

# MATERIAL FOR STUDY OF THE INFLUENCE OF STIMULATION OF INTEROCEPTORS OF THE DIGESTIVE TRACT ON UNCONDITIONED DEFENSE REFLEXES

## COMMUNICATION I. DEPENDENCE OF INFLUENCES OF INTEROCEPTORS ON CHARACTER OF STIMULUS

G. P. Mikhailovsky

(Received June 3, 1955. Presented by Acting Member of the Acad. Med. Sci. USSR V. N. Chernigovsky)

This investigation, carried out under the direction of Prof. D. E. Rozenblyum, was devoted to an analysis of the changes in unconditioned reflex activity under the influence of afferent impulses from the mechanoreceptors of the digestive tract. We studied the influence on the defense reflex of distention of the stomach or of a segment of the small intestine with electrical stimulation of the skin of the hind limb of a dog.

Study of the reaction of the organism with an increase in pressure in the gastrointestinal tract is of topical importance for aviation medicine, in particular, in understanding the mechanism of development of high altitude meteorism. According to W. V. Streltsov [5], the volume of gases in the body cavities at an altitude of 9760 m increases fourfold, at an altitude of 13,556 m by 7.6 times. The increase in the volume of gases in the digestive tract at high altitudes leads to mechanical hindrance of breathing, of blood and lymph circulation and also to stimulation of the interoceptors in the walls of the gastrointestinal tract.

The investigations of a number of authors [1, 3, 4, 7, etc.] have shown that stimulation of the interoceptors of the gastrointestinal tract can be a source of numerous reflex influences on various aspects of the vital activity of the organism. V. N. Chernigovsky [8] established that afferent impulses from the interoceptors can exert actuating and correcting influences on the somatic reflex arcs to the skeletal musculature. O. S. Merkulova [2] conducted a systematic investigation on the interoceptor influences on skeletal musculature. She studied this question in conditions of changes in the acid-bile balance and hypoglycemia. She demonstrated in this respect the importance of various sections of the central nervous system. The majority of these investigations were undertaken in acute experiments. Together with this it is known that the significance of the results of acute experiments is limited by a number of factors. Therefore, to solve the problem we used the method of chronic experiments.

In the first part of our investigation we studied the changes in the course of the defense reflex in relation to: 1) the magnitude of intracavity pressure in the stomach or a segment of the small intestine; 2) the speed of growth of intracavity pressure; 3) the size of the stimulated intestinal surface, 4) the duration of stimulation. In the subsequent stages we studied this question in various functional states of the cerebral cortex and in conditions of the hypoxic form of oxygen starvation.

## EXPERIMENTAL METHODS

Regulated stimulation of the mechanoreceptors of the gastrointestinal tract was carried out by means of a fine-walled rubber balloon, introduced through a fistula in the stomach cavity or in an isolated intestinal ansa.

This balloon was connected with a rubber bladder in which the necessary pressure had been obtained earlier (Fig. 1). The volume of the rubber bladder (a used automobile inner tube) greatly exceeded the volume of the fine-walled balloon and the whole connective system, which ensured the required pressure in the entire apparatus. The gages of all the cocks and of all the connecting pipes remained fixed in all experiments; inflation and its subsequent cessation were performed at the same moment (by means of turning the three-way cock); this excluded the many jolts which usually occur in blowing up a fine-walled balloon directly with a rubber bulb. Changes in pressure in the system were recorded by a mercury manometer and graphically on a kymograph drum.

