Saphenous Vein Aortorenal Bypass Grafts:

Serial Arteriographic Study

RICHARD H. DEAN, M.D., JAMES P. WILSON, M.D., HENRY BURKO, M.D., JOHN H. FOSTER, M.D.

From the Specialized Center of Research in Hypertension and the Departments of Surgery and Radiology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232

One-hundred and eight autologous saphenous veins were used to construct an aortorenal bypass in 94 patients and were followed from five months to nine years. There were three operative deaths. Twelve grafts thrombosed. In seven patients the thrombosis was demonstrated in the early postoperative period. In the other five patients an early postoperative arteriogram was not done, the thrombosis was first demonstrated arteriographically 4½–9 months following operation. In the latter patients it is impossible to determine when the thrombosis occurred. No graft demonstrated to be patent in the early postoperative period was subsequently found to be thrombosed. Therefore it is likely that almost all thromboses occurred in the immediate postoperative period and were the result of technical errors in the arterial reconstruction. A total of 130 followup arteriograms were done in 75 patients with 89 patent grafts. Long term, serial followup arteriograms were done in 29 patients with 39 vein grafts. Three different patterns were observed: 1) the vein graft maintained its initial size and configuration (62%); 2) the vein graft underwent uniform dilatation throughout its length (20%); and 3) the dilatation progressed to aneurysmal proportions (5%). Significant suture line stenosis developed in one patient who also had recurrent renovascular hypertension. Progression of severity of "apparently insignificant" stenosis or development of a new lesion in the contralateral renal artery was observed in 12 of the 29 patients (41%). These patients serve to emphasize the fact that nephrectomy is ill-advised in patients with renovascular hypertension except under the most demanding circumstances. Finally, there is an urgent need for a careful comparative study of the grafts that are currently being used to construct aortorenal bypasses.

ALTHOUGH the saphenous vein has been frequently used to replace or bypass arterial lesions over the last 20 years there is very little in the way of factual information regarding the long term performance, durability and patency of these vein grafts. Notable exceptions are the reports of Fry and his associates and of Szilagyi and his associates; as well as, the recent increasing frequency of reports of arteriographic studies of aortocoronary bypass grafts.[1,4,5,7,9,10] The main reason for the paucity of followup data has been a reluctance to perform followup arteriograms in patients who are otherwise doing well. However, the finding of aneurysmal dilatations and stenoses in 16% of 74 aortorenal vein grafts studied 8–109 months following implantation, as reported by Stanley, Fry and Ernst, clearly emphasizes the need for more such studies.[9]

From December 1962 through December 1973, over 1400 consecutive hypertensive patients have been studied at Vanderbilt University Medical Center. In each patient a rapid sequence excretory urogram and a renal arteriogram were done. A diagnosis of renovascular hypertension (RVH) was made in 253 patients and of these 217 had operative treatment prior to 1974. A segment of autologous saphenous vein was used to bypass a renal artery stenosis in 94 patients. In 14 patients bilateral saphenous vein aortorenal grafts were implanted. Thus a total of 108 saphenous vein aortorenal bypass grafts were done. There were three operative deaths. An attempt has been made to obtain followup arteriograms in the surviving patients. This has been accomplished in 75 of the patients in whom 89 saphenous vein grafts have been implanted. A total of 130 followup arteriograms have been done in these 75 patients. A smaller group of 29 patients with 39 vein grafts have had serial long term arteriographic studies 12 to 108 months fol-

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lowing implantation. A total of 72 arteriograms have been done in these 29 patients. Assessment of the fate of the vein grafts provide the basis of this report.

Materials and Methods

Our criteria for selection of patients for operative treatment has been described in detail elsewhere.[6] If the arteriogram shows a renal artery stenosis then renal venous renin assays and split renal function studies were done. If either of the latter two tests were positive a diagnosis of RVH was considered established and operative treatment was usually recommended.

In the 94 patients who underwent vein bypass the etiology of the renal artery stenosis was fibromuscular dysplasia in 41 (32 females and nine males). In six of these latter patients bilateral bypasses were done. Sixty-one vein grafts were used to bypass atherosclerotic renal artery stenosis, bilateral in eight patients. This group includes 25 females and 28 males. Only one patient was less than 20 years of age. The patients ages ranged from 13 to 67 years.

The operative technique was fairly well standardized in all patients. A 5 cm segment of the proximal most portion of the saphenous vein was mobilized, branch veins were ligated and divided. Following removal the vein was gently distended with heparinized saline and constricting adventitial bands excised. Mannitol (25 g) and Heparin (50 mg) were administered intravenously prior to application of occluding clamps on the renal artery. The renal artery anastomosis was done first. In the vast majority of the cases an end to side anastomosis was done. When the renal artery anastomosis was completed, the vascular clamp was removed from the renal artery and a bulldog clamp applied to the vein graft adjacent to the suture line. Thereafter the anastomosis between the graft and the aorta was done. On the right side the vein graft was generally brought retrocaval and on the left behind the renal vein. Of the 108 vein grafts 54 were implanted on the right and 54 on the left. For the past two years magnification and 5.0 or 6.0 Prolene sutures have been used in creating the anastomoses.

