SOURCES OF AUTONOMIC INNERVATION OF THE APPENDIX

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The problem of the sources of the autonomic innervation of the appendix has not received its due attention in the literature[3]. It has not yet been determined which parasympathetic fibers – vagal or sacral – take part in its supply. The situation is complicated by the fact that the sources of the parasympathetic innervation of those parts of the small and large intestines with which the appendix is related topographically have not yet been elucidated. According to some writers [6, 10], the pelvic nerves do not take part in the innervation of the large intestine proximally to the rectum. More recent investigations have shown that they may extend through the hypogastric nerves and the caudal mesenteric ganglion [11] as far as the initial portion of the large intestine [7].

So far as the cranial parasympathetic outflow – the vagus nerve – is concerned there is anatomical, experimental-morphological, and physiological evidence indicating that it takes part in the innervation of the small intestine, the ileocecal region, and the initial portion of the large intestine [1, 2, 4, 7, 8, 12, 14], i.e., of those segments closely related topographically to the appendix. Unfortunately, in the studies cited above, degeneration of the synapses on the Dogiel's Type 1 neurons could not be observed in these segments of the intestine, except in the small intestine [12].

The object of the present investigation was to make an experimental study of the sources of the sympathetic and parasympathetic innervation of the appendix.

EXPERIMENTAL METHOD

Experiments were conducted on rabbits. To study the parasympathetic innervation in 5 animals the cranial mesenteric and both semilunar ganglia of the solar plexus were extirpated [9]. To investigate the parasympathetic

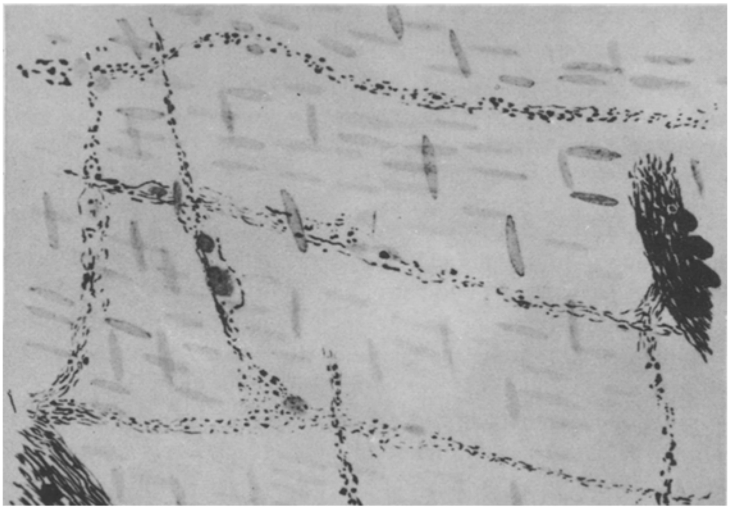

Fig. 1. Degeneration (cloudy swelling) of the branches of the terminal plexus in the rabbit's appendix (3 days after extirpation of the solar plexus). Impregnation by Bielschowsky–Gros method. Objective 90, ocular 15.

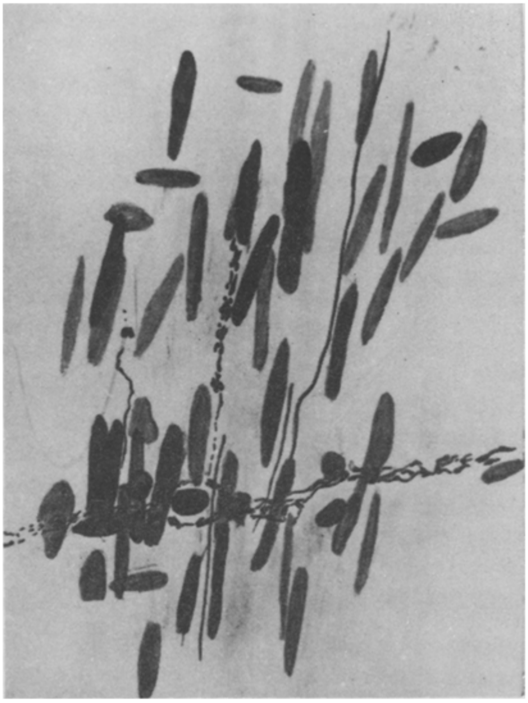

Fig. 2. Degeneration of thinnest twigs of the terminal plexus and endings on smooth muscle cells in the rabbit's appendix (3 days after extirpation of the solar plexus). Impregnation by Bielschowsky–Gros method. Objective 90, ocular 15.

innervation in 10 animals 2, 3, 4, or all the ventral sacral roots of the spinal cord were divided, and in 5 animals the vagus nerve was divided below the diaphragm.

The animals were sacrificed between 1 and 4 days after the operation. Some of the material was fixed in 12% neutral formalin, the rest in Lavrent'ev's AFA fluid. Mostly total sections were cut out and impregnated by the Bielschowsky–Gros method. For control purposes the nervous apparatus of the appendix was studied in normal conditions.

EXPERIMENTAL RESULTS

Experimental morphological investigations [5, 6, 10] have shown that the sympathetic efferent chain is interrupted in the extramural ganglia, and the sympathetic nerve fibers entering the organ are postganglionic. They pass through without communicating with the ganglion cells of the intramural plexuses, and reach the periphery where, in the substance of the smooth muscle, they form nerve endings on the smooth muscle fibers.

