EXPERIENCE WITH RADIOLOGY IN THE
DIAGNOSIS OF RENAL HYPERTENSION

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Since the work of Goldblatt, Lynch, Hanzal
and Summerville in 1934 on the production of
persistent hypertension in dogs there has been
sustained interest in investigating hypertensive
patients from the point of view of demonstrat-
ing a renal lesion, the surgical treatment of
which might lead to permanent relief of hyper-
tension. Many lesions of the kidney have been
found-to be associated with hypertension and
with wider use of renal arteriography, the
importance of renal artery occlusive disease as
an etiological factor in hypertension has been
amply demonstrated. (Howard, Berthrong,
Sloan and Yendt, 1953; Poutasse, Humphries,
McCormack and Corcoran, 1956; De Camp and
Birchall, 1958; Brown, Owen, Peart, Robertson
and Sutton, 1962). Smith (1956) estimated that
between $\frac{1}{2}$ to 2 per cent of all hypertensive
patients have surgically correctable renal lesions,
and recent estimates (Sutton, Brunton and
Starer, 1960; Maxwell and Prozan, 1962) indi-
cate that this figure may be as high as 10 per
cent.

Essential hypertension and reno-vascular
hypertension are often clinically indistinguish-
able (Maxwell, 1962; Wilson, Dustan, Page and
Poutasse, 1963) but an underlying renal cause
for hypertension may be suspected in the follow-
ing circumstances: —

1. Hypertension of recent onset at any age,
particularly if rapidly progressive.
2. Hypertension in a young patient with no
family history of high blood pressure.
3. A sudden increase in the blood pressure
in a patient known to have essential hyper-
tension.
4. A previous history of abdominal or loin
pain, of renal trauma or of peripheral
arterial emboli.
5. When a bruit is heard on auscultation over
the renal area.

Diagnostic studies that may be useful in
investigating patients selected by such criteria
are: —

1. Excretory urography.
2. Renal arteriography.
4. Individual renal function studies.
and some authorities would include: —
5. Renal biopsy. (Vertes, Grauel and Gold-
blatt, 1964).
6. Estimations of pressor substances in renal
venous blood. (Grollman, 1964.)

This paper is concerned with the assessment
of the value of the first two procedures, (a) in
the detection of unilateral renal disease in
hypertension and (b) in attempting to assess its
functional significance.

Materials and Methods
During the period April 1962 to March 1965 two
hundred and fifty-seven hypertensive patients were
referred for radiological investigation in an attempt
to demonstrate a renal cause of the hypertension. All
patients had excretion urography carried out. Renal
 arteriography was performed in 46 patients.
Excretion urography was preceded by dehydration
and adequate bowel preparation. Minute sequence
radiographs were taken for four minutes before the
application of compression to the ureters. If initial
radiographs suggested the possibility of renal artery
stenosis, a diuresis was induced by giving the patient
500 ml. of water by mouth and exposing further films
twenty to thirty minutes later.
Arteriography was performed by percutaneous
puncture of the femoral artery and retrograde cathe-
terisation (Seldinger, 1953). In all cases a non-selective
aortic injection was made. In some cases selective
renal arteriography was carried out.

Results
The excretion urogram was considered to be
abnormal in 62 of the 257 patients, i.e. 24 per
cent. Table 1 shows the wide range of abnor-
malities found.

Eighteen of the 62 patients with abnormal
excretion urograms were further examined by
eventually diagnosed by excretion urograms; confirmed since renal arteriography. In five of these 28 cases an abnormality was demonstrated. Three patients were found to have unilateral renal artery stenosis, one patient had a phaeochromocytoma (Welch and Davidson, 1965) and one had a left renal artery aneurysm. (Table 3.)

Results of Surgery

Seven patients underwent surgery in an attempt to cure hypertension. Four had renal artery stenosis; one had a poorly functioning ectopic pelvic kidney; one had a functionless kidney; one had a unilateral small kidney. In none of the patients was there permanent alleviation of hypertension.

