Papers and Originals

Stenosis of Renal Artery: An Unselected Necropsy Study*

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Over 50 years ago Janeway (1909) demonstrated an elevated blood-pressure level in the dog after constriction of the renal artery, an observation which was subsequently elaborated by Goldblatt *et al.* (1934). Since these studies the concept of renal hypertension has become firmly entrenched in the medical literature, and with the advent of improved techniques in radiology and reconstructive arterial surgery renal stenosis has assumed a new significance. But surgical intervention in patients with presumptive renal ischaemia and a raised arterial pressure by either nephrectomy or arterial reconstruction has produced variable results (Braasch, 1942; Smith, 1956; Kincaid-Smith, 1961).

With an ever-increasing interest in renal stenosis as a possible and remediable cause of hypertension in man, it is essential that the frequency and distribution of this lesion in both normotensive and hypertensive patients be clearly defined. Sutton *et al.* (1961) have shown radiologically demonstrable stenosis in 10% of 260 hypertensive subjects investigated by aortography. Eyler *et al.* (1962) reviewed a selected series of 500 patients, and found radiologically normal renal arteries in 75 out of 196 hypertensive subjects, and in 206 out of 304 normotensives. These workers emphasized that radiological renal artery stenosis, even with post-stenotic dilatation, can occur in normotensive subjects.

So far the few pathological studies reported have not clarified the picture. Blackman (1939) reported the necropsy findings in 50 cases with "hypertension" and 50 "controls" whose age and mode of selection were not defined, save that they were not hypertensive and had no cardiac hypertrophy. In his series the whole length of the renal arteries was not always available for study. Other studies include those of Richardson (1943), Lisa *et al.* (1943), and Holley *et al.* (1962). The latter authors concluded that renal arterial stenosis was common in both hypertensive and normotensive subjects aged 50 and over.

In this unselected necropsy study we have determined the prevalence and distribution of renal arterial stenosis in both the extrarenal and intrarenal segments of the arterial tree. The relation of stenosis to various clinical and pathological parameters is discussed.

Composition of the Necropsy Sample

During the years 1962-3 an unselected series of kidneys and renal arteries was obtained from 154 patients on whom necropsies were performed in the Royal Adelaide Hospital. This sample included all cases presenting on consecutive Wednesdays and alternate Sundays. Relevant clinical details including casual blood-pressure measurements were obtained

from the hospital in-patient and out-patient notes, and, wherever necessary, were amplified by discussion with the patients' private medical attendants. Representative blood-pressure records were available in 149 of the 154 patients, whose age-and-sex distribution is detailed in Table I. Cardiovascular disease was the main cause of death in this series (40 cases). Other causes were malignant disease, 25 patients; respiratory disease, including pulmonary embolism, 23; central nervous system disease, 27 (of whom 5 had cerebral infarction and 17 cerebral or subarachnoid haemorrhage); renal disease, 11; non-malignant gastro-intestinal disease, 9; trauma, 2; other causes—leukaemia and lymphoma 9, diabetic ketosis 2, sudden death of undetermined cause 3, myxoedema coma 1, septicaemia 1, and muscular atrophy 1.

TABLE I.—Age-and-sex Distribution of the Unselected Necropsy Series

Sex	No. of Patients				Total
	Age (years)				
	< 55	55-64	65-74	75 +	
Male	15	19	26	31	91
Female	14	11	23	15	63
Total	29	30	49	46	154

Methods of Study

At necropsy the intact kidneys, together with the perirenal fat, renal arteries, and unopened aorta, were removed *en masse*. Each aorta was opened in the midline anteriorly and the renal arteries were injected through the aortic ostia with a barium sulphate and gelatin mass, after perfusion with physiological saline at 45° C. Details of the injection technique, injection mass, and apparatus have already been described (Schwartz and Mitchell, 1962a). In this study both the warm saline perfusion and the injection were carried out at a constant pressure of 100 mm. Hg, each for a period of five minutes. On completion each renal artery was ligated near its origin, while the intraluminal pressure was maintained at 100 mm. Hg, and the injected kidney suspended in 10% formalin at 5° C. Subsequently the perirenal fat, renal capsule, and adventitial debris were removed. The injected kidneys, including the entire length of the renal arteries, were x-rayed. Polar length was measured with calibrated callipers, and the weight of the injected kidneys was recorded.

