

Autogenous Venous Bypass Grafts Five Years Later

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THE reconstruction of occluded arteries distal to the inguinal ligaments for relief of claudication and ischemia became an accepted form of treatment during the 1950's. Early experiences with the use of arterial homografts as bypass grafts were disappointing because of the high rate of thrombosis.⁷ In addition aneurysmal degeneration of the grafts occurred in time.² Synthetic grafts were unsatisfactory in our hands. Experimental studies in our laboratories and others indicated autogenous veins were superior to synthetic grafts for bypassing small arteries.^{7, 19, 20} Kunlin and later Linton demonstrated that autogenous veins could be successfully used as long femoropopliteal bypass grafts.^{12, 13}

On the basis of the above mentioned experiences autogenous veins became our preferred material for bypass grafts distal to the inguinal ligament in 1957. It was possible, therefore, to follow some of these grafts for as long as 13 years. For the purpose of this presentation, however, we selected 103 consecutive patients with 113 grafts who were operated on more than 5 years ago. The status of the *patient* and the *graft* at a time exactly 5 years following operation was analyzed. This retrospective study provides prognostic information useful in the evaluation of patients being considered for arterial reconstruction.

Clinical Material

There were 113 consecutive femoropopliteal reconstructions using autogenous venous bypass grafts, performed on 103 pa-

tients. The operations were performed by the authors and the Resident Staff at the University of Rochester Medical Center from May 8, 1957 to December 31, 1964.

The patients ages ranged from 29 to 87 years, but 72 per cent were between 50 and 70 years of age. There were 77 men and 26 women. There was electrocardiographic evidence of arteriosclerotic heart disease observed in 35 patients. A history of previous cerebrovascular accidents was obtained from four patients. Diabetes was recognized in 25 patients. There were 30 patients with either a history of treatment for hypertension or with blood pressures higher than 150/90 mm. Hg. Serum cholesterol levels greater than 300 mg./100 ml. were observed in 17 of 51 patients on whom the tests were performed.

The operations were performed for symptomatic atherosclerotic occlusive disease. The indications for operation were intermittent claudication in 46 extremities, rest pain in 26 extremities, and gangrene in 41. The patients with claudication requested operation because they felt the symptoms were interfering with their normal daily routine. Patients with rest pain were severely incapacitated. The pain interfered with sleep and ischemic changes were demonstrated. The patients with gangrene or nonhealing ulcers were also of such a serious nature that major amputations were planned if arterial reconstruction was not successful.

Technic

The saphenous vein was used for all bypasses. It was removed through a groin incision, short incisions in the thigh, and the

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distal longitudinal incision made for exposure of the popliteal artery either above or below the knee. The vein was removed, distended with saline, and all branches ligated. The vein was then reversed and end-to-side anastomoses to the arteries performed. The grafts were placed from the common femoral artery to the popliteal artery below the level of the knee joint in 51 extremities, from the common femoral artery to the popliteal artery above the knee joint in 43 extremities, and from the superficial femoral artery to the popliteal artery below the knee joint in 19 extremities. The operation was performed on 54 right legs and 59 left legs.

The patients were evaluated at 3 to 12-month intervals. All the patients in this series were personally examined 5 or more years after the operation, or were known to be dead. Details of the deaths were obtained from hospital records, referring physicians, or the patient's family. Arteriograms were performed if there was any question as to patency or for evaluation of the arterial reconstruction. There were 31 arteriograms performed on extremities with patent grafts of which 18 were obtained 5 years or more following operation.

Results

Mortality. There were three in hospital deaths following operations on extremities with gangrene. Thirty-one patients died within 2 years of their operation. At the end of 5 years there were 54 (52%) of the patients alive.