Case No. 1

A 41-year-old woman was known to be hypertensive for four months, with a blood pressure of about 240/140 mm. Hg. Renal function was normal. She was shown to have a stenosis of the right renal artery. A vascular repair was performed successfully but subsequently this was shown to be thrombosed and nephrectomy was performed. Her blood pressure fell to levels about 160/100 mm. Hg. for a year but then rose and hyptensive agents were exhibited.

Case No. 2

A 40-year-old woman had hypertension for 23 months (B.P. 215/130 mm, Hg.). Renal function was shown to be normal. She was found to have a lower polar artery stenosis. At operation the pressure over the stenosis was found to be reduced by 50 per cent. A partial nephrectomy was performed. The B.P. fell to 130/180 mm. Hg. for two months and then began to rise.

Case No. 3

A 47-year-old man had a preoperative blood pressure of 230/110 mm. Hg. He was shown to have a right renal artery stenosis. Renal function was normal. At operation the aortic pressure was 210/120 mm. Hg. and the pressure distal to the stenosis 80/60 mm. Hg. Nephrectomy was performed but the blood pressure subsequently showed no significant change from preoperative levels.

Case No. 4

A 40-year-old hypertensive female was shown to have a renal artery stenosis. At operation it was found technically impossible to reconstruct the artery but it was decided to spare the kidney.

Case No. 5

A 50-year-old male had a preoperative blood pressure of 190/110 mm. Hg. A functionless kidney was demonstrated and this was removed. There was no fall in blood pressure subsequently. The kidney contained numerous cysts and calculi and there was a degree of hydronephrosis.

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**TABLE 1.**

<table>
<thead>
<tr>
<th>Abnormalities Detected</th>
<th>Abnormalities</th>
<th>Excretion Urograms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal</strong></td>
<td>195</td>
<td></td>
</tr>
<tr>
<td><strong>Abnormal</strong></td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Calculi</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Stenosis Renal Artery</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Chronic focal pyelonephritis</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Ureteric obstruction</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Small kidney bilateral</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Small kidney unilateral</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Congenital abnormality:—</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Ectopic kidney</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Polycystic disease</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Rotated kidney</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Solitary kidney</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Bil. pelvi-ureteric obstruction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Space occupying lesion</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Renal scar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-functioning kidney</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcified tuberculosis</td>
<td></td>
<td></td>
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</tbody>
</table>

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**TABLE 2(a)**

<table>
<thead>
<tr>
<th>Abnormal Excretion Urograms</th>
<th>Abnormal Urograms</th>
<th>Arteriogram</th>
<th>Pathology confirmed</th>
<th>Pathology doubtful</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>18</td>
<td>17</td>
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</table>

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**TABLE 2(b)**

<table>
<thead>
<tr>
<th>Suspected Diagnosis (After Excretory Urography) in Eighteen Patients Undergoing Aortography for Confirmation</th>
<th>Congenital abnormalities:—</th>
<th>Rotated kidneys</th>
<th>Pelvic kidney</th>
<th>Polycystic kidney</th>
<th>Non-functioning kidney</th>
<th>Small kidney bilateral</th>
<th>Small kidney unilateral</th>
<th>Chronic pyelonephritis (bilateral)</th>
<th>Renal scar</th>
<th>Renal artery stenosis (confirmed in 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

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**TABLE 3**

<table>
<thead>
<tr>
<th>Further Investigation of Patients with Normal Excretion Urograms</th>
<th>Normal urogram</th>
<th>Arteriogram</th>
<th>Abnormal:—</th>
<th>Renal artery stenosis</th>
<th>Phaeochromocytoma</th>
<th>Aneurysm of left renal artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>195</td>
<td>28</td>
<td>23</td>
<td>3</td>
<td>1</td>
<td>1</td>
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</tbody>
</table>

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[Table content continued...]

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[Table content continued...]
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Case No. 6
A 48-year-old male had a blood pressure of 190/110 mm. Hg. of about 24 months duration. He was found to have an ectopic kidney situated in the pelvis and this was removed. Post-operatively there was no change in blood pressure.