After radiographic examination the extrarenal arteries were inspected, and the presence or absence of stenosis and occlusion was assessed by making serial transverse sections of the main renal artery and its branches at intervals of 2-3 mm. from the origin to the point where the branches enter the renal pelvis. The degree of stenosis was graded jointly by us, using the criteria recommended by the World Health Organization Study

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Group (1958): (a) *no stenosis* (N.S.); (b) *moderate stenosis* (M.S.): appreciable reduction in the size of the arterial lumen, but more than half the diameter of the original lumen remaining; and (c) *severe stenosis* (S.S.): less than half the diameter of the original lumen remains. In all cases with severe stenosis the internal and external diameters were measured at the points of maximum stenosis.

To identify the site of stenosis each unbranched renal trunk was divided into proximal, middle, and terminal thirds. Where stenosis were found in all three thirds, multiple stenosis was recorded.

All kidneys were serially sectioned in the coronal plane at 4-mm. intervals using a domestic bacon-slicer. Numerous observations were made on the slices, including the mean number of discrete indentations visible on the external cortical surface of the central four or five slices. This mean value was recorded as the "dent index." No attempt was made to distinguish indentations due to scarring or lobulation, as such a distinction was found to be impracticable. In addition, the presence of large discrete depressed scars having a diameter of 1 cm. or more was recorded separately. Cortical thickness was measured in the two or three central slices and the mean of 10 separate measurements was taken as representative.

After macroscopic examination the kidney slices were numbered, mounted in sequence between perforated zinc disks supported in brass tripods, and cleared in methyl salicylate as described earlier (Schwartz and Mitchell, 1962a). Each of the cleared slices was then examined under a dissecting microscope, with the intrarenal tree visible from the interlobar arteries to the glomeruli. The presence or absence of occlusion was noted, and the degree and number of intrarenal branches narrowed were recorded, using the same criteria for stenosis as were applied to the extrarenal vessels. Details of the changes in the interlobular arteries, arterioles, and glomeruli do not fall within the scope of the present paper. Normal and stenotic segments of artery, together with representative areas of renal parenchyma, were examined histologically.

Post-mortem blood urea nitrogen (B.U.N.) was determined on the serum from intracardiac blood, using the Technicon Autoanalyzer.

Results

Prevalence and Distribution of Renal Artery Stenosis

The percentage prevalence and distribution of the various grades of renal arterial stenosis according to the patients' age and sex are detailed in Table II. Stenosis is an age-dependent change in both men and women. In the younger age-groups the former show a greater frequency of stenosis than the latter, and in the older age-groups this sex difference is either abolished or reversed. Of particular interest is the marked predominance of a severe grade of intrarenal stenosis in females in the age-groups 65–74 and 75 years and over, where the

female: male ratio varies from 2:1 to 5:1. Essentially similar comments are valid for severe stenosis of the extrarenal branches, though the sex differences are not as great or as consistent.

There are slight and by no means consistent differences between the right and left renal arteries, but in general the left renal artery shows a slightly greater prevalence of stenosis than the right.

Although severe stenosis is most frequent in the main renal trunks, with a prevalence in the various age-groups varying from 0 to 36%, the frequency of severe intrarenal stenosis is by no means insignificant, reaching a peak of 17% on the right and 22% on the left in females in the group aged 65–74 years. Intrarenal stenosis was found to have an overall prevalence of 8% in males and 13% in females. In 4% of males and in all the females (13%) it was of a severe grade. One-third of all 12 cases of severe intrarenal stenosis were found in diabetics of long standing (up to 42 years), and 10 of the 12 (83%) had diastolic blood-pressure levels of 100 mm. Hg or more.

Sites of Stenosis

Table III shows the number of stenoses, both moderate and severe, which were found in the proximal, middle, and terminal thirds of the right and left renal trunks. (Stenosing lesions in all three thirds were classified as multiple.) Multiple stenosis in the extrarenal and intrarenal systems implies involvement of more than one arterial branch. It can be seen that stenosing plaques are clearly most frequent in the proximal third of the right and left renal trunks near the aortic ostia, and that lesions elsewhere in the trunk are relatively uncommon. Multiple stenosis is more common than single stenosis in the extrarenal and intrarenal systems. Sites of stenosis are essentially similar on both sides.

