DENERVATION OF THE KIDNEY

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by

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RENAL PAIN IS a common complaint. Fortunately, in most cases we can find the cause and treat it. Sometimes, however, we meet with patients who complain of pain which is undoubtedly renal, and yet the most careful urological examination fails to reveal any satisfying explanation of it.

We can hardly be content with the treatment which has usually been given to these patients. All sorts of medicines have been prescribed without rhyme, reason or result. Gall bladders and appendices, ovaries and tubes have been needlessly sacrificed; and, in the end, either the kidney has been removed, or refuge has been taken in that blessed word " neurotic " as a cloak for ignorance and an excuse for inaction.

During the last 20 years I have treated over 100 of these obscure cases of renal pain by denervation of the kidney, and this lecture is an account of my experience.

Renal denervation was first performed by Papin (1921), but he combined it with nephropexy and decapsulation. Milliken and Karr (1925) demonstrated experimentally in animals the effects of renal denervation upon the functional activity of the kidney, and formulated certain theoretical indications for the operation. In the succeeding years, isolated cases were reported mainly by French and Italian surgeons; and in America, Hess (1928, 1931) published a small series. In 1930, Harris and Harris published an important paper in the *British Journal of Urology* based on their investigations in 29 cases. I reported a few cases in 1932, and in 1936 published a detailed record of my first 28 cases. At that time my experience was too short and too small to allow any conclusions to be formed, but now I feel justified in proposing renal denervation as a logical and satisfactory treatment for many cases of renal pain.

It would be quite unreasonable to remove, deliberately, the nerve supply of one or both kidneys unless we could show that denervation would cause no untoward results, either temporary or permanent. Sufficient animal experiment has been done to establish this premise beyond all doubt, and this conclusion has been confirmed by operations performed on the human kidney.

While the powerful influence of the renal nerves must be taken into account when considering the activity of the kidney, yet it has been shown, quite conclusively, that secretion continues indefinitely after all connections with the central nervous system have been severed. The modern theory of urinary secretion set forth by Cushny (1917), and ably supported and practically confirmed by many other investigators, particularly A. N. Richards (1924), does not invoke the necessity or admit the existence of secretory nerves to the kidney. As long ago as 1906, Carrell

and Guthrie transplanted the kidney of a dog into a bitch, and removed the kidneys of the latter; the transplanted kidney functioned normally without any possible guidance from the nervous system. Ten years later, Quinby (1916) excised one kidney in a dog and then replaced it, suturing the vessels and the ureter. On comparing the secretion of the two kidneys, the operated one was found to secrete more than the normal one, though later the amount of urine became equal on both sides. The animal survived indefinitely after the normal kidney had been excised, without any increase in the blood urea or delay in the excretion of test substances. Similar experiments have been performed many times by different investigators with the same results.

FUNCTION OF THE RENAL NERVES

To appreciate the theoretical indications for renal denervation it is necessary to have a thorough understanding of the fundamentals of the physiology of the renal nerves. Unfortunately, there is no adequate account of this in the English language nor have I the time to describe it in the detail it deserves. Table I shows, in an over-simplified form, the main functions of the nerves.

TABLE I

Nerves	Stimulation	Depression or Section
Nerves to the blood-vessels	Vaso-constriction	Vaso-dilatation
	Decreased flow of blood through kidney	Increased flow of blood through kidney
	Anuria or oliguria	Increased urine of low specific gravity
Nerves to the pelvis, calyces and papillæ	Contraction of sphincters	Relaxation of sphincters
	Increased intra-pelvic pressure	
Sensory nerves	Pain	Anæsthesia of kidney

Undoubtedly the principal function of the renal nerves is vasomotor. Stimulation of the splanchnic or renal nerves produces vaso-constriction in the kidney. The lessened blood-flow results in diminished secretion of urine. Depression or section of the nerves results in vaso-dilatation and the secretion of an increased amount of urine of low specific gravity. The direct action of the nerves is entirely confined to the kidney on the side on which the nerves are stimulated (Burton-Opitz, 1916).

The calyces and pelvis constitute a hollow muscular viscus which, like all the other hollow viscera, exhibits spontaneous peristaltic movement. Though this movement is inherent in the muscle it is none the less

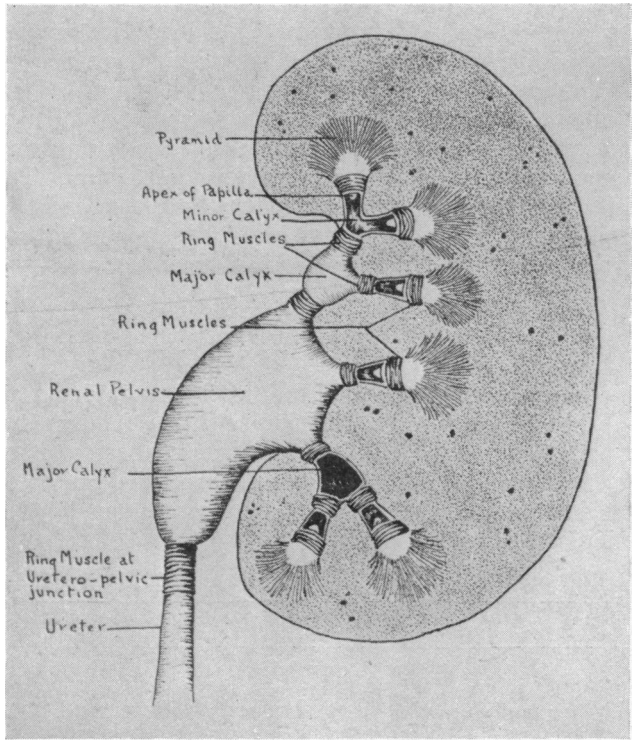

Fig. 1. Diagrammatic representation of the ring-muscle system modified from the original in Kelly and Burnam, " Diseases of Kidneys, Ureters, and Bladder." The anterior walls of all the minor calyces and lower major calyx have been cut away to expose the tips of the papillæ.

under the control of the autonomic nervous system. Max Brodel (1922) described a series of ring muscles surrounding the bases of the papillæ, the necks of the major and minor calyces ; and a stronger muscle at the pelvi-ureteric junction. These muscles, like other sphincters, are normally in a state of tonic contraction. Over-action of the renal nerves makes their relaxation difficult, induces increased intra-pelvic pressure and so causes urinary stasis, pelvic dilatation and pain.

Woodside (1944) has called attention to the fact that the kidney pelvis consists of a series of chambers, probably equivalent to each other in capacity. The minor calyces empty into the major calyces and these in their turn empty into the pelvis proper, and Woodside suggests that the whole system might be called the " Renal Heart."

