Ten Years Experience with the Surgical Management of Renovascular Hypertension

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EXPERIENCE with the detection and treatment of renovascular hypertension varies greatly from one medical community to another. In a few centers patients with this condition are being identified regularly, while in other institutions there is little or no interest in renovascular hypertension. There are a number of reasons for this disparity. They include: The belief that renal artery stenosis is an uncommon cause of high blood pressure; the belief that antihypertensive drug therapy is as good or better than operative treatment; apprehension about hazards of the diagnostic tests required to establish the diagnosis of renovascular hypertension; finally, the fact that many patients have had operative treatment for presumed renovascular hypertension which they did not have and were not benefited.

The incidence of renovascular hypertension is unknown. However, as this report will show, it is a common condition and is, in our opinion, the underlying etiology in about 5% of patients who have diastolic hypertension. A comparative study of drug therapy and operative treatment of renovascular hypertension has not been done. The hazards associated with aortography, split renal function studies and renal venous renin assays, although real, are very small. The finding of renal artery stenosis in a hypertensive patient does not suffice to establish the diagnosis of renovascular hypertension. Functional tests to determine whether or not the stenosis is the cause of the hypertension must be done.

For the past ten years at Vanderbilt University Medical Center, a multidisciplinary group has been studying hypertensive patients for evidence of an underlying correctable cause. This report will summarize the experience with renovascular hypertension.

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Clinical Material

During the ten-year period, 1070 hypertensive patients have been studied. Following hospitalization all patients underwent a detailed evaluation as shown in Table 1. Those patients who had renal artery stenosis demonstrated by renal arteriography then had split renal function studies (Howard and Stamey Tests)[5,9] and renal venous renin assays to ascertain the functional significance of the arterial lesion. By our criteria if either of these tests were positive the diagnosis of renovascular hypertension was established. Table 2 depicts the incidence of renal artery lesions and renovascular hypertension in this series. Four hundred and sixty patients had renal artery stenosis, of these 176 or 39% had renovascular hypertension. Sixteen per cent of the entire group of 1070 patients had renovascular hypertension. To date 148 of these patients have had operative treatment. Figure 1 shows the number of renal artery operations performed each year since 1961. However, for the purposes of this report, only the first 122 patients will be considered. This is done in order to provide a minimum postoperative follow-up of at least 6 months. The other 26 patients have been operated upon since May of 1972.

Clinical Data

Pertinent clinical characteristics in the 122 patients are summarized in Table 3. Fibromuscular dysplasia was

TABLE 1. *General Evaluation of Patient with Hypertension*

History and Physical Examination
Hemogram, SMA 12, Urinalysis, Urine Culture
Serum K × 3, Electrocardiogram and Chest X-Ray
Analysis of 24 Hour Urine Collection for:
Creatinine Clearance, Electrolytes,
Catecholamines, VMA, and 170H Steroids
and Ketosteroids
Rapid Sequence Intravenous Pyelogram
Renal Arteriography

the renal artery lesion in 44 patients, of which 70% were female. In 78 patients, atherosclerotic plaques were the cause of renal artery stenosis, of which 67% occurred in males. A family history of hypertension was common in both groups. Only 6% of the 122 patients were black although over 33% of the 1070 patients studied were black. The patients ranged in age from 4 months to 69 years, 43% of the patients were over 50 years of age. Although the patients with fibromuscular lesions were much younger than the atherosclerotic group the frequency of left ventricular hypertrophy, as determined by electrocardiogram, was about the same in the two groups. Similarly, the duration of hypertension was not greatly different in the two groups. The average preoperative diastolic blood pressure in patients from both groups ranged between 105 to 140 mm. Hg.

Special Diagnostic Studies

Rapid Sequence Excretory Urogram. Radiographs are made at 1, 2, 3, 4, 5, 10, and 30 minutes after injection of the contrast medium. The five criteria suggestive of renovascular hypertension are: (1) Unilateral delay in calyceal appearance in time; (2) Difference in renal length of 1.5 cm. or more as compared to the contralateral kidney; (3) Hyperconcentration of the contrast medium on the late films; (4) Ureteral notching secondary to increased size and tortuosity of the ureteral artery and (5) Defect in the renal silhouette suggestive of segmental renal infarction. Figure 2 shows that in 38 or 31% of the 122 patients the IVP yielded a false negative result, 18 in patients with unilateral stenosis and 20 in patients

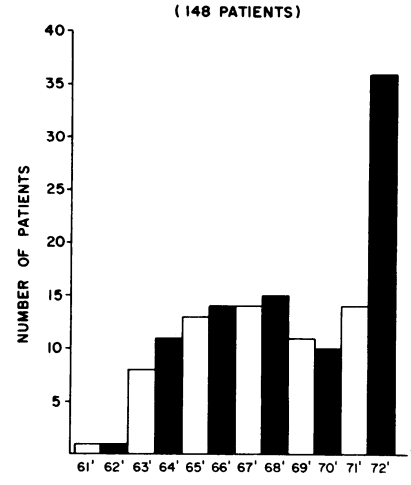

FIG. 1. Operations for renovascular hypertension as shown by year performed.

with bilateral lesions. The criteria for interpretation of the IVP depend on comparing one kidney to the other, as do some of the other diagnostic studies. Bilateral renal artery lesions complicate the interpretation of these tests. However, in many patients with bilateral lesions the stenosis is more severe on one side and the IVP, split function studies and renin assays will often lateralize to that side. In 20 of the 40 patients with bilateral lesions the IVP did lateralize.