TABLE III.—Location of Any Degree of Stenosis Within the Renal Arterial Tree, Expressed as the Number of Patients with Stenosis at Each Site. Further Details given in Text

Side	No. of Patients with Stenosis at Each Site							
	Trunk				Extrarenal Branches		Intrarenal Branches	
	Thirds			Multiple	Single	Multiple	Single	Multiple
	Proximal	Middle	Terminal					
Right	66	6	8	4	15	19	1	12
Left	70	4	3	7	11	17	2	10
Total	136	10	11	11	26	36	3	22

Number of Arterial Systems Affected

For each patient the renal vascular tree can be divided into six arterial systems—namely, the right and left trunks, together with the right and left extrarenal and intrarenal systems. All

TABLE II.—Prevalence, Degree, and Distribution of Renal Stenosis in the Six Arterial Systems, Expressed as a Percentage of the Number of Patients in Each Age-and-Sex Group

Age (years)	Sex	Percentage Prevalence of Renal Artery Stenosis																	
		Right Arterial System									Left Arterial System								
		Trunk			Extrarenal Branches			Intrarenal Branches			Trunk			Extrarenal Branches			Intrarenal Branches		
		N.S.	M.S.	S.S.	N.S.	M.S.	S.S.	N.S.	M.S.	S.S.	N.S.	M.S.	S.S.	N.S.	M.S.	S.S.	N.S.	M.S.	S.S.
<55	Male	80	20	0	93	7	0	93	0	7	87	13	0	87	13	0	93	7	0
	Female	93	0	7	100	0	0	100	0	0	86	7	7	100	0	0	100	0	0
55-64	Male	58	16	26	74	26	0	95	0	5	55	28	17	89	11	0	94	0	6
	Female	73	27	0	91	9	0	100	0	0	55	27	18	82	9	9	100	0	0
65-74	Male	42	46	12	73	19	8	96	0	4	23	62	15	69	23	8	96	0	4
	Female	61	17	22	74	4	22	79	4	17	57	26	17	78	9	13	78	0	22
75+	Male	54	23	23	64	23	13	90	7	3	26	39	36	87	10	3	94	3	3
	Female	27	53	20	73	20	7	87	0	13	34	53	13	67	27	6	86	7	7

N.S. = No stenosis. M.S. = Moderate stenosis. S.S. = Severe stenosis. Details of stenosis grading are given in text.

six or none of these systems may be involved in any one patient. Table IV shows the age-and-sex distribution of patients according to the number of arterial systems affected by severe stenosis and by any degree of stenosis. The results are expressed as a percentage of the number of patients in each age-and-sex group. The number of systems narrowed increases with age when all stenosis or a severe grade of stenosis is considered, and in the older groups the customary sex difference is either abolished or reversed. In both males and females aged 75 years and over the prevalence of stenosis reaches a peak of 87%, while the peak prevalence of a severe grade of stenosis is 42% in males and 40% in females.

TABLE IV.—Age-and-Sex Distribution of Patients According to the Number of Arterial Systems (see text) Affected by Severe Stenosis and by Any Degree of Stenosis. Results Expressed as a Percentage of the Number of Patients in Each Age-and-Sex Group

Sex	Age (years)	No. of Arterial Segments Stenosed (%)													
		All Stenosis						Severe Stenosis							
		0	1	2	3	4	5	6	0	1	2	3	4	5	6
Male	< 55	67	20	7	0	0	6	0	93	7	0	0	0	0	0
	55-64	26	42	16	5	11	0	0	58	37	0	5	0	0	0
	65-74	15	31	23	8	19	0	4	80	4	8	0	8	0	0
	75 +	13	13	42	19	7	3	3	58	19	13	7	0	3	0
Female	< 55	79	21	0	0	0	0	0	86	14	0	0	0	0	0
	55-64	36	46	0	9	9	0	0	82	18	0	0	0	0	0
	65-74	39	22	13	9	4	0	13	65	9	4	9	0	9	4
	75 +	13	20	27	26	0	7	7	60	20	13	7	0	0	0

Correlation Between Stenosis in the Various Anatomical Segments of the Renal Arteries