Myocardial infarctions were considered the cause of death of 28 (26%) of the patients, of which two died in the hospital following their operation. In 15 of these 28 patients the diagnosis was supported either by a convincing clinical course, positive electrocardiogram, or an autopsy. The diagnosis of myocardial infarction must be considered only probable in the other 13 patients who died at home, frequently suddenly, and on whom no autopsies were per-

TABLE 1. *Mortality Rate as Related to Preoperative Status*

	No.	Deaths	Mortality Rate %
Indication			
Claudication	42	11	26
Rest Pain	24	10	42
Gangrene	37	28	76
	103	49	48
Age—Years			
29–49	6	4	67
50–59	37	12	32
60–69	30	10	33
70–79	24	19	79
80–89	6	4	67
Hypertension			
Present	30	16	53
Absent	73	33	45
Arteriosclerotic Heart Disease			
Present	35	25	71
Absent	68	24	35
Diabetes			
Present	25	20	80
Absent	78	29	37
Arteriosclerotic Heart Disease and Diabetes			
Present	14	14	100

formed. Twelve deaths occurred in the 35 patients with preoperative evidence of arteriosclerotic heart disease whereas 16 of the deaths occurred in 68 patients without a previous history of coronary artery disease. Deaths were secondary to other complications of arteriosclerosis in 7 patients including; cerebrovascular thrombosis—2, mesenteric artery occlusion—2, and nephrosclerosis—3. Four patients died of cancer and ten from other causes.

The overall mortality rate of 48% during 5 years was analyzed in relation to the preoperative status of the patient (Table 1). If the indication for surgery was claudication the mortality rate was 26% as compared to 42% for rest pain and 76% for those patients with gangrene. The mortality rate for patients 70 to 79 years of age

TABLE 2. Status of 103 Patients and Venous Bypass Grafts 5 Years After Operation

Alive	Graft Patent*	32
	Graft Thrombosed	22
Dead	Graft Patent at Death*	28
	Graft Thrombosed at Death	21

* One patient had bilateral bypass grafts of which one graft was patent and one thrombosed.

was 79% as compared to 32% and 33%, respectively, for the 50 to 59, and 60 to 69 year age group. There was a 67% mortality rate for an insignificant number of patients under 50 and over 80 years old. Fifty-three% of hypertensive patients died and 45% of those without hypertension. There was a mortality rate of 71% in patients with arteriosclerotic heart disease as compared to 35% when arteriosclerotic heart disease was not present. It should be pointed out, however, that only 12 of 25 (48%) of the deaths in patients with arteriosclerotic heart disease were secondary to myocardial infarctions as compared to 16 of 24 (67%) in patients without arteriosclerotic heart disease. The mortality rate in patients with diabetes was 80% as compared to 37% in nondiabetics. All of the 14 patients with both diabetes and arteriosclerotic heart disease died within 5 years.

Nine of the 14 died less than two years after their operation.

Arteriosclerotic Complications

In addition to the deaths there were other complications of generalized arteriosclerosis which occurred in these 103 patients causing morbidity. Fifteen patients developed significant occlusion of the vessels of the opposite limb requiring arterial reconstruction in 12 instances and amputation in three others. There were at least three patients who suffered nonfatal myocardial infarctions. Thirteen patients suffered cerebrovascular accidents. Four of them were only transient neurologic deficits, seven caused residual deficits, and two resulted in paralysis which interfered with the activities of normal daily living. As previously recorded two patients died of strokes. The cerebrovascular accident was associated with an occlusion of the internal carotid artery in the five patients in whom angiograms or autopsies were performed.