Renal Arteriography. Counting follow-up studies, repeat studies and the primary arteriograms the 1070 patients in this study have had 1423 renal arteriograms. Major complications attended the procedure in six (0.4%) patients. In addition to the abdominal aortogram, selective renal arteriograms in various oblique projections were required to properly visualize the renal arteries. (These multiple injections of contrast medium are not counted as separate arteriograms in the above data related to complications.) In a number of patients the anterior-posterior aortogram failed to reveal a renal artery stenosis which was then clearly delineated on a selective oblique renal arteriogram (Fig. 3). A considerable portion of the course of the renal arteries is primarily in the anterior-posterior plane.

TABLE 2. *Results of Evaluation of 1070 Hypertensive Patients*

	Renal Arteriogram		Renovascular Hypertension*		
Normal	610	(57%)	—		16%
Renal Artery Stenosis Due to:					
Atherosclerosis	297	(43%)	114	39%	
Fibromuscular Dysplasia	163		62		

* Positive Functional Tests—Split Renal Function Studies or Renal Venous Renin Assay

TABLE 3. *Clinical Information*

	Fibromusuclar Dysplasia	Atherosclerotic	Total
Male	13 (30%)	52 (67%)	65 (53%)
Female	31 (70%)	26 (33%)	57 (47%)
White	41 (93%)	76 (97%)	117 (96%)
Black	3 (7%)	2 (3%)	5 (4%)
Family History of Hypertension	24 (55%)	40 (51%)	64 (52%)
Left Ventricular Hypertrophy	26 (59%)	49 (63%)	75 (61%)
Mean Age	32.6 years	50.4 years	
Mean Duration of Hypertension	4.6 years	5.1 years	

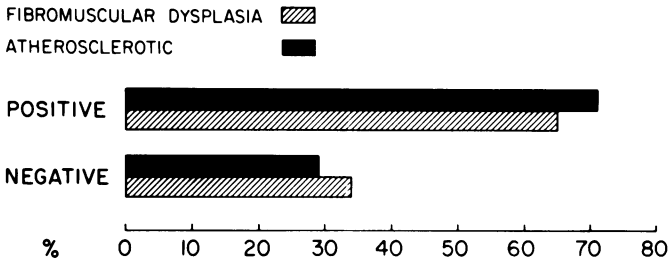

FIG. 2. Interpretation of the preoperative rapid sequence intravenous pyelogram in patients with fibromuscular dysplasia and atherosclerotic lesions of the renal artery.

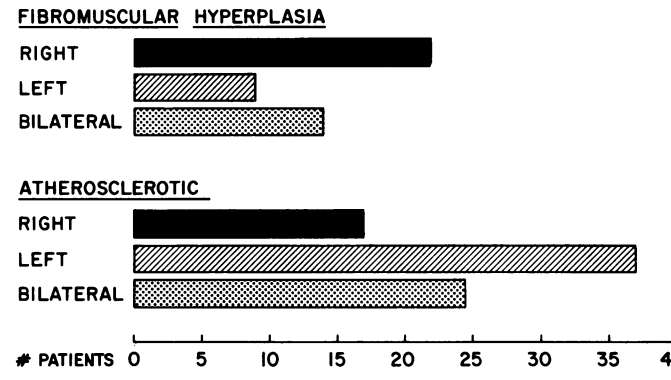

FIG. 4. Site of lesion as shown by arteriography in 122 patients with renovascular hypertension.

Figure 4 shows the site and nature of the renal artery lesions in the 122 patients. Unilateral fibromuscular lesions were more common on the right and unilateral atherosclerosis more frequent on the left side. Bilateral lesions were equally frequent in the two groups. Atherosclerosis typically involved the proximal third of the renal artery and fibromuscular lesions usually involved the middle and distal third of the renal artery.

Split Renal Function Studies. Preoperative split renal function studies (Howard and Stamey Tests) were obtained in 101 patients. In the other 21 patients the tests were not done or were technical failures. The following liberalized criteria for a positive test were utilized in interpreting the results; Howard Test—25% reduction in urine volume and 25% increase in creatinine concentration from the kidney with renal artery stenosis as compared with the contralateral kidney. Stamey Test—25% reduction in urine volume and 25% increase in PAH concentration from the affected side. In patients with unilateral lesions the Howard Test was positive in 70% of the cases and the Stamey Test was positive in 55% of the cases. However, if the results of the two tests are combined 97% of the patients had a positive Howard or Stamey Test (Table 4). In patients with bilateral lesions the test results lateralized to the dominant side in 78% of the cases.

Renal Venous Renin Assays. In preparation for obtaining renal venous blood samples, antihypertensive medication was discontinued 1 week in advance and the patient was placed on a 2 Gm. sodium diet at least 2 days before the test. The patient was kept in the supine position for 3 hours before the test and the blood samples were drawn with the patient in the supine position. The catheter was localized in the renal veins under fluoroscopic control and proper placement confirmed by checking oxygen saturation in the renal venous blood. When the ratio of the renin activity from the involved kidney to the uninvolved kidney was 1.5 or greater the test was considered positive.[7] Table 5 shows the results in 99 patients. In patients with unilateral lesions the test was positive in 80% of the cases. Bilateral lesions showed a dominant side in 65% of the cases.

If the results of the functional tests are combined then all 90 patients with unilateral lesions had either a positive Howard Test or a positive Stamey Test or a positive renin ratio.