Generally, an arteriogram has been done 7–8 days following operation. Thereafter, we have tried to obtain an arteriogram each year. In the early years covered by this report only a flush aortogram was obtained. For the past three years a flush AP aortogram, right posterior oblique flush aortogram and bilateral selective renal arteriograms have been done on almost every patient. During the last six months of 1973 our Department of Radiology did a special study.[2] The question they addressed related to the use of a pressure dressing following retrograde femoral catheter aortography (Table 1). They compared the use of a pressure dressing versus a bandaid following retrograde femoral arteriography in 754 consecutive patients. All patients had a 10–15 minute period of manual compression of the femoral artery puncture site prior to application of the pressure dressing or bandaid. Details of the study will be reported elsewhere.[2] In the pressure dressing group, delayed bleeding occurred in 0.52% while in the bandaid group delayed bleeding occurred in 3.76%. ($p. < 0.01$). In each patient who bled manual compression was reinstituted and effective hemostasis was obtained. One patient out of 754 had a significant complication, a femoral artery thrombosis which was easily corrected under local anesthesia.

TABLE 1. *Complications of Retrograde Femoral Catheter Aortography: 754 Patients at Venderbilt University Hospital 1973*

Complications	Pressure Dressing	Bandaid
Significant Groin Hematoma	2/382	2/372
Delayed Bleeding*	2/382	14/372
Femoral Artery Thrombosis	0	1/372 (0.27%)

* Fifteen minutes to eight hours after manual compression.

Results

There were a variety of observations in the followup arteriographic studies, some involved alterations and changes in the 89 vein grafts and in the renal arteries of the 75 patients. These are listed in Table 2. They include: thrombosis of the graft, thrombosis of the vein graft and renal artery, suture line stenosis, maintenance of a normal caliber, uniform dilatation of the graft, aneurysm of the graft, progression of renal artery lesions and the developmental of new renal artery lesions.

Thombosis of the Graft

In five patients the graft thrombosed but the stenotic renal artery remained patent. The cause of the thromboses could not be determined. In two patients the thrombosis was demonstrated in the early postoperative period (7–10 days). In three other patients it was dem-

TABLE 2. *Arteriographic Assessment of Saphenous Vein Aortorenal Grafts*

Graft Configuration	Assessment of Graft	Grafts at Risk*
Thrombosis of graft	5/89	6%
Thrombosis of graft and renal artery	7/89	8%
Suture line stenosis	15/89	17%
Patent and normal graft	24/39	62%
Dilatation of graft	8/39	20%
Aneurysm of graft	2/39	5%
Progression of renal artery lesions	11/29	38%
New renal artery lesions	1/29	3%

* The incidence of thrombosis and stenosis are based on early and/or late arteriographic studies. The incidence of the other changes is based on arteriograms done 12–108 months following operation.

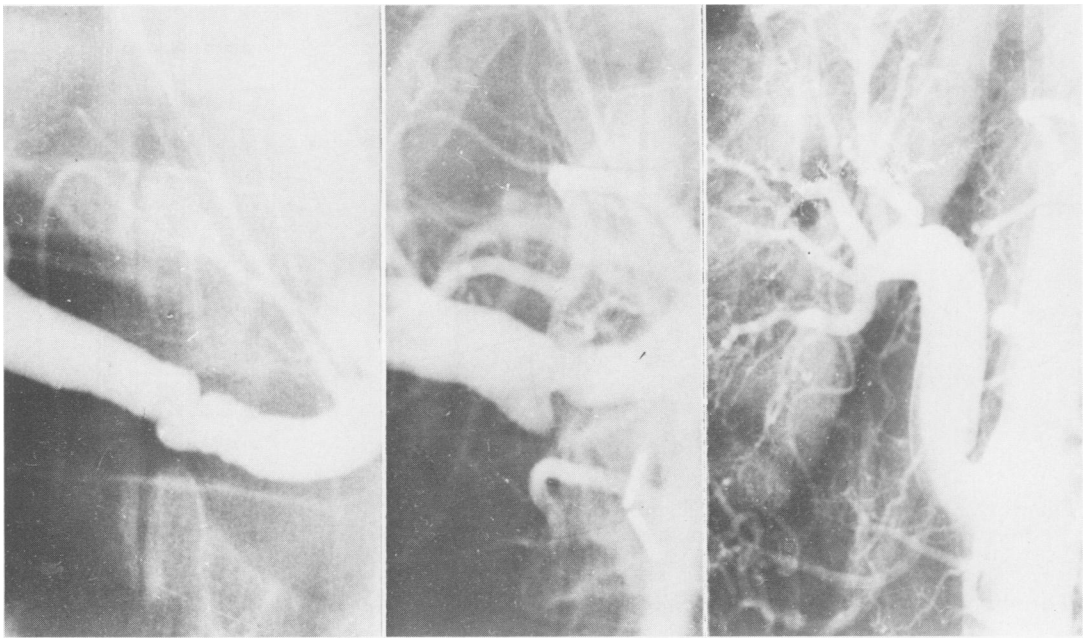

FIG. 1. Arteriograms showing: (Left) Stenotic right renal artery; (Center) Thrombosis of right aortorenal bypass graft with patent but stenotic renal artery; (Right) Patent Dacron aortorenal bypass.

onstrated 4½–24 months later; however, none of these patients had had an early postoperative arteriogram. Therefore it was not possible to determine when the thrombosis occurred. In two patients it was possible to perform a second and successful aortorenal bypass graft using a dacron prosthesis (Fig. 1).