Late Status of Patients and Their Grafts (Table 2)

There were 54 patients alive 5 years after their operation was performed. A venous

TABLE 3. Patency Rates: Factors Affecting Results in 113 Extremities

Indication	No.	Patent Early	Patent Late
Claudication	46	40 (87%)	33 (72%)
Rest Pain	26	20 (77%)	16 (62%)
Gangrene	41	26 (63%)	19 (46%)
	113	86 (76%)	68 (60%)
Length of Graft			
Common Femoral to Popliteal Below Knee	51	34 (67%)	26 (51%)
Common Femoral to Popliteal Above Knee	43	36 (80%)	27 (63%)
Superficial Femoral to Popliteal Below Knee	19	16 (84%)	15 (79%)
Runoff			
Two—three vessels	82	65 (80%)	54 (66%)
None—one vessel	31	21 (68%)	14 (45%)

bypass graft was patent in at least one extremity of 32 patients and occluded in the other 22 patients. There were 28 grafts patent in at least one extremity of 49 patients who died within the first 5 years after their operation. Twenty-one patients died with thrombosed grafts.

Patency Rates of 113 Grafts (Table 3)

There were 86 grafts (76%) patent one month after operation. Sixty-eight (60%) of the 113 grafts were patent at the time of death or 5 years following operation.

When the indication for operation was claudication 72% of the grafts remained patent. The patency rates were only 62% and 46% when rest pain and gangrene, respectively, were the indications.

Long bypass grafts from the common femoral to popliteal artery distal to the knee joint resulted in late patency rates of only 51%. Shorter grafts from the common femoral to popliteal artery above the knee and from the superficial femoral to popliteal artery distal to the knee joint resulted in late patency rates of 63% and 79%, respectively.

A patency rate of 66% was observed if two or three of the three major lower leg vessels were visibly patent on preoperative arteriograms. The patency rate was 45% if one or no vessels were seen.

Arteriograms

Postoperative arteriograms were performed on 41 extremities following discharge from the hospital. Patent vein grafts were visualized in 31 extremities. There were 18 examinations of patent grafts obtained at least 5 years after operation.

The grafts, in general, resembled normal arteries. They were smooth walled, without evidence of narrowing or aneurysmal dilatation. (Figs. 1, 2, 3).

A localized diaphragm-like stenosis was demonstrated in one graft 18 months after operation.⁵ The arteriogram was performed



FIG. 1. Preoperative arteriogram on the left demonstrates typical long occlusion of femoral artery from near the origin to the level of the adductor tendon. Arteriogram on the right was obtained 5 years after insertion of a vein graft from the common femoral to the popliteal artery at the level of the knee joint. The vein is smooth walled and without evidence of stenosis or aneurysm.

because of recurrence of claudication in a patient who was asymptomatic for 16 postoperative months. The narrowing proved to be caused by a fibrous nodule, presumably an organized thrombus. An endophlebectomy and venous patch graft restored patency. An arteriogram performed 82 months after the original operation demonstrated

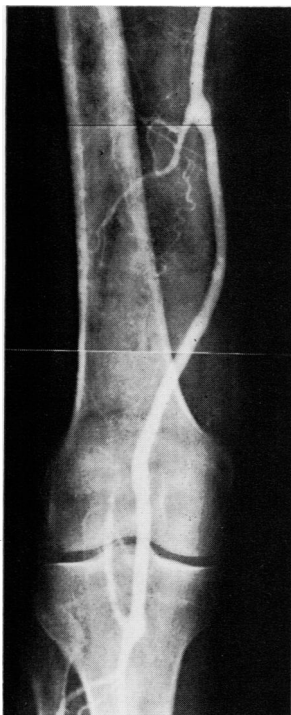


FIG. 2. This arteriogram was obtained 5 years after a venous bypass graft was performed from the superficial femoral artery to the popliteal artery distal to the knee joint. Except for a slight dilatation at the site of the proximal and distal anastomoses the vein graft looks like an artery.

continued patency. A similar stenosis causing thrombosis of the graft was observed 7 months following operation. Patency was restored and maintained as demonstrated by an arteriogram performed 72 months after the original operation.

Dilatations at the site of anastomoses were observed on three arteriograms.¹⁰ Arteriograms performed 6 months and 84 months following operations demonstrated little if any progression of this dilatation in one extremity. Another dilatation was thought to be an aneurysm of the vein graft at the site of the proximal anastomosis on an arteriogram obtained 72 months following operation. At subsequent operation, however, a common femoral artery aneurysm and a patent nondilated vein graft was demonstrated. Another anastomotic dilatation observed on an arteriogram 72 months following operation remains stable by clinical examination 4 years later.

