arteries with complete relief of symptoms during past 3 years. For this reason, no treatment was considered necessary for stenotic lesion of right vertebral artery.

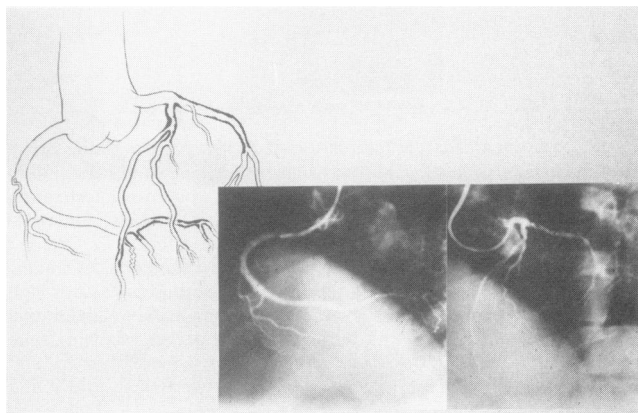
original type (Figs. 6, 7, 9, 11, 12, 14, and 16). For example, in Category II, the development of a contralateral lesion would be recorded as a Category II recurrence (Figs. 6 and 7). Similarly, the development of femoropopliteal disease after a previous successful aortofemoral bypass would be classified as a Category IV recurrence (Figs. 11, 14, and 16). Occurrence of a new category was defined as the development of disease in a new site outside the anatomic boundaries of the original category (Figs. 13, 18, 23, and 24).



**FIGS. 19A-E.** *A.* Drawing and carotid arteriograms showing severe, well-localized, occlusive disease of bifurcation of common carotid and origin of internal and external carotid arteries in a 58-year-old white man with transient ischemic attacks of cerebrovascular insufficiency and intermittent claudication of legs. Treatment consisted in endarterectomy and patch-graft angioplasty of both carotid arteries. *B.* Drawing, abdominal aortogram, and femoropopliteal arteriogram made a few weeks later showing severe aorto-iliac occlusive disease with little or no disease of superficial femoral and popliteal arteries. Treatment consisted in Dacron bifurcation bypass graft from abdominal aorta to both external iliac arteries. *C.* Drawing and coronary arteriograms made 7 years later after recent development of angina with occlusive disease involving right and left anterior descending coronary arteries. Treatment consisted in endarterectomy with patch-graft angioplasty of right coronary artery and autogenous saphenous-vein bypass graft to left anterior descending coronary artery. Patient has remained asymptomatic for past 5 years. *D.* Drawing and abdominal aortogram, made 4 years later and 11 years after first operation, after recent development of intermittent claudication of legs, showing false aneurysm at distal anastomosis to left external iliac artery and development of moderate stenotic disease of right superficial femoral artery and complete occlusion of left superficial femoral artery. *E.* Treatment consisted in correction of false aneurysm of left external iliac artery and Dacron bypass graft to left popliteal artery.



FIGS. 20A-E. *A.* Drawing and aortic arch aortogram showing severe stenotic disease of both carotid arteries at their bifurcation in a 63-year-old white woman with transient ischemic attacks of cerebrovascular insufficiency and intermittent claudication of legs. *B.* Drawing showing method of treatment consisting in endarterectomy with patch-graft angioplasty of both carotid arteries. *C.* Drawing and arteriogram of abdominal aorta and femoral and popliteal arteries showing aorto-iliac and superficial femoral occlusive disease bilaterally made a few months later. *D.* Treatment consisted in Dacron bifurcation graft from abdominal aorta to both common femoral arteries. *E.* Drawing and coronary arteriogram made 6 years later after recent development of severe angina showing complete occlusion of right coronary artery. Treatment consisted in autogenous saphenous vein bypass to right coronary artery. Patient has remained asymptomatic 13 years since this operation and 19 years since first operation.