The anatomical and experimental work of Brodel (1922), Muschat (1926), and others, has had ample confirmation from the pyeloscopic

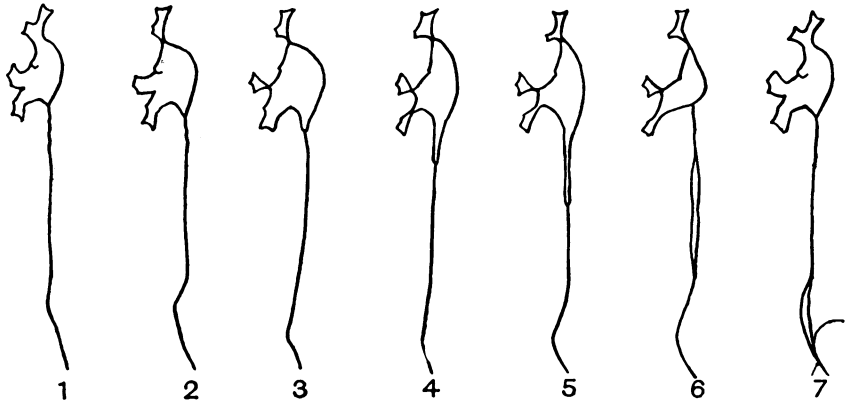

Fig. 2. The cycle of changes observed in the pelvis and calyces during pyeloscopy. (Modified from Herbst.)

investigations of Harris (1930), Jona (1937) and Legueu (1927). If pyeloscopy is done on a normal kidney we will see that the calyces, pelvis and ureter go through a regular cycle of movements every ten to 30 seconds. Starting from a diastolic stage, in which the pelvis and calyces are relaxed, but the pelvi-ureteric sphincter is contracted, the upper calyx empties its contents into the pelvis and remains contracted; it is followed by the middle and lower calyces and then the pelvis itself undergoes systole and, the pelvi-ureteric sphincter relaxing, it forces some of its contents into the ureter. The ureteric spindle is at first an appendix to the pelvis but, when it is about 10-15 cms. long, the pelvi-ureteric sphincter closes and the spindle passes down the ureter at the rate of 20-30 cms. a second. Soon after the spindle has separated from the pelvis a period of diastole sets in before the cycle is repeated. A normal pelvis ejects about 1 cc. per minute so that if the pelvis has been filled with 5-10 ccs. of dye it should not take more than 10 minutes to empty.

The relationship of these sphincters to the formation of hydronephrosis is interesting. In the earlier stages of hydronephrosis the pelvis proper may be seen considerably dilated, but the major and minor calyces are quite unaffected, protected by their ring muscles. In cases of longer or more rapid development the major calyces share in the distension, but the minor calyces still retain their slender structure; later, all or some of these expand and the cup-shaped terminations become globular. In each stage a marked constriction will be seen at the junctional zone—this is due to the contraction of the sphincter.

As might be expected, the sphincters at the junctional zones may sometimes themselves be the site of an achalasia, without involvement of the pelvi-ureteric sphincter. Three of my cases showed this dilatation of a single major or minor calyx.

In addition to the nerve fibres supplying the vessels and musculature of the kidney, the renal plexus also possesses some afferent fibres which are distributed almost entirely to the pelvis, calyces, papillæ and upper ureter, and reach the spinal cord through the dorsal roots of the tenth, eleventh and twelfth dorsal and first lumbar nerves. The kidney itself receives very few sensory fibres and is insensitive to most stimuli—pressure, cutting, puncture, faradic stimulation. It is, however, slightly sensitive to distension, especially if the distension is rapid. The renal pedicle is sensitive to touch, torsion or traction. The pelvis is exquisitely sensitive especially to distension and undoubtedly most cases of renal pain are due to increased intra-pelvic pressure.

INDICATIONS FOR RENAL DENERVATION

If it is granted that no ill effects are likely to attend the operation it follows as a corollary that we may expect favourable results from severing the renal nerves in any condition in which vaso-constriction is excessive, an increased blood supply to the kidney is desirable, diuresis might be advantageous, the sphincters are hypertonic or pain demands relief. The following theoretical indications for the operation have been suggested :—

(1) Reflex anuria.
(2) To prevent the reformation of calculi after nephrolithotomy.
(3) Certain types of nephritis.
(4) Hypertension.
(5) Essential hæmaturia.
(6) Early tuberculosis of the kidney.
(7) Non-mechanical hydronephrosis.
(8) Nephroptosis.
(9) Nephralgia.

In practice, I believe renal denervation is indicated only in painful non-mechanical hydronephrosis, in pain due to nephroptosis, or for renal pain of unknown origin. I have tried the operation for most of the other theoretical indications, but I have found the results either uncertain or unsatisfactory and I do not intend to discuss them further in this lecture.

Non-mechanical Hydronephrosis

While some cases of hydronephrosis are due to well-defined mechanical obstruction of the ureter, there are others in which no such obstruction can be found. As these non-mechanical hydronephroses progress, secondary mechanical factors, such as aberrant vessels, nephroptosis, stricture or stenosis of the ureter, may come into play and help to increase the size of the hydronephrosis.

Hydronephrosis of the idiopathic type is much more common than was formerly suspected. Von Lichtenburg (1939) found that 33 per cent. of

his cases were purely non-mechanical, and more than half of my cases were free from any organic obstruction.

The anatomical researches of Brodel (1922) and Muschat (1926) and the pyeloscopic investigations of Jona (1937) and Legueu (1927) give us a logical explanation of non-mechanical hydronephrosis; and it is now commonly accepted that these cases are due to some disturbances of the muscle-nerve impulses to the kidney as a result of which inhibitory influences gain the upper hand and the sphincters of the pelvis are prevented from relaxing.

Harris and Harris (1930) were the first to introduce the term "sympatheticotonus" in connection with these disturbances of the nerve-muscle mechanism of the kidney and they described the condition as passing through three stages:—

(1) The stage of systole or irritability in which contraction of the pelvis and calyces predominates and they may appear to be even smaller than usual. The pain is usually intermittent, colicy and severe. Delayed emptying is the rule. My first case of denervation was of this type. (Fig. 3)

(2) The stage of exhaustion or diastole in which relaxation predominates. The pelvis and calyces are larger than normal though there may be no definite dilatation or clubbing of the calyces. The contractions of the atonic pelvis are irregular, inefficient and often infrequent. In this stage there are usually long periods of dull pain in the loin with periodic acute exacerbations.

(3) The stage of dilatation or paralysis in which any degree of hydronephrosis may be present. This is the stage of retention with overflow.

Harris laid great stress on the action of hypodermic injections of eserine (gr. 1/50) on renal sympatheticotonus. He claimed that within 15 seconds from the injection there was rapid emptying of the pelvis with relief of pain. I do not deny that in some cases eserine acts as Harris describes, but on the whole I have found it unreliable and a fatal case of acute pulmonary œdema, occurring a few minutes after the injection of 1/50th grain of eserine (Cooke, 1937), has not increased my liking for it.