A tortuous, irregular walled vein graft, with localized aneurysmal dilatation was observed on one arteriogram obtained 64 months following operation.⁸ The patient's serum cholesterol was not elevated. No pathologic material is available to date.

Significant progression of atherosclerotic lesions proximal or distal to the vein grafts were demonstrated 2, 6, 12, and 60 months following operation on four arteriograms.¹⁰ Three of the four lesions were localized stenoses. Arterial reconstructions were performed on two of the extremities. These two vein grafts remain patent 5 years following the original operation.

Graft Thrombosis

Forty-five of the 113 grafts thrombosed prior to death or within 5 years of operation. Twenty-nine of the grafts thrombosed within 30 days, 14 more were occluded within 1 year, and two other grafts failed before 5 years after operation.

Graft thrombosis occurred during or following wound infections in eight extremities. Infection followed by hemorrhage from anastomotic sites and then thrombosis or ligation of grafts was observed three times. Thrombosis occurred in the hospital during treatment of acute infection in three other extremities. The wound infection appeared controlled in two other extremities in which thrombosis occurred after leaving the hospital but within 30 days of the operation.

Treatment for thrombosis of the graft, when indicated, consisted of either arterial reconstruction, sympathectomy, or amputation (Table 4). Secondary operations were advised and accepted by five of 14 patients in whom claudication was the indication for operation. One patient successfully underwent thrombectomy, endophlebectomy, and patch grafting.⁵ Sympathectomy

was performed on four patients whose symptoms worsened following thrombosis of their graft. No patient operated on for only the symptom of claudication required amputation.

Graft thrombosis occurred in ten patients whose indication for operation was rest pain. Amputation was necessary for the relief of pain in eight patients and the other two patients died of myocardial infarction and stroke before amputation was performed.

There was thrombosis of grafts in 22 extremities originally operated on because of gangrene or nonhealing painful ulcerations. Amputations were performed on 16 patients. Two patients died before amputations could be performed. Four patients healed their ulcerations or minor amputations before their grafts thrombosed and were left with symptomatic but viable extremities.

Discussion

The 5-year mortality rate of 48% in these 103 patients was initially surprising to us. It conforms, however, to some previous observations. Allen¹ reported that 54.6% of 116 patients died within 3 years of their first visit to the Mayo Clinic for symptomatic arteriosclerosis obliterans of the lower extremity. The presenting symptoms were not recorded. Boyd carefully followed 1,476 patients for several years after they first developed intermittent claudication of the lower extremities.⁴ The 5-year mortality rates for the 45-54, 55-64 and 65-74 age groups were 21%, 28%, and 39.7%, respectively. These results can be compared to the 26% 5-year mortality rate we observed in patients with intermittent claudication.

Localized complications of generalized arteriosclerosis were the most common causes of death.^{1,4} Myocardial infarctions, cerebrovascular occlusions, and other arteriosclerotic complications caused 35 of

