Reconstructive vascular surgery for renovascular hypertension

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Summary: Forty-six patients who underwent renal artery repair for presumptive renovascular hypertension are presented. Preoperative investigation included a rapid sequence IVP, a high quality angiogram and split function studies, as well as renin assays of renal venous blood in the more recent cases. Atherosclerosis was the causative pathological lesion in 60% of the patients, with fibromuscular dysplasia or miscellaneous causes of stenosis accounting for the remaining 40%.

Surgical correction was usually obtained by bypass grafting (57%). Hypertension was cured or significantly improved in 36 patients (78%).

Optimal results are dependent upon complete preoperative investigation and surgical repair of all the stenotic areas.

Résumé: Chirurgie vasculaire reconstructive pour hypertension rénovenare

Nous présentons 46 malades qui ont subi des réparations de l'artère rénale. Dans tous les cas, il y avait présomption d'hypertension rénovenare. Parmi les examens préopératoires, figuraient une PIV à séquence rapide, un angiogramme de bonne qualité, une étude fonctionnelle fractionnée, et des essais de la rénine dans le sang veineux rénal dans les cas les plus récents. Chez 60% des malades, l'athérosclérose était la lésion pathologique causale et, chez les 40% restants, de la dysplasie fibromusculaire ou diverses causes de sténose.

La correction chirurgicale a été généralement pratiquée par greffe de pontage, dans 57% des cas. L'hypertension a été guérie ou a été considérablement améliorée chez 36 malades (78% des cas).

Les résultats optimaux dépendent d'un examen préopératoire complet et de la correction chirurgicale de toutes les régions sténosées.

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There is general agreement that 5%1 of patients with hypertension have renal artery stenosis. This group presents a challenge to the internist and the surgeon, in that renal artery stenosis is not synonymous with renovascular hypertension and, accordingly, not all patients are improved by reconstructive vascular surgery.

It is the purpose of this paper to re-examine this subject by reviewing the experience of the two senior authors (DRW and RJB) over the last 15 years in the repair of renal artery stenosis in patients with presumptive renovascular hypertension.

Interest in this lesion began with the classical animal experiment by Goldblatt et al2 in 1934 and the condition was recognized in man four years later.3 Enthusiasm grew as reports of hypertension responsive to nephrectomy began to appear.4 The advent of renal arteriography allowed direct observation of the offending lesions and soon raised the question whether the removal of an ischemic kidney free of intrarenal disease was necessary so long as surgical correction of the stenosis was performed.5 Reports of hypertension responsive to restoration of normal renal blood flow began to appear in increasing numbers6 and, as they did, it was apparent that not all patients responded to surgery. Accordingly, more sophisticated investigative procedures became necessary to help select those patients who would benefit from operation.

Clinical material

This study is divided into two parts: the first covers the period 1957 to 19644 and the second considers the period 1965 to December 1972. Throughout this paper reference will be made to Series I and Series II in order to compare results.

A total of 46 patients underwent renal artery reconstruction from 1957 to 1972. There were 27 women and 19 men (ratio 3:2) with ages ranging from 19 to 67 years (mean 43 years). The duration of hypertension varied from two months to eight years (mean two years) and the predominant symptom was headache in 65% of cases, but 20% of patients were asymptomatic. The only significant finding, aside from elevated blood pressure and hypertensive retinopathy, was the presence of an abdominal bruit in 62% of patients, usually heard over the affected kidney.
Investigations

1. Intravenous pyelogram (IVP)

Unilateral renal artery stenosis produces a delay in appearance and hyperconcentration of contrast material in the affected pelviccalyceal system once opacification occurs. Rapid sequence pyelography (hypertensive IVP or rapid sequence IVP), alone or in combination with forced diuresis, has remained the mainstay in the renovascular work-up and has yielded an accuracy rate as high as 90%. In Series I, when only the standard IVP was employed, only 20% of IVPs were positive. Accuracy rose to 56% true positives* with the use of rapid sequence pyelography in Series II.