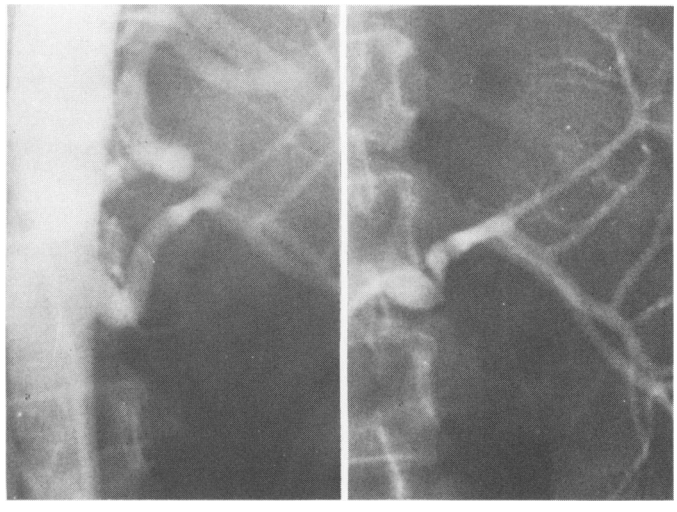

FIG. 3. Comparison of antero-posterior and oblique projections of renal arteriogram showing lack of demonstration of lesion on antero-posterior projection.

Preoperative Preparation

Thirty-three patients had significant blood volume deficits. Table 6 shows the mean and range of the deficit in this series. Any patient with blood volume deficit of 500 cc. or greater had it replaced in the 24 hours prior to operation.

TABLE 4. *Preoperative Split Renal Function Studies (101 Patients)*

	Unilateral Lesion		Bilateral Lesion	
	# Patients	Per Cent	# Patients	Per Cent
Positive	62	97%	29	78%
Negative	2	3%	8	22%

TABLE 5. *Preoperative Renal Vein Renin Determination (99 Patients)*

	Unilateral Lesion # Patients	Unilateral Lesion Per Cent	Bilateral Lesion # Patients	Bilateral Lesion Per Cent
Positive	49	80%	24	65%
Negative	12	20%	14	35%

$$\frac{\text{Renin Activity—Involved Kidney}}{\text{Renin Activity—Uninvolved Kidney}} = 1.5 \text{ or } > = \text{Positive}$$

Patients with severe hypertension, diastolic pressures in excess of 120 mm. Hg, received antihypertensive drug treatment for several days prior to operation. Alpha methyldopa was the drug used most frequently. Ordinarily it was discontinued 24 hours prior to operation but in many cases it was continued up to the time of operation. There were no anesthetic or postoperative complications attributable to the use of this agent.

Finally, operative treatment was not undertaken until it was certain that split renal function studies or aortography had not caused an elevation in the blood urea nitrogen level. If such was encountered operation was delayed until it returned to normal. Following aortography there may be a marked fall in the hematocrit. The day following aortography the hematocrit was checked.

Operative Management

The variety of operative procedures performed are shown in Table 7. An aorto-renal bypass graft was done in 72 patients, of which 16 were bilateral. Thus 93 bypass grafts were implanted. The bypass material was saphenous vein in 63, hypogastric artery in three and dacron in 27. Nineteen patients had thromboendarterectomy with or without a patch graft, of which three were bilateral. In 16 patients renovascular reconstruction was combined with other vascular operations; abdominal aortic aneurysmectomy in six cases, aortoiliac or femoral bypass in five cases and operations for occlusive lesions of the celiac or superior mesenteric artery in three cases.

Aortorenal bypass graft has been the most common operation and saphenous vein the usual graft material. The details of the operative technic as it has evolved over the years are as follows: A transverse, supra-umbilical incisis made. Mannitol, 12.5 Gms., is administered slowly by intravenous route. Heparin, 50 mg., is given intravenously

TABLE 6. *Preoperative Blood Volume Deficit in 33 Patients*

	Blood Volume Deficit	Red Blood Cell Deficit	Plasma Volume Deficit
Mean	997 cc	560 cc	438 cc
Range	504–1740 cc	90–984 cc	45–1140 cc

TABLE 7. *Primary Operative Procedures*

Procedure	Fibro-muscular Dysplasia	Athero-sclerotic	Total
Vein Bypass Grafts			
Single Aorto-Renal	22	25	47
Bilateral Aorto-Renal	3	5	8
Dacron Bypass Grafts			
Single Aorto-Renal	1	10	11
Bilateral Aorto-Renal	1	7	8
Thromboendarterectomy (TEA)			
Single	3	13	16
Bilateral		3	3
Nephrectomy	11	15	26
Other			
Autogenous Arterial Bypass	3		3
	44	78	122

just prior to application of the occluding vascular clamps. The aorta is exposed at the base of the small bowel mesentery, the fourth portion of the duodenum is mobilized to the right and the left renal vein is then exposed and mobilized. For a left renal artery bypass the renal vein is usually retracted anteriorly and the end-to-side anastomosis between the graft and renal artery is done posterior to the vein. Occasionally it is easier to retract the renal vein caudally and do the anastomosis above the vein. For a right renal artery bypass the vena cava is mobilized, two or three pair of lumbar veins are divided and ligated and the vena cava retracted laterally so that the anastomosis is done behind the cava. Sometimes it is easier to do the anastomosis on the right lateral side of the cava. In an occasional case it is easier to mobilize the right colon and duodenum medially in order to expose the distal portion of the right renal artery. In any event the graft is usually brought retrocavally over to the aorta. Early on the continuous suture lines were interrupted in two places, more recently it is interrupted in four places. After the anastomosis between the graft and renal artery is completed the occluding clamp is removed from the renal artery and a small bulldog clamp is placed on the graft adjacent to the suture line. Thereafter the aortic anastomosis is done.