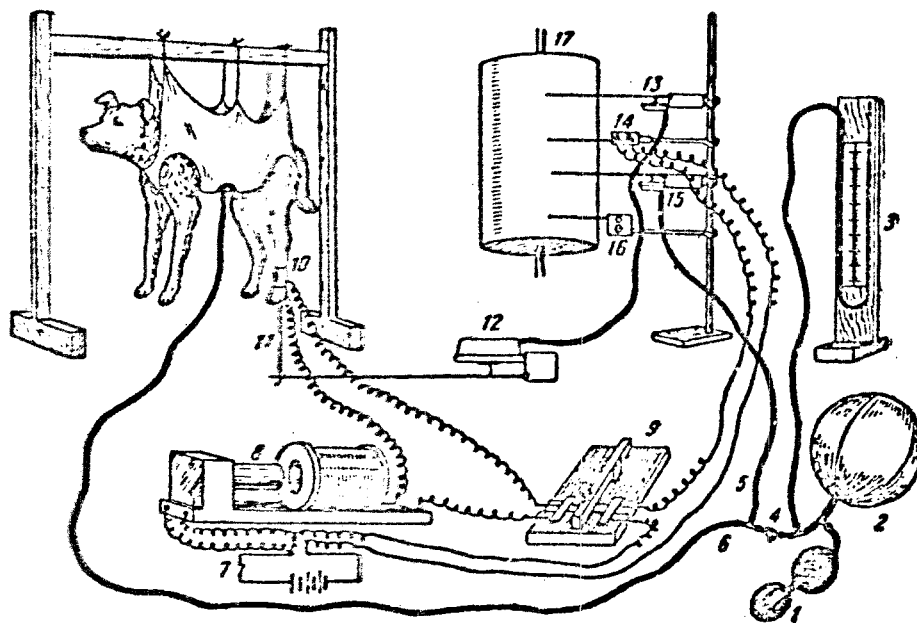


Fig. 1. Scheme of Experimental Procedure. 1) Rubber bulb; 2) rubber bladder; 3) mercury manometer; 4) three-way cock; 5) rubber tube to Marey tambour; 6) rubber tube to fine-walled rubber balloon, introduced in cavity of stomach; 7) accumulator; 8) induction coil; 9) electric switch; 10) electrodes; 11) cord; 12, 13, 15) Marey tambour; 14) electro-indicator; 16) time recorder; 17) kymograph.

The defense reflex was produced by the action of a variable current from an induction coil on the skin of the rear surface of the left hind paw; the source of the current was a 6 v accumulator. On the kymograph drum the moment of application of electrical stimulation to the skin was noted. The defense reflex was recorded graphically by means of pneumatic transmission and a Marey tambour.

The experiments were conducted on the dogs Nochka and Elka with fistulas of the intestines according to Thiry-Bell and on the dog Sharik with a fistula of the stomach according to Basov. The dogs were last fed on the evening before the experiment. In the morning, before the experiment, the animals were taken out for a walk for the purpose of evacuating the urinal bladder and intestines; in the dog with fistula of the stomach, before the commencement of the experiment, the stomach was washed with warm water (36-37°C); then the dogs were suspended on a frame in a special hammock. Such a methodical procedure, according to V. N. Chernigovsky and O. S. Merkušova [9], simplifies transmission of the interoceptor impulses to the somatic reflex arcs. This required repeated experiments to train the dogs after which they usually showed no uneasiness in the course of the entire experiment.

At the beginning of each experiment the minimum electrical current producing a distinct defense reflex was determined. Subsequently by closing a telegraph switch the limbs of the dogs were rhythmically stimulated every 15 seconds with an induction current of the ascertained strength. When equal movements were established in the stimulated limb, two-minute inflation of the stomach or the isolated intestinal ansa was carried out.

In order to prove that in our experiments the defense reflex was an unconditioned reaction we investigated the isolated influence of the noise of the workings of the induction coil and closing the switch. No motor reactions to the stimuli of noise were observed.

## EXPERIMENTAL RESULTS

In the investigations conducted it was made clear that the threshold values of interoceptor stimulation are not stable and vary from one experiment to another. Nevertheless one may point to the values of the threshold stimulations which we observed most frequently. In the chronic experiments for the gastric mechanoreceptors in the dog with a fistula of the stomach, the threshold stimulation at which changes were found in the course of the defense reflex, was an intracavity pressure of about 40 mm Hg (Fig. 2, A). For the mechanoreceptors of the small intestinal segment the most frequently observed threshold value of stimulation was a pressure of about 80 mm Hg.

The change in the course of the defense reflexes was most often expressed in the form of inhibition. In single experiments stimulating influences were observed. With an increase in intracavity pressure the interoceptor influences on the course of the defense reflex were intensified. With considerable inflation of the stomach (pressure 80 mm Hg) distinct inhibitory influences on the reflex contractions of the limb muscles were seen; at the same time contractions of the smooth musculature of the stomach and a manifestation of emetic movements (Fig. 2, B) were observed.