2. Renal scan and renogram

Radioisotopes may be employed to outline renal size (renal scan) as well as to provide a curve to demonstrate renal blood flow (renogram). In Series I too few were done to permit any conclusions, but in Series II these studies were done in 16 patients with true-positive results in 11 (68.8%), approximately a 12% improvement over the rapid sequence IVP.

3. Renal arteriography

Once the suspicion of renovascular hypertension is supported by the hypertensive IVP and/or isotope studies, the next step is to demonstrate the lesion by arteriography. There are two methods: selective renal arteriography via the retrograde femoral route (Fig. 1), or the translumbar aortogram. The former allows for oblique positioning of the patient and perhaps better demonstration of the lesion, whereas the latter is somewhat simpler and requires only one injection.

From the angiogram one can observe the degree of stenosis, as well as ascertain the nature of the pathology. Lesions encroaching on the luminal diameter by less than 50% are not likely to be significant more than one stenotic site is present.

4. Split function studies

The physiologic concept that reduced renal blood flow results in a decreased glomerular filtration rate and therefore a decreased filtered load of sodium led Howard et al13 to the clinical observation of decreased urine flow and sodium concentration from the offending kidney in unilateral renal artery stenosis. Rapoport14 further modified the "Howard Test" by introducing the tubular rejection fraction ratio (TRFR) which ignores urine volume but relies on urinary creatinine and sodium concentrations.

$$TRFR = \frac{U_{Na}}{U_{creat}} \times \frac{U_{creat}}{U_{Na}}$$

where $U_{Na}$ = urinary sodium concentration, $U_{creat}$ = urinary creatinine concentration, and L and R refer to left and right ureters. TRFR values less than 0.6 indicate left-sided lesions, whereas values greater than 1.6 suggest involvement of the right side. In significant renal artery stenosis, the urine volume will be decreased by 50%, urinary sodium concentration will be decreased by 15% and urinary creatinine concentration will be increased by 50%.

Split studies were done in 22 patients in Series I and gave true-positive results in 60% of cases. In Series II 14 studies were done and in 11 (78.6%) results were true-positive.

5. Renin

When renin was first named in 1898 it was thought to be a pressor substance. It is only within the last 10 years that our knowledge of the renin-angiotensin system has unfolded.14,15

It is now agreed that renin is an enzyme produced by the juxtaglomerular cells, which activates the circulating globulin angiotensinogen to angiotensin I, which is further converted into the vasoactive octapeptide angiotensin II.

FIG. 1—Retrograde femoral arteriogram showing stenosis at site of anastomosis to internal iliac artery following renal homograft.

ETIOLOGY OF RENOVASCULAR HYPERTENSION

Atherosclerotic Stenosis

Non Atherosclerotic Stenosis

INTIMAL FIBROPLASIA

MEDIAL FIBRO-MUSCULAR DYSPLASIA

a. Medial fibroplasia
b. Perimedial fibroplasia
c. Medial hyperplasia
d. Medial dissection

PERIARTERIAL FIBROPLASIA

FIG. 2—Classification of lesions in renal artery stenosis.
With the advent of renal vein catheterization and measurement of renal vein renin,16,17 the renin ratio (RR), i.e. affected kidney: unaffected kidney, has become a useful diagnostic tool. It is generally accepted that a ratio greater than 1.5 is significant, and prognosis for cure or improvement following renal artery reconstruction has ranged from 80 to 100%.2-4 More recently, ratios of 1.3 have also been considered meaningful.1

Pathology

The most common cause of renal artery stenosis, considering all ages, is atherosclerosis (60 to 70%). These lesions are more frequently found in the older age range and are identical to atherosclerotic lesions elsewhere in the body. Fibromuscular dysplasia (a rather poor term) accounts for approximately 25% of cases, but if one considers only those patients under 30 years of age with renovascular hypertension, the incidence increases markedly. Harrison and McCormach20 classified these non-atherosclerotic lesions of the renal arteries according to which layer of arterial wall was involved, i.e. intimal fibroplasia, medial fibromuscular dysplasia or periarterial fibroplasia (Fig. 2). Of these, the most common is medial fibroplasia, one form of medial fibromuscular dysplasia, in which thickening of the media alternates with mural aneurysms, giving the classical "string of beads" appearance on angiography.