Case No. 7
A 45-year-old female had been hypertensive (B.P. 240/120 mm. Hg.) for about 18 months. A small kidney was demonstrated on one side and this was removed. It was scarred on the surface and microscopic examination revealed marked cortical scarring with sclerosis and narrowing of the vessels. There was evidence of chronic pyelonephritis. Post-operatively there was no change in blood pressure and hypotensive agents were required.

Discussion
The changes produced in an excretory urogram by renal artery stenosis are a result of diminished blood flow to the kidney and will be observed in a given case only if narrowing of an artery has a functional effect. The changes usually seen are diminution of the size of the affected kidney and other abnormalities which are due to disturbances of tubular function (Hodson, 1961). A difference of more than one-and-a-half centimetres in length between the two kidneys should be regarded as suspicious of renal artery stenosis, in the presence of a normal collecting system. In this respect it should be remembered that the normal left kidney is frequently up to one centimetre longer than the right so that a small left kidney should be regarded with greater suspicion. While such differences in size are a common manifestation of unilateral renal artery stenosis, they should by no means be regarded as essential to the diagnosis, since severe functional stenosis can be present without significant difference in size. In a recent unselected post mortem study Schwartz and White (1964) showed that the weight of the majority of kidneys associated with severe focal arterial stenosis is not reduced and concluded that the presence of kidneys of normal radiological dimensions does not preclude the possibility of severe renal arterial disease. In this connection it is of interest to note that of our eleven patients with small kidneys (Table 1) five were subjected to renal arteriography and none of these was found to have renal artery stenosis.

Decreased blood flow in a functional renal artery stenosis leads to a slower tubular urine flow rate with resultant increased reabsorption of sodium and water. Such changes may produce the following observed effects on the excretory urogram:

1. Delayed excretion of contrast on the affected side. This can be demonstrated by exposing films of the kidneys at minute intervals after injection of the contrast medium, and before compression (Hodson, 1962) (Fig. 1).

2. Increased density of the pyelogram on the affected side. The contrast media used in excretory urography are excreted by glomerular filtration and because of increased water re-absorption a hyperconcentration of contrast medium in the urine of the stenosed kidney may be expected (Hodson, 1962). This effect may only be evident after hydration of the patient, (Amplatz, 1964) since a diuresis will occur on the normal side, so “washing out” the contrast medium. This has been described as a “radiological Howard test” (Fig. 2).

3. The small volume of urine produced on the affected side distends the pelvi-calyceal system poorly, producing a “low volume collecting system” (Whitely, Witcofski, Quinn and Meschan, 1962) (Fig. 2).

Other features suggestive of renal artery stenosis which may be seen on excretory urography include “ureteral scalloping” due to tortuous collateral vessels (Halpern and Evans, 1962) and localised contraction of renal substance, associated with normal calyces, which may indicate stenosis or thrombosis of a branch vessel.

It is well established that excretion urography may be essentially normal in patients who subsequently prove to have renal artery stenosis of functional significance. Using standard techniques and even with experienced observers interpreting the radiographs there may be no abnormality in 25 per cent or more cases of renal artery stenosis as compared with perhaps 10 per cent of false negatives in isotope renography (Howard and Connor, 1962; Morris and De Bakey, 1962). The routine use of minute sequence films for estimating excretion rate and urea infusion diuresis techniques may increase the diagnostic accuracy (Amplatz, 1964). While admittedly far from perfect, excretory urography is at present more widely available than isotope renography and when carefully carried out continues to be a useful screening procedure. At present it should be considered as complementary to the isotope renogram, and the two together can succeed in demonstrating the great majority of significant renal artery stenoses.