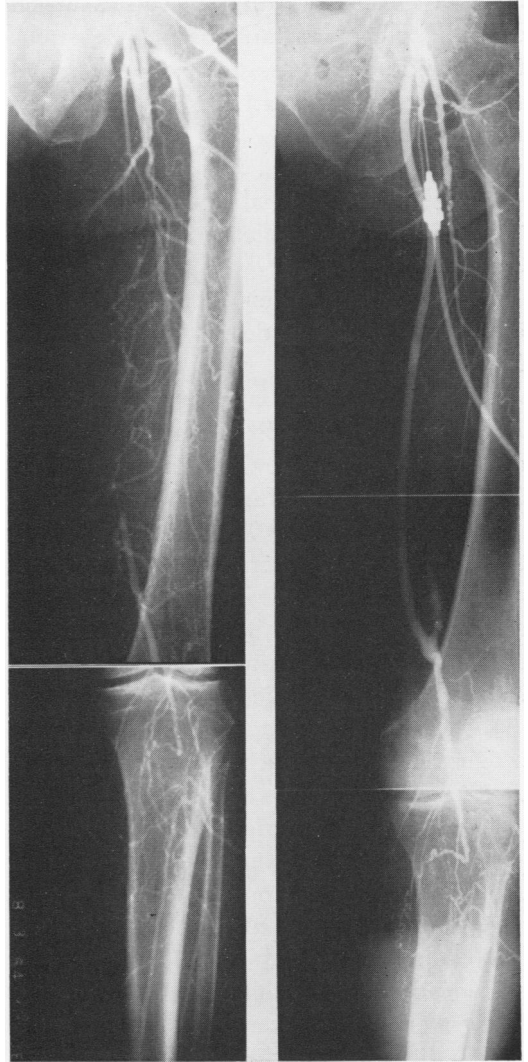


FIG. 3. Preoperative arteriogram on the left demonstrates a long occlusion of the femoral artery and also a complete occlusion of the distal popliteal artery. There is reconstitution of the distal arteries of the lower leg through collaterals. Arteriograms on the right were obtained 5 years after a venous graft was implanted from the common femoral artery to the proximal popliteal artery. The vein graft remains widely patent despite the distal poor runoff.

49 (71%) of the deaths in our series. The mortality rate for patients with rest pain was 42% and for those with gangrene was 76% as compared to 26% for those with claudication. It would appear, therefore, that the increased arteriosclerotic involve-

ment of the lower extremity vessels which caused ischemic symptoms more serious than claudication was a reflection of a more severe generalized arteriosclerosis which led to an earlier death.

Mauney, Ebert, and Sabiston reported a 4.4% incidence of fatal myocardial infarctions immediately following major operations in 265 patients with abnormal preoperative electrocardiogram.¹⁷ Two of the three postoperative deaths in our series occurred in patients with abnormal preoperative electrocardiograms. In addition 12 of the 35 (34%) of the patients with abnormal preoperative electrocardiograms died of myocardial infarction within 5 years as compared to 16 of 68 (24%) of the patients without preoperative abnormalities.

The well recognized increased severity of arteriosclerosis in diabetics and their decreased longevity was once again observed. Known arteriosclerotic heart disease and diabetes together were particularly poor prognostic signs since all 14 of those patients died within 5 years of the operation.

Patency rates of arterial reconstructions are reported in various ways. The most common method is to determine the percentage of grafts patent at the time of last follow-up. For example, in 1966 we reported an overall patency rate of 61% for 116 grafts followed zero to 7 years.¹⁰ The zero indicated that the last follow-up examination in some of these patients was done in the hospital either because they died or were recently operated upon. Other authors prefer to report accumulative patency rates as calculated by the life table method.^{15, 21, 22} All of the extremities in this series were operated on more than 5 years ago and follow-up was terminated at 5 years. It was possible to follow them, therefore, either until death or until 5 years after the operation. With the tabulated results different patency rates can be reported, e.g. 60% (68 of 113) of the grafts were patent at the time of death or at 5 years. On the

other hand, because of the 49 deaths only 31% (35 of 113) were actually patent 5 years after operation. If one is interested in the comparison of the vein with other materials used for arterial reconstruction another patency rate can be determined.⁸ There were 56 grafts which could be followed for 5 years and 35 (63%) of these grafts remained patent.

