INFLUENCE OF THE SYMPATHETIC NERVE ON THE SMOOTH MUSCLE OF THE STOMACH IN THE POSTNATAL ONTOGENESIS OF THE RAT

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S. E. Belen'kaya

Laboratory of Evolution of Neuromuscular Function
(Head, Dr. Biol. Sci. A. K. Voskresenskaya), I. M. Sechenov Institute of Evolutional Physiology
(Director, Corresponding Member AMN SSSR E. M. Kreps) of the AMN SSSR, Leningrad
(Presented by Active Member AMN SSSR V. M. Karasik)
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Some authors have concluded from experiments on adult animals that the sympathetic nerve has an inhibitory effect on the muscles of the gastro-intestinal tract [12, 13, 16, 19], while others observed an excitatory effect under the same circumstances [15, 17, 18]. These workers attributed the difference in responses to variations in the initial functional state of the effector or to the conditions of stimulation of the nerve—whether a high or low frequency of stimulation was used. The dual effects were also explained by postulating that the structure of the sympathetic and parasympathetic nerves was mixed. There are few reports in the literature of investigations of the influence of the splanchnic nerve on the musculature of the stomach [6, 9] and intestine [5, 7, 14] in the process of individual development of mammals.

Since the ontogenetic aspect of the study of this problem may help to explain some of these conflicting results observed in the adult animal, in the present investigation we studied the dynamics of the development of the function of the splanchnic nerve.

EXPERIMENTAL METHOD

Acute experiments were performed on rats ranging in age from a few hours after birth to the adult state. Because of the comparatively slow maturation of the young rat, all the details of the course of development of a particular function and its physiological attributes can be traced through the various age periods. More than 100 animals were used in the experiments. The rats were anesthetized with urethane in doses of 0.8-1.0 g/kg, injected intramuscularly. The abdomen was opened and the left splanchnic nerve was mobilized and taken up on a ligature. In some experiments the nerve was divided and its peripheral end placed on buried platinum electrodes, while in others the nerve was ligated with thread and the segment distal to the ligature placed on the electrodes. Stimulation of the nerve for 30-60 sec was applied by means of an induction current, and the strength of stimulation was varied by altering the distance between the coils of the induction apparatus. The intervals between stimuli ranged from 5 to 15 min. At the beginning of each experiment the threshold of excitability of the nerve was determined, and the optimal strength of current was then selected for each age period. The reaction of the musculature of the three divisions of the stomach (fundus, cardia, and pylorus) was recorded in isotonic conditions on the paper of a kymograph. After the experiment, the accuracy of the dissection and the position of the nerve on the electrodes were verified. Otherwise, the experimental method corresponded completely to that described previously [4].

EXPERIMENTAL RESULTS

Stimulation of the splanchnic nerve in the newborn rats did not cause relaxation of the musculature and cessation of rhythmic activity, as in the adult animal, but the opposite reaction—excitation, in the form of a uniform contracture in all parts of the stomach (Fig. 1, a). This reaction was found when the strength of the current was considerable (distance between coils 6-8 cm), indicating a low level of excitability of the neuromuscular apparatus.

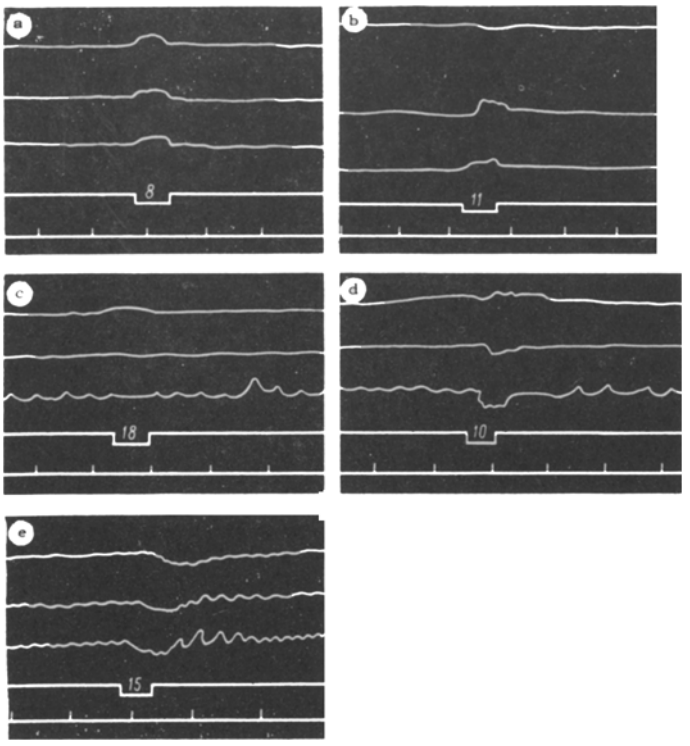

Fig. 1. Reaction of the smooth muscle of different parts of the stomach to stimulation of the peripheral end of the splanchnic nerve in the postnatal ontogenesis of the rat. a) in a rat 1 day old; b) 8 days old; c) 14 days old; d) 25 days old; e) 33 days old. Significance of curves (from top to bottom): myographic tracing of response to muscle of fundal, cardial, and pyloric divisions of the stomach; marker of stimulation; time marker (in minutes). The numbers over the line of stimulation represent the distance between the coils of the induction apparatus (in cm).