During the first 8½ years of this study a braided polyester suture material was used. One and one-half years ago we changed to a monofilament polypropylene suture. Figure 5 compares blood replacement with the two types of suture material, all patients had a unilateral aortorenal bypass utilizing saphenous vein. In these 38 comparable procedures over twice as much blood replacement was required when the braided polyester suture was used. The difference was related to blood loss from the suture lines. Examination of the braided suture under the microscope reveals it to be quite porous with an irregular surface.

When pulled through an artery or vein a sawing effect might result. We believe this accounts for the greater suture line leakage. The monofilament polypropylene suture pulls through tissue so easily and smoothly that one must guard against a purse string effect. The suture line should be interrupted in two places and preferably four.

Postoperative Management and Course

In addition to the usual postoperative measures hourly urinary out-put was monitored closely. In an occasional patient a massive diuresis (4–5 liters per 24 hours) occurred with attendant electrolyte losses. Urinary electrolyte levels were determined daily. A more frequent problem was fluid overload. Daily body weights and monitoring central venous pressure are helpful in avoiding this problem. Many patients remained hypertensive for days, weeks and sometimes months following a successful revascularization. For this reason alpha methyldopa was begun promptly if the diastolic pressure exceeded 100 mm. Hg. About half the patients in this study were sent home on this medication and then had the drug gradually withdrawn over a period of weeks or months.

Prior to discharge from the hospital a rapid sequence IVP was obtained. If the preoperative study was positive and the postoperative study was normal, the revascularization is considered to be successful. If the postoperative study remained "positive" or if renal function had deteriorated, an aortogram was obtained.

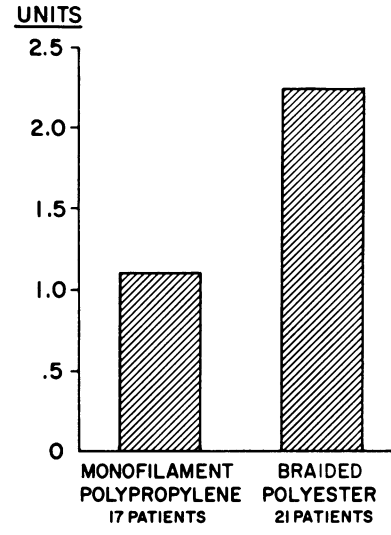

FIG. 5. Comparison of the blood replacement required when using monofilament polypropylene and braided polyester suture material in 38 patients undergoing saphenous vein aortorenal bypass.

There were five deaths following 122 primary operations, an operative mortality of 4%. There were 26 secondary operations. Four patients had repeat ipsilateral aorta-renal bypass, it was successful in three and resulted in an operative death in the fourth. Four patients had successful contralateral bypasses. Sixteen patients with

TABLE 8. *Operative Mortalities*

Patient	Primary Operation	Entity	Cause
L.R.	Left Vein Bypass Right Nephrectomy	Atherosclerotic	Myocradial Infarction
J.W.	Wrapping of Abdominal Aortic Aneurysm Right Renal TEA	Atherosclerotic	Aortic Thrombosis Acute Tubular Necrosis
M.G.	Celiac Thromboendarterectomy Right Vein Bypass	Atherosclerotic	Undetermined
F.S.	Aorto-Bilateral Femoral Dacron Bypass Left Renal and Superior Mesenteris REA Right Nephrectomy	Atherosclerotic	G. I. Bleeding
W.G.	Right Nephrectomy Secondary Operation	Fibromuscular Dysplasia	Septicemia Acute Tubular Necrosis
J.P.	Aorto-Bilateral Femoral Dacron Bypass Left Nephrectomy Right Dactron Bypass (A Previous L. TEA)	Atherosclerotic	Pulmonary Embolus
W.G.	Previous Bilateral Bypass with Unilateral Thrombosis and Contralateral Bleeding Requiring Bilateral Nephrectomy—One Year Later Renal Homotransplantation	Atherosclerosis	Transfusion Reaction
C.M.	Previous Bypass Thrombosed Left Nephrectomy	Atherosclerosis	Congestive Heart Failure and Acute Tubular Necrosis

TABLE 9. *Postoperative Complictainso*

Complication	# Patients
1. Thrombosis of Bypass or TEA	24
2. Congestive Heart Failure	4
3. Acute Tubular Necrosis	4
4. Intestinal Obstruction	2
5. Aortic Suture Line Disruption	1
6. Basilar Artery Thrombosis	1
7. Hemolytic Crisis	1
8. Bracheal Plexus Stretch Injury	1
9. Renal Arterio-Venous Fistula	1
10. Abdominal Angina	1

thrombosed arterial reconstruction underwent nephrectomy, there was one operative death. Finally one patient who had bilateral bypass, bilateral thrombosis, bilateral nephrectomy underwent renal homotransplantation 1 year later and died in the early postoperative period secondary to a transfusion reaction. Thus the 122 patients had a total of 148 operations with eight operative deaths, an overall operative mortality of 5.4%. Table 8 lists the operative procedures done and causes of death in the eight patients. Most of them presented with complex vascular lesions requiring multiple, simultaneous vascular operations.