### Results

Of the 13,827 patients, 77.3% had been readmitted for evaluation one or more times. The mean duration from original admission to the first readmission was 20 months, with a range of 1 to 306 months, and the mean follow-up interval from the original admission to their



FIG. 21. Drawing and photograph of right and left coronary arteriograms showing predominantly distal arterial occlusive disease in a 52-year-old white man with a 1-year history of myocardial infarction and subsequent progressively severe angina. Left ventricular function was severely impaired, as evidenced by an ejection fraction of 20%. Patient was treated medically.

last admission was 52.5 months, with a range of 1 to 324 months. The number of patients, mean age, and sex distribution for each of the five categories are shown in Table 1. Only 5.7% (793/13,827) of all patients (Category V) had a diagnosis of clinically significant atherosclerosis in more than one site during initial admission. Patients in Categories I and III were significantly younger ( $p < 0.0001$ ), whereas the ages of patients in Categories II, IV, and V were not significantly different ( $p > 0.05$ ). Although male patients predominated in all categories, significantly more female patients ( $p < 0.0001$ )

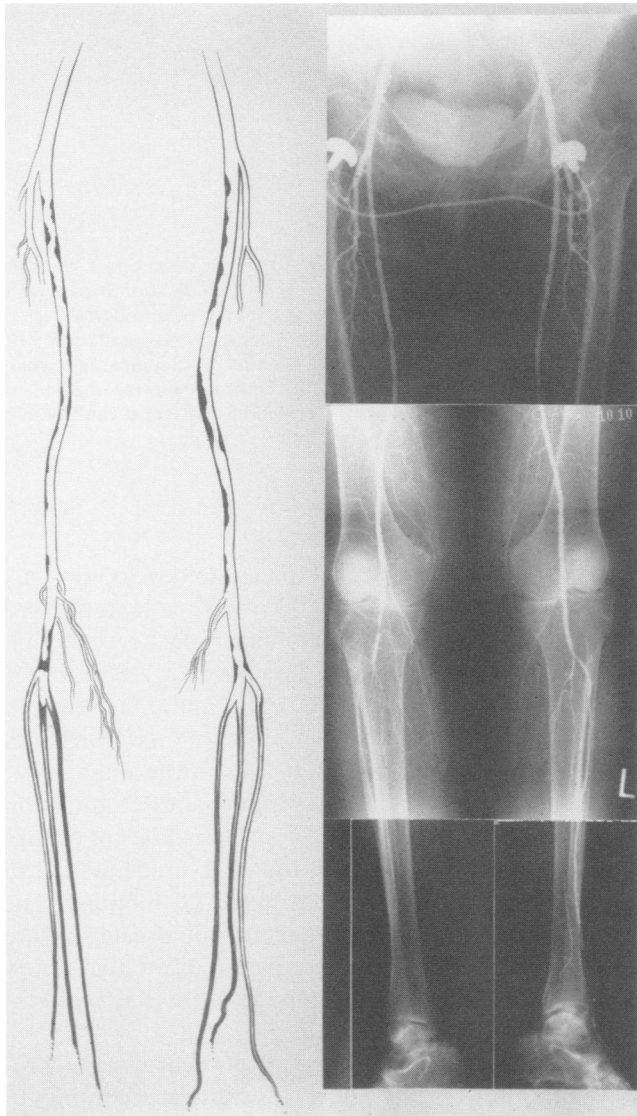
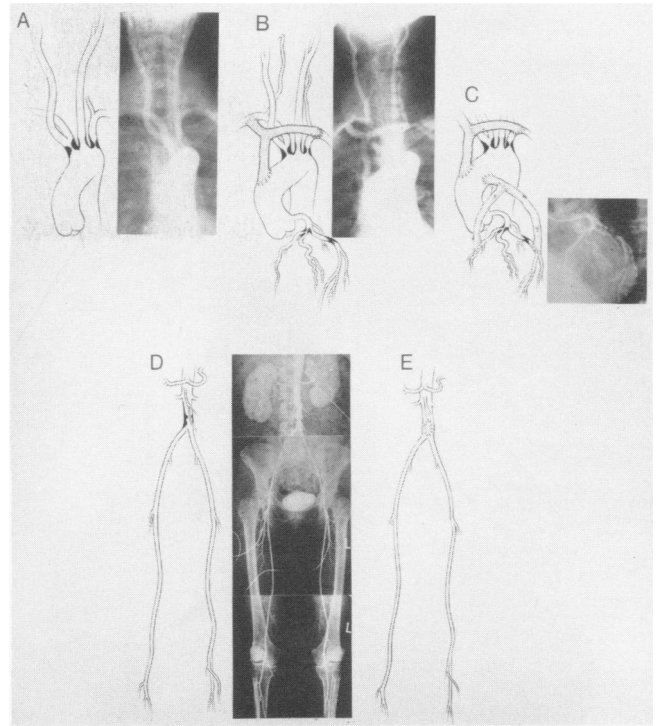


FIG. 22. Drawing and femoropopliteal arteriogram showing extensive occlusive disease of popliteal artery and its major branches bilaterally in a 63-year-old white woman with intermittent claudication of legs. Treatment consisted in bilateral lumbar sympathectomy.