FIG. 2. Arteriograms showing renal artery stenosis and postoperative thrombosis of both the graft and the renal artery.

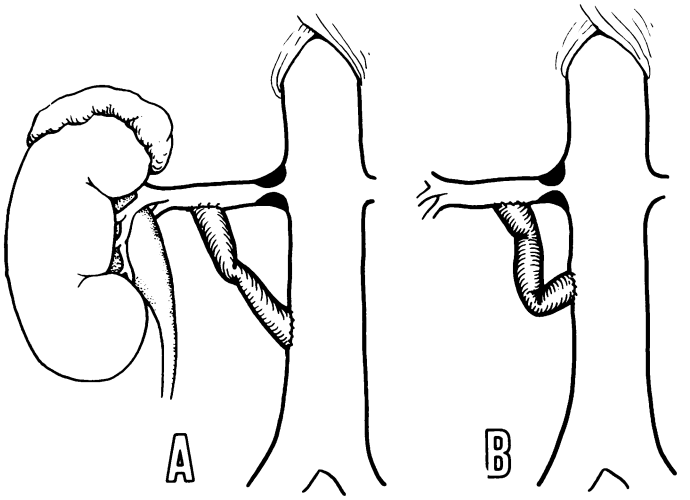

FIG. 3. Drawing depicting: (A) Malalignment of graft producing twisting effect; (B) Kinking from excessive length.

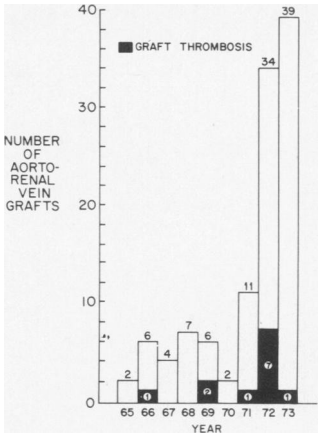

FIG. 4. Graph showing the number of aortorenal vein grafts performed each year with the number of thrombosed grafts also indicated.

Thrombosis of Vein Graft and Renal Artery

There were seven patients who had thrombosis of both the vein graft and renal artery (Fig. 2). In two patients there was a mild kink in the vein graft as shown in Fig. 3, but there was also a vigorous pulse in the distal graft and renal artery, both grafts thrombosed. Five of the seven patients underwent nephrectomy; in the other two patients nephrectomy was not done because the patient or his physician have opposed another operation. There were two patients who were found to have a thrombosed graft 3–24 months postoperatively, but these patients had not had an early postoperative arteriogram. Any graft that was patent, as determined by arteriography, in the early postoperative period has remained patent on subsequent examination.

Of the 12 vein graft thromboses ten were on the left side and only two on the right. Figure 4 shows the incidence of graft thrombosis each year since 1965. The operative case load increased sharply in 1972. In 1973 we began using magnification, prolene sutures and modified our operative technique.

The remaining results refer to the 29 patients with 39 vein grafts who have had long term serial followup arteriography one to nine years following operation.

Patent and Normal Graft

Twenty-four of the vein grafts maintained patency and a normal configuration (Fig. 5). These 19 patients ranged in age from 33 to 67 years. Followup ranged from 12 to 108 months. In three patients the early postoperative arteriogram showed a mild to moderate suture line stenosis which resolved and was no longer demonstrable on subsequent arteriograms. Nine patients had fibromuscular dyspasia, the remainder had atherosclerosis.

Dilatation of the Vein Graft

Eight of the 39 vein grafts when studied 2–6 years following implantation were found to be dilated (Fig. 6). The dilatation was uniform throughout the length