Table 9 lists the non-fatal postoperative complications. Thrombosis of the reconstructed renal artery occurred in 24 patients. There were 155 arterial reconstructions at risk, the thrombosis rate was 21%. While most of these occurred early in our experience, some are most recent. Thrombosis of a renal artery bypass or thromboendarterectomy usually occurs within the first postoperative week. This can be documented in 16 (67%) of the 24 technical failures. In the other eight patients there is no way of determining when the thrombosis occurred, the occlusion was demonstrated 3 to 24 months later. None of the patients had a proven patent reconstruction and then a subsequent thrombosis. A normal rapid sequence urogram does not assure a patent arterial reconstruction. As was noted early in 31% of the cases in the study the preoperative IVP was normal. A renal artery bypass can thrombose without further encroachment on the lumen of the renal artery. We have documented this arteriographically in four patients. In these instances the pre- and postoperative IVP were normal and identical. A successful second bypass was done in all four patients.

Results of Treatment

Patients who are normotensive (diastolic blood pressure < 90 mm. Hg) are classified as cured. Those who had a reduction in their diastolic blood pressure of at least 20 mm. Hg but still have pressures between 90–100 mm. Hg are considered improved. Patients who are unimproved were classified as failures. Those patients who were initial technical failures (thrombosis) but underwent reoperation are classified according to the results of the final operation.

Figure 6 shows the overall early results of operative treatment. Ninety per cent of the patients were either cured or improved, there were four failures and eight operative deaths.

Early results in treating fibromuscular dysplastic and atherosclerotic lesions are compared in Figure 7. Seventy-two per cent of the patients with fibromuscular dysplasia were cured and 24% were improved. In comparison only 53% of the patients with atherosclerotic lesions were cured while 36% were improved.

Comparison of the technical failure rates with dacron and saphenous vein aorta-renal bypass showed a slightly higher failure rate with dacron prostheses (Fig. 8). However, the difference was not statistically significant.

Figure 9 shows the results with combined operations. In addition to renal artery reconstruction these patients had simultaneous repair of complex extra-renal vascular lesions. The operative mortality was high in this group. However, many of these operations were salvage procedures in desperately ill patients. Seventy per cent of the patients were either cured or improved. Figure 10 shows the results in 20 patients who had thrombosis of an arterial reconstruction and subsequent reoperation. Eighty-five per cent of the patients were either cured or improved.

Follow-up Evaluation and Late Results

The 114 patients who survived operative treatment have been followed from 6 months to 11 years. Nine patients,

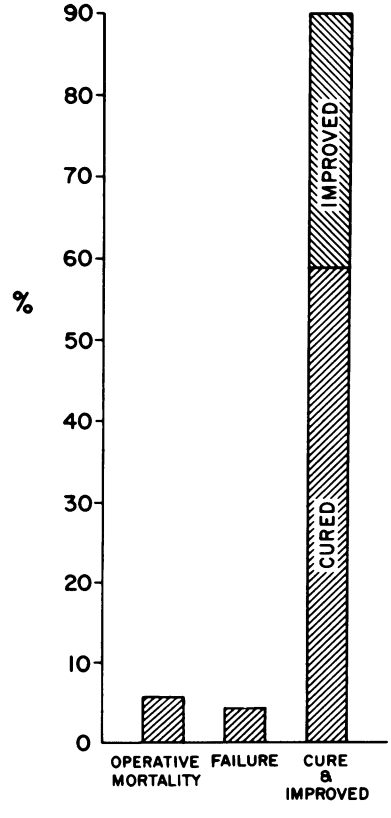

FIG. 6. Early results of operative treatment of 122 patients with renovascular hypertension.

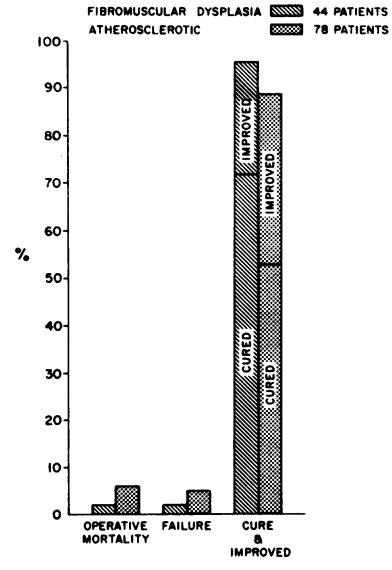

FIG. 7. Comparison of early results in the operative treatment of atherosclerotic and fibromuscular dysplastic renal artery lesions.

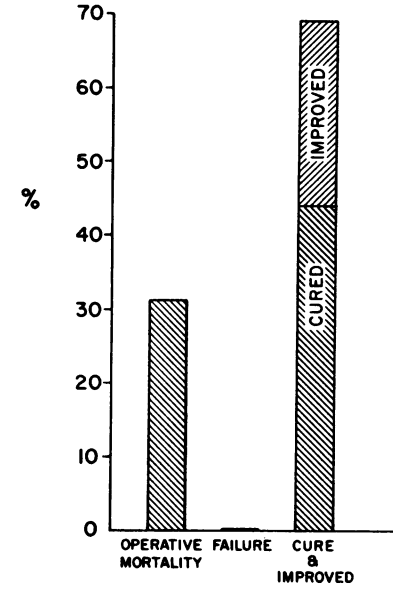

FIG. 9. Results in the simultaneous treatment of renovascular and other associated abdominal aortic lesions (16 patients).

all from the atherosclerotic group, died 1½ months to 5 years later. The cause of death was myocardial infarction or congestive heart failure in six patients, renal failure in one, unknown cause in one and following subsequent aorto-iliac operation in one. As nearly as can be determined none of the deaths were related to operative treatment or the original renal artery lesion. The death due to renal failure occurred in a 4-year-old boy who had severe hypertension and unilateral stenosis. After nephrectomy he became normotensive. One year later he became hypertensive again and developed severe progressive occlusive lesions of the branch arteries of the contralateral kidney. Figure 11 shows the late results in the 105 surviving patients. Three patients with thrombosed bypass grafts, who have not had further operative treatment, remain as failures. The other 102 patients are either cured or improved. Again the incidence of cure is much higher in the fibromuscular group.

