THE SPINAL SENSORY COMPONENT OF THE GANGLIA OF THE SYMPATHETIC NERVOUS SYSTEM

N. K. Landshman

Department of Histology and Embryology (Head – Corresponding Member AN SSSR Prof. G. K. Khrushchev, Director of Research – Prof. T. A. Grigor'eva) of the Second Moscow Medical Institute (Director – Docent M. G. Sirotkina)

(Presented by Active Member AMN SSSR V. N. Chernigovskii)

Translated from Byulleten' eksperimental'noi biologii i meditsiny Vol. 49, No. 1, pp. 122-125, January, 1960

Original article submitted July 29, 1959

The sensory innervation of the internal organs by the peripheral processes of neurones whose bodies lie in the spinal ganglia is now accepted beyond doubt. An important part in the discovery of the spinal sensory innervation of the internal organs was played by B. I. Lavrent'ev and his pupils, who proved experimentally the spinal sensory innervation of the heart [16], the blood vessels [3], the adrenals [9], and the urinary bladder [17]. Thd spinal sensory innervation of all the internal organs [6] and blood vessels [5, 8] was subsequently demonstrated.*

The spinal sensory fibers pass into the sympathetic trunk from the spinal nerves, via the rami communicantes, and then pass both caudally and cranially along the sympathetic trunk [2, 7, 20, 21]. Therefore, through any given segment of the sympathetic nervous system, spinal sensory fibers pass from the whole series of intervertebral ganglia. For instance, through the greater splanchnic nerve and the celiac ganglion pass spinal sensory fibers from the lower cervical [14] and thoracic [7, 10, 19] intervertebral ganglia, the bulk of them being derived, according to these authors, from the spinal ganglia $D_6 - D_{10}$. Through the stellate ganglion pass spinal sensory fibers from intervertebral ganglion $C_5 - L_2$ [13].

We have been unable to find in the literature any reports giving an accurate quantitative description of the sources of the spinal sensory fibers passing rhrough the individual sympathetic ganglia. The aim of the present research was to make quantitative analysis of the segmental distribution of the spinal sensory component of the celiac, stellate, and superior cervical sympathetic ganglia.

METHODS

In 3 series of experiments the celiac, stellate, and superior cervical sympathetic ganglia were extirpated unilaterally or bilaterally in adult cats. In each series the extirpation was done unilaterally in 3 animals and bilaterally in 2-5 animals. Control operations were also performed (under the same conditions, but the corresponding ganglia were not removed). The animals were killed with ether 8-19 days after operation. With unilateral extirpation of the sympathetic ganglia, all the cervical, thoracic, and lumbar intervertebral ganglia on both sides were taken for examination, and with bilateral extirpation and after the control operations, the same intervertebral ganglia from one side of the body of the animal were taken.

In addition, the spinal ganglia of clinically healthy, unoperated animals were studied. The ganglia were fixed in alcohol and embedded in paraffin wax. Serial sections of the intervertebral ganglia were cut to a thickness of 8 μ, every tenth section being retained for examination. The sections were stained with toluidine blue, and also with gallocyanine.

In extirpating any sympathetic ganglion, naturally all the spinal sensory fibers passing through it were divided. In consequence of this, retrograde changes arose in the corresponding neurones of the intervertebral ganglion (Fig. 1, a and b). By employing this phenomenon we were able to determine both the localization of the neurones whose processes passed through the extirpated sympathetic ganglion, and the number of these neurones in all the cervical, thoracic, and lumbar intervertebral ganglia. The latter was done by counting the number of nerve cells undergoing retrograde changes in the serial sections of all the intervertebral ganglia taken from the animals after unilateral extirpation of the sympathetic ganglia. We estimated the total number of neurones undergoing retrograde changes separately in the intervertebral ganglia on right and left sides. Then, also separately in the ganglia of the right and left sides, we calculated the percentage content of these neurones in each interverte-

*Questions relating to the role of the Dogiel Type 2 cells are not discussed in this paper.

bral ganglion. Mean values were deduced for all the series of experiments.

RESULTS

After extirpation of the celiac ganglion of the solar plexus, we found retrograde changes in neurones in all the cerebrospinal ganglia at the level of the segments C_5-L_4. This meant that through the celiac ganglion of the solar plexus passed processes from neurones whose bodies were situated in intervertebral ganglia C_5-L_4 on the ipsilateral side of the animal's body. The bulk of these neurones (89.6%) were concentrated in the intervertebral ganglia D_7-L_3 (Fig. 2). Through the celiac ganglion also passed processes from nerve cells of intervertebral ganglia C_6-L_4 of the contralateral side; these cells, however, were only one fifth as frequent as in the cerebrospinal ganglia after removal of the ipsilateral celiac ganglion. These nerve cells were also distributed irregularly in the intervertebral ganglia on the contralateral side.