Our findings fully confirmed this description. A typical, well-defined picture of massive degeneration of nerve fibers, which were in a state of fragmentation, was observed in the rabbit's appendix, in the thick and thin bundles of the terminal plexus, 72-74 h after removal of the ganglia (Fig. 1). Thinner, delicate strands began to detach themselves from these bundles, following the course of the muscle bundles. Finally, a few degenerated terminal filaments branched from these strands and ran towards the muscle fibers, on which they terminated not far from the nucleus (Fig. 2). Intact fibrils also were present here, evidently belonging to nerve fibers of a different nature.

The ganglia of the intermuscular plexus showed only very slight changes. Only one or two nonmedullated nerve fibers in a state of argentophilia and varicosity were seen. No degeneration of the pericellular apparatuses on the Dogiel's Type 1 neurons was observed.

Hence, the participation of the solar plexus in the sympathetic innervation of the appendix was established beyond doubt [13]. We next attempted to demonstrate the connections between the intramural parasympathetic neurons and the center.

The picture of the changes in some of the thin medullated and nonmedullated nerve fibers in the principal and accessory intermuscular plexuses of the appendix 20-24 h after division of the ventral sacral roots of the spinal cord was not rich in detail. In some cases the degenerated fibers were few in number or absent altogether. No changes were seen in the ganglia in the intercellular plexus, and no degenerating synapses were observed on the neurons of the ganglia. In other cases the number of abnormal fibers increased considerably, and the bundles of the plexus then consisted almost entirely of highly argentophilic and varicose fibers, mixed with only a very few nerve fibers in a state of cloudy swelling. Along the course of the bundles of the plexus strongly argentophilic, large, globular structures of different configuration were very frequently seen, possibly consisting of bulbs of growth. In these cases massive, intensive argentophilia and varicosity of the nerve fibers and, rarely, cloudy swelling were observed in the intercellular plexus of some ganglia. In other ganglia only isolated fibers were abnormal. Modified pericellular apparatuses were observed on individual neurons of the ganglia of Auerbach's plexus 20 h after operation. The synapses were strongly argentophilic, large endings in the form bulbs with irregular outlines. The innervated neurons also showed changes in these circumstances: they were irregular in outline, their neurofibrillary apparatus was ill defined, and they were weakly impregnated; their processes were distinguished with difficulty, and as a result the type of the neurons could not be determined.

In the terminal plexus an ill defined argentophilia and weak varicosity of a small number of nerve fibers were observed.

The changes developing 3-4 days after division of the sacral roots in the nerve fibers in the intermuscular plexus showed a certain qualitative difference from the changes observed 24 h after division: argentophilia and varicosity were observed, but fragmentation was absent; the varicosity had become less coarse, possibly indicating impending normalization of the state of the nerve fibers. In the intercellular plexus of most of the ganglia solitary varicose fibers were seen but no degeneration of the synapses could be detected. The changes in the nerve fibers in the terminal plexus were slight in degree.

At the same period (3-4 days) after subdiaphragmatic vagotomy (division of all the fibers of the posterior cord at the cardial end of the stomach) changes were found in the nerve fibers in the bundles of the intermuscular plexus (principal and accessory) and, to a greater degree, of the subserous plexus. They mainly took the form of argentophilia and varicosity, often fairly coarse in character; sometimes cloudy swelling of the fibers was also present, especially in the subserous plexus. Often the course of the fibers was tortuous. The number of abnormal fibers in the bundles of the plexuses varied; in the majority of bundles the changes were massive in character, while in the minority the abnormal fibers were few in number or absent. In the intercellular plexus of the ganglia varicose fibers were sometimes fairly, sometimes very numerous. In some cases the neurons of the ganglia were poorly impregnated. Abnormal synaptic structures in the form of severely argentophilic, small bulbs were found in only one ganglion of the subserous plexus. It was impossible to determine the type of the neurons on which they were situated because of their weak impregnation. In the terminal plexus in the substance of the smooth muscle severe varicosity of the fibers was sometimes observed and, rarely, cloudy swelling.

It follows from the results obtained after division of the parasympathetic fibers that the participation of the ventral sacral roots in the innervation of the appendix is doubtful. As mentioned above, the most marked changes in the nerve fibers in the plexuses of the appendix appear very early – at the end of the 1st day, becoming less intensive on the 3rd-4th day. These changes in the nerve fibers, neurons, and synapses during the first day may be the result of the reaction of the rabbit to the very severe operative trauma associated with division of the sacral roots.

The participation of the vagus nerve in the innervation of the appendix appears more likely; the presence of changes in the nerve fibers after vagotomy, such as argentophilia and varicosity (even on a massive scale), is not, of course, sufficient to solve the problem, but the discovery of a small number of nerve fibers in a state of cloudy swelling (and in one case, degeneration of the pericellular apparatuses) makes it possible to express more definite views.

Because of the indecisiveness of the morphological results of the experiments in which the vagus nerve and sacral roots were divided, the variant proposed by several authors seems a likely solution: the fibers of the cranial and sacral parasympathetic outflows do not terminate on the ganglion cells of the appendix or adjacent regions of the small or large intestine, but they communicate with them through an intermediate chain of intraganglionic connections.

SUMMARY

An experimental investigation of the sources of the sympathetic and parasympthetic innervation of the appendix was carried out by Bielschowsky Gros method. The sympathetic innervation is effected by the solar plexus ganglia. Participation of the ventral sacral roots in the parasympathetic innervation is doubtful, whereas participation of the vagus is more probable. Due to the obscurity of morphological results obtained it may only be supposed that the fibers of the cranial and the sacral parasympathetic do not terminate on the cells of the appendix ganglia, but are connected with it through an intermediate link of intraganglionic neurons.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