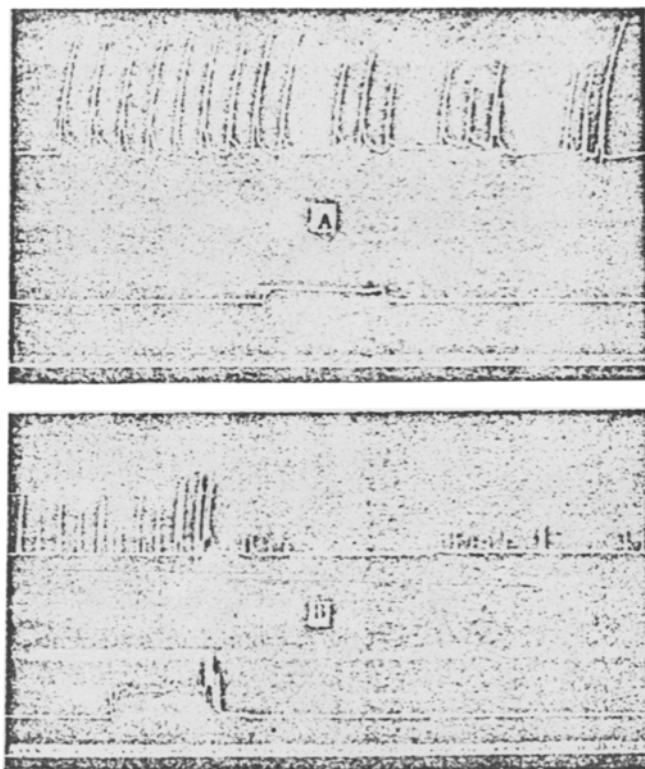


Fig. 2. Dependence of defense reflex on value of intracavity pressure in stomach. Dog with fistula of stomach. A) Experiment No. 80 of May 27, 1950. During reflex contractions of hind limb inflation of stomach performed (pressure 40 mm Hg). Corresponding to moment of inflation in the period of aftereffect, inhibition of defense reflex is noted. Distance between coils of inductor 13 cm; B) experiment No. 90 of June 20, 1950. In conditions of reflex contractions of hind limb stomach is inflated (pressure 80 mm Hg). Sharp inhibition of defense reflex corresponding to contractions of smooth musculature of stomach and in the aftereffect period. Distance between coils of inductor 11 cm. Significance of tracings (top to bottom): reflex changes in left hind limb, indication of stimulation of mechanoreceptors of stomach, indication of time (1 second).

The intensification of inhibitory influences on the reflex contractions of the limb muscles was usually also noted with greater inflation of the isolated intestinal ansa (pressure 120-150 mm Hg).

The investigations of the role of sharpness of rise in pressure were conducted on the dog Nochka with an isolated ansa of the small intestine. The findings obtained allow us to draw the conclusion that the rate of increase in pressure in the intestinal cavity plays a definite part in the formation of the effect of the interoceptor reflex.

With a steep rise in intracavity pressure we found greater inhibition of the reflex contractions of the limb muscles of the dog than with a slow increase.

The significance of the magnitude of the fields of interoceptor stimulation was clarified in experiments on the dogs with isolated intestinal loops. The isolated segment of the intestines was inflated with fine-walled balloons, varying in volume in the ratio 1:1.5:3.

It was established that increase in the fields of interoceptor stimulation with an unchanged value of intracavity pressure usually leads to intensification of the inhibitory interoceptor influences on the defense reflex.

In some experiments a change in the character of the influences on the defense reflex in relation to the area of stimulated surface was noted. With inflation of the balloon with a relative volume of 3 (pressure 120 mm Hg) a general motor reaction which was replaced by distinct inhibition of the defense reflex was observed.

With the use of the balloon of a relative volume of 1, inflation of the segment of the intestines with the same intracavity pressure exerted a stimulating influence on the defense reflex.

Our experiments, as a rule, were carried out with a two minute stimulation of the mechanoreceptors of the gastrointestinal tract. In the dogs with isolated small intestinal ansas the duration of stimulation of the mechanoreceptors was 30-60 minutes with constant threshold values of intracavity pressure of 80 mm Hg.

At the start of inflation of the intestine the behavior of the dogs did not change. Within 15-20 minutes from the commencement of inflation contractions of the muscles of the abdominal wall set in. Then 30-50 minutes later vomiting of bile occurred.

In one experiment the intestinal peristalsis proved to be so strong that the balloon introduced in the cavity of the isolated intestinal loop (Fig. 3) was ejected.