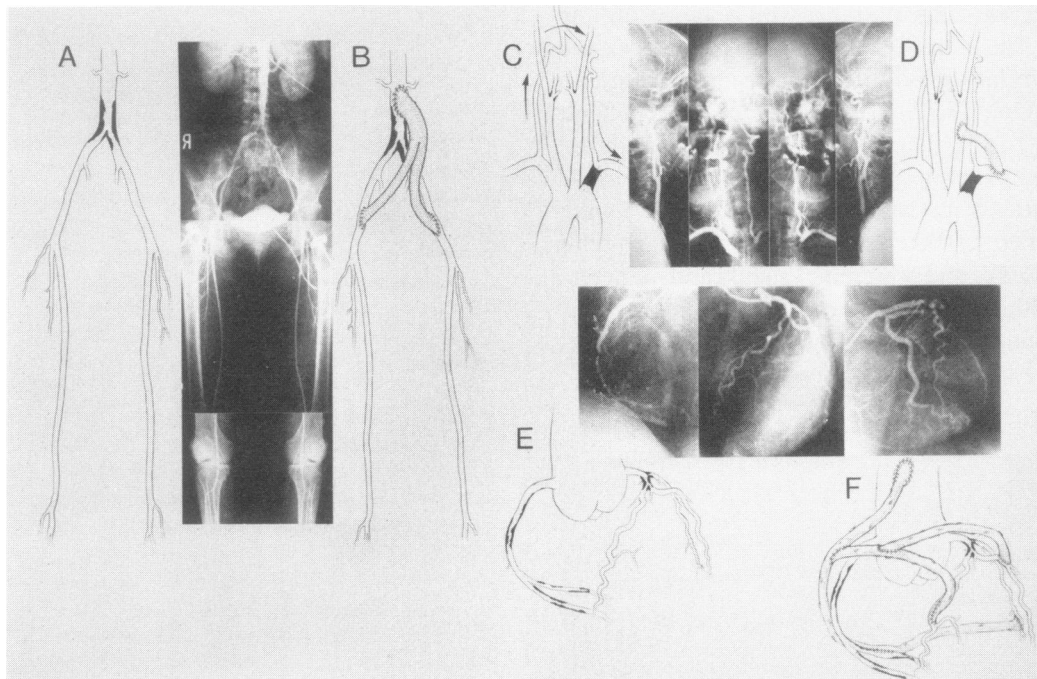


FIGS. 23A-E. *A.* Drawing and arch aortogram showing well-localized, severe, occlusive disease of proximal segment of innominate and left subclavian arteries with mild disease of left common carotid artery in a 43-year-old white woman, complaining of dizziness and intermittent claudication of both arms, treated by Dacron bypass graft from ascending aorta to both subclavian arteries. *B.* Drawing and arch aortogram and coronary arteriograms in same patient 6 years later, with recent development of severe angina, showing previous bypass graft to subclavian arteries functioning well. *C.* Drawing and coronary arteriograms showing stenosis of proximal segments of left anterior descending and circumflex coronary arteries. Treatment consisted in autogenous saphenous-vein bypass grafts from ascending aorta to left anterior descending and circumflex coronary arteries. *D.* Drawing and abdominal aortic, femoral, and popliteal arteriograms showing severe aorto-iliac occlusive disease in same patient, made 2 years later, after recent development of progressive intermittent claudication of legs. *E.* Drawing showing method of surgical treatment consisting in endarterectomy and Dacron patch angioplasty of abdominal aorta. Patient has remained asymptomatic during the 9 years since last operation and 17 years since first operation.

were in Categories II and III than in Categories I, IV, and V.

The incidence of patients' initial admission before and after 1970 according to initial category is shown in Table 2. These statistics are important with regard to available follow-up intervals. For example, whereas most patients in Categories II, III, and IV were seen before 1970, most in Category I were seen after 1970.