Through the stellate ganglion passed processes of neurones whose bodies lay in intervertebral ganglia C_2-L_4 on the ipsilateral side of the body. These neurones were mainly in intervertebral ganglia C_6-D_5 (74% Fig. 3). Neurones of spinal ganglia C_2-L_3 of the contralateral side also sent their processes to the periphery through the stellate ganglion, but such neurones were from 2 to 2.6 times less frequent than in the cerebrospinal ganglia of the ipsilateral side, although the gradient of their distribution among the spinal ganglia of the contralateral side was similar to that of the ipsilateral side.

Through the superior ceruical ganglion passed processes of nerve cells in intervertebral ganglia C_2-D_4 of both ipsilateral and contralateral sides. The numbers of these nerve cells, however, were comparatively small. For instance, whereas through the celiac ganglion passed 913-1204 processes of spinal sensory neurones from the ipsilateral side, and through the stellate ganglion 450-714 processes, through the superior cervical sympathetic ganglion only 30-35 processes passed from the intervertebral ganglia on the ipsilateral side. In intervertebral ganglia C_2 and C_3 the number of nerve cells sending processes through the superior cervical sympathetic ganglion was as a rule larger (5-7 neurones in each ganglion) than in ganglia C_4-D_4 (2-4 neurones in each ganglion).

In the intervertebral ganglia of the control and clinically healthy animals, neurones showing retrograde changes were encountered extremely rarely; only in occasional ganglia did we find solitary nerve cells with signs of retrograde changes.

D. M. Golub [1] showed that through any given ganglion of the sympathetic nervous system pass processes from neurones of a large number of intervertebral ganglia; the bulk of these neurones, however, lies in intervertebral ganglia situated close to this particular area of the sympathetic nervous system, and only a

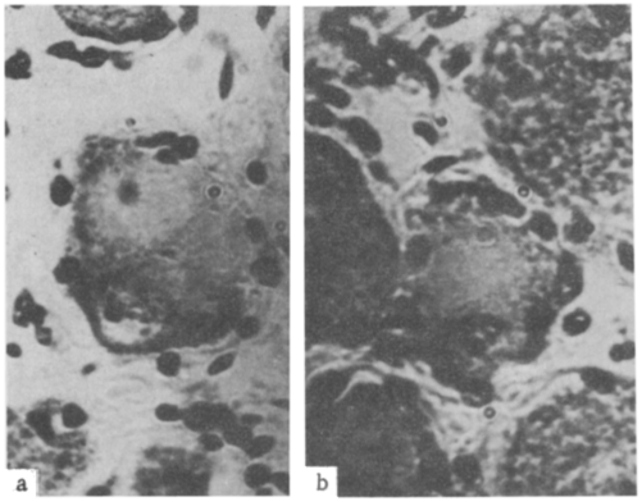

Fig. 1. Retrograde changes in a cell in cerebrospinal ganglion D_2 on the right side 12 days after extirpation of the right stellate ganglion (a). Retrograde changes in a cell in cerebrospinal ganglion C_3 on the right side 16 days after extirpation of the right superior cervical sympathetic ganglion (b). Alcohol. Toluidine blue. Magnification: ocular 10 ×, objective 40 ×.

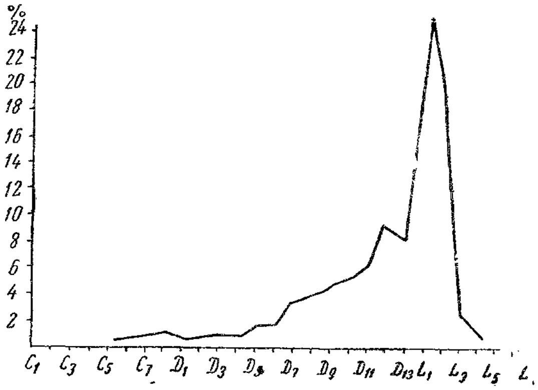

Fig. 2. Gradient of distribution of the sources of the spinal sensory fibers passing through the celiac ganglion.

small number of neurones is derived from more distant ganglia. Our findings confirmed this view and provided more accurate quantitative details. Many reports speak of the same multisegmental principle of the sensory innervation of the internal organs and blood vessels [4, 5, 11, 13, etc.].

It must be considered that this multisegmental principle arose in the course of evolution. In Amphioxus the visceral branches leave the posterior roots metamerically; the visceral branches proceed equally metamerically in the Cyclostomata, and in these, moreover, the ganglia of the sympathetic trunk are still without longitudinal interconnections; only in the bony fish do longitudinal connections appear between the sympathetic ganglia [18, 22]. In Amphibia, the longitudinal connections of the sympathetic trunk are more highly developed, but a large number of visceral branches still follow a metameric path; in birds there are far fewer of these metameric visceral branches, and in mammals

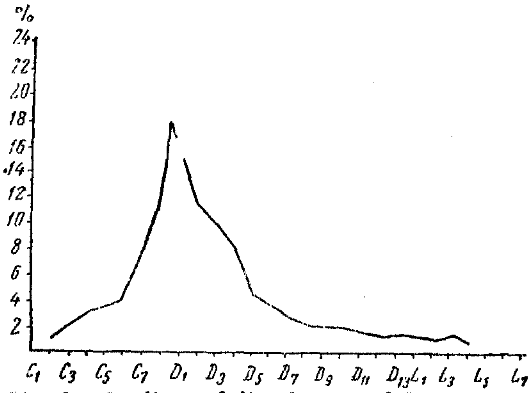

Fig. 3. Gradient of distribution of the sources of the spinal sensory fibers passing through the stellate ganglion.

and in man they are concentrated to the greatest degree in individual trunks [15].