Female, aged 19 years, had been having attacks of renal pain but no organic abnormality could be found. A diagnosis of renal sympatheticotonus was made and she was discharged with a recommendation to her doctor that, if she had any more attacks, she should be given an injection of eserine. Some time later the patient went to her doctor's surgery in an attack of her pain and was given a subcutaneous injection of eserine ($^1/_{50}$ grain). Almost immediately she developed acute dyspnœa and within 15 minutes was dead. A post-mortem examination showed that she had died from acute pulmonary œdema. Nothing else abnormal was found and both kidneys were quite healthy looking.

The experimental work of Underwood (1939), the cases reported in the literature, particularly by Riches (1939), and my personal experience, all support the views of Harris and prove that in non-mechanical hydronephrosis the pain can be cured, the pelvic stasis relieved, the renal

Fig. 3. Case 1. Female, aged 31 years. Attacks of left renal colic for four years. X-ray 30 mins. after injection of uroselectan. Dilatation of right kidney and ureter ; spasm of left pelvis and calyces.

function improved and the size of the pelvis gradually diminished by denervation alone.

The following three cases, which have been followed over many years, illustrate the results that can be obtained by denervation :—

Case 12. Female, aged 26 years (Figs. 4, 5, 6). For three years this patient had been having recurrent attacks of left renal pain. They had become much more frequent and she had been forced to give up her work as a housemaid. X-ray examination showed a very large hydronephrosis, delayed secretion and pelvic stasis—the upper calyx was especially large. At operation, in August 1933, no cause for the hydronephrosis was found and the kidney was denervated. She has had no pain since operation, returned to her work till she married in 1937, and has had two children. The dilatation was slow in contracting down, but after seven years the size and shape of the pelvis and the renal function are almost perfect.

Case 15. Female, aged 15 years (Figs. 7, 8, 9, 10). This girl, a mill hand, had had attacks of left renal colic every week for ten months. The attacks were very severe, usually lasting two or three days, and had forced her to stop work. X-ray examination showed marked hydronephrosis of the left kidney with delayed secretion of the dye. There was some infection of the urine which improved on medical treatment. At operation, in March 1933, a non-mechanical hydronephrosis was found and renal denervation was done. She has had no pain since operation. X-ray examination after one year showed considerable improvement in the dilatation and secretion. This patient has been examined again since the war — her pain and her hydronephrosis are cured.

Case 22. Female, aged 17 years (Figs. 11, 12). For ten months this patient had been having attacks of right renal colic, vomiting, etc., every seven to ten days. She had been working in a factory but had had to give it up. Investigation showed a marked hydronephrosis on the right side and at

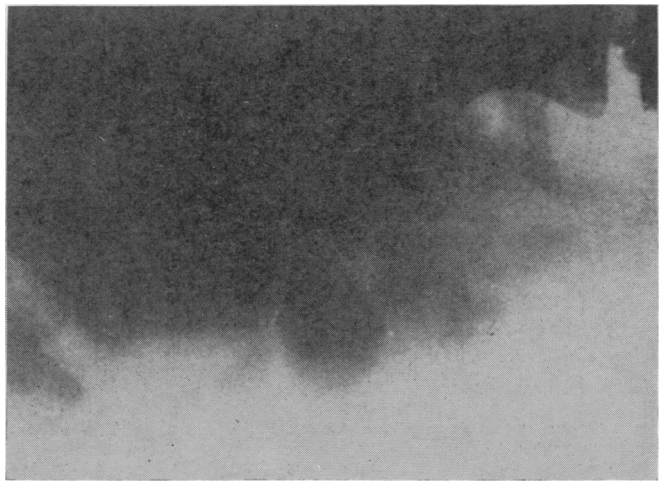

Fig. 4. Before Operation. X-ray 30 mins. after injection of uroselectan. Marked hydronephrosis, poor concentration of dye.

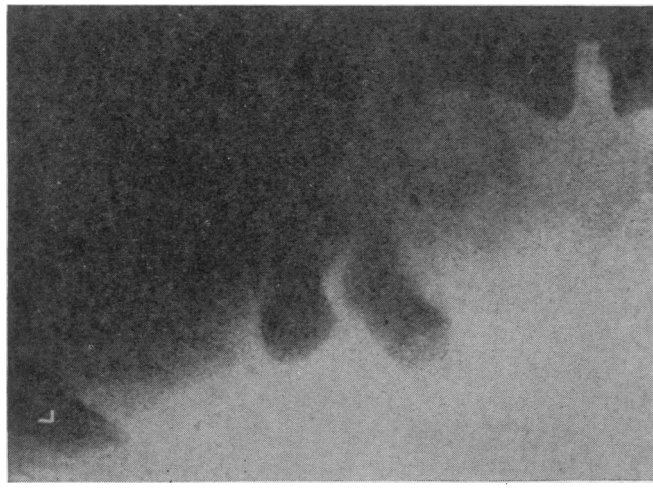

Fig. 5. Two years after denervation. X-ray 30 mins. after injection of uroselectan. Hydronephrosis slightly diminished, improved concentration of dye.

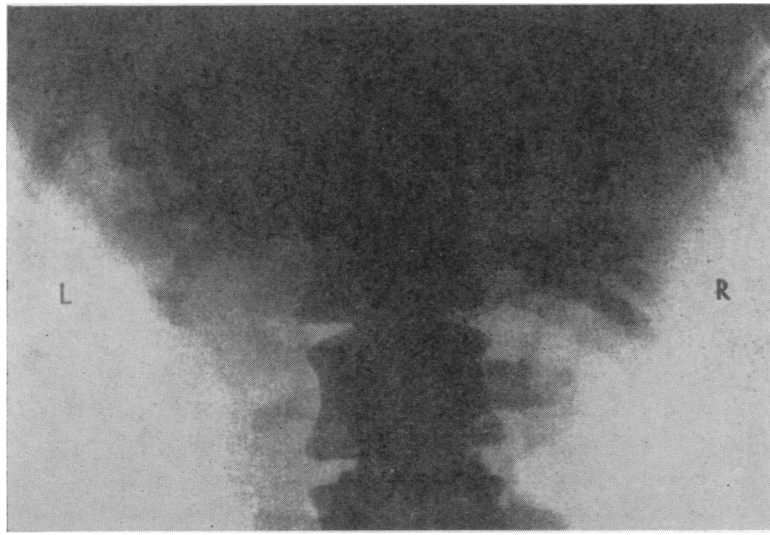

Fig. 6. Seven years after operation. X-ray 30 mins. after injection of uroselectan. Pelvis and calyces now practically normal.