Since arterial biopsies are rarely taken, the pathological diagnosis is inferred from the angiographic findings rather than from histological examination. In our series of 46 patients 27 had atherosclerotic lesions (60%) and 13 had fibromuscular dysplasia (28%). Of the remaining six patients, three (6%) had focal stenosis of unknown etiology, one had renal artery thrombosis following aortic aneurysm resection, one had stenosis at the anastomotic site following renal transplantation and one had renal artery stenosis secondary to coarctation of the abdominal aorta.

Surgical techniques

There are several surgical procedures designed to correct renovascular hypertension which may be broadly categorized as reconstructive or resective. Included in the former are arterial reimplantation, arterial resection and reanastomosis, angioplasty and/or endarterectomy and bypass grafting. By resective management is meant partial or total nephrectomy. Since preservation of renal tissue is the prime aim, renal artery reconstruction should be done whenever possible, and nephrectomy performed as a last resort.

The abdominal incision used requires brief comment. Some favour an extended supra-umbilical transverse incision,23 others prefer the extended midline approach.24 We have used the latter in all 46 cases. Once the peritoneal cavity has been opened, the manner of approaching the kidney varies. A direct approach by dissection to display the anterior surface of the aorta and cephalic retraction of the left renal vein is adequate for proximal lesions such as are found in atherosclerosis. When dealing with the more distal lesions of fibromuscular dysplasia a lateral approach by reflecting either the left or right colon medially provides far better exposure (Fig. 3).

Discrete atherosclerotic plaques may be easily dealt with by endarterectomy alone25 or in combination with patch angioplasty.26 Another useful technique when dealing with localized lesions within the central portion of the renal artery is local resection and end-to-end anastomosis (Fig. 4). Should the lesion be in the proximal portion of the artery, then reimplantation of the vessel at a lower site on the aorta may be employed. Carrying this latter technique one step further has led to autotransplantation of the offending kidney with reanastomosis of the renal

**FIG. 3**—Surgical approach to the renal artery: (above) cephalic retraction of left renal vein; (below) medial reflection of colon.

**FIG. 4**—Surgical techniques for lesion localized to central portion of renal artery.

**FIG. 5**—Surgical techniques for lesion localized to proximal portion of renal artery.
vein and artery to the appropriate iliac vessels (Fig. 5).

Despite the availability of the above methods, bypass grafting remains the most popular surgical technique. It was first described in the late 1950s by Morris et al. who presented more than 200 cases and were greatly impressed by its simplicity and versatility.

The choice of conduit has varied from autogenous hypogastric (internal iliac)34 or splenic artery,35 autogenous saphenous vein34 and synthetic grafts5,7 (Fig. 6). The latter two remain the most popular, each having its proponents. Fry, Brink and Thompson,33 advocates of the saphenous vein graft, recommend complete transection of the affected renal artery with graft interposition and reimplantation at a lower site on the aorta. They use graded dilators passed distally to dilate the secondary branches of the renal artery before suturing to the graft (Fig. 7). Our own experience has been mainly with Teflon knitted grafts and, like De Bakey et al. who favour Dacron knitted grafts, we have found no reason to change to autogenous saphenous vein. The use of a synthetic graft is not limited to aortorenal bypasses, for this type of graft may be used in iliorenal bypasses as well.