In Table V we show the frequency with which patients having a severe grade of stenosis in the extrarenal arteries on one side (trunk and extrarenal branches combined) have a specified grade of stenosis in the other three sites. It can be seen that stenosis has a marked propensity to affect both sides, and in both males and females with severe extrarenal stenosis the opposite extrarenal vessels are normal in only 9-18% of cases, and are severely narrowed in 55-64%. The intrarenal vessels likewise show severe stenosis in 10-36% of cases, and the predominance of severe intrarenal stenosis in females is once more apparent. Using the right and left main renal artery trunks as index arteries, Table VI shows the frequency with

TABLE V.—Correlation Between Stenosis in Various Segments of the Renal Arteries, Expressed as a Percentage of the Number of Patients with Severe Stenosis of the Index Artery (Trunk and Extrarenal Branches) having a specified Grade of Stenosis in the Other Sites

Index Artery	Sex	Percentage of Male and Female Patients with Severe Stenosis of Index Artery Having Specified Grade of Stenosis in Other Sites											
		Other Sites											
		Right Extrarenal			Right Intrarenal			Left Extrarenal			Left Intrarenal		
		N.S.	M.S.	S.S.	N.S.	M.S.	S.S.	N.S.	M.S.	S.S.	N.S.	M.S.	S.S.
R. extrarenal	Male	—	—	—	76	6	18	18	18	64	76	6	18
	Female	—	—	—	55	9	36	18	27	55	64	9	27
L. extrarenal	Male	10	35	55	85	5	10	—	—	—	85	5	10
	Female	9	36	55	55	9	36	—	—	—	64	0	36

TABLE VI.—Correlation Between Stenosis in Various Segments of the Renal Arteries, Expressed as a Percentage of the Number of Patients With Severe Stenosis of the Index Artery (Trunk) Having a Severe Grade of Stenosis in the Other Sites

Index Artery	Sex	Percentage of Male and Female Patients with Severe Stenosis of Index Artery Having Severe Stenosis in Other Sites					
		Other Sites					
		R. Trunk	R. Extra-renal Branches	R. Intra-renal Branches	L. Trunk	L. Extra-renal Branches	L. Intra-renal Branches
R. trunk	Male	—	27	13	60	7	13
	Female	—	44	22	44	33	33
L. trunk	Male	50	22	6	—	6	6
	Female	44	44	22	—	22	22

which patients having severe stenosis of one trunk have a severe grade of stenosis in the other five sites. It can be seen that when one trunk is severely narrowed between 6 and 44% of patients exhibit severe narrowing of the extrarenal branches and between 6 and 33% have severe intrarenal stenosis. The opposite trunk is severely affected in between 44 and 60% of patients, while the greater frequency of both severe extrarenal and intrarenal stenosis in females can be seen.

Thrombotic Occlusion

Table VII details the percentage prevalence of complete thrombotic occlusion in the 154 patients studied. Thrombotic occlusion was not noted in males and females under the age of 55 years, and was found thereafter with a frequency of from 1.1 to 4.6% with no consistent sex difference. The occlusions were not found within the main renal trunk, but were invariably located either in the distal parts of the extrarenal arteries or in the interlobar divisions. Some were possibly of embolic origin associated with cardiac infarction or atrial fibrillation, but the distinction between *in situ* thrombosis and embolism could not be made with any degree of certainty.

TABLE VII.—Age-and-Sex Prevalence of Thrombotic Occlusion in the Renal Arteries

Sex	No.	Percentage Prevalence of Thrombotic Occlusion			
		Age (years)			
		<55	55-64	65-74	75+
Male	91	0	1.1	2.2	2.2
Female	63	0	0	4.6	1.5

Renal Stenosis and Diastolic Blood-pressure

In many pathological studies it has been customary to analyse data such as these according to the presence or absence of hypertension, with a dividing line set at the arbitrary diastolic figure of 90 mm. Hg. As we are uncertain of the validity of this dividing line scatter diagrams have been employed, and the

relation between diastolic blood-pressure levels in males and females on the one hand and the presence and degree of renal artery stenosis on the other is analysed according to age (Figs. 1 and 2). The latter parameter, which is linked to both the prevalence of renal stenosis and the diastolic blood-pressure level must be considered at all times unless a false association is to emerge.

