AN EXPERIMENTAL MORPHOLOGICAL STUDY OF THE NERVOUS APPARATUS OF THE KIDNEYS *

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No complete study has been made of the innervation of the mammalian or human organs of urinary excretion. The distinctive embryogenesis of the kidneys, which are the only organs which in the course of development become displaced rostrally, complicates the description of their innervation. In schemes which have been published, innervation of the kidneys [2, 9] is usually shown only as an association of the organ with the plexuses of the abdominal cavity and with the splanchnic nerves, as demonstrated by dissection. Nevertheless, to study nervous renal regulatory activity and the reflex relationships of the kidneys with other viscera a more precise knowledge is needed of the sources of their innervation and the pathways involved.

In order to study the renal nervous apparatus we have used the method of experimental and morphological analysis of innervation of the viscera, a method which has been proved first of all by an experiment of the Kazan' School of Neurohistology, which is the oldest in the country. The method consists in separating the peripheral nerve fibers from their trophic centers - the neurones - and establishing in the organ a secondary (Wallerian) degeneration of the severed distal segments of the fibers and their terminations.

EXPERIMENTAL METHOD

In the work we used the method of Bielschowsky-Gros-Lavrent'ev, Bielschowsky-Buke, and of Cajahl-Favorskii. We studied material taken after 119 operations on dogs, cats, rabbits, white rats, ducks, and chickens. We carried out 5 series of experiments: I - removal of the spinal ganglia at various levels (43 cases); II - division of the splanchnic nerve (22 cases); III - removal of the sacral plexus (10 cases); IV - division of the vagus (25 cases); V - denervation of the kidneys (9 cases).

EXPERIMENTAL RESULTS

On the 1st and 2nd days after extirpation of the spinal ganglia reactive changes were found in the afferent terminations in the renal parenchyma: there was an argentophilia, swelling, and an increased impregnation, and the terminations had become coarser. Then degenerative changes ensued: on the 3rd day there were indications of breakdown of the receptors. Material obtained after unilateral extirpation of the spinal ganglia indicated the existence of a marked crossed afferent innervation of the kidneys.

The results of the I set of experiments allowed us to conclude that chiefly five of the inferior thoracic and all the lumbar spinal ganglia are involved in renal innovation. The densest afferent supply was from the 3 lower thoracic and the 2 upper lumbar pairs of spinal ganglia.

According to most authorities [2, 6, 7, 8], the splanchnic nerves contain most of the sensory nerve fibers of the abdominal cavity. However, until now there has been no opportunity for studying degeneration of sensory terminations

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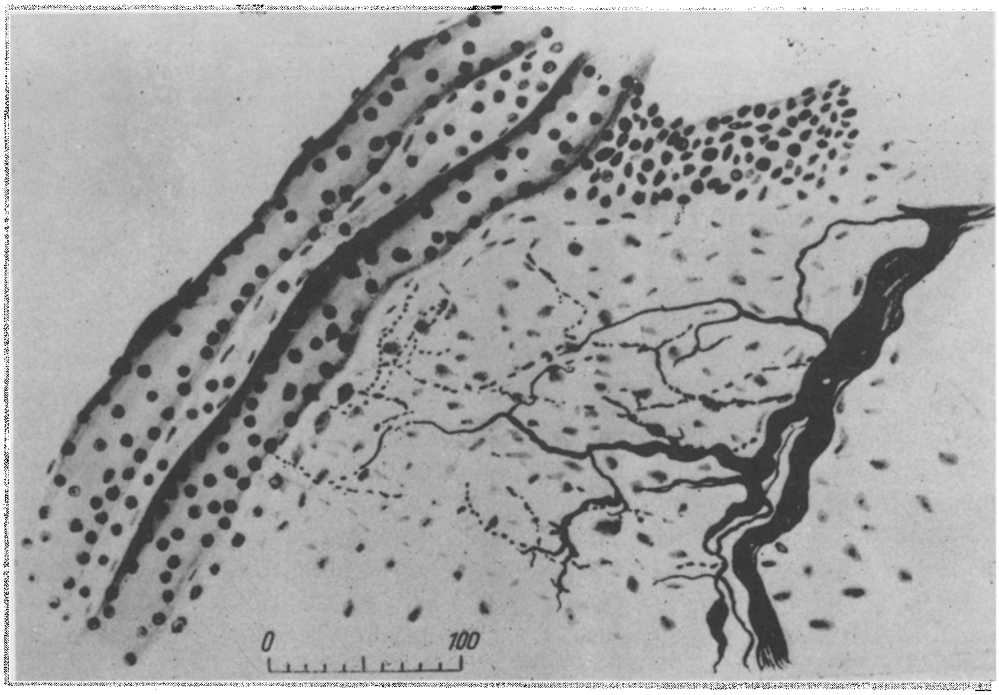