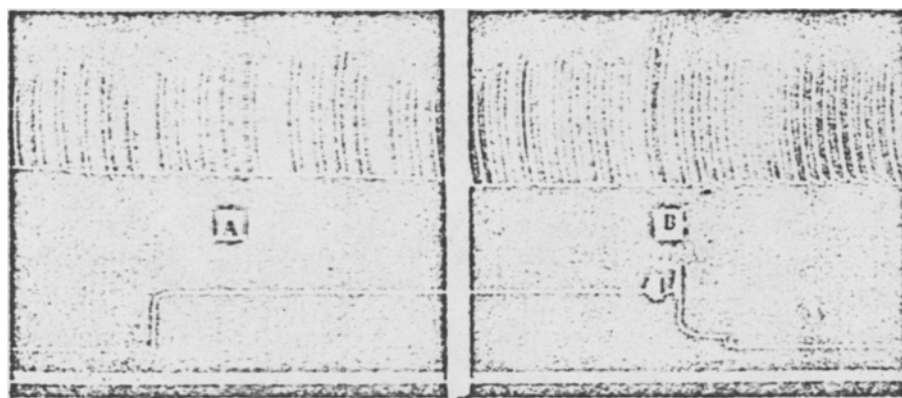


Fig. 3. Influence of prolonged stimulation of mechanoreceptors of small intestine on defense reflex. Experiment No. 118 of July 27, 1950. Dog Nochka. Inflation of isolated intestinal ansa (pressure 80 mm Hg) for 30 minutes. A) Commencement of stimulation; B) end of stimulation. At conclusion of inflation vomiting movements appear; as a result of powerful intestinal peristalsis the balloon was ejected from the intestinal loop (corresponding to this — transverse markings seen on tracing of indication of stimulation of intestinal mechanoreceptors, then a sharp fall in pressure). Distance between induction coils 3.7 cm. Significance of tracings as in Fig. 2.

With prolonged stimulation of the mechanoreceptors of the small intestine (pressure 80 mm Hg) in the dog Nochka no significant changes in the defense reflex were noted and in the dog Elka an insignificant wave-like inhibition of the defense reflex was seen. But in both dogs in all experiments with prolonged inflation there occurred summation of the stimulation; reflex vomiting, actuating influences on the muscles of the frontal wall of the abdomen, sharply intensified peristalsis of the intestine.

In order to demonstrate the reflex nature of the effects induced, a series of experiments was conducted on the dog (with fistula of the stomach), in which novocain was used for the purpose of functional exclusion of the interoceptors. After washing the stomach with warm water (37°C) a gauze tampon was introduced into it moistened with a 2% novocain solution. In 20-30 minutes the tampon was removed and inflation of the stomach was carried out (pressure 40 and 80 mm Hg) in conditions of rhythmical contractions of the hind paw, induced with electrical stimulation of the skin.

After subjecting the mucous membrane of the stomach to novocain the influences of the mechanoreceptors of the stomach on the defense reflex were usually considerably diminished or almost entirely absent.

In the control experiments performed after triple novocain administration the influence of novocain lasted for more than a day.

Thus, we established that in animals (dogs) the thresholds of stimulation of the mechanoreceptors of the stomach and intestines are not stable. The changes in the defense reflex most often occurred with an increase in pressure in the stomach up to 40 mm Hg and in the segment of the small intestine up to 80 mm Hg. With stimulation of the mechanoreceptors of the gastrointestinal tract inhibitory influences on the defense reflex were most often observed; in single experiments stimulating influences were observed. The inhibitory influences on the unconditioned reflex activity depend on the strength of interoceptor stimulation, the size of its fields and the speed of growth in pressure in the intestines. With prolonged inflation of the isolated intestinal loop for 30-50 minutes (pressure 80 mm Hg) actuating influences on the muscles of the frontal wall of the abdomen, sharply intensified intestinal peristalsis and reflex vomiting were observed. Novocain treatment of the mucous membrane of the stomach almost completely removed the influence of the mechanoreceptors of the stomach on change in the defense reflex, which proves the reflex nature of the effects observed.

#### LITERATURE CITED

- [1] K. M. Bykov, *Cerebral Cortex and Internal Organs\** (Moscow-Leningrad, 1947).
- [2] O. S. Merkulova, *Problems of the Physiology of Interoception\** (Moscow-Leningrad, 1952), No. 1, pp. 323-395.
- [3] I. P. Pavlov, *Bolnichnaya Gazeta* 1898, No. 11, pp. 465-470; *Complete Collected Works\** (Moscow-Leningrad, 1951), Vol. 1, pp. 550-563.
- [4] N. P. Simanovsky, *Question of the Influence of Stimulation of the Sensory Nerves on the Management and Nutrition of the Heart, dissertation\** (St. Petersburg, 1881).
- [5] V. V. Streltsov, *Influence of High Altitude and Acceleration on the Pilot's Organism\** (Moscow-Leningrad, 1945).
- [6] A. A. Ukhtomsky, *Dependence of Cortical Motor Effects on Subsidiary Central Influences, dissertation\** (Yuryev, 1911); *Collected Works\** (Leningrad, 1950), Vol. 1, pp. 31-162.
- [7] V. N. Chernigovsky, *Afferent Systems of Internal Organs*, Kirov, 1943.
- [8] V. N. Chernigovsky, *Fiziol. Zhur. SSSR*, Vol. 33, No. 5, pp. 657-672 (1947).
- [9] V. N. Chernigovsky and O. S. Merkulova, *Byull. Eksptl. Biol. i Med.*, Vol. 29, No. 1, pp. 43-47 (1950).

\* In Russian.