SOURCES AND PATHWAYS OF AFFERENT INNERVATION OF THE ADRENALS

P. I. Lobko

UDC 612.45 : 612.811.3

By unilateral extirpation of the spinal ganglia at the level C_5-S_1 and impregnation of sections through the adrenals with silver, the afferent innervation of these glands in cats was studied. The results showed that the adrenals possess a multisegmental unilateral and bilateral afferent innervation, the sources of which are cells of the spinal ganglia. The peripheral sources are afferent neurons located in the gland itself and in the trunks connecting the adrenals with the central nervous system.

The problem of transplantation of viscera, including parenchymatous organs, necessitates the study of sources of afferent and efferent innervation of these organs, paying particular attention to the role of peripheral intrinsic afferent neurons in the maintenance of viability of the transplanted organ.

The object of the present investigation was to determine the gradient of the principal and accessory central and peripheral sources of afferent innervation of the adrenals.

EXPERIMENTAL METHOD

Unilateral extirpation (on the right and left sides separately) of the spinal ganglia at the level of between C_5 and S_1 was carried out on 96 cats under general ether anesthesia. The animals were sacrificed between 24 h and 14 days after the operation. Material was treated by the Bielschowsky-Gros, Campos, and Rasskazova methods. The sources and pathways of afferent innervation of the adrenals were studied.

EXPERIMENTAL RESULTS

The results showed that the adrenals possess a multisegmental unilateral and bilateral afferent innervation. After unilateral extirpation of the spinal ganglia from C_5 to D_3, no changes were found in the nervous structures in the adrenals. After extirpation of spinal ganglia D_{4-b} solitary degenerating nerve fibers and their endings were found in the ipsilateral adrenal. Degenerating nerve endings in the adrenal were found more frequently after extirpation of ipsilateral spinal ganglia D_{7-10}. A sharp increase in the number of degenerating nerve fibers and endings was observed in the adrenal after unilateral extirpation of spinal ganglia D_{11-13}. Extirpation of spinal ganglia L_{5-6} resulted in degeneration of single fibers and their endings in the adrenal. After removal of spinal ganglia caudally to L_6, no degenerating nerve fibers were found in the adrenals.

Data in the literature [1, 8, 11] indicate that between 3 and 7 different spinal segments are concerned in the afferent innervation of the adrenal. The results of the present investigation agree with other data in the literature [9] and demonstrate that processes from cells in 16 spinal ganglia (D_4-L_6), located at different distances from the gland (Fig. 1), participate in the afferent innervation of the adrenals. Hence, with the example of the adrenal, these investigations confirm the previous hypothesis [2] regarding the

Department of Human Anatomy, Minsk Medical Institute. (Presented by Academician of the Academy of Medical Sciences of the USSR A. P. Avtsyn.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 70, No. 8, pp. 111-115, August, 1970. Original article submitted April 21, 1969.

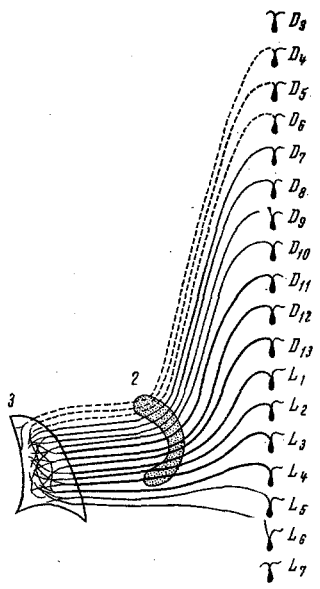

Fig. 1

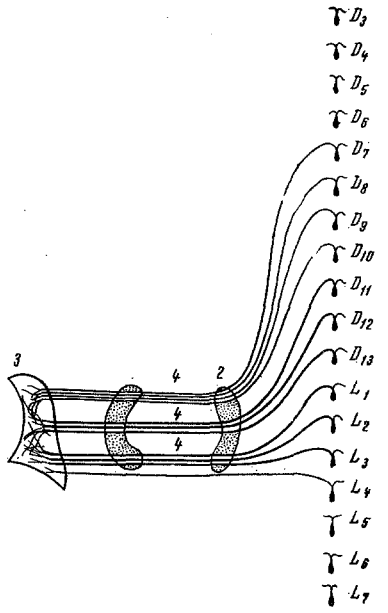

Fig. 2

Fig. 1. Sources of afferent spinal nerve fibers of the ipsilateral adrenal (cat). 1) Cells of spinal ganglia; 2) celiac ganglion; 3) adrenal.