In our series of 46 patients a total of 53 reconstructive procedures were done, 30 in Series I and 23 in Series II. The most frequent procedure (24 cases) was an aortorenal bypass, using a knitted Teflon graft. In three cases the graft was from the common iliac to the renal artery. Reimplantation of the renal artery was performed 10 times and local resection and anastomosis in eight cases. Endarterectomy and patch angioplasty were carried out five times and a splenorenal shunt was performed on three occasions. This latter procedure was abandoned after Series I because of the excessive tortuosity and fragility of the splenic artery and the frequent presence of calcification. Autotransplantation was not performed because it was believed to offer no advantage over alternative procedures, especially bypass grafting.

Though renal artery aneurysm per se does not cause hypertension, but is rather a manifestation of the underlying pathological change, none the less the risk of rupture still exists. In our most recent case (not included in this series) we used a Haeftelz neurosurgical clip to occlude a saccular renal artery aneurysm.

More recently, extracorporeal renal perfusion combined with microsurgical techniques has added yet another approach to the repair of distal segmental lesions.1

Results

In order to decide whether the patients' blood pressures had been significantly affected by surgery, we compared the postoperative pressures with normal pressures for individuals of the same age and sex as determined from the tables of Master, Dublin and Marks.36 Results were classified into four groups. In the first group, both the systolic and diastolic pressures had returned to within one standard deviation of normal values. The diastolic pressures in the second group were within one standard deviation, but the systolic pressures remained elevated. In the third group, both diastolic and systolic pressures were reduced to within two standard deviations but not within one standard deviation of normal and, finally, the fourth group showed no significant response at all (Table I).

Those patients in groups I and II were considered cured, those in group III improved and those in group IV failures.

Many patients in Series I were followed up for as long as seven years and it was apparent that there was no tendency to recurrence of hypertension if a patient was considered cured or improved at six months.4 Accordingly, all patients had their blood pressures recorded approximately six months postoperatively. In Series I 40% were considered cured, 40% improved and 20% unimproved. In Series II the figures were 50, 25 and 25% respectively. Combining both series, 78% were considered cured or improved. The results of investigations and surgical procedures in Series II are summarized in Table II.

FIG. 6—Various methods of bypass grafting.

FIG. 7—Distal dilatation of secondary branches of renal artery combined with autogenous saphenous vein aortorenal bypass graft.
Discussion

One question always recurs in any discussion on renovascular hypertension: why not a 100% cure rate following surgery? This desirable result must certainly depend on proper patient selection. In order to help answer this question we examined the four surgical failures in Series II.

Case 3 was a 44-year-old woman whose laboratory investigations indicated a significant right-sided lesion, secondary to fibromuscular dysplasia, for which an aortorenal graft was inserted. Her postoperative course was complicated by hypotension secondary to hemorrhage. At follow-up she showed no improvement in her hypertension and accordingly repeat angiography was carried out which showed graft thrombosis. Nephrectomy was therefore performed with prompt lowering of her blood pressure. This case demonstrates that, despite proper patient selection, clinical failure may still result from graft failure, be it technical in origin or secondary to postoperative hypotension. One must therefore perform postoperative angiography in all clinical failures in order to clearly outline the operative site.

Case 13 was a 56-year-old woman whose IVP and renogram indicated a left-sided lesion, whereas the split function studies suggested a right-sided lesion. Aortography showed bilateral lesions secondary to atherosclerosis. The lack of significant improvement following a left-sided graft is not surprising. As has been demonstrated in many reports, in cases of bilateral stenosis both renal arteries must be repaired.87

Case 14 was a 28-year-old woman with fibromuscular dysplasia whose laboratory investigations suggested a left-sided lesion; however, a renin assay was not performed. Moreover, a postoperative angiogram was omitted and therefore we are unable to state whether this case represents a technical failure secondary to graft occlusion, or perhaps a case of significant disease beyond a patent graft. Should the latter be true, one cannot help but ponder the theoretical advantages of distal dilatation as advocated by Fry, Brink and Thompson.81

Case 17 was a 33-year-old woman whose investigations, including a renin assay, were negative with the exception of the arteriogram which showed a right-sided lesion. It is likely that the diagnosis of renovascular hypertension was incorrect and accordingly the treatment ineffectual.