The number of patients in whom a new category developed and the duration between assignment of the original category and identification of a new occurrence are shown in Table 3. These data indicate that it is



FIGS. 24A-F. *A.* Drawing and abdominal aortogram showing extensive, well-localized, atherosclerotic aorto-iliac, occlusive disease in a 41-year-old white woman with intermittent claudication of legs. *B.* Drawing showing method of treatment consisting in Dacron bifurcation bypass graft from abdominal aorta to both external iliac arteries. *C.* Drawing and carotid and subclavian arteriograms, made in same patient 3 years later, showing complete occlusion of left subclavian artery. *D.* Drawing showing method of treatment consisting in Dacron bypass graft from left common carotid to left subclavian artery. *E.* Drawing and coronary arteriograms in same patient, made 5 years later after development of angina, showing occlusive disease of right and left anterior descending, diagonal, and circumflex coronary arteries. *F.* Drawing showing method of treatment consisting in autogenous saphenous-vein bypass graft to right posterior descending, left anterior descending, diagonal, and obtuse marginal coronary arteries. Patient has remained well 3 years since last operation and 11 years since first operation.

TABLE 1. *Patients by Category of Atherosclerosis: Distribution by Mean Age and Sex*

Category of Atherosclerosis	Patients		Mean Age	Per cent Male
	Number	Per cent		
I	4427	32.1	55.4	84
II	2380	17.2	61.7	65
III	361	2.6	49.4	60
IV	5866	42.4	59.4	80
V	793	5.7	60.8	73
Total	13,827	100.0		

TABLE 2. *Distribution of Patients with Initial Admission Before and After 1970 by Category of Disease*

Category of Atherosclerosis	Per cent Before 1970	Per cent After 1970
I	13	87
II	61	39
III	73	27
IV	76	24
V	49	51

unusual for new Category III disease to develop (in only 0.22 to 2.5% of patients). Category V patients showed the greatest tendency for development of a new category; an additional new category developed in 2.5 to 14.9% of these patients. Categories I, II, and IV, however, showed similar rates of occurrence of new categories over mean time intervals of 28.4 to 77.6 months.

The interval from initial admission to readmission with a new category was used to classify rates of change in disease into rapid (0 to 36 months), moderate (37 to 120 months), and slow (more than 120 months). The rates of development according to initial category are summarized in Table 4. These data indicate that a new category developed in most patients in the rapid-to-moderate groups.

The frequency of development of recurrence or progression of disease requiring operation according to original category is shown in Table 5. Category IV patients had the greatest tendency to recurrence. Here again, the interval from initial admission to readmission for recurrence or progression of disease within each

TABLE 3. *Development of New Atherosclerotic Categories among Patients, with Interval between Initial and Subsequent Category*

Initial and Subsequent Atherosclerotic Categories	Number Patients	New Occurrence Per cent Patients	Interval	
			Mean	Median
I-II	143	3.2	40.3	28
I-III	10	0.22	57.1	39
I-IV	111	2.5	28.4	12
II-I	105	4.4	59.8	47
II-III	26	1.1	38.8	34
II-IV	174	7.3	30.9	17
III-I	13	3.6	70.8	55
III-II	13	3.6	75.2	48
III-IV	15	4.2	75.7	63
IV-I	247	4.2	77.6	60
IV-II	417	7.1	63.7	52
IV-III	46	0.8	53.7	42
V-I	56	7.1	45.2	29
V-II	116	14.6	40.9	31
V-III	20	2.5	43.2	26
V-IV	118	14.9	33.8	22

category was used to classify rates of change in disease into rapid (0 to 36 months, Figs. 7, 11, and 25), moderate (37 to 120 months, Figs. 9, 16, and 26), and slow (more than 120 months, Figs. 6, 14, and 27). The distribution of recurrence of disease according to these

TABLE 5. *Incidence of Recurrence of Same Atherosclerotic Category Requiring Operation, according to Original Category and Corresponding Intervals for Each Category*