Fig. 1. Disintegration of a nerve termination in feline renal parenchyma 74 h after extirpation of the pelvic plexus. Method of Bielschowsky-Gros. Scale in μ .

in the kidney after division of these nerves. We have, therefore, paid particular attention to the condition of the afferent endings after splanchnotomy. Analysis of the preparations in the kidney and its capsule revealed degenerating receptor endings.

In the II set of experiments we were able to show that in the rabbit the splanchnic nerves grow into the metanephros on the 14th-16th day, whereas in man they do so between the 6th and 7th week of intra-uterine life. In the rabbit embryo the nerve fibers penetrate into the kidney on the 17th day, and in the human embryo they do so in the 3rd month.

In undertaking the III series of experiments (removal of the pelvic plexus) our starting point was that the kidney is the only organ in the abdominal cavity which becomes shifted forward during development. During the "ascent" of the metanephros into the lumbar region, judging by the embryological data which we collected, the kidney nerve fibers grow out from the sacral plexus and run immediately behind the kidney along the ureter [8]. To test this hypothesis concerning the connections of the sacral plexus with the kidneys, we extirpated it. Degeneration of some of the nerve endings in the parenchyma of the organ could be observed 74 h after the operation (Fig. 1).

In the IV set of experiments we studied the influence of vagotomy on the renal nervous apparatus in birds (chickens and ducks), and in mammals. In the former we were able to observe a change in the pericellular apparatus of neurones in the metanephros, though we failed to observe any degeneration of nerve fibers on the nephrons in representatives of either class. When we consider results obtained by physiologists on the action of the vagi on the kidney, in particular on the uriniferous tubules, we may suppose that the preganglionic fibers of the vagus make connection chiefly with neurones of the renal plexus, and, to some extent, with the neurones which we have described [4, 8] within the organs, but that no direct vagal fibres in the renal parenchyme penetrate directly into the nephrons. In the literature of the embryogenesis there is no information concerning the entry of the vagal fibers into the kidney.

Recently, the author together with Kh. S. Khamitov [3], as a result of a comparative histological study of both normal and pancreatectomized animals have found a small number of cholinergic fibers in the renal nervous apparatus, a result in line with the veiw that there is a low density of parasympathetic fibers in the kidney.

In studying the nervous apparatus of kidneys after denervation and removal of the capsule, a varied picture of changes in the nervous elements can be observed. By the 3-4th day in the renal parenchyma and along the nerve-fiber bundles, growth cones were very evident. The changes in the receptor structures were particularly clearly shown.