Ninety-seven follow-up renal arteriograms were done in 68 patients 1 to 10 years after operation. Four technical failures (thrombosis) were encountered, it is felt these probably occurred early but were not recognized, and each patient was either cured or improved following nephrectomy. In 15 patients follow-up arteriography revealed progression or development of new lesions in the contralateral renal artery (Fig. 12). Nine of these were in the fibromuscular group and six had atherosclerosis. In four patients the progression of new lesions resulted in recurrent hypertension and contralateral aorto-renal bypass again cured the hypertension. Development of a significant lesion distal to a previous bypass was not encountered.

After 4 to 6 years the saphenous vein bypass grafts have typically increased in diameter. This has been a uniform increase through the length of the graft (Fig. 13). In one patient the vein has had a 100% increase in width over 6 years, she is normotensive and is followed

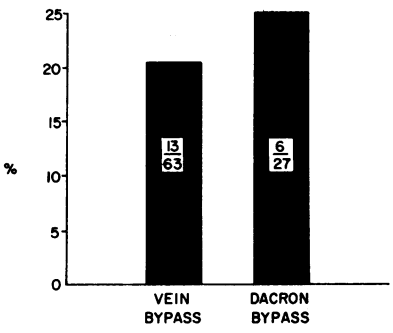

FIG. 8. Comparison of the failure rates of 63 vein and 27 dacron aorto-renal bypasses.

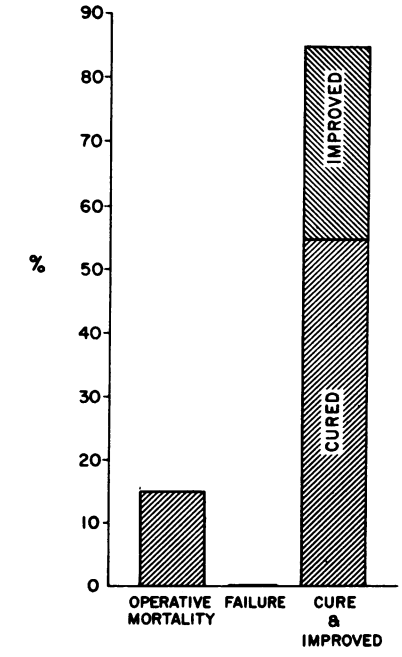

FIG. 10. Results of reoperation in 20 failures of primary operative procedure.

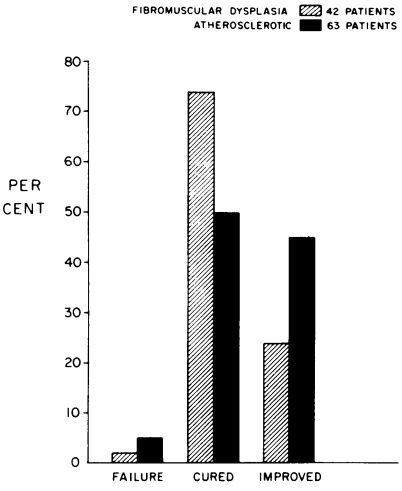

FIG. 11. Comparison of the late results in the operative treatment of atherosclerotic and fibromuscular dysplastic renal artery lesions.

closely. One patient has developed aneurysmal changes in a renal artery bypass and in an aorto-superior mesenteric artery bypass as well. Hypogastric artery was used for the renal bypass and external iliac vein for the mesenteric artery bypass. This young boy, now 11 years old, has severe multicentric fibro-dysplastic arterial disease.