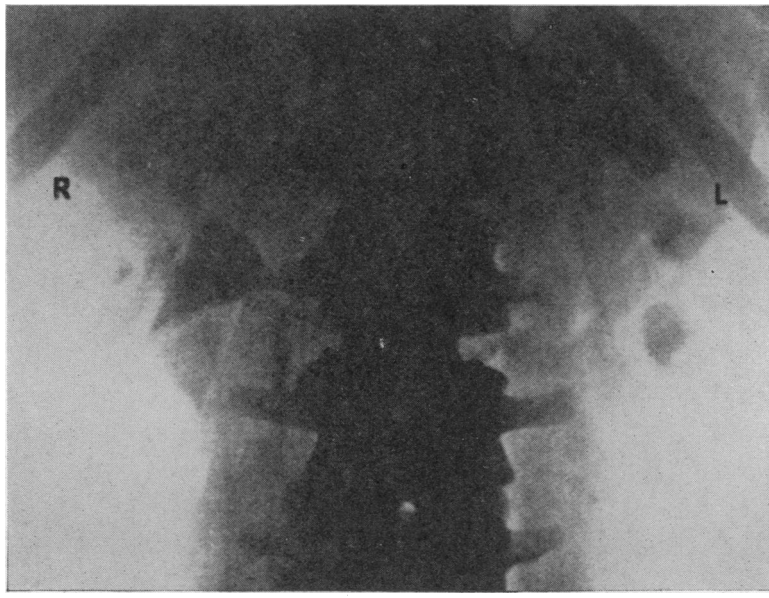

Fig. 7. Before operation. X-ray 10 mins. after injection of uroselectan. Hydronephrosis of left kidney, defective secretion of dye.

Fig. 8. One year after denervation of left kidney. X-ray 10 mins. after injection of uroselectan. Hydronephrosis diminished, marked improvement in secretion of dye.

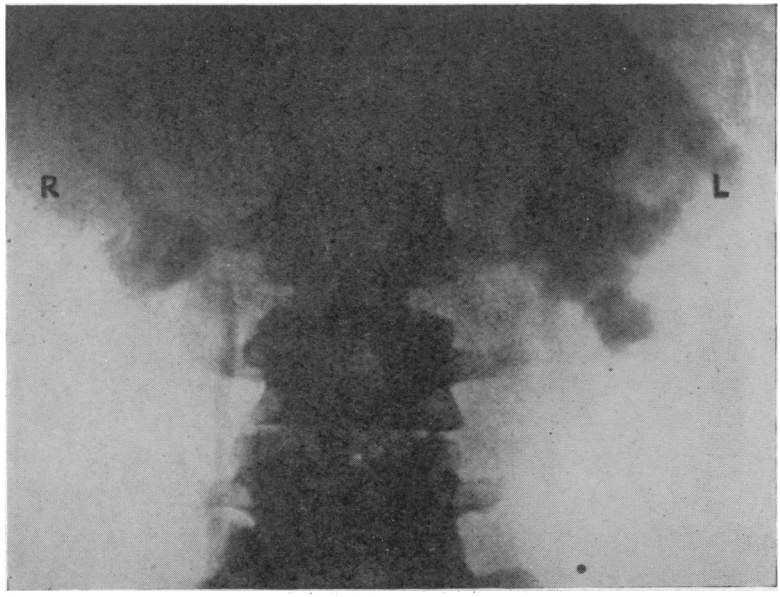

Fig. 9. Before Operation. X-ray 30 mins. after injection of uroselectan. Large left hydronephrosis.

Fig. 10. One year after operation. X-ray 30 mins. after injection of uroselectan. Hydronephrosis now very slight.

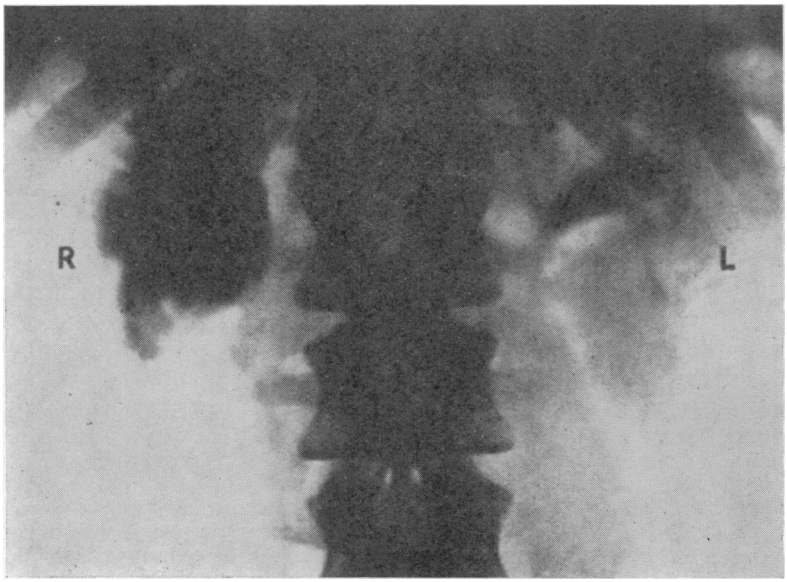

Fig. 11. Before Operation. X-ray 30 mins. after injecti n of uroselectan. Right hydronephrosis.

Fig. 12. Four months after denervation of right kidney. X-ray 30 mins. after injection of uroselectan. Hydronephrosis diminished.

operation, in May, 1934, no organic cause for the dilatation was found, though a large accessory artery was found running to the lower pole. Denervation was done. The patient was back at work within six weeks and has remained free of pain ever since. In this case there was considerable improvement in the hydronephrosis within four months. I have seen her since the war; she is perfectly well and has a daughter aged five. Her renal pelvis remains almost exactly as it was four months after operation.

In all, I have denervated 25 cases of well-defined hydronephrosis—the third stage of Harris's sympatheticotonus. In two cases, the hydronephrosis arose in solitary kidneys. In four patients the other kidney had already been removed on account of hydronephrosis, and in two patients, though the other kidney was present, it was functionless. All the patients have remained free from pain since operation. So far only one of the denervated kidneys has had to be removed and in this case it may almost be said that the nephrectomy was done by the patient.

Case 66. Male, aged 23. A Polish sailor, seen in 1940, had had intermittent attacks of renal pain in both loins for 12 months. The attacks had become more and more frequent. Investigation showed very gross hydronephrosis on the left side and a moderate hydronephrosis on the right side, both apparently dynamic in type. At operation, in December 1940, a huge left hydronephrosis was found. A plastic resection of the pelvis was done by Von Lichtenburg's method and the pedicle was denervated. On the day after operation he became maniacal, and succeeded in cutting open his wound with a safety razor blade and, pulling on the nephrostomy tube, tore out the stitches in the pelvis. The kidney was hanging out of the wound on the artery; the renal vein was torn off. The bleeding was severe and he was *in extremis* but recovered after nephrectomy. A year later I denervated the other kidney and he subsequently returned to duty and when I last heard from him, in 1943, he was serving in a ship in the Pacific.