It should be noted that if these patency rates are to be used for prognosis that they are minimal rates. The series represents the initial clinical experience with vein grafts of most of the surgeons. Early thrombosis of vein grafts is almost always due to technical errors. The early failure rate varies in vessels with the experience of the surgeon. Our own early patency rate during the first 4 years of our experience was 62% whereas during the next 4 years it rose to 82%.⁶ The patency rates of large series where the operations were performed by small groups of surgeons should be expected to be much better than those reported here. Patency rates are affected by technical skill but they are just as dependent upon the patient selected for operation. Patients with claudication alone are more likely to undergo successful procedures than those in whom the operation is performed for rest pain or gangrene. Short bypass grafts are more likely to remain patent than those performed from the groin to below the level of the knee. The graft is slightly more likely to remain patent if two or all three of the distal calf vessels are patent than if none or only one of the vessels are patent. It should be emphasized, however, that length of the graft needed and the poor runoff are not contraindications to the use of a vein graft, particularly if the operation is being performed for rest pain or gangrene. There are abundant examples of venous grafts remaining patent in the face of what appears to be poor runoff on a arteriogram (Fig. 3).^{9, 16}

TABLE 4. *Treatment for Thrombosis of Venous Bypass Grafts*

	Thrombosed Grafts	No Rx	Arterial Reconstruction	Sympathectomy	Amputation
Claudication	14	9	1	4	0
Rest Pain	10	2	0	0	8
Gangrene	22	5	0	1	16
Totals	46	16	1	5	24

The continued use of arterial reconstruction with venous bypass grafts for limb salvage is supported by the results of this study. It is true that 38 (62%) of the 61 patients whose indication for operation was rest pain or gangrene died in less than 5 years. However, it was possible to avoid amputation of 43 of 67 (64%) of extremities where the original choice of treatment was either arterial reconstruction or amputation. Twelve of the 23 extremities of patients who survived 5 years were viable.

The results of this study also indicate that we should continue to recommend operation for those patients with significant intermittent claudication. There was no operative mortality and 32 of 42 (74%) of the patients lived for at least 5 years after operation. Thirty-three of 46 (72%) of the grafts remained patent until death or for 5 years. Five years after operation 73% of the 33 grafts in living patients were patent. The patients with patent grafts did not have claudication. None of the patients operated on for claudication alone lost their limbs during the 5 years after operation. This 0% amputation rate is better than that reported in studies of the natural history of peripheral arteriosclerotic occlusive disease. Boyd described a 7% amputation rate in 1,476 untreated patients within 5 years after their initial diagnosis of claudication due to arteriosclerosis of the vessels of the lower extremity. Humphries described a 24% amputation rate in 650 legs originally examined for claudication

and followed for an average of 4 years without operation.

When vein grafts were first being used as arterial replacements there was considerable concern expressed that aneurysmal dilatation would occur and that veins might be more susceptible to arteriosclerosis than arteries. At the present time there is a renewed interest in the fate of autogenous veins since they are being used so extensively as aortocoronary bypass for occlusive coronary artery disease. The arteriographic appearance of grafts 5 years after implantation described here and the previously described late pathologic changes in vein grafts indicate that veins are very satisfactory arterial replacements.¹⁰ The pathologic changes observed in seven patent grafts consisted of the thickening of all three layers of the vessel wall, primarily due to fibrous tissue, and the preservation of smooth muscle and most elastic fibers. A particularly marked intimal thickening was observed in four grafts which were patent for 9-180 days and then thrombosed. They were not removed for another 3-120 days, however, so it cannot be determined whether the intimal thickening occurred before or after thrombosis of the graft. Dilatations were noted at the site of large "cobra mouth" anastomoses in two vein grafts but if these were aneurysms they did not progress during the next 5 years. Fibrous nodules which partially occluded the vein grafts were observed in two patients and were also observed by others.^{5, 11} Pathologic examination supports the theory that

these are organized clots, possibly forming at the site of valves, rather than a degeneration process. Tortuosity, irregular walls, and aneurysmal dilatation was observed in one graft 60 months after operation.⁸ These changes resembled those in a graft previously seen which proved to be atherosclerotic.⁸

Conclusions

The status of 103 patients and 113 autogenous venous femoropopliteal bypass grafts 5 years following operation was analyzed.