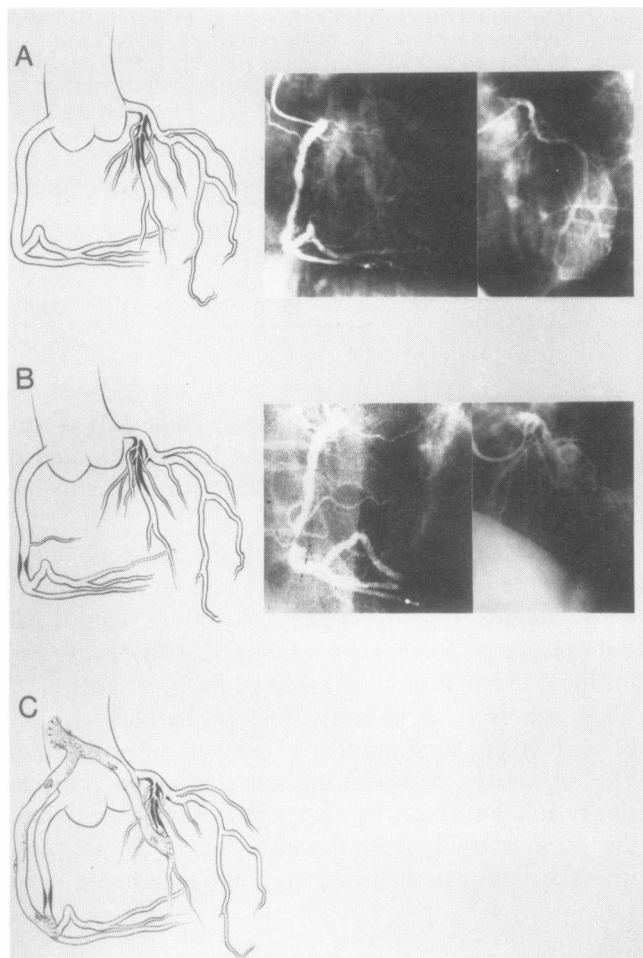
Atherosclerotic Category	Number Patients	Per cent Recurrence	Interval from Initial Admission	
			Mean	Median
I	80	2.56	62.3	59.5
II	133	7.12	35.9	20.0
III	6	1.51	34.7	32.5
IV	881	15.70	38.8	23.0

defined intervals is shown in Table 6. These data suggest that rates of recurrence were most frequently rapid or moderate in Categories II and IV and most frequently moderate or slow in Category I.

The effect of various factors on the development of additional disease was examined by an analysis of variance. Patients in whom a new category developed had a mean age of 56.88 years compared with 58.29 years for those in whom no new category had been identified. These ages were significantly different by Duncan's test because of the large number of patients in each group. The differences, however, are not considered clinically significant. Patients who had had a recurrence within the same category had a mean age of 56.91 years, whereas those who had had no recurrence had a mean

TABLE 4. *Incidence of Progression to a New Atherosclerotic Category according to Original Category*

Rate of Progression	Original Category	New Category of Atherosclerotic Disease									
		I		II		III		IV		Overall	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
I	Rapid			80	56	5	50	83	75	168	64
	Moderate			59	41	3	30	26	23	88	33
	Slow			4	3	2	20	2	2	8	3
II	Rapid	43	41			13	50	120	69	176	58
	Moderate	46	44			12	46	45	26	103	34
	Slow	16	15			1	4	9	5	26	8
III	Rapid	5	38	6	46			5	33	16	39
	Moderate	6	46	3	23			7	47	16	39
	Slow	2	15	4	30			3	20	9	22
IV	Rapid	71	29	168	40	22	48			261	37
	Moderate	124	50	189	45	20	43			333	47
	Slow	52	21	60	15	4	9			116	16
V	Rapid	32	57	65	56	13	65	75	64	185	60
	Moderate	18	32	46	40	6	30	39	33	109	35
	Slow	6	1	5	4	1	5	4	3	16	5