We have found no clear or consistent relation between the degree of stenosis and the diastolic blood-pressure levels in either males or females (Figs. 1 and 2), and in this respect severe bilateral renal stenosis does not differ appreciably from unilateral stenosis. Both severe unilateral and bilateral stenosis often occur in the absence of an elevated diastolic blood-pressure. Conversely, patients with an elevated diastolic blood-

pressure may show either no stenosis or only a moderate grade of stenosis, the latter probably having no functional significance.

FIG. 1.—Relation between renal stenosis severity and diastolic blood-pressure levels in males according to age. ○=No stenosis. ●=Moderate stenosis, unilateral or bilateral. △=Severe unilateral stenosis. ▲=Severe bilateral stenosis.

FIG. 2.—Relation between renal stenosis severity and diastolic blood-pressure levels in females according to age. Symbols as for Fig. 1.

Relation Between Renal Stenosis and Kidney Weight

Figs. 3 and 4 depict the relation between injected renal weights in males and females, and the presence and severity of renal artery stenosis analysed according to age. The renal weight in both sexes declines progressively with age in the absence of stenosis and the weights in women are lower than in men. In patients with a moderate grade of stenosis the renal weight shows no consistent or significant reduction when compared with the weights from patients of the same age without stenosis. When severe focal stenosis (stenosis at one point only in the renal arterial tree) is considered, occasional kidneys exhibit weights below the range for each age-group without stenosis, or with only a moderate stenosis grade. Nevertheless the weight of the majority of kidneys associated with severe focal arterial stenosis is not reduced. In those patients with severe stenosis affecting more than one arterial system, be they male or female, renal weights tend to be lower than in any of the other stenosis categories, although there is considerable overlap within each age-group. We may conclude that the tendency for a reduction in renal weight in those cases with severe focal arterial stenosis is accentuated when the stenosis affects more than one arterial system. However, a not insignificant number of kidneys maintain weights within the normal range for each age group, in spite of severe multiple renal arterial stenoses.

Polar Length and Renal Stenosis

Figs. 5 and 6 show the relation between polar length and renal stenosis severity in males and females according to age.

FIG. 3.—Relation between renal weight, age, and renal stenosis severity in males. ○=No stenosis. ●=Moderate stenosis. △=Severe focal stenosis affecting one system only. ▲=Severe stenosis affecting more than one system.

FIG. 4.—Relation between renal weight, age, and renal stenosis severity in females. Symbols as for Fig. 3.

FIG. 5.—Relation between polar length, age, and renal stenosis severity in males. Symbols as for Fig. 3.

It can be seen that the polar length is shorter in women than in men, an observation which is in keeping with the sex difference in renal weights (Figs. 3 and 4). In both males and females the polar length declines with age in the absence of renal arterial stenosis, necessitating the comparison of patients of comparable age. Little or no difference in polar length can be noted when kidneys without renal stenosis are compared with those having arterial stenosis of a moderate grade. Likewise the effect of severe focal stenosis is negligible, but when severe stenosis affecting more than one arterial system is considered there is a length-reduction in some instances in both men and women, although many kidneys of normal polar length exist in the presence of severe multiple stenoses. From the clinical and radiological viewpoints the presence of kidneys of normal radiological dimensions does not preclude the possibility of severe renal arterial disease.

FIG. 6.—Relation between polar length, age, and renal stenosis severity in females. Symbols as for Fig. 3.

Renal Stenosis and Cortical Thickness

The relation between cortical thickness, age, sex, and the degree of renal arterial stenosis is depicted graphically in Figs. 7 and 8. As with weight and polar length, the cortical thickness decreases with age in the absence of arterial stenosis. When severe focal arterial stenosis is considered the cortical thickness is reduced in some instances, a trend which is again visible for severe stenosis affecting more than one arterial system. There is no significant association between cortical reduction and a moderate grade of renal stenosis, while many

FIG. 7.—Relation between cortical thickness, age, and renal stenosis severity in males. Symbols as for Fig. 3.

instances of severe stenosis, both focal and multiple, exist in the presence of a renal cortex of normal thickness.

FIG. 8.—Relation between cortical thickness, age, and renal stenosis severity in females. Symbols as for Fig. 3.