Forty-eight per cent of the 103 patients died within 5 years. Seventy-one per cent of the deaths were secondary to arteriosclerosis. The mortality rate for patients operated on for claudication was only 26% as compared to 42% and 76% for patients with rest pain and gangrene, respectively. Mortality rates of greater than 70% were also observed if the preoperative evaluation indicated that; 1) the patient was over 70 years of age; 2) there was a previous history of arteriosclerotic heart disease; 3) diabetes was present.

Sixty per cent of the grafts remained patent either until death or for 5 years. Only 51% of grafts from the groin to below the knee remained patent as compared to 63% and 79% of short grafts ending above or below the knee. Only 45% of grafts implanted in extremities with poor arterial runoff remained patent as compared to a 66% patency rate in the presence of good runoff.

The best results were obtained in patients operated on for claudication. Seventy-four per cent of the patients lived for at least 5 years, and 74% of their grafts were still patent. None of them lost their limb.

Sixty-two per cent of patients with rest pain or gangrene died within 5 years. On the other hand, successful bypass grafts prevented the need for amputation of 64% of their extremities.

Arteriographic and histologic evaluation indicate that veins serve as arterial replacements with little chance of aneurysmal or atherosclerotic changes.

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DISCUSSION

DR. GEORGE COOPER MORRIS (Houston): As a 15-year veteran of the saphenous autograft procedure, I have enjoyed this paper very much. My comments are primarily directed to the long-term metamorphosis of these grafts.

(Slide) With practically no exceptions, the only long-term degenerative changes in these grafts have been seen in children. This is an example of an 8-year-old boy with a saphenous vein patch graft on the renal artery. Early the graft appears normal, but after 4 years you can see there has been aneurysmal dilatation.

(Slide) For this reason, in children I believe the hypogastric artery is the autogenous reconstructive material of choice, and here you see a typical example of the hypogastric artery being used to substitute for a right renal artery.

(Slide) The metamorphosis of these grafts in long-term studies arteriographically is rather dramatic. Here you can see a typical saphenous vein in the early postoperative period in the left renal artery, in the second arteriogram, but after a period of 8 years you can see the arterialization that typically takes place in these venous autografts.

(Slide) We have had recent studies now in the coronary area. In the early studies, for example, in this patient on the left you can see a 10-day study after a coronary bypass, and it is obviously a vein that has been used. In fact, in the distal end there is a venous valve which disturbed the cardiologist a great deal, but after a year in place the vein has assumed the typical appearance of an artery.

(Slide) This same patient returned after 2 years with recurrence of angina. The angina was caused by the development of stenosis in the left

anterior descending artery, which had progressed from 10 to 90 per cent. This provided a good opportunity to obtain a biopsy specimen by removing a plug from a 2-year-old graft and using the defect as a point of origin for a secondary bypass to the left anterior descending artery. As the photomicrographs indicate, the artery appears to be perfectly normal. At least that is what our pathologist told us.

(Slide) I am sure that in 10 years in this Association we will be hearing reports of arteriosclerosis occurring in vein grafts in increasing numbers, but in the vernacular of the day, that's living.

DR. W. ANDREW DALE (Nashville): This report by Dr. DeWeese and Dr. Rob certainly furnishes some significant facts to help us determine what happens after femoral-popliteal grafting. I would like to discuss two points.

First is the importance of placing the distal anastomosis far enough down the leg. Earlier it was believed that it was well to place the distal anastomosis above the knee to avoid crossing the joint, but it has now become apparent that the popliteal artery below the knee is often more suitable for anastomosis because of lesser involvement with arteriosclerosis.

The second point concerns the patient whose graft is still pulsatile, but who has secondarily developed ischemia in the foot. I would like to illustrate this point with three slides which show errors in judgment.

(Slide) This is taken from an amputated extremity 29 days following placement of the graft. There was a small clot present which, had it been recognized, could have been removed or bypassed,