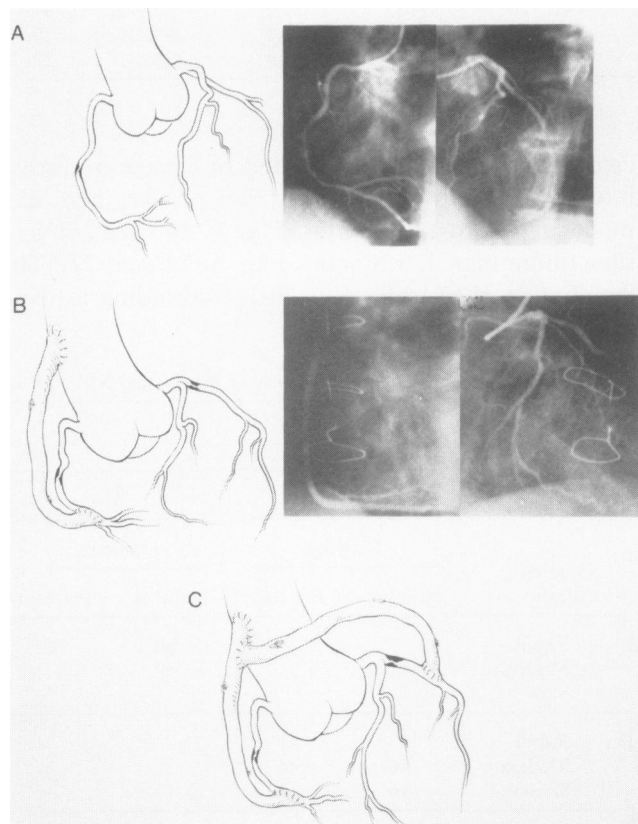
FIGS. 25A-C. *A.* Drawing and coronary arteriogram showing occlusive disease of left anterior descending coronary artery and mild disease of right coronary artery in a 57-year-old white man complaining of stable mild exertional angina. Patient was treated medically. *B.* Drawing and coronary arteriograms, made 3 years later in same patient after development of progressively severe angina, showing well-localized, severe stenosis of right coronary and left anterior descending coronary arteries. *C.* Drawing showing method of surgical treatment consisting in autogenous saphenous-vein bypass graft from ascending aorta to right and left anterior descending coronary arteries. Patient has remained asymptomatic during past 5 years.

age of 58.34 years. These differences were also significant according to the Duncan test, but again, this may not have clinical significance. Nonetheless, the tendency to development of additional disease was somewhat greater among younger patients.

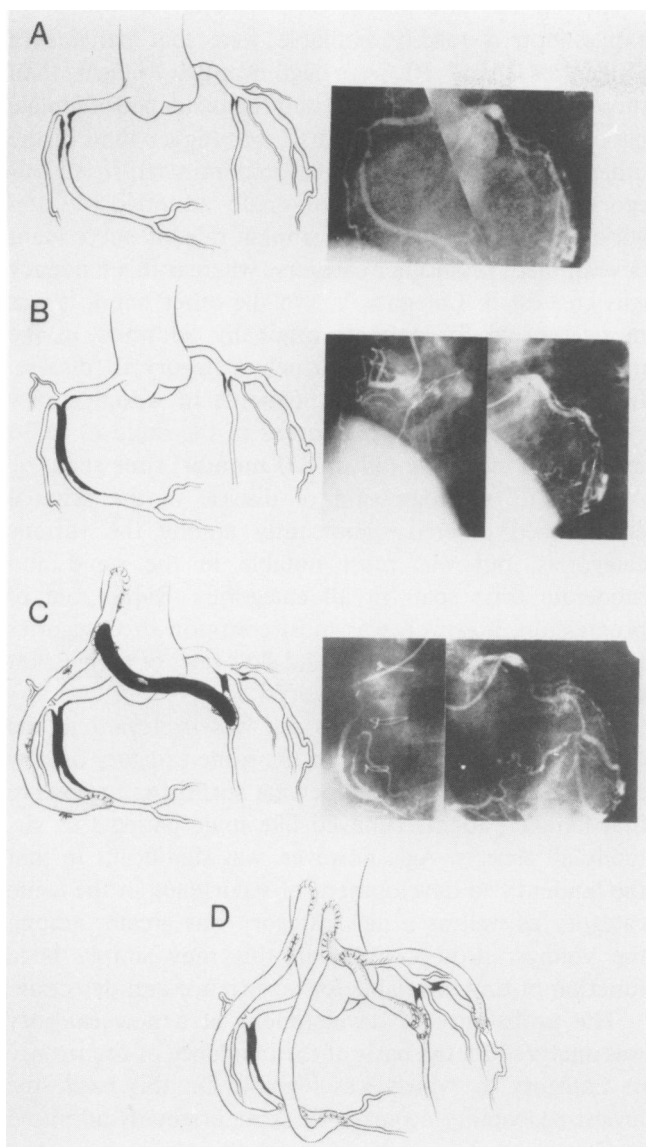
The patient's sex had no significant effect on development of a new occurrence. Of the male patients, 9.5% had a new occurrence, compared with 10.7% of the female patients. These rates were not significantly different ( $p > 0.5$ ).

New disease occurred in 7.9% of patients first seen after 1970, compared with 11.6% of those first seen before 1970. This difference was highly significant ( $p < 0.0001$ ), but it may be a reflection of the longer follow-up period available for patients classified before 1970 than for those classified after 1970. Whether patients were admitted before or after 1970 had no effect on recurrence within the same category.

