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THE EFFECT OF PARTIAL AND TOTAL EXTIRPATION OF THE CEREBRAL CORTEX ON THE "MECHANICAL SECRETION" OF GASTRIC JUICE

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(Received August 10, 1957. Presented by Academician K. M. Bykov)

As can be seen from the correspondence of I. P. Pavlov with S. I. Chechulin, I. P. Pavlov not only agreed with the stimulatory role of a mechanical factor (which he had earlier denied) [6] in gastric secretion, but also indicated ways of future investigation of this problem: "Because your fact was hidden from me so well and for so long, more and more tests of all kinds now need to be performed, for example, is not standing in the apparatus a conditioned stimulus that slowly develops its action; is the reflex not concerned with time, and so on"****

Thus in I. P. Pavlov's view, in order to accept finally the intrinsic importance of the mechanical factor as a stimulus of gastric secretion, the most important consideration was to exclude all the purely conditioned reflex factors which could in some way hide the other mechanisms lying at the basis of this phenomenon.

Pavlov's view was particularly clearly and succinctly expressed in the following letter to S. I. Chechulin. "Well," asked Pavlov, "haven't you received your dogs without cerebral hemispheres yet to solve your elusive problem of the mechanical stimulation of gastric juice? Best of luck! Yours, I. Pavlov."****

However, the experiments were not carried out, for Prof. S. I. Chechulin died.

Our aim was to continue these investigations along the lines suggested by I. P. Pavlov [7, 8, 9, 10].

* In Russian.

** Original Russian pagination. See C. B. translation.

*** Letter of September 7, 1933.

**** Letter dated January 21, 1934. Published in Fiziol. Zhur, SSSR No. 5, 626-627 (1954).

EXPERIMENTAL METHOD

In experiments of long duration on 19 cats and 5 dogs with gastric fistulae the mechanical secretion of gastric juice was investigated in normal conditions and also with unilateral (7 cats, 1 dog) or total (12 cats, 4 dogs) extirpation of the cerebral cortex.

As a control, animals in which the cerebral cortex had not been removed were used, but only the first stage of the procedure was carried out: incision with extensive trauma to the skull.

As a mechanical stimulus to the stomach, we used (with the cats) a rubber balloon; it was introduced through the fistula into the stomach and inflated to a volume of 25 ml; in the dogs we used a rubber tube 75 cm long and with an external diameter of 1.5 cm.

"Mechanical secretion" was studied on an empty stomach (after starvation for 20-21 hrs), with an alkaline reaction of the gastric juice. The volume of gastric juice was estimated at intervals of 15 min and 1 hr; its acidity was determined by titration with decinormal alkaline solution, and its digestive power by means of Mette's albumin tubes (digestion in an incubator for 20 hrs at 37-38°C).

In solution of the problem posed by I. P. Pavlov, the results obtained in the first few days after decortication are of particular interest, i. e., in the period when all the workers in this field (I. P. Pavlov, E. A. Asratian, D. S. Fursikov, B. I. Balandurov, N. T. Shutova, N. F. Popov, and others) observed not only total loss of the old conditioned connections but also the impossibility of formation of new ones.

In the first 5-10 days after decortication and also after trauma (control experiments) the cats and dogs showed spontaneous secretion of gastric juice, and in the decorticated animals it reappeared during the last 3-4 days before death.

EXPERIMENTAL RESULTS

Experiments performed against a background of spontaneous secretion on the 1st, 2nd and 3rd day after operation beyond doubt, even in animals in a state of severe postoperative shock, that after bilateral decortication the mechanical factor retains its physiological importance. This was shown by the total increase in the volume of gastric juice and by the rise in its acidity and digestive power during mechanical stimulation of the stomach in the decorticated animals, and by the return of the secretion to its initial level when the stimulus was removed from the stomach.

On the cessation of spontaneous secretion and the establishment of an alkaline reaction of the juice of the empty stomach, a further most important index of gastric secretion could be considered — the latent period of stimulation.

Experiments set up on subsequent days (period of observation up to 6 months) with mechanical stimulation of the stomach showed an ever-increasing secretion of gastric juice which, in the majority of cases observed, became transformed into a well-marked hypersecretion. The volume of gastric juice secreted during a 3-hr period of mechanical stimulation in some of the decorticated animals was more than 2-3 times as great as in control experiments (Figs. 1 and 2).