Renal arteriography is essential for confirmation of a diagnosis suspected by other techniques and also supplies anatomical information to the surgeon which may indicate the feasibility of a particular vascular reconstructive technique.
The presence of post-stenotic dilatation or of differences in flow-rate and nephrogram density on the two sides indicate that an arterial narrowing is producing a functional effect on blood supply (Figs. 3, 4). Schwartz and White (1964) have shown that severe intrarenal stenosis is a common accompaniment of extrarenal stenosis and they stress the need for adequate visualisation of the intrarenal arterial tree at angiography before embarking upon reconstructive arterial surgery. They also point out that severe extrarenal stenosis on one side implies that the opposite extrarenal arteries will be normal in only 9 to 18 per cent of cases. There is no doubt that selective renal arteriography is the method of choice for demonstrating the intrarenal arterial tree, and we now consider that both non-selective aortic injection and bilateral selective renal arterial injections should be carried out in cases of extrarenal stenosis.
The reasons for performing arteriography in patients with normal excretion urograms are shown in Table 4. It will be seen that in one patient phaeochromocytoma had been suspected on clinical grounds and arteriography was performed for localisation. The patient with the renal artery aneurysm had a definite bruit on auscultation of the abdomen. An isotope renogram carried out in this patient showed no evidence of a functional lesion due to the aneurysm. In 21 patients below the age of 50 arteriography was felt to be indicated despite a normal excretion urogram. No lesion was found at arteriography in any of these patients. In five patients over 50, although all three renal artery stenoses were found in this group, arteriography was probably not indicated, since it was evident for other reasons that a surgical approach to the treatment of hypertension was unlikely to be successful. There was no radiological evidence that the stenosis was producing a functional effect in any of these patients.

When a functional renal vascular lesion has been demonstrated there remains the problem of attempting to predict whether surgical cure is possible. We share the concern expressed by Chamberlain and Gleeson (1965) regarding the results of surgery and in our own series these results do not seem to be commensurate with the effort expended in investigation. Because medical management is today so successful in the control of both essential and renal hypertension the selection of those patients who should be submitted to surgery becomes even more important (Maxwell, 1962). It seems likely that the cause of failure of surgical treatment in many cases is the presence of irreversible pathology in the contra-lateral kidney. All methods of establishing the normality of that kidney prior to surgery would therefore seem to be justified. For example it has been recommended that bilateral renal biopsy should be carried out in all cases being considered for surgery (Vertes, Grauel and Goldblatt, 1964). Bilateral selective renal arteriography should also be carried out in order to determine the presence of intrarenal arterial disease. Even where there is a diseased or non-functioning kidney which may be the causal factor, complete investigation of the apparently normal kidney is necessary. It is important that renal tissue should be preserved whenever possible by reconstructive operations in renal artery stenosis since the ischaemic kidney may be protected from the effects of prolonged high blood pressure by the stenosis.

Conclusions

The cure rate in patients subjected to surgery for renal hypertension is very variable and it seems likely that this is due to differences in selection. A large amount of time and money is spent in investigating these patients, in many of whom the hypertension can be adequately controlled by medical measures. Before initiating renal investigation in a hypertensive patient the physician should consider carefully whether a surgical approach would be possible if a remediable lesion were found. If so both excretion urography and isotope renography are indicated. Where these investigations show evidence of a functional renal lesion renal arteriography including bilateral selective studies should be carried out. In patients in whom both excretion urography and isotope renography...
are normal arteriography should be performed only in the younger age groups or where clinical indications are very strong.

Prediction of surgical cure will be dependent on establishing the normality of the intrarenal arterial tree and of a normal renal histology.

Summary

Two hundred and fifty-seven hypertensive patients were investigated by excretion urography. Renal pathology was demonstrated in 62 patients. Renal arteriography was carried out in 46 patients.

Six patients had surgical treatment—either nephrectomy or an attempted vascular repair. In none of these patients was there a permanent return of blood pressure to normal levels.

The radiology of renal hypertension is discussed along with the indications for embarking upon detailed investigation.

We would like to express our sincere gratitude to the physicians of the Southern General Hospital, Glasgow who referred the cases for investigation, to the surgeons who performed the operations, Mr. R. B. Wright (Case 2 to 7) and Mr. K. Bloor (Case 1) and to Drs. G. B. Shaw, A. G. Melrose and A. C. Kennedy who provided helpful advice and useful criticism.

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