In three cases, the dilatation was limited to the upper calyx. Five of the patients had a major plastic operation on the renal pelvis in addition to the denervation. One patient died 11 days after operation.

Case 87. Female, aged 54 years. Fifteen years previously the left kidney had been removed for hydronephrosis. For over two years she had had an ache in her right loin and this was getting steadily worse. X-rays showed a huge hydronephrosis of the right kidney. The renal function was poor and diminishing—N.P.N. 130. Operation December 1948. No organic obstruction seen, nephrostomy and renal denervation. After operation renal function failed to improve and the patient died 11 days later.

Of the 16 remaining cases all showed varying degrees of reduction in size of the pelvis; but one case, after a temporary improvement, has been found to have regressed recently.

Case 73. Seaman, aged 24 years. For six months had been having recurring attacks of right renal pain. Attacks had become more severe and frequent and on admission were occurring two or three times daily. Investigation showed hydronephrosis of the right kidney and congenital absence of the left. At operation in October 1945 no cause for the hydronephrosis was found and renal denervation was done. He has had no pain since operation. Radiography shortly after operation showed considerable improvement in the hydronephrosis and this was continued until recently when it was seen that the hydronephrosis was returning. The X-ray suggests that a stenosis

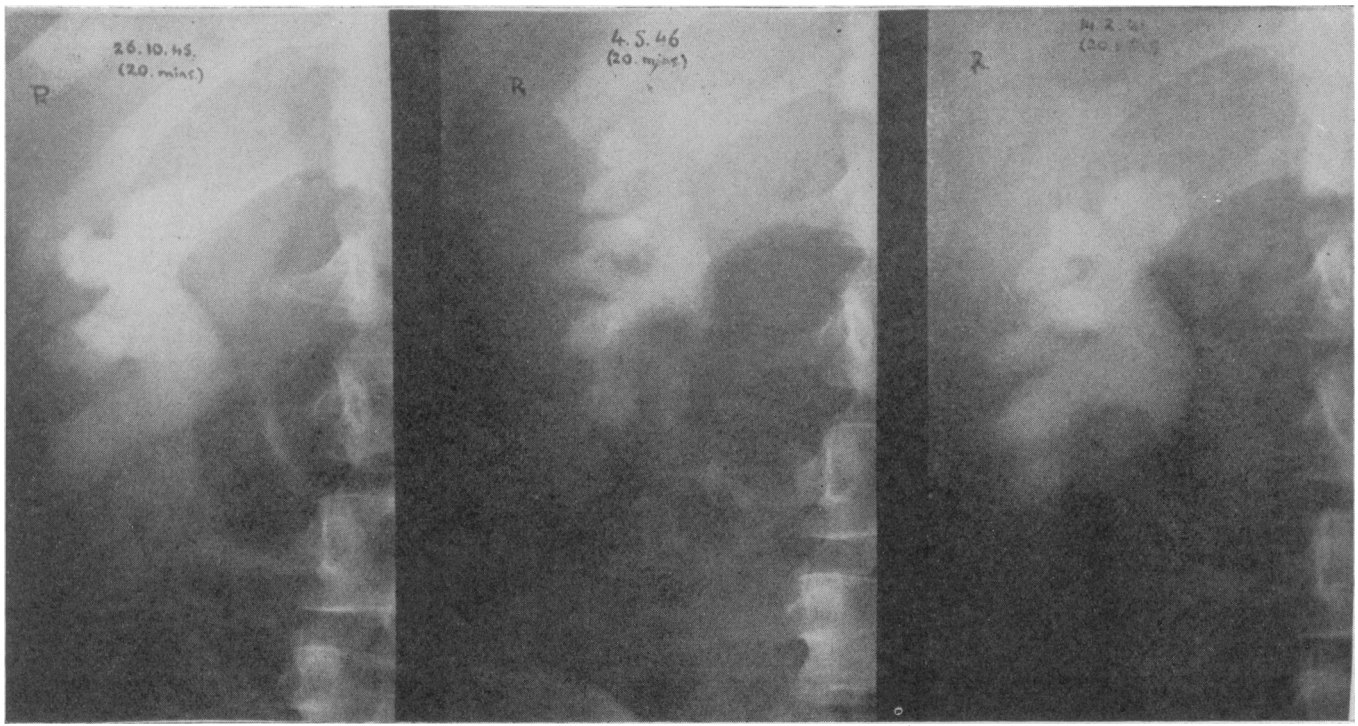

Fig. 13. X-ray 30 mins. after injection of uroselectan. (*a*) Before operation. (*b*) Six months after operation. (*c*) Five years after operation.

of the pelvi-ureteric function may be forming and urethral catheterisation and dilatation has been advised. (Fig 13.)

My present views on the treatment of hydronephrosis may be summarized as follows :—

(1) In the lesser degrees of hydronephrosis
  (*a*) If there is no mechanical obstruction—denervation.
  (*b*) If there is mechanical obstruction—correct or remove the obstruction and denervate the kidney.
(2) In gross hydronephrosis—a major plastic operation and denervation.
(3) If there is severe infection or the kidney is functionless, nephrectomy is indicated provided the remaining kidney is sound.

Nephroptosis

Most patients with nephroptosis have no symptoms, but if they have, they can usually be classified as belonging to one of four groups.

(1) Those with general visceroptosis. These patients should be treated conservatively. There is no indication for any surgical intervention on the kidney.

(2) A group with definite symptoms referable to the urinary tract. I believe that in these cases the pain is due to stasis in the renal pelvis, and that this stasis is a functional disturbance from dragging or twisting of the renal nerves, rather than to any mechanical obstruction from kinking or angulation of the ureter.

(3) In this group the symptoms are outside the kidney and there is nausea, abdominal pain and neurotic symptoms. It seems probable that in this group the symptoms are due to the kidney dragging and pulling on the various plexuses connected with the renal plexus. Stimulation of the solar plexus would cause the nausea and pain, and the pull on the supra-renal nerves might well explain the asthenia and neurasthenic symptoms.

(4) This group is a combination of both the preceding groups.

If surgical treatment is called for, I would suggest renal denervation as a substitute for nephropexy. The results of nephropexy are notoriously uncertain. I admit that some surgeons not infrequently get good results from nephropexy, but I think that their successes are only obtained because they unwittingly perform a more or less complete denervation when clearing the kidney and ureter, preparatory to fixing it.

Denervation will stop the pain in the kidney and cut off the reflex gastro-intestinal and other sympathetic disturbances. Freeing the ureter will straighten out any true or false ureteric kinks that may be present and, if the foot of the bed is elevated for one or two days after operation, the kidney will be held in a high position until adhesions form between it and Gerota's fascia.