Renin assays were performed in only six cases, thereby limiting any significant conclusions. Nevertheless, if we include the 1.3 result in case 15, the overall accuracy was 80%.

Pre- and/or intra-operative renal biopsy has been advocated by Vertes, Grauel and Goldblatt88 to predict the response to renovascular reconstruction. Their findings suggest that, in the presence of bilateral intrarenal arteriolar nephrosclerosis, a response to surgery is not to be expected.

Table I—Results of renovascular reconstruction

| I | Normal systolic + 1 S.D. | Cured |
| II | Normal diastolic + 1 S.D. | |
| III | Normal systolic + 2 S.D. | |
| IV | Normal diastolic + 2 S.D. | |
| IV | Normal diastolic + 2 S.D. | |

S.D. = one standard deviation from the table of Master, Dublin and Marks.26

Table II—Summary of results in Series II

<table>
<thead>
<tr>
<th>Age and sex</th>
<th>IVP</th>
<th>Renal scan and renogram</th>
<th>Split function test</th>
<th>Renin ratio</th>
<th>Arteriogram</th>
<th>Surgical procedure</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>67 F</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>L + R</td>
<td>L + R/AR/G</td>
<td>C</td>
</tr>
<tr>
<td>2.</td>
<td>51 M</td>
<td>+ L</td>
<td>+ L</td>
<td>+ L</td>
<td>&gt; 1.5L</td>
<td>L</td>
<td>L/AR/G</td>
</tr>
<tr>
<td>3.</td>
<td>44 F</td>
<td>+ R</td>
<td>+ R</td>
<td>+ R</td>
<td>ND</td>
<td>R</td>
<td>R/AR/G</td>
</tr>
<tr>
<td>4.</td>
<td>56 M</td>
<td>-</td>
<td>+ L</td>
<td>+ L</td>
<td>ND</td>
<td>L</td>
<td>L/E &amp; P</td>
</tr>
<tr>
<td>5.</td>
<td>54 M</td>
<td>-</td>
<td>+ L</td>
<td>+ L</td>
<td>ND</td>
<td>L</td>
<td>L/Re</td>
</tr>
<tr>
<td>6.</td>
<td>50 M</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>R</td>
<td>R/AR/G</td>
</tr>
<tr>
<td>7.</td>
<td>47 F</td>
<td>-</td>
<td>ND</td>
<td>ND</td>
<td>R</td>
<td>R/IR/G</td>
<td>C</td>
</tr>
<tr>
<td>8.</td>
<td>66 M</td>
<td>+ L</td>
<td>+ L</td>
<td>+ L</td>
<td>ND</td>
<td>L</td>
<td>L/IR/G</td>
</tr>
<tr>
<td>9.</td>
<td>53 F</td>
<td>+ R</td>
<td>+ R</td>
<td>+ R</td>
<td>ND</td>
<td>R</td>
<td>R/Re</td>
</tr>
<tr>
<td>10.</td>
<td>53 F</td>
<td>+ L</td>
<td>+ L</td>
<td>+ L</td>
<td>ND</td>
<td>L</td>
<td>L/Re</td>
</tr>
<tr>
<td>11.</td>
<td>44 F</td>
<td>+ R</td>
<td>+ R</td>
<td>ND</td>
<td>ND</td>
<td>L + R</td>
<td>L + R/AR/G</td>
</tr>
<tr>
<td>12.</td>
<td>47 F</td>
<td>+ L</td>
<td>-</td>
<td>+ L</td>
<td>ND</td>
<td>L</td>
<td>L/AR/G</td>
</tr>
<tr>
<td>13.</td>
<td>56 F</td>
<td>+ L</td>
<td>+ L</td>
<td>+ R</td>
<td>ND</td>
<td>L + R</td>
<td>L/AR/G</td>
</tr>
<tr>
<td>14.</td>
<td>28 F</td>
<td>+ L</td>
<td>+ L</td>
<td>+ L</td>
<td>ND</td>
<td>L</td>
<td>L/P</td>
</tr>
<tr>
<td>15a</td>
<td>19 M</td>
<td>-</td>
<td>-</td>
<td>+ R</td>
<td>1.3R</td>
<td>R</td>
<td>R/P</td>
</tr>
<tr>
<td>16.</td>
<td>17 F</td>
<td>-</td>
<td>ND</td>
<td>ND</td>
<td>1.0</td>
<td>R</td>
<td>R/AR/G</td>
</tr>
<tr>
<td>17.</td>
<td>33 F</td>
<td>-</td>
<td>ND</td>
<td>ND</td>
<td>0.84</td>
<td>R</td>
<td>R/IR/G</td>
</tr>
<tr>
<td>18.</td>
<td>27 M</td>
<td>ND</td>
<td>ND</td>
<td>880a</td>
<td>R</td>
<td>R/R &amp; R</td>
<td>I</td>
</tr>
<tr>
<td>19.</td>
<td>32 F</td>
<td>ND</td>
<td>ND</td>
<td>0.84</td>
<td>R</td>
<td>R/IR/G</td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>50 M</td>
<td>+ R</td>
<td>+ R</td>
<td>TF</td>
<td>1.8*</td>
<td>L + R</td>
<td>R/AR/G</td>
</tr>
</tbody>
</table>

