MORPHOLOGY AND PATHOMORPHOLOGY

INTERNEURONAL SYNAPTIC CONTACTS IN THE PERIPHERAL SECTION OF THE VEGETATIVE NERVOUS SYSTEM

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Clinical observations as well as experimental studies have proven that internal organs preserve their functional capacities, up to a certain extent, even when there is complete rupture of communications with the central nervous system, this giving the organism a greater ability to survive. It is for this reason that there is a special significance in the study of the construction of the peripheral nerve ganglia, the clarification of their morphology and the connections existing between the intramural and the extramural ganglia. As is known, A. S. Dogiel [12] believed that the peripheral ganglia possess sensory neurons (Type II cells) which have synapses with motor neurons (Type I cells), this forming a reflex arc.

However, after the studies by John Langley [17], it was generally accepted that the peripheral neurons are effector only and that in the ganglia there is merely a transmission of the nerve impulse from the pre- to the postganglionic fibers.

There are many studies indicating that A. S. Dogiel was right in ascribing sensory capacities to cells of Type II and that there are indeed synaptic ties among peripheral neurons [1,3,6,7,8,9,11,16].

We were able to demonstrate along with I. F. Ivanov [1] that servering mesenteric nerves leads to degeneration of the proximal or central portions of the nerve and that this degeneration can be followed into the ganglia of the solar plexus. Under such conditions there is an alteration in the synaptic apparatus of the nerve cells composing the solar plexus [8].

The aim of the present study is to analyze the interneuronal connections existing in the solar plexus when its cells lose all ties with the central nervous system.

EXPERIMENTAL METHODS

We developed a procedure involving the total extirpation of the spinal cord in cats, followed by a series of measures permitting these animals to live long enough to show the transformations of the preganglionic fibers which occur at the synapses of the peripheral ganglia.

When the required care was given the animals would survive for quite some time, and so proved to be a convenient animal in which to study the many problems of the peripheral nervous sytem, its morphology and physiology, the activity of internal organs, the regulation of peripheral circulation and so on.

The operation was performed under ether-chloroform narcosis.

In two places: at the level of thoracic 5-7 segment and, then, (after severing cord) at the sacral segment we opened paths to the spinal cord, first making a long skin incision, separating muscle attachments from the bodies and processes of the vertebra and finally opening the spinal canal by means of Luer forceps.

To perform the operation successfully, especially considering its immediate postoperative condition, local anesthesia is required. It is especially important to remove sensation while the spinal cord is being manipulated. It is for this reason that, having made the small aperture into the thoracic portion of the spinal canal, we would immediately introduce through it 0.2 cc of 1% novocaine. After a lapse of some time novocaine would also be introduced into the subdural space. Still later small quantities of novocaine were put very gradually into the various levels of the thickness of the spinal cord itself. It can be seen that the use of these procedures resulted in all manipulations of the cord, including the sectioning, being done under complete local anesthesia, independent of the general narcosis.

At the very end of the operation we introduced novocaine into the entire thickness of the central portion of the severed cord creating a sort of a local depot.

After severing the cord, the ends of the isolated portions were ligated. The dura matter had to be included in the ligatures, this facilitating the removal of the spinal cord from the vertebral canal. For the same reason the maximum number of spinal roots that could be reached were severed.

The spinal cord was pushed out by using a metal rod having the curve of the spinal canal. Simultaneously, there was exerted a pull on the ligature holding the caudal end of the cord.

The portions of the spinal cord remaining within the spinal canal were destroyed using as a cautery the heated end of a metal rod, thus also helping control bleeding. After satisfactory hemostasis, the muscles and then the skin were sewn in layers. The animal's greatest postoperative dangers to life are excessive hemorrhage, disturbance of heat regulation and the rather frequent severe upset of cardiac rhythm. For this reason we always gave immediately after operation, up to 20 cc of physiological saline subcutaneously (amount depending on weight of animal), camphor also being used when needed.

For the first postoperative day artifical heat would be given, the body temperature being measured at regular intervals thus allowing normal body temperature to be maintained.

For the first few days animals would refuse food and water, as a usual rule. Feedings were given by stomach tube milk and beef broth being used.

The system of postoperative care included periodic emptying of the bladder, pressure being used, and removal of feces from the rectum. With the aim of either preventing or minimizing trophic sores, the position of the animal would be altered at frequent intervals while, later, the posterior portion of the body as well as the rear limbs would receive frequent massages.

Altogether 8 cats were operated. One perished on the 4th day as a result of inspiration pneumonia. The others were sacrificed between the 12th and 21st days postoperatively. In the last operation a second operation was performed on the 15th day following removal of the spinal cord: sub-diaphragmatic vagotomy and section of the splanchnic nerve with the sympathetic chains. The aim of this second operation was to eliminate the possibility that vagal and sympathetic fibers originating from the first thoracic segments of the spinal cord would form synaptic apparati in the solar plexus.

The solar plexus was stained with silver using the Campos procedure, with the method of Gross-Bielschowsky using the B. I. Lavrentiev modification and with the Cajal pyridine procedure, the tissues being placed in celloidin.

EXPERIMENTAL RESULTS

Study of the preparations made showed that exclusion of the synaptic apparatus and the preganglionic nerve fibers of central nervous sytem origin greatly simplified and clarified the analysis of the structural relationships existing in the peripheral nerve ganglia.

Upon many nerve cells of the solar plexus there was demonstrated an elaborate synaptic apparatus, this being represented by a pericellular network of the very finest nerve fibers coming into the most intimate contact with the cell bodies themselves and their dendrites. It cannot be doubted that at least a portion of these fibers represent the axons coming from sensory neurons (Type II Dogiel) lying within the walls of the digestive tract. It is precisely these synapses that degenerate when the mesenteric nerves are severed, this being observed by us in our previous experiments. This is proven also, partially, by the observation that the altered synapses of the present experiments are seen most often and in the largest number on the periphery of the nerve ganglia.