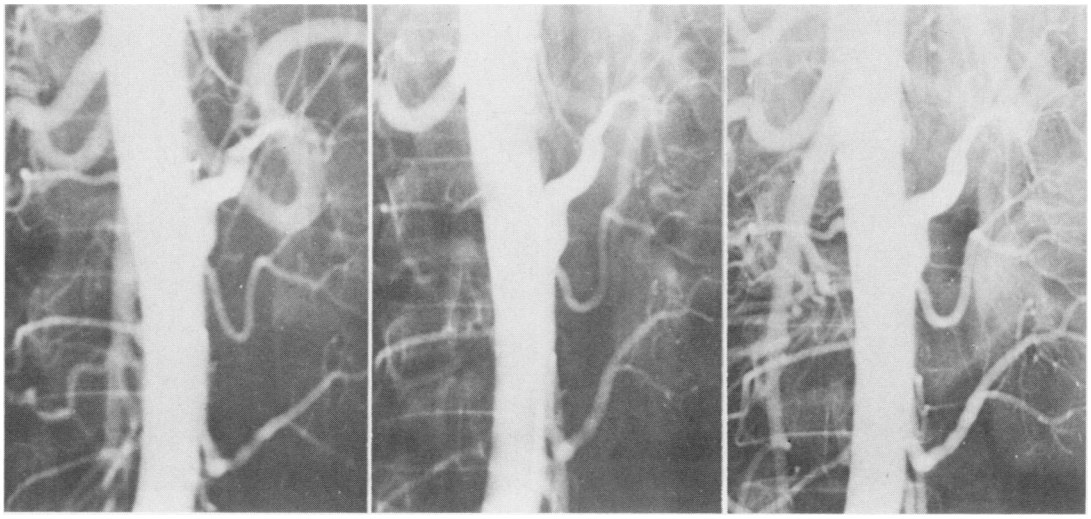

FIG. 5. Serial arteriograms one, four and nine years following saphenous vein aortorenal bypass showing maintenance of original size and configuration.

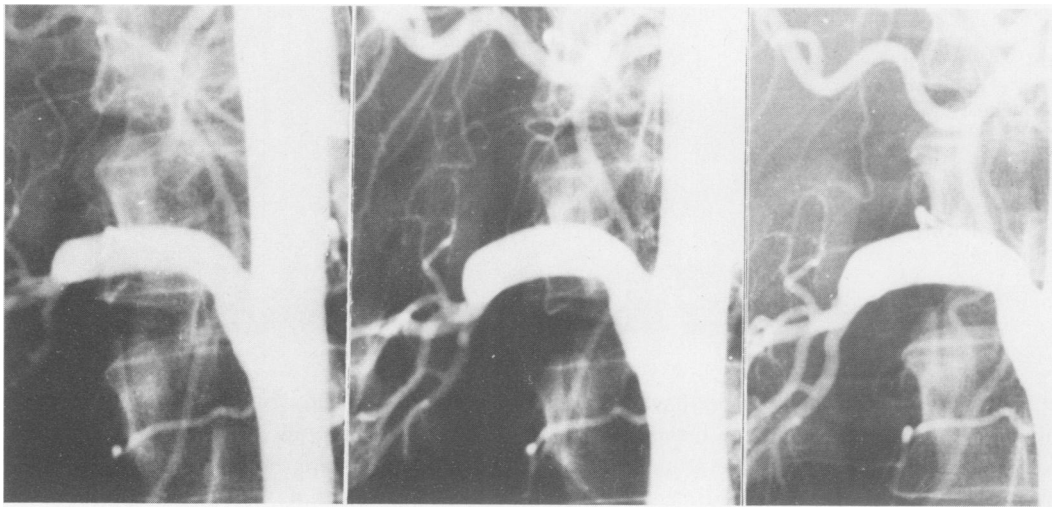

FIG. 6. Serial arteriograms one, two and six years following saphenous vein aortorenal bypass showing mild dilatation of vein graft.

of the vein graft and ranged from a 17% to a 47% increase in graft diameter. None of these grafts has shown a further increase in diameter on subsequent arteriograms. The eight patients ranged in age from 31 to 51 years. Six had fibrodysplastic lesions and the others had atherosclerosis. Each of these patients have maintained a good blood pressure response.

Aneurysm of the Graft

Two vein grafts underwent an increase in diameter of greater than 50% and are classified as aneurysms (Fig. 7). The increase in diameter ranged 87–106%. The development of aneurysmal change was recognized in these grafts three and six years following implantation. In each of the patients there has been no further increase of graft diameter. Each patient has remained normotensive so that nothing more has been done except for periodic repeat arteriograms.

Another patient, a nine-year-old boy who had renovascular hypertension due to left renal artery stenosis and abdominal angina due to celiac artery stenosis and complete occlusion of the superior mesenteric artery, underwent an aortorenal bypass graft and an aorto-superior mesenteric graft three years ago. The hypogastric artery was used for the renal graft and external iliac vein for the superior mesenteric graft. Within three years the hypogastric artery had increased in diameter by 100% and the iliac vein diameter had increased 300% (Fig. 8). He subsequently developed occlusion of his right subclavian and iliac arteries. The iliac artery occlusion necessitated a below the knee amputation. He is now asymptomatic, normotensive and completely rehabilatated with a BK prosthesis and nothing, other than periodic observation, has been done. The etiology of the vascular disease in this patient remains uncertain.