Between 1931 and 1935 I denervated nine kidneys for pain which I believed to be due to nephroptosis. Since then nephroptosis has been

the indication for the operation in only six cases. Two of the first nine and one of the later cases must be classed as failures in so much as the patients complained either that their pain had continued or returned. In all three patients the pelvis, on the painful side, has remained insensitive to distension and I feel that it was not the operation that had failed but my diagnosis.

I would exclude as unsuitable for operation all cases with general visceroptosis. I should avoid operating on neurasthenics. I should not consider operation in any case unless there was definite renal pain and pyelography or pyeloscopy showed evidence of renal stasis, and, unless there was definite evidence of hydronephrosis, I would insist on every case being given a prolonged trial with conservative treatment.

Nephralgia

There is a third group of patients with renal pain in which routine examination, both before and at operation, is entirely negative. Whatever may be the source of this pain which, lacking a definite pathology, is sometimes called " nephralgia ",—whether it is a true neuralgia or neuritis, or is a sympatheticotonus causing increased intrapelvic pressure —division of the renal nerves is as logical a procedure as is division of the fifth nerve in trigeminal neuralgia. The work of the French and Italian urologists, the brilliant surgery of Hess (1928, 1931) in America, Harris (1930, 1935) in Australia and Bauer (1939, 1944) in Sweden, and the results reported by Woodside (1944), Wells (1935), myself and others in this country, all give practical proof of the value of denervation in this type of case.

Half of my cases can be classified as nephralgias though many of them could equally well be included in the second stage of sympatheticotonus and probably most of the remainder belong to Harris's first stage. A disproportionately large number of these cases showed congenital renal malformations. There were three horse-shoe kidneys and in one of these the painful side had a double pelvis. There were five cases of double pelvis. There was one case of crossed renal ectopia—here there was pain in both iliac fossæ and denervation was unsuccessful, though retrograde pyelography a year later was painless. Twice before 1930 I had to remove a congenital polycystic kidney as it was causing a great deal of pain ; if I had to deal with this problem to-day I should do a renal denervation.

Of the 52 cases which I have classed as nephralgia or sympatheticotonus, all but four have been free from their pain as long as I have been able to follow them—only three were followed for less than a year and were then lost during the war. Several have been kept under observation foı more than 18 years.

THE PRE-OPERATIVE EXAMINATION AND SELECTION OF PATIENTS

Renal denervation should never be considered in a case of renal pain until a complete urological examination of the patient has been made

and disease of the gall-bladder, gastro-intestinal tract, pelvic organs, spine and nervous system excluded. In my earlier cases I relied on indigo-carmine as a test of the function of the kidney but I now use intravenous pyelography for this purpose. In every case cystoscopy must be done and the ureters catheterized to make sure that there is no organic obstruction, and to collect a sample of urine from each kidney for examination. Gross infection of the urine is a contra-indication to denervation.

Retrograde pyelography is always done to confirm the results obtained with intravenous pyelography and because I put the greatest reliance in what we may call the pain reproduction or " filling test." When retrograde pyelography is done, careful note is made of the amount of fluid which, on injection, causes pain and the patient is then asked if this pain is similar to the pain which has caused him to seek treatment. It is remarkable how definite patients are in answering this question ; they never seem to have any doubt, and answer " Yes " or " No " without hesitation. Only if this test is positive should renal denervation be considered.

If it is clear that the pain is arising in the kidney, and there is definite non-mechanical hydronephrosis, there is no point in delaying operation ; but if the kidney seems to be normal then I believe that in the first place the patients should be treated conservatively. It should be explained to them that though their kidney was hypersensitive it was comparatively healthy and secreting urine well. If their symptoms persist and they appear to have real discomfort the urological investigation should be repeated later, and if it confirms the original findings then, and then only, should denervation be considered. The final decision in all cases can only be made when at operation it is found that there is no organic lesion and no other form of operation is indicated.

ANATOMY OF THE RENAL NERVES

I have referred to the lack of a good account in English of the physiology of the renal nerve supply ; it is remarkable that there is also no adequate description of the anatomy.

I have tried to depict in simple diagrammatic form (Fig. 14) the usual formation of the renal plexus as I have observed it at operation and in dissections.

The plexus arises by numerous small roots coming from the semilunar, superior mesenteric, and aortico-renal ganglia, direct from the lesser splanchnic and from the least splanchnic nerve, if it is present, and occasionally direct from the greater splanchnic. Only the right vagus nerve sends fibres to the solar plexus and all the evidence is against it having any connection with the renal plexus, or playing any part in the function or sensation of the kidney.

The various roots from which the plexus arises are collected together in three bundles—superior, inferior, and posterior. The superior renal

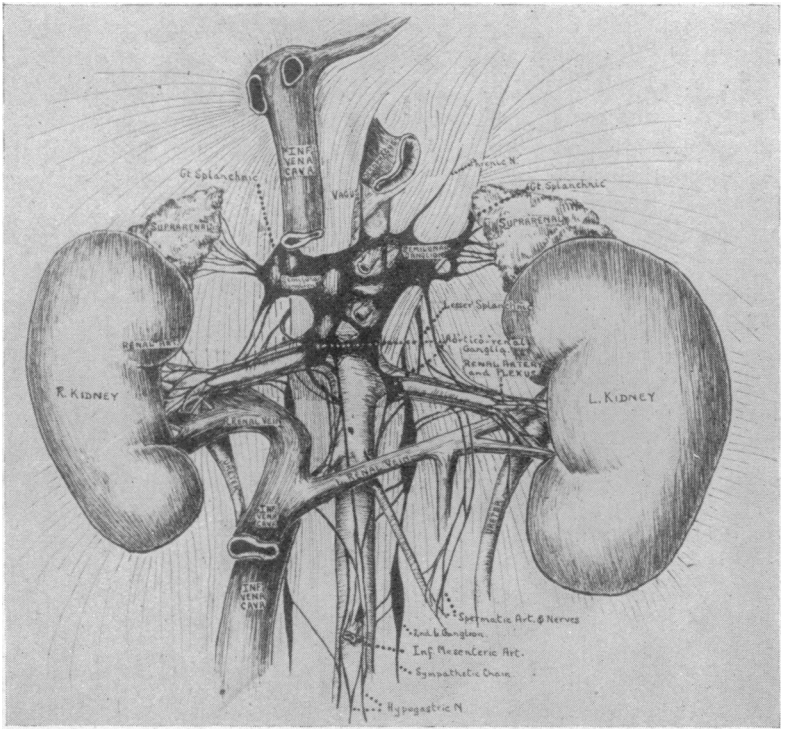

Fig. 14. Semi-diagrammatic representation of the Renal Plexus and its connections. The Inferior Vena Cava has been divided and the lower end has been turned down.

nerves—the largest bundle—consist of eight to ten nerves arising mainly from the superior mesenteric ganglion. They are at first about one centimetre above the renal artery, towards which they run obliquely downwards and outwards joining it usually over its outer third on the right side and over its middle on the left side and running along its upper surface. The inferior renal nerves, four to six in number, arise mainly from the aortico-renal ganglion and run along the inferior surface of the artery. The posterior nerves arise mainly from branches coming from the lesser or least splanchnic nerves; they are present only over the outer two-thirds of the artery and generally communicate with the first lumbar sympathetic ganglion. Near the hilum the posterior nerves give off a large branch—the superior nerve to the ureter.