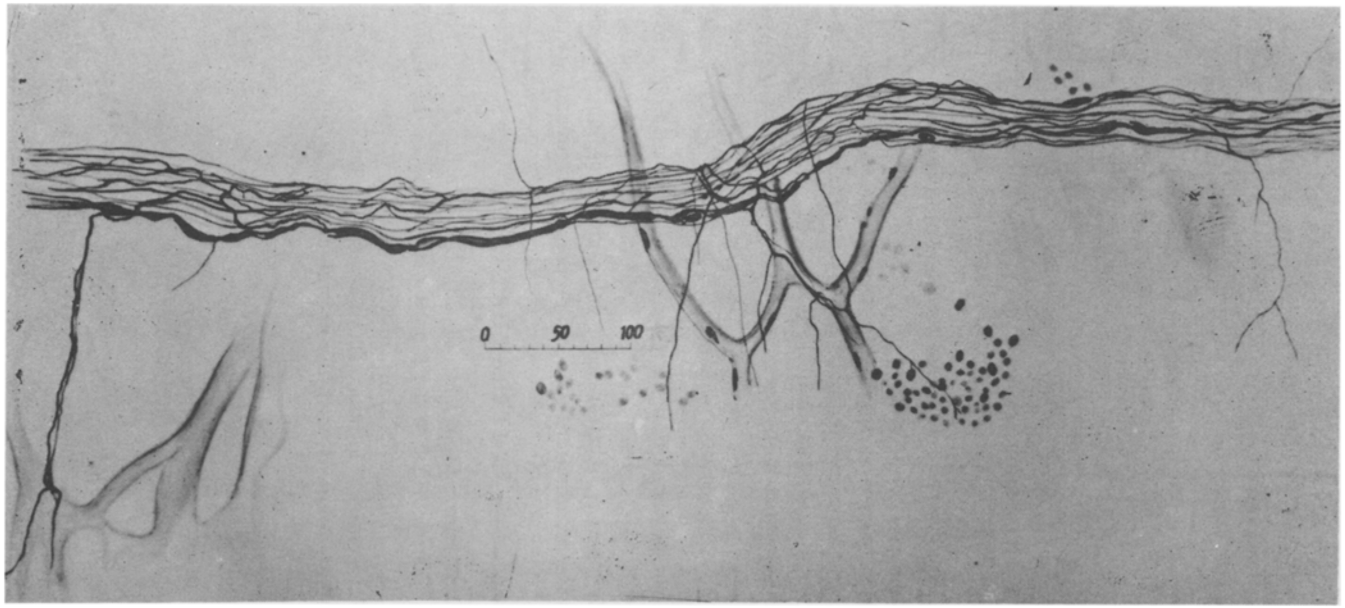

Fig. 2. Distribution of the terminal receptor endings within an autonomic nerve trunk. Renal pelvis of cat. Method of Bielschowsky-Gros. Scale in μ .

On some of the afferent fibers huge swellings had formed, as well as areas which, in some places, were as large as moderate-sized nerve cells. At various times after the operation, completely undegenerate and unchanged nerve fibers could be seen alongside a mass of degenerating nerve fibers. This phenomenon could also be observed 5-10 days after denervation of the kidneys, although the question of regeneration of the nerve fibers was still quite out of the question.

It remained to determine whether we were concerned with some unusual source of the fibers, or whether the remaining fibers belonged to neurones of the kidney itself. Although it has been studied for about a hundred years [4, 5], the problem of the existence of true nervous elements within the kidney, has not as yet been solved.

By using the Lavrent'ev method of fixation, and studying the urinary organs of representatives of various vertebrate classes we demonstrated that nervous elements were present in the kidneys of all the animals, and found that in the mammals they were concentrated in the renal pelvis.

Thus, it was found that the nerve fibers which could be seen 5-10 days after denervation belonged to the neurones proper to the kidney itself, a circumstance which has not been envisaged even in the most recent and specialized studies. We also investigated the nervous elements of transplanted kidneys up to 3 years after the operation on material offered to us by V. L. Balakshina. Only some of the nerve fibers had regenerated after this long time. At earlier times (1-2 weeks after denervation or after transplantation of the kidney) the only neurones that remained were those proper to the kidney itself. The discovery in the kidney of neurones of which a proportion belonged to cells of type II Dogiel convinced us of the existence of a genuine nervous apparatus within the kidney [8].

Another proof of the existence of innate renal nervous apparatus has been the discovery in most recent neurohistological work [1] of nervous plexuses of afferent terminations of cerebrospinal nerve fibers. It is known that the presence of an afferent innervation of the kidneys, as of other viscera, is a morphological expression of a control over the activity of the nervous apparatus exerted by the nervous system [4, 8]. One of the pictures of the receptor innervation of the nerve trunks of a kidney is shown in Fig. 2: from a thick afferent fiber running in a bundle of unmyelinated nerve fibers there emerge free bushy receptor structures terminating directly between the other fibers.

SUMMARY

The presence of an independent nervous apparatus in the kidneys with ganglion cells was found when the kidneys of certain mammals and birds were studied after removal of the spinal ganglia, after splanchnotomy, vagotomy, or extirpation of the pelvis nerves, or after denervation and transplantation of the kidneys. Afferent nerve endings belonging to this nervous apparatus were found to be present in several areas.

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