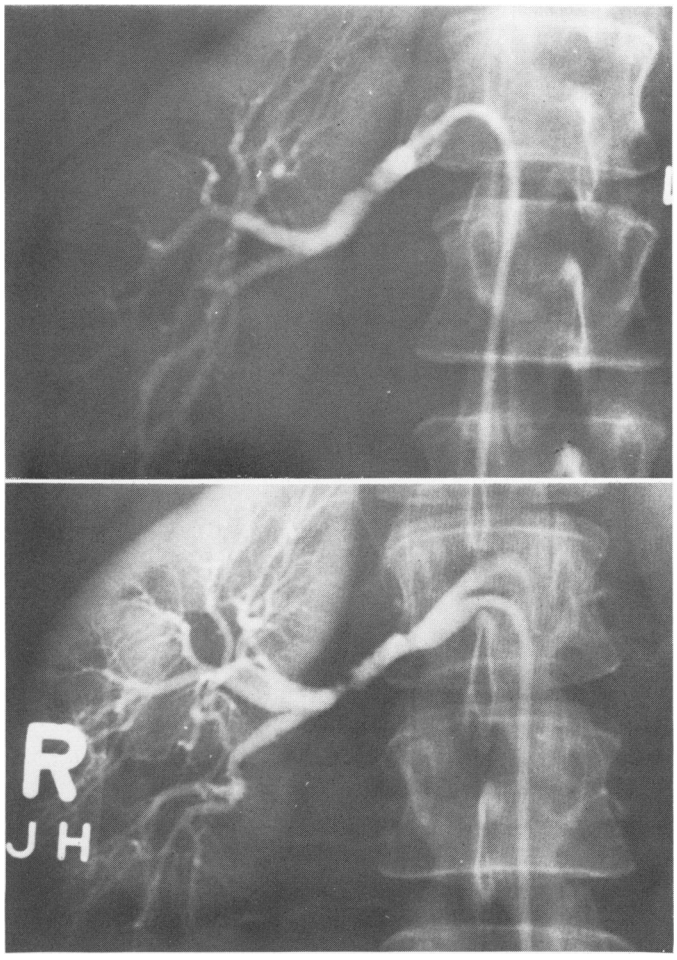

FIG. 12A&B. Demonstration of the progression of fibromuscular dysplasia in a contralateral renal artery three months following unilateral vein bypass.

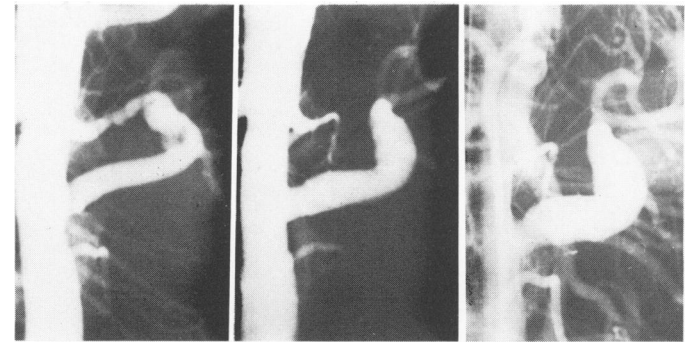

FIG. 13. Demonstration of the dilatation of a saphenous vein aorto-renal bypass graft during 5 years of follow-up.

Forty-seven patients have had follow-up renal venous renin assays: in 39 renin activity from the two kidneys are equal; in four the renins lateralize to the contralateral side and in the other four they lateralize to the operated side despite the amelioration of the hypertension. Follow-up split renal function studies have been done in 33 patients. In 31 patients the two sides are equal. Two patients, both with bilateral fibromuscular lesions who had unilateral bypass, now lateralize to the contralateral kidney but both are normotensive.

Comments

The fact that 16% of 1070 hypertensive patients in this series had renovascular hypertension can not be interpreted as the incidence of the condition in the hypertensive population. Referral to our group constituted considerable selection. Many patients had had a suggestive IVP and in a few, renal arteriography had been done. Nonetheless we believe 5% is a reasonable estimate of the incidence of the disorder among hypertensive patients. If there are 30 million people in the USA, as some have suggested, then renovascular hypertension is a common condition.

We do not advocate complete work-up of every patient with hypertension. We do recommend it in any patient in whom operative treatment would be recommended if a significant renal artery stenosis were found. Thus patients with mild hypertension are excluded, as a general rule the patient must have diastolic blood pressure consistently above 100 mm. Hg. Some patients who are unacceptable operative risks are also excluded. However, this decision requires careful clinical judgement. The patient in whom hypertension is causing severe cardiac, central nervous system or renal problems can often be greatly benefited by operative treatment. The risk is high but so are the possible benefits.

Shapiro and others have stated that patients with renovascular hypertension who are over 45 years of age should not have operative treatment because the risk is too great and the benefit to small.[2,8] Over 43% of the patients

in this study who had operative treatment were over 50 years of age and they did about as well as the younger patients. The operative mortality was higher in the older patients but it was primarily in patients with associated extra-renal vascular lesions.

While the renal arteriogram is extremely valuable in the evaluation of the patients with hypertension it has several limitations. In many instances precise labeling of a renal artery stenosis as atherosclerotic or fibroplastic is arbitrary. In a similar manner grading the severity of a stenosis on an arteriogram lacks precision. The location and course of the renal arteries do not lend them to accurate anterior-posterior and lateral studies as can be done with the carotid arteries. Surgeons and radiologists familiar with carotid arteriograms are familiar with studies showing a normal carotid in the A-P plane and severe stenosis on the lateral projection or vice versa. The same is true of the renal artery but it is more difficult to delineate. Oblique aortograms and selective studies are helpful in this regard. Fibromuscular dysplasia is certainly bilateral in more cases than are being detected on routine renal arteriograms. Magnification renal arteriography may improve the accuracy of the studies.

We are probably in the minority in continuing to use split renal function studies in the evaluation of patients with renal artery stenosis. Now that renin assays are more widely available they have largely supplanted split function studies. The data presented show that we find the information gained to be valuable. Among the merits of the studies is an evaluation of the individual creatinine clearance and effective renal plasma flow of the two kidneys. Part of the problem with split renal function studies has been the rigid criteria for a positive test. We have used liberalized criteria for the last 6 years. We are only rigid in requiring that all three urine collections show consistent lateralizing disparities between the two kidneys.

The high incidence of false negative results (20%) in our experience with renin assays is probably related to the way the patient was prepared for renal venous renin assay. The method we have used probably results in basal renin activity. Others have advocated measures to stimulate renin release. Methyldopa, the drug we have used if the patient requires drug therapy during the work-up, depresses renin out-put. Some antihypertensive drugs do not cause suppressed renin release, guanethidine is notable in this regard. Drugs such as hydralyzine stimulate the release of renin as does severe salt restriction. It may be that the methods we have used has masked lateralizing renin values. The number of methods used for preparing a patient for renal venous renin assays seems to approximate the number of institutions doing the assay. A standardized technic is needed but it must be based on firm supporting evidence.