It should be noted that the renal nerves do not form a network around the artery, but run parallel to it and that there are no fibres running along the front of the artery apart from an occasional fibre joining the inner ends of the superior and inferior renal nerves. Over the outer part of the

artery, as it divides, the nerves criss-cross in front and behind it to form a network around its branches. Everywhere the nerves are peri-arterial in arrangement. There are no nerves running with or in front of the renal vein but every artery, normal or abnormal, has its own plexus.

There are numerous anastomotic and other connections between the renal and the other abdominal nerve plexuses. Through its connections with the solar plexus it is closely related to the plexuses of all the upper abdominal organs. It plays a large part in the formation of the lateral inter-mesenteric nerve which, with its fellow, forms the inferior mesenteric plexus and carries on to take a part in forming the hypogastric plexus.

The suprarenal gland gets a double nerve supply ; a posterior group coming from the greater splanchnic nerve and joined by branches from the renal plexus, and a leash of nerves coming direct from the solar plexus and unconnected with the renal plexus. One can see how, when the kidney is prolapsed and the suprarenal remains in place, the suprarenal branches of the greater splanchnic will be dragged upon. Has this a part in the collapse and violent pain which sometimes occur in nephroptosis ?

The spermatic, or ovarian, plexus arises mainly from the aortico-renal ganglion but in addition often receives branches from the lower fibres of the renal plexus.

These anatomical points will explain why excising the nerves over the outer half of the renal artery is the best, easiest, and safest method of denervating the kidney. Nearer in, the fibres are fanned out and it is easier to miss dividing some of them ; moreover, the nerve supply of other organs will be damaged. Nearer the hilum the intimate investment of the branches of the artery by the nerves makes it difficult to excise them without tearing the vessels.

TECHNIQUE OF OPERATION

Renal Denervation requires great gentleness and patience. Good exposure and illumination are essential, otherwise the operation is difficult and dangerous.

No special instruments are needed ; but it will help to have long, fine dissecting forceps, hæmostats and scissors.

Spinal anæsthesia (nupercaine 1 : 1500), with the addition of gas, oxygen and ether or cyclopropane, gives not only complete muscular relaxation but with it the peritoneum falls away and exposes the root of the pedicle in a way which cannot be obtained with any other form of anæsthesia.

Almost always I have used an approach through the bed of the twelfth rib, which is resected sub-periosteally. Sames (1950) has recently described in the *Lancet* the technique and advantages of this incision. If the twelfth rib is very short, the eleventh rib may be excised instead ; this incision originally described by Fey (1926) has more recently been advocated by Mouat (1939). The kidney is delivered into the wound and, particularly

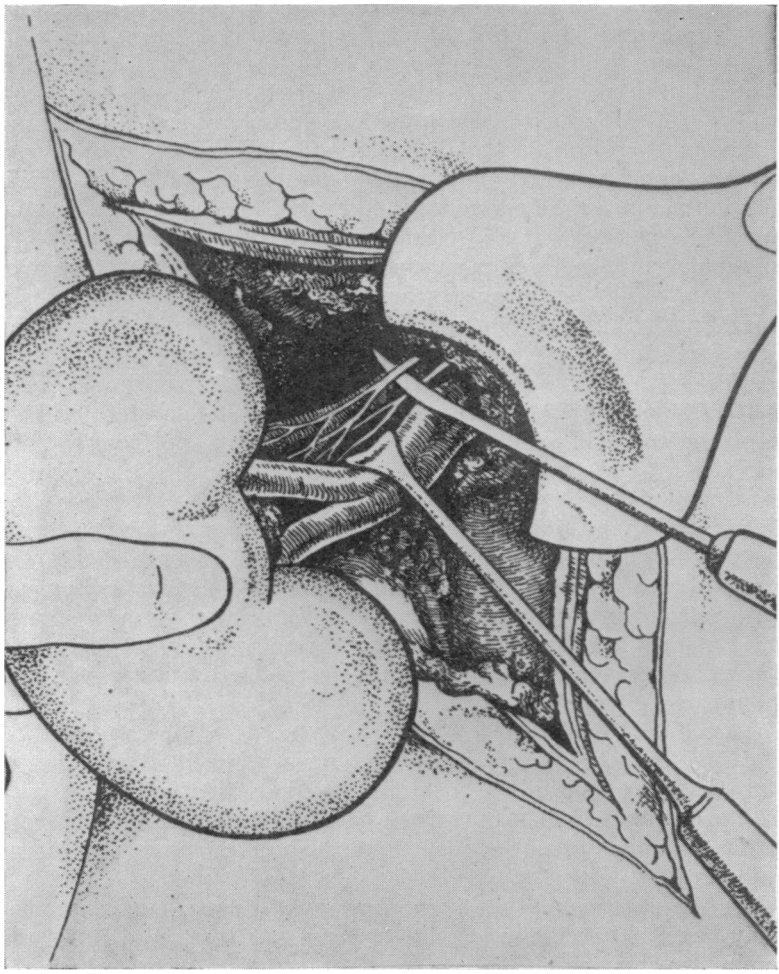

Fig. 15.

if the pedicle is short, a long strip of gauze is placed around the pedicle to retract and steady the kidney.

The fatty tissues are stripped away from the kidney and then comes the most difficult and delicate step in the operation—the cleaning of the pedicle and pelvis. In my earlier cases I followed the technique originally described by Papin (1921) by which the adventitious tissue is cleaned from the pedicle working inwards from the kidney towards the aorta. This is the natural and apparently the easiest way to clean the pedicle, but it is very prone to cause venous bleeding—the only real danger of the operation. The nerves and fatty tissue invest the renal vessels and their branches like a long glove and must be removed by working outwards from the inner end of the pedicle towards the kidney. If they are pulled off in the opposite direction something must give, and it is the most delicate structures, the finer veins and arteries, that are torn.

When the pedicle has been cleared of fatty tissue, the nerves will be seen running in bundles along the artery and its branches. The actual denervation can be begun on whichever aspect of the pedicle affords the readiest approach ; usually it is easier to start on the back of the pedicle, for the vein overlaps the artery in front. The nerve fibres are picked up over the inner end of the artery on a dissector or a strabismus hook (Fig. 15) and divided with fine pointed scissors. The cut distal ends are held with forceps and stripped gently towards the renal hilum and there cut. The process is repeated again and again until the artery is dissected clean for at least one inch.