The length of the latent period, normally very labile, was noticeably shortened, and in some experiments was not longer than 5 or even 3 min. The acidity and digestive power of the gastric juice, expressed as average values, either varied within the limits of the original basic level, or in some cases exceeded it, as was shown particularly clearly in the days preceding the death of the animal.

We succeeded in discovering one further relationship demonstrating the extremely increased excitability of the neuro-glandular apparatus of the stomach in the decorticated animals: the process of extinction of gastric secretion was very greatly prolonged — to 2, and sometimes 3 hrs (Fig. 3), while in the normal animal cessation of mechanical stimulation of the stomach leads even after 15-30 min to a sharp fall in gastric secretion and to the establishment of an alkaline character of the gastric juice.

The increased secretory activity of the glandular cells of the stomach in the decorticated animals is also confirmed by histological examination of the gastric mucosa, especially of the lesser curvature of the stomach. This showed that the glands of the fundus of the stomach are characterized by signs of hypersecretion. A consider-

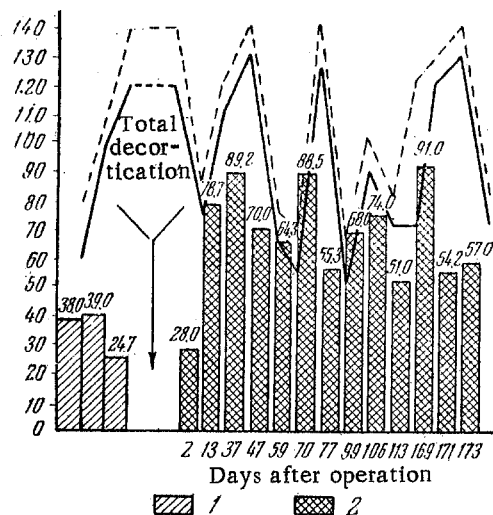


Fig. 1. Changes in the "mechanical secretion" of cat No. 14 after total decortication. 1) Control experiments; 2) main experiments. Each column—total secretion (in ml) during 3 hrs of stimulation. Curve of acidity during the last hour of stimulation. ---) Total acidity; —) free hydrochloric acid. The mechanical stimulus—a rubber balloon introduced into the stomach.

able number of parietal cells with acidophilic protoplasm, filled with secretory granules are found in them. They are easily distinguishable from the chief cells.

As a rule the secretory activity of the stomach was disturbed only in the decorticated animals and not in the controls.

The brain of the decerebrate animals was carefully examined macroscopically and microscopically after death (stained by Nissl's, van Gieson's or Foot's method or with hematoxylin-eosin).

We carried out the morphological examination of the brain of the decorticated animals in collaboration with the pathologists A. S. Iontov and V. K. Skobnikova.

Examination of the residual areas of the brain of the decorticated cats and dogs showed that only the medio-basal areas of the cerebral hemispheres remained, and in the deeper portion of the brain the boundary of the corpus callosum was preserved. The nerve cells of the cortex lying close to scar formation were in a markedly abnormal state. In the cortex at a distance from the scar the nerve cells appeared swollen. The majority of them showed the picture of vacuolization, tigrolysis and edematous dystrophy. Considerable changes in the giant pyramidal Betz cells led to disturbance of the architec-