Suture Line Stenosis

Fifteen of the vein grafts showed some degree of suture line stenosis. In ten patients the stenosis was demonstrated in the early postoperative period. The other five patients did not have an early arteriogram and the stenosis was discovered one to two years following

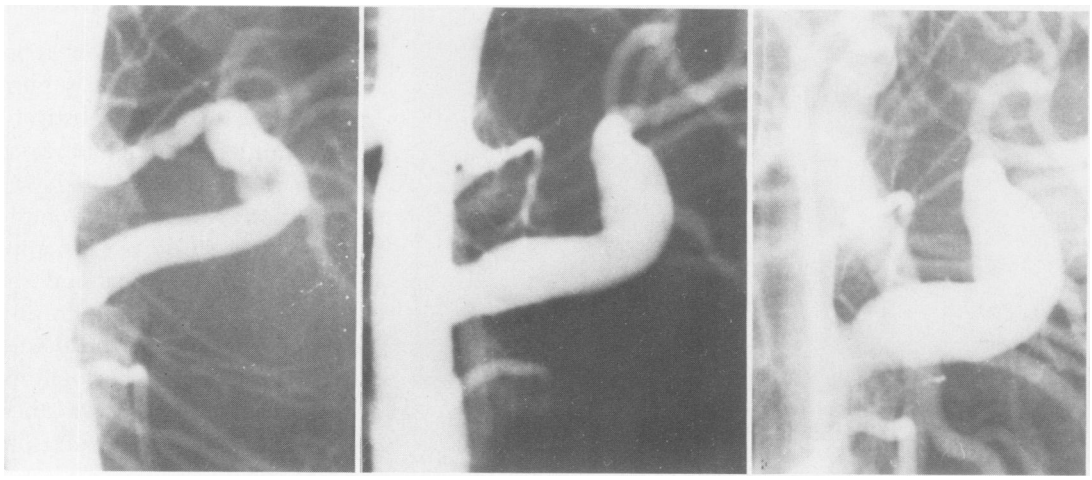

FIG. 7. Followup arteriography one, three and six years after saphenous vein aortorenal bypass demonstrating progressive aneurysmal dilatation.

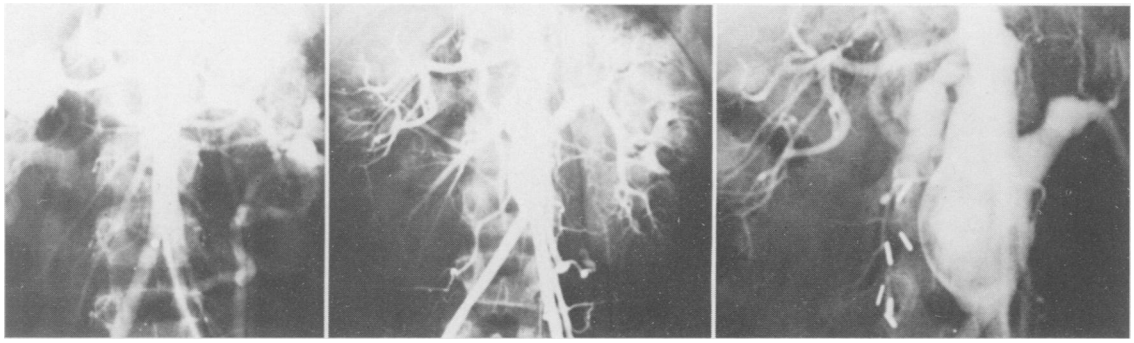

FIG. 8. Preoperative, immediate and three years postoperative arteriograms following hypogastric artery aortorenal bypass and iliac vein aorto-superior mesenteric bypass showing massive aneurysmal dilatation of both.

the operation. In only one patient was the stenosis severe and associated with recurrent hypertension (Fig. 9). In the remaining 14 patients the stenoses have been mild, have remained stable 1–96 months, and they have remained normotensive. Nine of the patients had atherosclerosis and six fibromuscular disease. They ranged in age from 28 to 56 years. In two patients there were stenoses at both suture lines, in five only the aortic suture line was involved and in the other eight patients the stenoses involved the renal artery anastomosis. The recurrent single stenoses involved the left renal artery in six patients and the right in seven. None of the right sided grafts developed a stenosis in its mid-portion as has been noted by the Michigan group and attributed to retrocaval cicatrix formation.[9] As was noted earlier three patients who had stenosis noted on an early postoperative arteriogram were later found to have a normal caliber graft without any narrowing.

Progression of Renal Artery Lesions

In 11 patients the original renal arteriograms showed very mild to moderate and "apparently insignificant" lesions in the contralateral renal artery which have subsequently progressed in severity (Figs. 10, 11). These changes were recognized three months to five years following ipsilateral aortorenal grafting. Seven of these patients had fibrodysplastic lesions and four had atherosclerosis. In three patients the lesion progressed to functional significance and resulted in recurrent RVH which required another aortorenal graft. In the other eight patients the lesions have remained stable, are not functionally significant and RVH has not recurred. These patients ranged in age from 13 to 57 years.