Cortical Scarring and Severity of Renal Stenosis

Figs. 9 and 10 show the macroscopic extent of renal cortical scarring in males and females, according to age and the presence and degree of renal arterial stenosis. In both males and females the dent index shows a definite increase with age in the absence of stenosis, while the index in cases with a moderate grade of arterial stenosis shows no clear difference from the index in those without stenosis. In those kidneys associated with

FIG. 9.—Relation between severity of renal cortical scarring (dent index), age, and renal stenosis severity in males. Symbols as for Fig. 3.

severe focal arterial stenosis, occasional cases exhibit extensive cortical scarring, an association which is only a little clearer when severe multiple system stenosis is analysed. Extensive cortical scarring is, however, considerably more age-dependent than stenosis-dependent, and factors other than renal arterial stenosis—for example, disease of the small cortical arteries, and pyelonephritis—are probably implicated.

Large depressed scars, with a diameter of more than 1 cm., were found in 28 kidneys. Such scars were often multiple, and it was thought that these might well have a vascular basis, representing the end-result of small cortical infarcts. These

lesions showed no clear relation to severe extrarenal or intrarenal arterial stenosis, although there was a clear age-dependence. Furthermore, no associated subtending arterial stenosis or occlusion could be demonstrated, the only definite vascular changes being in the scars themselves, which were hypovascular with considerable distortion of the normal pattern of the cortical vessels.

FIG. 10.—Relation between severity of renal cortical scarring (dent index), age, and renal stenosis severity in females. Symbols as for Fig. 3.

Blood Urea Nitrogen (B.U.N.) Levels and Renal Stenosis

Post-mortem B.U.N. was determined in 137 of the 154 patients studied. The levels ranged from 5 to 324 mg./100 ml. Higher values were obtained in older patients, but throughout the age range there was no clear or consistent relation between the presence and degree of arterial stenosis on the one hand and the B.U.N. level on the other. A small number of patients with severe renal arterial stenosis showed levels at the upper limits of the range for each age-group, but many with both severe focal and severe multiple arterial stenoses fell within the normal range. Using B.U.N. as one index of renal function, it is concluded that the latter may be unimpaired in the presence of severe renal stenosis.

Discussion

Stenosis of the renal arteries is a common necropsy finding (Table II). In both males and females the prevalence of stenosis is clearly age-dependent, and while the former are more frequently and severely affected in the younger age-groups this sex difference is either abolished or reversed with increasing age, a pattern which is typical of stenosing plaques in many different arterial sites (Mitchell and Schwartz, 1964). In general, stenosing plaques are most common in the proximal segment of an artery arising at approximately right angles from the parent trunk, a site where vascular turbulence is likely to be greatest (Schwartz and Mitchell, 1962b). The renal arteries provide ample support for such an opinion concerning plaque location (Table III).

Of both clinical and radiological significance is the relative frequency of severe intrarenal stenosis in this study, particularly in females in the age-groups 65–74 and 75 and over (Table II). We can provide no explanation for the marked predominance in females. Hall (1952) noted this lesion in eight cases with long-standing diabetes mellitus and renal failure, and suggested that intrarenal stenosis might contribute to glomerular loss and renal failure in diabetic glomerulosclerosis. In this regard, it is of interest that one-third of the cases with severe intrarenal stenosis in this study were diabetics, with diabetic histories ranging from 23 to 42 years, and in these the post-mortem

B.U.N. levels ranged from 65 to 250 mg./100 ml. Severe intrarenal stenosis is, however, not restricted to patients with diabetes mellitus. Although a severe grade of intrarenal stenosis was found with an overall prevalence of only 8% in this study, it is clearly related to the presence of severe stenosis in either the trunk or the whole of the extrarenal arteries (Tables V and VI). With a severe grade of stenosis in the main renal trunk, 6–13% of males and 22–33% of females exhibit severe intrarenal stenosis (Table VI), and when the extrarenal arteries are the site of severe stenosis severe intrarenal stenosis is found in 10–18% of males and 27–36% in females. These figures stress the great need for visualization of the intrarenal arterial tree at angiography before embarking upon reconstructive arterial surgery for severe stenosis in any part of the extrarenal arteries.