The thresholds of stimulation at this period were 10-12 cm. The contractile responses were seen to be unchanged during the first week after birth, and did not alter with changes in the conditions of stimulation of the nerve. A weak inhibitory response—a reduction of muscle tone—was recorded for the first time in the fundal portion of the stomach of a rat at the age of 8 days; in the other portions of the stomach only an excitatory effect was observed as before (Fig. 1, b). The inhibition in the fundus was not yet constant, and it alternated repeatedly with absence of any effect, with contraction, or with a biphasic reaction. However, until the age of 2 weeks, contraction of the muscle was the predominant form of response in all divisions of the stomach.

In the later age periods the reaction of the muscle was characterized by greater variability. Responses of different character were observed, not only in animals of different ages, but also in the course of an experiment on the same animal. It is clear from Fig. 1, c, that stimulation of the splanchnic nerve of a rat at the age of 2 weeks was accompanied by a different, although slight, reaction in each division of the stomach. In the fundus a slight increase in tone was observed, in the cardia no visible response, and in the pylorus—inhibition of rhythmic contractions. In a rat aged 25 days, besides fully developed inhibitory reaction—relaxation of the muscle—in the pyloric and cardial divisions, an increase in tone could be observed at the same time in the fundus (Fig. 1, d). Complete inhibition of rhythmic activity and a lowering of tone in all divisions of the stomach were observed in the animals at the age of 1 month in response to stimulation of the splanchnic nerve (Fig. 1, e).

At approximately 1-1$\frac{1}{2}$ months of life stable thresholds of stimulation were established at the level of 25-30 cm, corresponding to the values found in the adult animal. Contractile reactions were, however, recorded later still. From the age of 2 months the inhibitory reaction of the muscles to stimulation of the nerve became almost the sole type of response, as characteristically observed in the adult animal. It is clear from Fig. 2, a, that an inhibitory reaction was observed unequally in the different portions of the stomach. It was most marked in the fundus.

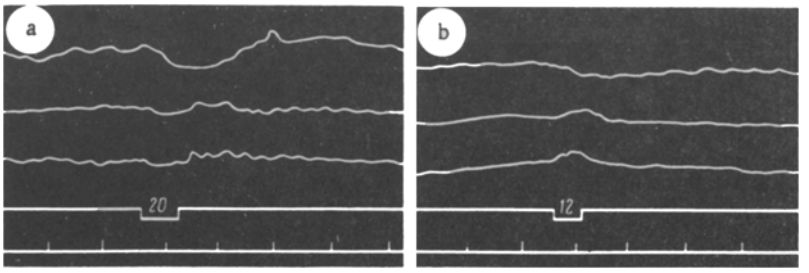

Fig. 2. Reaction of the musculature of different divisions of the stomach of an adult rat to stimulation of the peripheral end of the splanchnic nerve: a) in a rat aged 2 months; b) 9 months. Legend as in Fig. 1.

After the cessation of stimulation of the splanchnic nerve the inhibitory effect in the fundal portion persisted for a considerable time longer (70-120 sec). It is interesting to note that in the fundal portion, whose function in the adult is tonic, the effect of the splanchnic nerve was mainly to cause prolonged relaxation of the muscle; in the pyloric portion, on the other hand, characterized by rhythmic activity, stimulation of the splanchnic nerve led more often to the cessation of contractions without prolonged relaxation of the muscle. In the adult animal, however, in response to stimulation of the splanchnic nerve contractile reactions of the muscle were observed in 29% of experiments (see Fig. 2, b). Usually reactions of this type were found at the end of the experiment after repeated stimulation of the nerve, i.e., in a "fatigued" neuromuscular apparatus. Consequently, while possessing specificity of action, the autonomic nerves in the adult animal also may, under certain conditions, act as synergists. Other investigators have mentioned this feature [10, 11].

It follows from the findings described above that between the two extreme forms of reaction of the musculature in response to stimulation of the sympathetic nerve—excitation in the early postnatal period and inhibition after 2 months of age—a period may be distinguished from the second week after birth until the age of 2 months which is characterized by instability of the responses of the gastric musculature to stimulation of the splanchnic nerve.

A similar sequence of changes in the reactions of the smooth musculature of the alimentary tract was found during the study of the reaction of the rat's stomach [1, 2] and the gut of the frog tadpole [8] to adrenalin. For this reason the contractile responses of the gastric musculature to stimulation of the sympathetic and vagus nerves [3, 4], observed in the early period of development, are evidently associated with the undifferentiation of muscular chemoreception.

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