Fig. 2. Sources of afferent spinal nerve fibers of the contralateral adrenal (cat). 1) Cells of spinal ganglia; 2) celiac ganglia; 3) adrenal; 4) cross-connections.

multisegmental nature of the sources of afferent innervation of the internal organs. The multisegmental principle does not mean that all spinal ganglia participate to an equal degree in the innervation of individual organs. On this basis the hypothesis [3] of principal and accessory sources of spinal sensory innervation of internal organs has been put forward.

The writer considers that it is best to separate the whole group of sources of afferent innervation of internal organs into central and peripheral. The central sources are cells in the dorsal root ganglia of spinal nerves and corresponding ganglia of the cranial nerves. In accordance with D. M. Golub's terminology, in this case it is possible to distinguish the principal sources, namely spinal ganglia from which the greatest number of fibers run to a particular organ, and accessory, from which a few nerve fibers participating in the innervation of these organs arise.

On the basis of these results, the central sources of afferent innervation of the adrenal can be subdivided into principal ($D_{11}-D_{13}$ and L_1-_4) and accessory. The latter are represented by sensory neurons whose bodies lie in 7 spinal ganglia (D_4-D_{10}), cranially to the principal source, and in 2 ganglia (L_5-L_6), located caudally to the principal source.

The pathways along which afferent nerve fibers reach the ipsilateral adrenal are the white rami communicantes of the corresponding spinal nerves. Along these rami the nerve fibers reach the sympathetic trunk. They run along this trunk for varying distances and leave it to form the splanchnic nerves or individual branches to the solar plexus. Some fibers pass through the ganglia of the solar plexus, and proceed to the adrenal in branches leaving these ganglia. Other fibers, arising mainly from the dorsal lumbar spinal ganglia, in their journey to the adrenal pass through the abdominal aortic and renal plexuses.

Besides their ipsilateral innervation, the adrenals also possess a crossed afferent innervation [2, 7]. Following unilateral extirpation of the more cranial spinal ganglia (down to L_6 inclusive), no degenerating nerve fibers or receptor endings could be found in the opposite adrenal. Subsequent extirpation of spinal ganglia from D_7 to D_{10} caused a gradually increasing degree of destruction of nerve fibers and endings in the contralateral adrenal. Massive degeneration of afferent nerve structures in the contralateral adrenal appeared following extirpation of spinal ganglia D_{11-13} and L_{1-3}. Extirpation of spinal ganglion L_4 led to degeneration of only a few fibers in the contralateral adrenal. These experiments showed that processes

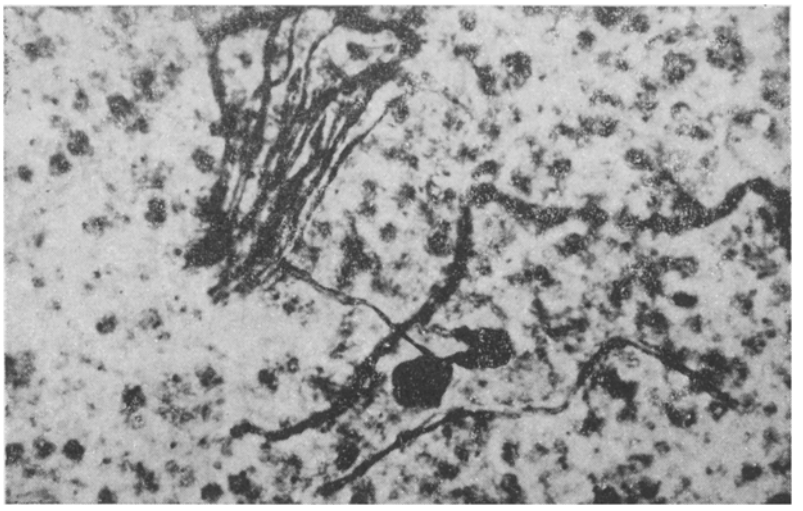

Fig. 3. Sensory nerve cell in medulla of the right adrenal of a cat 3 days after extirpation of spinal ganglia $D_{13}-L_1$ on the left side. Bielschowsky-Gros, 600 ×.

from cells in 11 spinal ganglia participate in the afferent innervation of the contralateral adrenal. Here also principal and accessory central sources can be distinguished The principal sources are cells of spinal ganglia D_{11-13} and L_{1-3}. The accessory sources are located in spinal ganglia D_{7-11} and L_4 (Fig. 2).

According to data in the literature [2] and the writer's own observations, the pathways along which afferent nerve fibers reach the contralateral adrenal are cross connections (commissures) joining symmetrically opposite structures of the autonomic nervous system at the periphery (Fig. 2). In addition, remembering the findings obtained by other workers [10], the possibility that afferent nerve fibers may cross to the opposite side in commissures located in the central nervous system likewise cannot be ruled out.