Like stenosis in the carotid and vertebral arteries (Schwartz and Mitchell, 1961), renal stenosis has a marked propensity to occur bilaterally (Tables V and VI). As both the trunk and its main extrarenal branches are usually visualized at angiography, we have analysed the relation between severe stenosis in the extrarenal vessels and severe stenosis in other sites (Table V). Severe extrarenal stenosis on one side implies that the opposite extrarenal arteries will be normal in only 9–18% of cases, and have a 55–64% chance of being severely stenosed. In approximately one-half of the patients with severe stenosis on one side, the opposite side is similarly affected. It is therefore essential that both renal arteries are adequately visualized before surgical intervention for renal stenosis. This need for defining the vascular status on the “good” side was mentioned by Eyler *et al.* (1962), who suggested the possibility of disease in the arteries of the normal side. They went on to suggest that compensatory hypertrophy after nephrectomy might accentuate ischaemia in the presence of bilateral renal artery stenosis.

Because renal artery stenosis is age-dependent, and an elevated blood-pressure is more common with increasing age, a false relation between renal stenosis is likely to emerge if patients with differing pressure levels are compared without careful reference to age. Thus the results of Blackman's (1939) necropsy study are hard to assess, not only because the selection and age of his “controls” were not detailed, but also because the entire length of the renal arteries was not always examined. He found marked or moderate stenosis in 10% of the controls and 86% of the 50 hypertensives. Richardson (1943) demonstrated renal arterial stenosis at necropsy in 25 out of 32 hypertensives and in only 8 out of 113 controls. Our calculations based upon his data reveal that 72% of the hypertensives were aged 50 years and over, while 50% of the normotensives were under 50 years of age. Even allowing for this age-discrepancy, one cannot reconcile the low stenosis frequency in his control series with the results of the present study. The results of Holley *et al.* (1962) are rather more in keeping with our own observations. They found moderate or severe renal stenosis in 12 and 64% of normotensive subjects aged under 50 and 50 and over respectively. Of the 38 hypertensives, 29 had renal stenosis and 26 (90%) of these were aged 50 and over.

Figs. 1 and 2 show the relation between diastolic blood-pressure levels and renal stenosis in the present study. We have found no consistent relation between diastolic pressure and the presence or severity of renal stenosis in this series. As raised arterial plaque severity is significantly related to diastolic blood-pressure (Mitchell *et al.*, 1964) in sites other than the renal arteries, any marginal association between renal stenosis and blood-pressure could reflect the effect of a raised pressure rather than a cause. Severe renal stenosis can certainly occur in patients with normal blood-pressure levels, and the converse is equally true (Figs. 1 and 2).

In considering the relation between kidney dimensions and the presence and severity of renal stenosis, it is apparent from Figs. 3 and 4 that a small proportion of patients with severe renal artery stenosis exhibit weights which are less than or

at the lower limits of the range for each age-and-sex group, but many patients with severe stenosis have kidneys of normal weight. Moreover, renal weight shows a progressive decrease with age in the absence of renal stenosis. These results pose two questions which at present cannot be answered: firstly, the severity of stenosis necessary to produce a significant reduction in renal blood flow; and, secondly, whether atrophy is an essential response to renal ischaemia. When other parameters of renal size are considered—namely, polar length and cortical thickness (Figs. 5–8)—essentially similar relations between age and the presence and severity of renal artery stenosis are apparent. From a clinical and radiological viewpoint, it should be noted that if 9 cm. is taken as the lower limit of normal for polar length, then an extremely small proportion of kidneys with severe renal stenosis will be detected. In establishing standards of radiological normality age is obviously an important factor.

The extent of renal cortical scarring has been found to increase with age in both males and females, showing a marginal and inconsistent relation to the presence and severity of renal artery stenosis (Figs. 9 and 10). When only large scars (1 cm. or greater) are considered, a similarly inconclusive relation with renal stenosis was found. It is suggested that disease of the small cortical arteries, and/or infection, as in pyelonephritis, are more likely to be important in the genesis of cortical scarring than stenosis of the extrarenal and main intrarenal arteries.

Summary

The frequency, severity, and location of renal arterial stenosis, in both the extrarenal and intrarenal arteries, have been determined in 154 patients comprising an unselected hospital necropsy sample, using the techniques of injection, serial section, and clearing. Severe renal stenosis was found to be bilateral in approximately half of the patients. Intrarenal stenosis of a severe grade was much more common in women than in men, and in the presence of severe extrarenal stenosis

occurred with a frequency of 10–18% in males and 27–36% in females. No clear or consistent relation between the presence and severity of renal stenosis and the diastolic blood-pressure levels was found when the age of the patients was considered. It is suggested that the marginal differences could be the result and not the cause of elevated blood-pressure levels.