The incidence of thrombosis of renal arterial reconstruction in this series was too high. Although many thromboses occurred in the early experience, further refinements in the technic of aorto-renal reconstruction should allow additional reduction of technical failures.

Saphenous vein has been our graft of choice for aorto-renal bypass. Dacron grafts, especially in patients who have post-stenotic dilation of the renal artery function equally well. Wylie and associates prefer to use the hypogastric artery as their graft material.[10] Our experience with this technic is limited to three cases. We have used the end-to-side anastomosis between the graft and renal artery in most cases, others have preferred an end-to-end anastomosis.[3,10] Thromboendarterectomy is a useful technic in patients with atherosclerotic orficial lesions.

The high incidence of new and progressive lesions in the contralateral renal artery make the use of nephrectomy unwise except in the most pressing circumstances. In addition to the amelioration the hypertension another important aim in treating these patients is preservation of renal function. We will not perform nephrectomy upon a patient with fibromuscular dysplasia unless the hyptertension is severe and uncontrollable by any other means. About the only circumstances under which we perform nephrectomy today is in the atherosclerotic patient with a tiny, atrophic kidney which has been destroyed by the ravages of hypertension and atherosclerosis. Split renal function studies are hepful in assessing the contribution of such a kidney to total renal function. More long-term arteriographic assessment of vein grafts implanted in the renal arterial system is needed. In this study 3 to 6 years follow-up of such grafts was obtained. In most instances the vein undergoes uniform dilatation through its length. In one this has reached aneurysmal proportions. The Michigan group made a similar assessment of 73 vein grafts and found late stenoses in five and aneurysmal dilatation in five.[3]

Finally, there are two continuing problems in the field of renovascular hypertension. The first is the hypertensive patient with bilateral renal artery stenosis and no lateralization on the split renal function studies or renal venous renin assay. If the renin activity on both sides is very high we have interpreted this as meaning bilaterally significant stenosis and proceed with bilateral reconstruction. Very often the renin levels are in the medium to low range. Especially in the patients with fibrodysplastic lesions it is hard to know how to proceed. If one could do arterial reconstruction with virtually no morbidity or mortality repair would be justifiable in all. If the patient had extremely severe hypertension and is difficult to control with drugs, we have chosen to operate on the side which appears more severe on the arteriogram. We then repeat the functional tests postoperatively and proceed accordingly. We have

a number of patients with bilateral, non-lateralizing lesions who are being followed on drug therapy.

The second problem is somewhat related, namely renal arterial lesions which occupy the distal third of the renal artery and extend into the segmental renal arteries. Early in our experience we performed nephrectomy upon a few of these patients who had lateralizing functional tests. Several patients developed recurrent hypertension and contralateral progressive renal artery lesions. This prompted us to abandon nephrectomy in these patients. The Michigan group reported the use of transluminal dilation of segmental renal artery lesions and presented convincing follow-up arteriographic evidence of success after 1 year.[4] We have been using this technic ever since their report but do not yet have enough experience or follow-up evidence to evaluate the procedure. Now we have a third approach to the operative treatment of these patients: *ex vivo* or extracorporeal repair of segmental renal artery lesions. Lim, Belzer and others have reported the use of this technic.[1,6] Our method of procedure involves dividing the renal artery and vein near the aorta and cava. The ureter is mobilized but not divided. The kidney is brought out on the abdomen wall where it is perfused and colled with the Belzer pump. Segmental arteries are occluded one at a time and repaired using microsurgical technics while the remainder of the kidney is perfused. This technic has been used successfully in three patients. One patient underwent staged bilateral repair. It is too early to evaluate the technic but it is an exciting development.

Conclusions

Our experience leads us to the following conclusions:

1. Renovascular hypertension is a fairly common condition.
2. While the rapid sequence program is a useful screening test, there is a high incidence of "false negative" results (31%) in proven cases of renovascular hypertension.
3. The history and physical examination are not helpful in differentiating essential hypertension and renovascular hypertension.
4. Renal arteriography, including selective oblique study is the best screening test.
5. If a renal arterial occlusive lesion is found, split renal function studies and renal venous renin assays should be done to determine the significance of the lesion.
6. If those tests are positive a beneficial result can be expected to follow operative treatment in about 90% of the cases.
7. Although the long-term results of renal revascularization are still uncertain the results to date are encouraging.

Summary

A group of 1070 hypertensive patients have been studied during the past ten years. One hundred and seventy-six proved to have renovascular hypertension by our criteria, positive split renal function studies and/or renal venous renin assays. The rapid sequence IVP yielded false negative results in 31% of the patients with renovascular hypertension. Renal arteriography proved to be the best screening test. Selective oblique renal arteriograms were extremely valuable in the assessment and management of the patients. Of the 176 patients with renovascular hypertension 122 have had operative treatment and a minimum follow-up of 6 months. There were eight operative deaths, mostly in patients who required simultaneous extra renal vascular operations as well. Aortorenal bypass graft using saphenous vein was the most common and preferred operative technic. Ninety per cent of the patients were either cured or improved. Although more patients with fibromuscular dysplasia had an excellent result than the patients with atherosclerotic lesions, this latter group received substantial benefit also. Meticulous attention to a number of points in pre, intra and postoperative care is essential in renovascular surgery. The use of excorporeal perfusion of kidney and microsurgical technics is an exciting new development for repair of segmental renal arterial lesions.

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