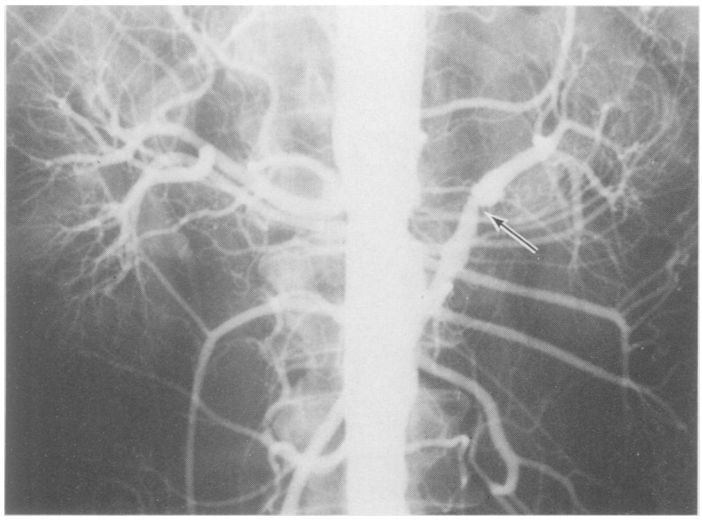

FIG. 9. Postoperative arteriogram of patient with stenotic distal suture line and recurrent renovascular hypertension.

New Renal Artery Lesions

In one patient the initial arteriogram showed the contralateral renal artery to be normal. The followup arteriogram 24 months later showed contralateral renal artery stenosis (Fig. 12). Atherosclerosis was the etiology in that 33-year-old man. RVH recurred and another bypass graft was done. We have not noted development of new lesions in the renal artery beyond an aortorenal bypass graft.

During the followup period three of the 94 patients died. They ranged in age from 33 to 65 years. None of the deaths were related to the vein graft or to hypertension. One death was due to a myocardial infarction, one due to suicide and the final one secondary to an operation for aorto-iliac occlusive disease.

Discussion

There have been a few reported studies of long term followup of autologous saphenous vein grafts used as arterial bypasses or substitutes. Physicians have been understandably reluctant to do followup arteriograms in a patient who is doing well. This is because of apprehension concerning complications attendant to arteriographic studies. This appears to be an unjustified apprehension provided an experienced and skillful arteriographer is available to do the examination. This belief is supported by the data in our report of 754 consecutive abdominal aortograms done in 1973 with but a single serious complication and that one (a femoral artery thrombosis) was easily and promptly corrected.[2] Arteri-

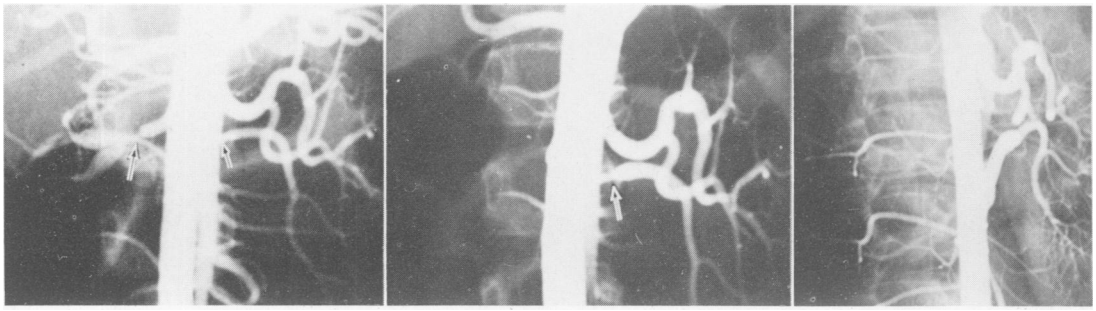

FIG. 10. Serial arteriograms in a child showing right and minimal left lower renal artery lesions (1963). Ten years later severe left lower renal artery stenosis had developed necessitating saphenous vein aortorenal bypass.

ography does carry some risk to the patient but when properly done it is minimal or negligible.

There are several reasons why serial arteriographic followup studies of the various grafts used in renal artery reconstruction are needed. At present saphenous vein, hypogastric artery and dacron prostheses are being implanted as bypasses or replacements of the renal artery in many hospitals throughout the country. The most important consideration is the need to determine which of these arterial replacements, if any, is superior. Each has technical advantages and disadvantages. The fact that many of these grafts are being implanted in relatively young patients adds to the urgency of the problem. There is considerable evidence that autogenous vein grafts in the patient under 20 years of age is particularly susceptible to aneurysmal dilatation. Four of the six vein graft aneurysms occurring in aortorenal grafts reported by Stanley, *et al.* were in patients under 20 years of age.[9] These four aneurysms occurred in a group of 12 children subjected to renal artery reconstruction with a saphenous vein.