Kidney weight, polar length, and cortical thickness decrease with age in the absence of renal arterial stenosis, and only a small number of kidneys show a significant reduction in these parameters in association with severe stenosis. Renal cortical scarring was found to show but little relation to the calibre of the extrarenal and main intrarenal arteries, although its severity showed a definite increase with age.

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REFERENCES

- Blackman, S. S. (1939). *Bull. Johns Hopk. Hosp.*, **65**, 353.
 Braasch, W. F. (1942). *Canad. med. Ass. J.*, **46**, 9.
 Eyler, W. R., Clark, M. D., Garman, J. E., Rian, R. L., and Meininger, D. E. (1962). *Radiology*, **78**, 879.
 Goldblatt, H., Lynch, J., Hanzal, R. F., and Summerville, W. W. (1934). *J. exp. Med.*, **59**, 347.
 Hall, G. F. M. (1952). *J. Path. Bact.*, **64**, 103.
 Holley, K. E., Hunt, J. C., Brown, A. L., Kincaid, O. W., and Sheps, S. G. (1962). *Circulation*, **26**, 731.
 Janeway, T. C. (1909). *Proc. Soc. exp. Biol. (N.Y.)*, **6**, 109.
 Kincaid-Smith, P. (1961). *Aust. Ann. Med.*, **10**, 166.
 Lisa, J. R., Eckstein, D., and Solomon, C. (1943). *Amer. J. med. Sci.*, **205**, 701.
 Mitchell, J. R. A., and Schwartz, C. J. (1964). *Arterial Disease*. Blackwell, Oxford. In press.
 ——— and Zinger, A. (1964). *Brit. med. J.*, **1**, 205.
 Richardson, G. O. (1943). *J. Path. Bact.*, **55**, 33.
 Schwartz, C. J., and Mitchell, J. R. A. (1961). *Brit. med. J.*, **2**, 1057.
 ——— (1962a). *Brit. Heart J.*, **24**, 761.
 ——— (1962b). *Circulat. Res.*, **11**, 63.
 Smith, H. W. (1956). *J. Urol.*, **76**, 685.
 Sutton, D., Brunton, F. J., and Storer, F. (1961). *Clin. Radiol.*, **12**, 80.
 World Health Organization (1958). *Techn. Rep. Ser.*, No. 143.

Causes and Prevention of Domestic Burning Accidents

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In the eight years since the last review from the Birmingham Burns Unit of the causes and prevention of burns (Colebrook *et al.*, 1956) there have been important legislative and social changes. The Heating Appliances (Fireguards) Act, 1952, which requires all gas and electric fires to be guarded when sold has been in force; British Standards have been introduced for ordinary fireguards (B.S.2788), for nursery fireguards (B.S. 3140), for flammability of fabrics (B.S.3120 and B.S.3121), and for paraffin heaters (B.S.3300). The Oil Burners (Standards) Act, 1960, requires that all oil fires must comply with new safety standards. Improved flame-resistant fabrics and garments have been on the market, and since 1961 there has been a testing scheme for safe nylon nightwear.

General changes in social habits include the increased use of gas and electric convactor fires and the trend towards central heating, both of which might be expected to reduce accidents from burns. This, however, may have been offset by the in-

creased use of portable oil-burning heaters, particularly those made before 1960. It is therefore appropriate to examine what changes have occurred in the numbers and types of burning accidents and in the availability and application of methods of prevention.

Incidence of Burning Accidents

The Registrar-General's figures for deaths from burns and scalds since 1955 are summarized in Table I. These figures show somewhat reduced numbers of deaths among children under 15 years, an appreciable increase in those aged 15–64, and a continuing large number of deaths in people of 65 years and over. During the eight-year period there has been an increase of 5% in population, particularly marked in the 65+ age-group, which has increased by 12%. When the figures in Table I are corrected for the population at risk, young children (0–4 years) show a fairly steady death rate from burns of about 29 per million at risk per annum. Both boys

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