Introduction of the term "peripheral sources" (P. I. Lobko) has the advantage that it is possible to unify into one group the numerous afferent neurons located within the organ (intramurally), and also in the autonomic ganglia, trunks, and plexuses providing the afferent innervation of the internal organs and connections between these organs and the central nervous system.

The peripheral sources of afferent innervation of the adrenals are sensory neurons of varied structure, located in the substance of the adrenal gland, in ganglia of the extramural adrenal plexus, or in the ganglia and nerve trunks along the pathway from the central nervous system to the adrenals. The presence of such neurons in the ganglia and plexuses of certain divisions of the autonomic nervous system has been demonstrated [4-6].

In the study of material obtained from the experimental animals, sensory neurons were found in the adrenals themselves. A sensory bipolar nerve cell with its processes close together, found in the medulla of the right adrenal of a cat 3 days after extirpation of spinal ganglia D_{13} and L_1 on the left, is illustrated in Fig. 3. The body of the neuron and one of its processes is strongly impregnated, and along the course of the process, pools of neuroplasm can be seen. The second process is normal in structure. This observed reactivity of the sensory neuron lying in the substance of the adrenal is evidently similar in character to the retrograde reactive changes in response to division of the process running to the central nervous system in the dorsal root of spinal nerves D_{13} or L_1. Such changes in the structure of afferent neurons lying within the adrenal after extirpation of spinal ganglia or division of the corresponding autonomic trunks is evidence of a direct connection between the intramural sensory neurons and the central nervous system or of the influence of processes of cells in the spinal ganglia on the structure of peripheral afferent neurons.

Peripheral sources, like central, can evidently be divided into principal and accessory. The principal sources are most frequently single afferent neurons or groups of neurons; they constitute the intramural nervous apparatus of the internal organs (adrenals). Accessory sources include sensory nerve cells scattered along the course of the conducting pathways.

The pathways connecting peripheral neurons with the central nervous system evidently run in the nerve trunks and plexuses through which the adrenals are connected with the spinal cord and brain. Processes of peripheral sensory neurons running to the central nervous system can also run a crossed course. These cross-communications may take place both in intraspinal commissures and in fibers connecting symmetrical opposite structures of the autonomic nervous system at the periphery. Crossed central processes of peripheral afferent neurons of the adrenals in such cases enter the central nervous system along the vagus nerves and dorsal routes of the spinal nerves on the opposite side.

The results given in this paper may be important for cybernetics. This example of the afferent innervation of the adrenal demonstrates, on the one hand, the reliability of information based on the excessive character of organization of the nervous system (the multisegmental principle). On the other hand, it illustrates the multiplicity of channels of communication between an organ and the central nervous system.

The presence of sensory neurons in the adrenals, and their dispersion in the peripheral portion of the conducting pathways, plus the central (spinal) sources of afferent innervation of the adrenals illustrate the excessive character of organization of the nervous system which, by forming multiple channels of communication with the central nervous system, ensures a smooth and reliable system of compensatory and adaptive mechanisms in the activity of the nervous system and in the receptor innervation of internal organs.

LITERATURE CITED

1. A. D. Baturina, in: Problems in Clinical and Experimental Neurology and Psychiatry [in Russian], Khar'kov (1936), p. 431.
2. D. M. Golub, in: Problems in Morphology of the Peripheral Nervous System [in Russian], No. 2, Minsk (1953), p. 5.
3. D. M. Golub, in: Problems in Morphology of the Peripheral Nervous System [in Russian], No. 6, Minsk (1963), p. 3.
4. D. M. Golub, in: Morphology of the Peripheral Nervous System [in Russian], Minsk (1966), p. 12.
5. N. G. Kolosov, Dokl. Akad. Nauk SSSR, 161, No. 2, 490 (1965).
6. L. A. Leontyuk, in: Morphology of the Peripheral Nervous System [in Russian], Minsk (1966), p. 112.
7. P. I. Lobko and D. M. Golub, in: Problems in Morphology of the Peripheral Nervous System [in Russian], No. 4, Minsk (1958), p. 80.
8. E. S. Fridman, in: The Nervous System and Internal Secretion [in Russian], Leningrad (1932), p. 60.
9. D. Kh. Khamidov, N. K. Landshman, and K. A. Zufarov, Dokl. Akad. Nauk Uzbek SSR, No. 11, 67 (1964).
10. M. B. Shtark, Abstracts of Proceedings of the 1st Belorussian Conference of Anatomists, Histologists, Embryologists, and Topographic Anatomists [in Russian], Minsk (1957), p. 359.
11. T. Kiss, Acta Anat. (Basel), 13, 81 (1951).