The Michigan group has previously reported a study similar to the one herein recorded.[9] Table 3 compares the two studies. The incidence of vein graft thrombosis in the two groups is similar as is the incidence of aneurysm formation, thereafter the results become divergent and for the most part unexplainable. There is a difference in the operative technique employed in the two groups of patients. The vast majority of the cases in the Michigan group had an end to end anastomosis between the saphenous vein and the renal artery; whereas an end to side anastomosis was done in most of our patients. Whether this difference influenced the results is unknown. It should be strongly emphasized that in Tables 2 and 3 the stenoses for the most part (14 of 15) were mild, insignificant and that patients have maintained a good blood pressure response. The same is true for the blood pressure in the patients with dilatations and aneurysmal changes. Finally, two of the patients with graft thrombosis had a second and successful arterial reconstruction while three others have not yet accepted that option.

In our experience, thrombosis of the vein graft, when it occurs, does so in the early postoperative period and is probably related to technical, operative errors. Others have reported a similar belief.[9] The evidence supporting this belief is that every graft which was shown to be patent 7–10 days following the operation has remained patent on subsequent arteriography. Obviously, many

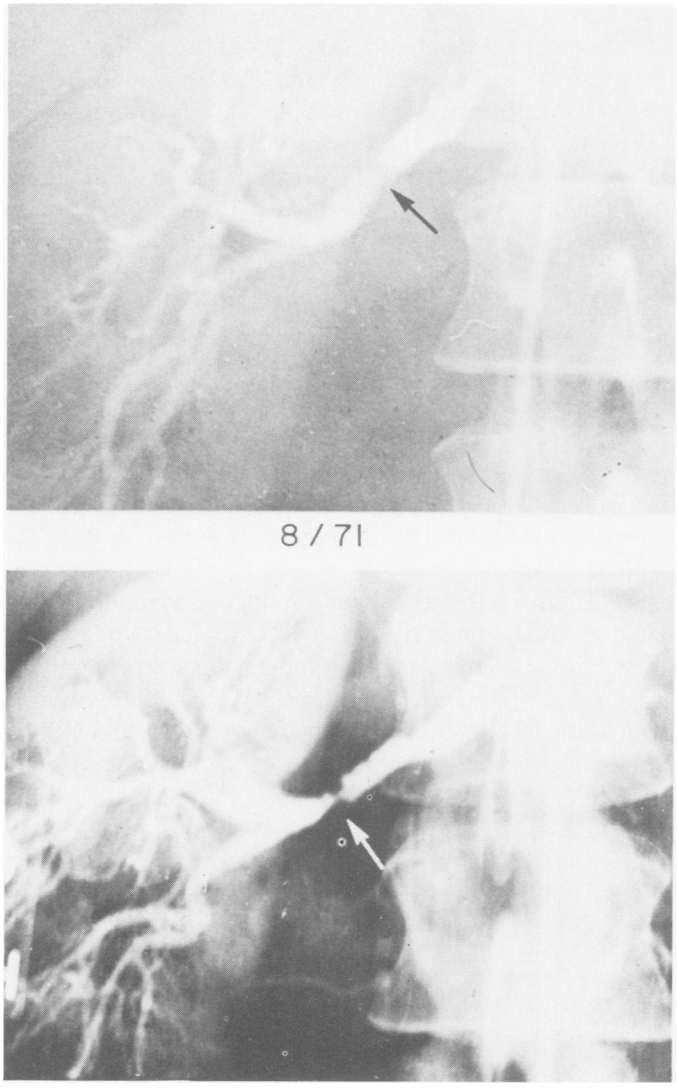

FIG. 11. Selective right renal arteriograms showing dramatic progression of the renal artery stenosis which occurred in a three month period.

FIG. 12. (Left) Arteriogram prior to left renal artery bypass showing normal right renal artery. (Right) Two years later hypertension recurred and arteriogram showed a patent left renal artery bypass and a severe, new right renal artery stenosis which was successfully bypassed.

factors can contribute to graft thrombosis. Kinking or longitudinal twisting of the graft, as shown in Fig. 2, are two notable ones. When doing the anastomosis between the graft and the lateral wall of the aorta, if one rotates the aorta to the contralateral side in order to facilitate the procedure, it is easy to make the length of vein graft too great. When the aorta is de-rotated the vein graft is redundant and may kink.

One unique virtue of doing an end to side anastomosis between the graft and the renal artery is that if the graft thromboses, the renal artery may not. On six occasions (one from elsewhere and not included in this report) we have seen graft thrombosis but continued, although stenotic, patency of the renal artery. In three instances we have done a successful second bypass graft. As a rule when an end to end vein graft thromboses, so does the renal artery.

The uniform dilatation of saphenous vein grafts implanted in the renal artery is poorly understood. By contrast, saphenous veins implanted in the femoropopliteal system or in the coronary arteries have frequently undergone fibrotic stenosing changes.[1,5,7,10] In Szilagyi's report, an arteriographic followup of 260 saphenous veins implanted into the femoropopliteal artery, ten of the vein grafts developed aneurysmal dilatations while 75 developed stenosing lesions.[10] Furthermore, the aneurysmal dilatation did not involve the entire length of the femoropopliteal vein graft, as is the case with the renal artery vein grafts, but rather were localized dilatations of a short segment of the vein graft. Renal blood flow is much greater than coronary or femoral artery flow. Flow meter studies on coronary vein bypasses average 70–90 ml/min, whereas renal bypass blood flows average 300–400 ml/min. The dilatation of the vein graft in the renal artery usually develops slowly over a period of several years, usually reaches a given degree of dilatation and remains stable thereafter. In most patients if the initial blood pressure was favorable, it has remained so in spite of the dilatation.