Harris (1930) and others insisted on the need to strip the nerves right up to the hilum. That it is unnecessary to do so has been shown when discussing the anatomy of the nerves and this has been confirmed by the experimental observations of Hamburger (1935), and the results obtained in my patients. It is also dangerous, for it is well nigh impossible to strip the nerves off the smaller branches of the artery and vein near the hilum without causing bleeding.

The renal vein and its tributaries are as thin as tissue paper and tear very easily. Fortunately, the vein is free from nerve fibres and does not need to be stripped clean like the artery. Venous bleeding is at its worst when the kidney is pulled out of the wound. Even very severe venous bleeding can usually be controlled by replacing the kidney in its normal position and applying a muscle graft to the bleeding point.

When the main artery has been denervated, a search must be made for any abnormal arteries and they, too, must be stripped clean of their accompanying nerves. Finally, the upper ureter is separated from its bed and its fascial attachments, but no effort is made to clean it as completely as the artery. The kidney is now attached solely by its denervated pedicle and ureter. At this stage the artery will usually be found to have contracted down to a calibre hardly thicker than the lead of a pencil. Bauer (1939), who has written one of the best accounts of renal denervation, tells how in his first three cases a nephropexy was added not because

of any real ptosis, but because he was afraid to leave the kidney hanging by the fragile-looking vessels. I can sympathise with these fears which I, like him, have learnt to disregard.

To complete the process of denervation I paint the vessels and upper ureter with 10 per cent. phenol—this solution will destroy sympathetic nerve fibres without harming the ureter or vessels. Quite apart from any effect the phenol solution may have in destroying any filaments that have not been cut, it rapidly whitens them so that they can be more easily seen and divided.

The wound is closed with a small drain. After the operation the patient is kept lying flat and the foot end of the bed is raised for two to three days in order to keep the kidney in an approximately normal position until adhesions form.

In none of my first 40 cases did I combine renal denervation with nephropexy, decapsulation or plastic operations on the pelvis—not because I thought it would be wrong to do so, but because I wished to be able to present unequivocal evidence of the effects of denervation. In some of my later cases I have combined denervation with nephrostomy and with partial resections of the pelvis.

In two cases denervation has been performed transabdominally. In these cases there was some evidence suggesting lesions in the gall bladder. This approach which has been suggested by Quinby and others allows the renal nerves to be cut very close to their origin, but it is significant that both of these patients developed acute dilatation of the stomach post-operatively. Unfortunately, in the first case in which this happened, I was unable, owing to illness, to see this patient until the fourth day after operation when she was *in extremis*. The appropriate treatment was immediately adopted but it was too late. Post mortem examination showed acute dilatation of the stomach, but there was nothing else wrong apart from a small hæmatoma around the proximal cut end of the plexus. The second case was recognised immediately and cured by gastric aspiration.

Consideration of the anatomy of the renal nerves shows how interference with the nerves close to the aorta may involve the nerves of the stomach and intestines. I have met with acute dilatation of the stomach in one case in which the kidney was approached by a lumbar incision. In this case no drain had been inserted and a large collection formed; the dilatation responded promptly to treatment. It is interesting to note that of the only other two recorded fatalities after denervation, one—a case reported by Stone (1934)—showed profound intestinal stasis and distension.

RESULTS OF THE OPERATION

During the first two or three days after the operation practically all patients complain of severe pain—much more severe than one usually expects after most renal operations—but in the next two or three days the

pain eases off and it is completely relieved inside a week. Particularly in my earlier cases, repeated urological investigations were made at intervals after operation. In all cases there was a marked diminution in the secretion, but after a day or two the secretion usually increased and the denervated kidney was usually found to be secreting more than the normal kidney. After denervation indigo-carmine usually appears sooner in the urine, the jets from the ureteric orifice are more frequent and the volume of the stream greater, but concentration is not as deep as in the urine from a normal kidney. Within a few weeks these changes diminish and the secretion from the two kidneys becomes equal.

These clinical findings confirm the experimental work of Dogliotto (1930), who found that in the dog there was a partial regeneration of the renal nerves starting about three months after denervation.

In no case did any dilatation of the ureter or renal pelvis follow operation.

In all cases before operation pyelography caused severe pain and nausea, even when only a small amount of opaque medium had been injected. After operation it was impossible to cause pain or discomfort no matter how much fluid was injected into the pelvis. I have at times injected as much as 40 to 50 ccs., without the patient feeling anything. I admit that this experiment deserves severe condemnation; I must plead as my excuse experimental enthusiasm and the fact that uroselectan subsequently showed that the kidneys were still functioning perfectly. It may be said that probably part of the fluid injected in these cases escaped down the side of the ureteric catheter, but for all that the contrast between pre- and post-operative reactions and between the operated and normal kidneys was extraordinary. Between six and twelve months after operation some sensation returns and it is no longer possible to inject such large quantities into the renal pelvis without the patient having some discomfort; after 15 to 30 ccs. of fluid are injected they may complain of a dull ache in the loin, but they never have any of the severe pain, nausea or vomiting which occur so regularly before operation. Clinically, therefore, it would appear that, though some regeneration of the nerves takes place this regeneration is never complete.

It is customary to end a lecture with some well-turned and elegant phrases, but I shall refrain from this for I feel I must end with a warning; a warning of the need for discretion in the selection of patients and of the necessity for complete and careful investigation of every case before renal denervation is considered. Thus, and thus only, shall we avoid the risk of this valuable operation falling into disrepute.

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THIRD ANNIVERSARY OF THE FACULTY OF DENTAL SURGERY

THE THIRD ANNIVERSARY of the Faculty of Dental Surgery of the Royal College of Surgeons of England was held at the College on 14th July, 1950.

The President of the College, Sir Cecil Wakeley, K.B.E., C.B., addressed the meeting, as did also Professor R. V. Bradlaw, C.B.E. (Dean), and Dr. E. W. Fish, C.B.E.

The Meeting was followed by two Charles Tomes Lectures, given by Professor Lester Cahn on " The Jaws in Generalised Skeletal Disease " and by Professor A. B. P. Amies on " Epulides."

The Third Anniversary Dinner was held in the evening at which a number of distinguished guests were present, including :— Mr. V. K. Krishna Menon, Miss E. M. R. Russell Smith, Professor and Mrs. Amies, Professor and Mrs. Lapira, Sir Luigi and Lady Preziosi, Dr. Hosam El Din, Dr. M. A. W. and Mme. Mooro Pasha, Admiral and Mrs. Forsyth, Professor and Mrs. Cahn.