Logistic regression analysis was performed to determine the factors predictive of occurrence of a new category (Table 7). The variables analyzed were age at first admission, sex, initial admission before or after 1970, and original category of disease. The results of these analyses indicated that category, age, and time period were important factors influencing the frequency



FIGS. 26A-C. *A.* Drawing and photograph of coronary arteriograms showing severe, well-localized stenotic disease in right coronary artery in a 52-year-old white man with severe angina. *B.* Drawing and photograph of coronary arteriograms in same patient, complaining of recent development of angina 8 years later, showing patent bypass to right coronary with development of severe, localized, stenotic disease in circumflex coronary. *C.* Drawing showing method of surgical treatment consisting in additional bypass to circumflex coronary artery. Patient has remained asymptomatic for past year.



FIGS. 27A-D. *A.* Drawing and coronary arteriogram in a 55-year-old white man complaining of mild, stable angina, showing mild-to-moderate localized stenosis in right and left anterior descending coronary arteries. Patient was treated medically. *B.* Drawing and coronary arteriograms made 10 years later, after development of progressively severe angina during past year, showing localized, complete occlusion in midportion of right coronary artery and severe, localized stenosis in proximal segment of left anterior descending coronary artery. Patient was treated by autogenous saphenous-vein bypass from ascending aorta to right and left anterior descending coronary arteries. *C.* Drawing and coronary arteriograms made 5 years later, after development of progressive angina associated with dyspnea on exertion during past few months, showing occlusion of previous bypass graft to left anterior descending coronary artery and development of new occlusive disease in distal right and circumflex coronary arteries. *D.* Drawing showing method of treatment consisting in additional autogenous saphenous-vein bypass grafts to distal right and left anterior descending and circumflex coronary arteries. Patient has remained well during past 5 years.

TABLE 6. Incidence of Recurrence of the Same Category Requiring Operation, according to Rate of Recurrence

Category	Incidence of Recurrence					
	Rapid Patients		Moderate Patients		Slow Patients	
	Number	Per cent	Number	Per cent	Number	Per cent
I	26	32.5	46	57.5	8	10.0
II	85	63.9	41	30.8	7	5.3
III	3	50.0	3	50.0	0	—
IV	546	62.0	283	32.1	52	5.9
Total	660	60.0	373	34.0	67	6.1

of occurrence of new categories of disease. Of the first four categories, in comparison to Category V, which had the greatest probability, Category I had the lowest probability of development of a new category, and Category IV the highest. Sex had no effect on new occurrence, but age did, increasing age decreasing the likelihood of new occurrence. Patients classified before 1970 were more liable to development of new disease.

Similar analyses were performed for factors predictive of recurrence of the same category (Table 8). After Category V, the Category IV pattern was the most predictive of recurrence. Increasing age made recurrence less likely. The time period of admission had little influence on recurrence, and the patient's sex had none.

The factors predictive of the time required for a new category to develop were analyzed by the stepwise proportional hazards model of Cox (Table 9). Operation before 1970 was predictive of a longer interval to a new occurrence than was operation after 1970. The interval to a new occurrence was shorter in younger patients. Category IV was predictive of a longer interval to a new occurrence.

## Discussion

This study provides a number of interesting and significant observations about the various patterns of

TABLE 7. Stepwise Logistic Regression Analysis for Factors Predictive of Occurrence of New Atherosclerotic Category

Variable	Beta	Chi Square	Probability
Intercept	-0.47297906	3.97	0.0464
Category I	-1.60703289	129.48	—
Category IV	-1.26766272	116.52	—
Age	-0.01920239	30.28	0.0000
Category II	-0.92168871	48.23	0.0000
Category III	-1.53731650	37.04	0.0000
Time	0.25812681	8.22	0.0042

TABLE 8. *Stepwise Logistic Regression Analysis for Factors Predictive of Recurrence of Same Atherosclerotic Category*