ND = not done. TF = technical failure, G = graft, P = patch, E = endarterectomy, AR = aortorenal, IR = iliofemoral, L = left, R = right, R & R = resection & reanastomosis, Re = reimplantation, C = cured, I = improved, F = failure

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In Series II we performed nine biopsies. In the four cases of arteriolar nephrosclerosis there were three cures and one failure. Two biopsies showed juxtaglomerular hyperplasia (one case showed also arteriolar nephrosclerosis) and both patients were cured. Our conclusion regarding the role of renal biopsy is that it seems to add little to the prognosis, except in cases showing juxtaglomerular hyperplasia. Therefore we see no need to perform preoperative transcutaneous needle biopsy with its associated dangers. We are also unimpressed with the usefulness of intra-operative biopsy under direct vision.

Intra-operative measurement of pressure gradients, though performed frequently in Series I, was abandoned in the latter part of Series II. It is now generally believed that the absence of a significant gradient, as measured at the time of operation, is meaningless and should not deter the decision to carry out surgical correction of the stenosis.

The argument continues as to whether autogenous saphenous vein is preferable to synthetic grafts. It is our opinion at present that aortorenal bypass in cases of arteriosclerosis is best done using a synthetic graft. This is based entirely on the ease of the aortic Anastomosis when using a more rigid and larger-bore synthetic graft, rather than the softer and smaller autogenous vein. In the young woman with fibromuscular disease and a normal aorta, autogenous saphenous vein may be a more appropriate choice, because the vein is more flexible and can be anastomosed more distally to the renal artery using fine suture material.

Summary

The cases of 46 patients with presumptive renovascular hypertension who underwent renal artery repair from 1957 to 1972 are presented. The pathologic lesion was atherosclerosis in 27 (60%) and fibromuscular dysplasia or stenosis due to miscellaneous causes in 19 (40%). Surgical procedures included bypass grafts in 30 cases (57%), renal artery reimplantation in 10 (19%), resection and reanastomosis in 8 (15%) and endarterectomy with patch angioplasty in 5 (9%). Hypertension was not relieved in 10 patients (22%) but was cured or significantly improved in 36 (78%).

For optimal results the vascular surgeon must have an accurate diagnosis based on a rapid sequence IVP, split function studies and renin assays, in addition to a high quality angiogram. He must also deal with both renal arteries when the above tests suggest bilateral lesions. In cases of fibromuscular dysplasia with distal stenotic lesions, the use of intra-arterial dilators is recommended.

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