Among the synapses of the solar plexus which remain intact after the removal of the spinal cord are axons from the cells of the Type II Dogiel, these forming an organic part of the solar plexus itself. Here can be seen also other forms of interneuronal communication, generally grouped under the term "horizontal connections" [2], these being recognized by the manner in which the dendrites or axons of one cell make contact with the dendrites and cell bodies of other cells, the anastomoses from cell to cell and so on.

The pericellular apparatus of the various cells composing the solar plexus attains unequal degrees of development. Some cells are thickly covered by a net of the finest nerve fibers which approach the cell from all sides (Fig. 1). Other cells are covered by only one or two such fibers (Fig. 2). Finally, in the third type, there is no pericellular apparatus that can be seen at all.

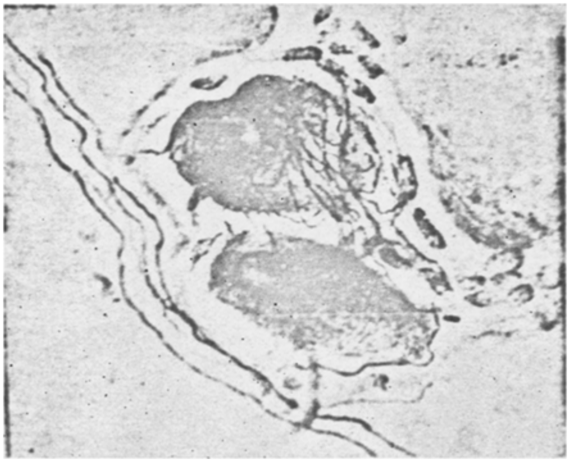

Fig. 1. The pericellular apparatus of a nerve cell from the solar plexus 19 days after extirpation of the spinal cord.

Only in exceptionally rare instances do these fine nerve fibers terminate as slight thickenings making contact with the bodies and extensions of the nerve cells. Somewhat more often, there can be seen on these uniformly thin, fine nerve fibers of the pericellular apparatus single, tiny, varicose-like thickenings which also make contact with the bodies of the nerve cells (Fig. 3).

It is of interest to note that the nerve fibrils from a nerve fiber may form part of the pericellular network around one cell body and then extend to the pericellular apparatus around adjoining nerve cell bodies. This makes possible the transmission of a nerve impulse from a single axon of a Type II Dogiel cell to several effector neurons just as is the case for preganglionic fibers of central origin ([Langley, 17], [B. I. Lavrentiev, 6], [Kirsche, 14], and others).

When the synaptic apparatus of the solar plexus is studied in the normal animal and then the same apparatus is compared with what remains of it after the spinal cord has been extirpated, substantial differences are uncovered between the synapses formed by axons of cell Type II Dogiel II and the synapses formed by preganglionic cell fibers of central origin. The synapses formed by the dendrites of peripheral sensory neurons form the finest of pericellular fibrils enlacing the cell bodies and only rarely do they terminate in button-like thickenings. In our experiments with sectioning the mesenteric nerves [8], it is precisely these synapses that became altered.

The synapses described in the literature [4, 14, 15], forming the typical loops or rings making contact with the cell bodies and their extensions similar in their pattern to what is observed in the central nervous system, belong to the preganglionic fibers of central origin. Kirsche [15] in one of his studies classifies the morphologic and physiologic peculiarities of the various synapses as those with a "large" or "small area of transmission."

The presentation of the data given above when added to that previously advanced testifies to the fact that the interneuronal connections within the solar plexus as well as in other peripheral connections within the solar

Fig. 2. Pericellular nerve fibers in the solar plexus 21 days after extirpation of the spinal cord and 6 days following sub-diaphragmatic vagotomy and sectioning of the splanchnic nerve.

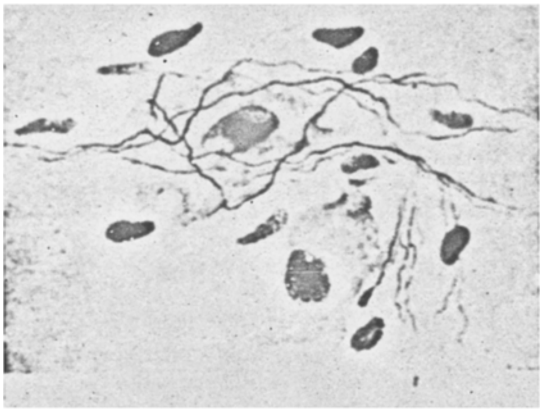

Fig. 3. Terminal thickenings and thickenings along the course of pericellular fibrils (synaptic buttons) 21 days after extirpation of the spinal cord and 6 days after sub-diaphragmatic vagotomy and sectioning of the splanchnic nerve.

plexus as well as in other peripheral ganglia are considerably more complex than is assumed by the hitherto generally accepted, well-known Langley schematic representation.

The ganglia of the peripheral nervous system must be thought of, first of all, as peripheral reflex centers which play a most significant role in the regulation of the activities of the internal organs.

SUMMARY

A method of complete exirpation of the spinal cord in cats and postoperative care of the animals has been elaborated. A study of slides of the solar plexus from animals killed on the 12-21 day after extirpations con-

firmed the presence of interneuronal synaptic contacts in the peripheral section of the vegetative nervous system. Interneuronal contacts in the solar plexus are more complex than was previously thought due to the Langley schematic representation.

Ganglia of the peripheral nervous system should be regarded first of all as peripheral reflex centers which are very important to the regulation of the activities of the internal organs.

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