Variable	Beta	Chi Square	Probability
Intercept	-4.18481190	89.63	—
Category IV	3.55342283	74.44	—
Category II	2.71735186	41.86	0.0000
Age	-0.02353598	62.97	0.0000
Time	0.54661600	43.92	0.0000
Category I	1.84454312	18.71	0.0000

atherosclerotic arterial occlusive disease, some of which confirm previously held clinical impressions and others of which were unexpected. Thus, the data herein presented substantially confirm the concept that the occlusive process tends to assume distinctive patterns in the four major arterial beds as previously described<sup>2,4,7</sup> and as presented here. Moreover, the site and distribution of the atherosclerotic disease in each arterial bed are essentially similar. Of great clinical significance is the fact that these data support our long-standing clinical impression that the initial clinical manifestation of patients with atherosclerotic occlusive disease tends to reflect involvement predominantly of one of the four categories, as evidenced by the fact that only 5.7% of all the patients initially had more than one category of disease. In addition, these data support the clinical impression about the relative frequency of the various categories according to clinical manifestations. Thus, Category IV was by far the most common, occurring in a little more than two-fifths of the series, with Category I second (almost one-third of the series). Not surprisingly, Category III was least frequent, a fact that has been long recognized although the reasons for it are not clear. Also confirming our clinical impressions was the fact that patients in Category IV had the greatest tendency to recurrence in some portion of the original arterial bed of involvement. As might be expected, increasing age decreases probability of recurrence. It is unclear at present, however, whether this is due to a less virulent disease or to shorter survival times providing less opportunity for recurrence.

TABLE 9. *Results of Stepwise Proportional Hazards Model of Cox for Factors Predictive of Time Required for Development of New Atherosclerotic Category*

Variable	Beta	Chi Square	Probability
Time	-0.61747866	57.38	0.0000
Age	0.02770670	41.72	0.0000
Category IV	-0.48484402	38.26	0.0000

Among the unexpected observations for which no explanation is readily available were that patients in Categories I and III were significantly younger than those in the other categories, and the incidence of female patients in Categories II and III was higher than in the others, although male patients predominated in all categories. Moreover, patients originally admitted in Categories I, II, and IV had a similar rate of subsequent development of another category, whereas this tendency was greatest in Category V. On the other hand, it was most unusual for patients originally admitted in the other categories to acquire a new Category III disease. In this connection, in most patients in whom a new category developed, this occurred in the rapid (0 to 36 months) to moderate (37 to 120 months) time span.

The rate of progression of disease in the original arterial bed differed significantly among the various categories, but was most notable in the rapid and moderate time span in all categories. Rapid rate of progression, however, was most common in Categories II and IV, whereas moderate and slow rates of progression were most common in Category I.

Interestingly, the patient's sex was irrelevant to the development of recurrence in the same category or new category. Indeed, it was somewhat surprising to observe that female patients behaved like male patients in virtually all aspects. Age, however, was significant in that the tendency to development of recurrence in the same category as well as a new category was greater among the younger groups, although this may simply be a function of time available for occurrence and detection.

The probability of development of a new category was analyzed on the basis of the incidence of occurrence in Category V, which was highest. On this basis, the lowest probability occurred in those originally admitted in Category I. The explanation for this observation may lie in the duration of observation for most patients in Category I, which was significantly less (about 15 years) than in the other categories (from two to more than three decades).

Of further interest in this connection is the observation that patients originally in Category II had a somewhat increased tendency to subsequent development of Category IV, and those originally in Category IV, to subsequent development of Category II (Table 3).

The various patterns of occlusive disease and rates of progression have great prognostic and therapeutic significance. For those patterns, for example, characterized by localized disease in the proximal or midproximal portions of the arterial bed, effective methods of surgical treatment are available but are essentially precluded for



those affecting predominantly the distal arterial bed. Long-term prognoses of patients who have had surgical treatment obviously depend on precise application of the appropriate surgical procedure but, as evidenced by this study, are also greatly influenced by the rate of recurrence or progression of the disease (Figs. 2, 3, 5, 6, 8, 10, 14, 17, and 18). These data give added emphasis to the need for careful and continuing follow-up of patients with occlusive arterial disease who, according to these data, are at risk of development of new or recurrent critical lesions.

We realize that there are a number of other considerations than those analyzed in this study that may significantly influence both the patterns and rates of progression of this disease. These include certain risk factors, such as hypertension, cigarette smoking, hyperlipidemia, obesity, diabetes mellitus, and stress. Although in our previous publications reference was made to the fact that preliminary observations did not show a strong correlation between these factors and the various patterns or rates of progression of the disease, we recognize the need for more definitive data analyses along these lines.

Such studies are now in progress and will be presented at a later date.

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