TABLE 3. *Comparative Results of Saphenous Vein, Aortorenal Grafting*

Vein Graft Configuration	Vanderbilt Number of Grafts*		Michigan Number of Grafts*	
Thrombosis	12/89	13%	9/100	9%
Normal	24/39	62%	29/74	40%
Dilatation	8/39	20%	33/74	44%
Aneurysm	2/39	5%	6/74	8%
Stenosis	15/89	17%	7/74	9%

* The incidence of thrombosis and stenosis are based on early and/or late arteriographic studies. The incidence of the other changes is based on arteriograms done 12–108 months following operation.

Currently there is much interest in whether the method of harvesting, handling and preparing the saphenous vein for implantation influences subsequent graft performance and configuration. Evidence has been presented which indicates that forceful dilatation, distension or excessive adventitial disection of the graft has a deleterious effect.[9,10] Placing the vein in saline, especially at room temperature, has also been indicted as a cause of injury to the vein. Storage in cold Ringers lactate solution, cold blood, cold glucose and other solutions have been recommended. It is far too early to evaluate the evidence supporting these concepts. Certainly, more investigation in this area is urgently needed.

When the severity of the dilatation of the vein graft caliber exceeds 50% of the original diameter it has been classified as an aneurysm. We have had two such cases, both have remained normotensive and nothing further has been done except for periodic reevaluation. Of the six cases of aneurysmal vein grafts reported by the

Michigan group, two reached proportions which prompted resection of the vein graft and creation of a second aortorenal vein graft. Both of the original vein grafts revealed degenerative changes of a rather nonspecific nature. These aneurysmal changes in the saphenous vein implanted in the renal artery are cause for great concern. However most of the aortorenal vein grafts have held up quite well. It is likely that they should *not* be used in children. The saphenous vein in the child is structurally an anatomically different than in the adult.[9] The arterial blood supply of the saphenous vein in the child and in the adult are apparently different. The frequency of aneusysmal dilatation of vein grafts in children has been attributed to these differences. Information concerning the long term performance of the hypogastric artery implanted in the renal system is not yet available. Early in our experience we felt that the dacron prosthesis, implanted in the renal artery was more likely to thrombose. What we were actually comparing was our first three or four year experience with our second three to four year experience with renal arterial revascularization. In actual fact, in our experience, if the Dacron graft was initially patent, it has remained patent on subsequent examinations. If the renal artery beyond the stenosis is large (6–8 mm in diameter) and the saphenous vein is less than 4 mm in diameter, we do not hesitate to use a Dacron prosthesis, especially in a child. The ultimate fate of these grafts remains to be determined. We have never seen or heard of a false aneurysm developing in an anastomosis between the saphenous vein and an artery. False aneurysm formation in a Dacron prosthesis-renal artery anastomosis has been observed.[8]

We have rarely encountered a functionally significant stenosis in an aorto renal vein graft (e.g. a stenosis causing recurrent RVH). Stanley *et al.* reported a 9% incidence of such stenoses.[9] The etiology of these stenoses is also obscure. Once again vein graft handling has been incriminated as has the retrocaval course of a right aortorenal graft. In the latter type of stenosis retrocaval hematoma and subsequent cicatrix formation has been cited as the inciting factor in causing a stenosis in the mid-portion of a right aortorenal vein graft. We have not observed a stenosis other than at the suture lines in any of our patients. Conkle, et al have reported experimental canine studies which indicate that both arteries and veins when transplanted in an arterial system develop proliferative intimal lesions which might produce significant stenoses—these studies were done in the femoral arteries of the dog.[3] The one vein graft that we have recovered following thrombosis showed similar fibrotic intimal proliferation.

Another observation encountered in this study was the frequency of development of new or progressive stenotic lesions in the contralateral renal artery. The importance of this observation relates to avoiding nephrectomy in patients with RVH. In many of the early reports on treating patients with RVH, nephrectomy was the mode of treatment in over 50% of the patients. It is now apparent that nephrectomy should not be done except in the case of a destroyed kidney or in patients who are uncontrollable and whose renal artery can not be reconstructed.

The most satisfying observation in the study was the sharp decline in graft thrombosis in 1973 as compared to 1972. This improvement is attributed to modifications in operative technique.

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Discussion

Dr. George Cooper Morris, Jr. (Houston): Our experience in the long-term state of the vein in the renal artery position has been exactly similar to Dr. Foster's and his group. True aneurysms developing in adults have been extremely rare in our experience. (Slide) Here is an example of a patient who has been followed