The appearance of this multisegmental principle of the spinal sensory innervation of the internal organs and blood vessels in the course of evolution may be associated with the necessity for improving the nervous connections between the internal organs, and also between the internal organs and the central nervous system. The large number of connections permits the nervous system to obtain better correlation of the work of the internal organs, and to switch the maximum load rapidly from some organs to others. This promotes greater stability of the animal in the constantly changing conditions of the external environment.

The exteroceptive innervation of the skin and the proprioceptive innervation of the muscles have preserved their strictly segmental character, for the first enables localized perception of external stimuli, necessary for the organization of a purposive response reaction, to be obtained, and the second provides information about the position of parts of the body in space, which is important for the accuracy and precision of locomotor acts.

The different trends of evolution of the sensory innervation of the internal organs, on the one hand, and of the exteroceptive innervation of the skin and the proprioceptive innervation of the muscles on the other hand, have thus been conditioned by different principles of the structural organization of these afferent systems.

SUMMARY

The author studied the sources of the spinal sensory fibers of the celiac, stellate and superior cervical sympathetic ganglia.

These ganglia were removed in cats and in 8-19 days all the cervical thoracic and lumbar spinal ganglia were studied in serial sections to reveal retrograde changes in the neurones.

It was established that the neuron processes of the spinal ganglia C_5 and L_1 of the ipsilateral side pass through the celiac ganglion. The bulk of these neuroneslies in the spinal ganglia D_7-L_3. The neurone processes of the spinal ganglia C_2-L_4 pass through the stellate ganglion, but mainly – C_7-D_5; the neurone processes of the spinal ganglia C_2-D_4 pass through the superior cervical sympathetic ganglion.

The neurone processes of the spinal ganglia of the contralateral side pass through all the sympathetic ganglia mentioned.

LITERATURE CITED

[1] D. M. Golub, Problems of the Morphology of the Peripheral Nervous System [in Russian] (Minsk, 1953) Vol. 2, p. 5.

[2] D. M. Golub and B. M. Kichina, Problems of the Morphology of the Peripheral Nervous System [in Russian] (Minsk, 1953) Vol. 3, p. 11.

[3] T. A. Grigor'eva, Morphology of the Sensory Innervation of the Internal Organs [in Russian] (Moscow, 1947) p. 84.

[4] T. A. Grigor'eva, Uspekhi sovremennoi biol. 28, 1, 150 (1949).

[5] T. A. Grigor'eva, Innervation of the Blood Vessels [in Russian] (Moscow, 1954).

[6] T. A. Grigor'eva, Arkh. anat. gistol. i embriol. 36, 3, 11 (1959).

[7] A. S. Gusev, The Structure of the Splanchnic Nerves [in Russian] Candidate's dissertation (Leningrad,1954).

[8] B. A. Dolgo-Saburov, Innervation of the Veins [in Russian] (Leningrad, 1958).

[9] V. I. Il'ina, Morphology of the Sensory Innervation of the Internal Organs [in Russian] (Moscow, 1947) p. 135.

[10] B. M. Kichina, Problems of the Morphology of the Peripheral Nervous System [in Russian] (Minsk, 1958) Vol 4, p. 29.

[11] E. M. Krokhina. The Sensory Innervation of the Large Intestine in Mammals [in Russian] Candidate's dissertation (Moscow, 1947).

[12] B.I. Lavrent'ev, Zhur. obshchei biol. 4 4, 232 (1943).

[13] V. F. Lashkov, Arkh. anat., gistol. i. embriol. 31 (1952).

[14] P. I. Lobko, Proceedings of the Sixth All-Union Congress of Anatomists, Histologists, and Embryologists [in Russian] (Khar'kov, 1958) p. 407.

[15] G. A. Orlov, The Surgical Anatomy of the Sympathetic Trunk [in Russian] (Arkhangel'sk, 1946).

[16] E. K. Plechkova, The Sensory Innervation of the Internal Organs [in Russian] (Moscow, 1947) p. 46.

[17] E. K. Plechkova, The Sensory Innervation of the Internal Organs [in Russian] (Moscow, 1947) p. 167.

[18] B. M. Sokolov, A General Study of the Ganglia [in Russian] (Perm', 1943).

[19] F. B. Kheinman, Problems of the Morphology of the Peripheral Nervous System [in Russian] (Minsk, 1958) Vol. 4, p. 41.

[20] J. Fischer, Anat. Ans. 26, 388 (1905).

[21] W. H. Gaskell, J. Physiol. 7, 1 (1886).

[22] C. U. A. Kappers and others, The Comparative Anatomy of the Nervous System of Vertebrates, Including man (New York, 1936).