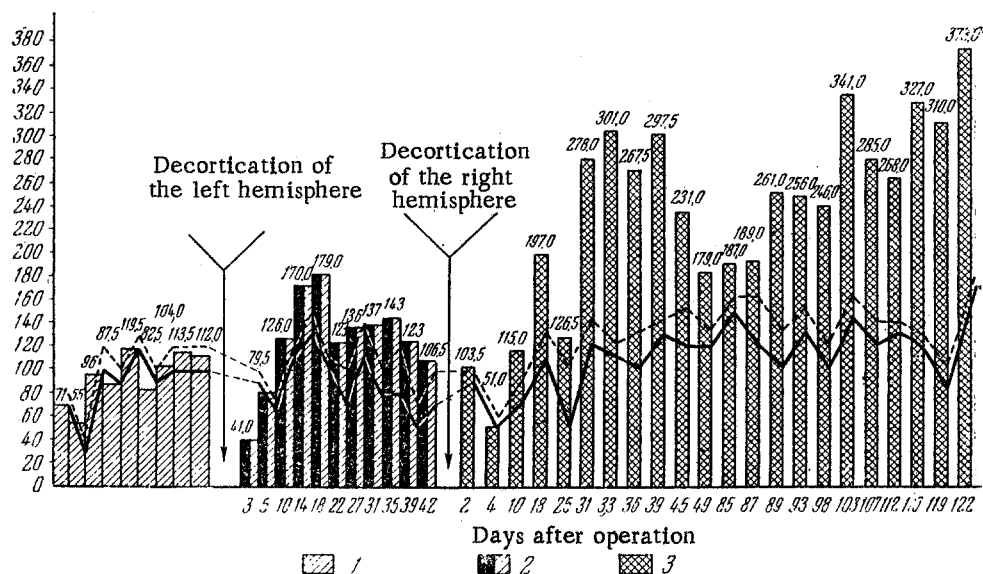


Fig. 2. Changes in the "mechanical secretion" after partial and total decortication of the dog Ryzhla in an experiment in which the mechanical stimulus was a rubber tube 75 cm long and 1.5 cm in diameter, introduced into the stomach. 1) Control experiments; 2) unilateral decortication; 3) bilateral decortication. Each column—volume of secretion (in ml) during 3 hrs of stimulation. ---) Total acidity; —) free hydrochloric acid.

tonic structure of Area 5. These pathological changes in the nerve cells develop on a basis of severe congestion and edema of the brain not only near the scar but also in the more remote areas (thalamus, caudate nucleus, etc.).

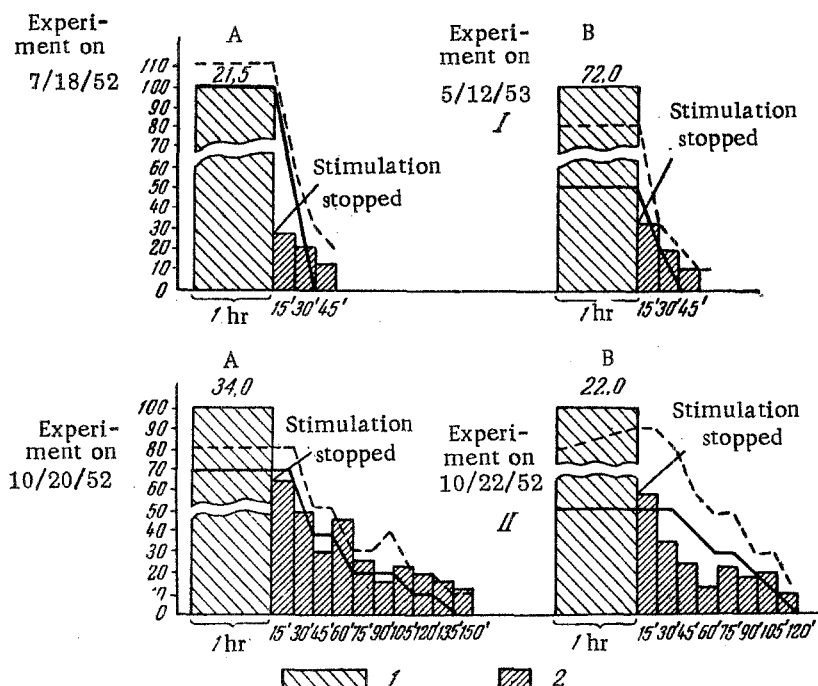


Fig. 3. Rate of cessation of gastric secretion after removal of the mechanical stimulus from the stomach. I) In the intact animal; II) after extirpation of the cerebral cortex. A) In cat No. 14; B) in the dog Mika. 1) Volume of secretion (in ml) during one hour of mechanical stimulation; 2) volume of secretion (in ml) after removal of the mechanical stimulus. ---) Total acidity; —) free hydrochloric acid.

Thus we see that in consequence of operative interference persistent disturbances of the circulation of the blood and cerebrospinal fluid have developed, on which is superimposed the process of scar formation.

As shown by examination of the surviving areas of the cortex, the pathological changes in the neurons were the most pronounced, shown by various forms of dystrophy, leading in some cases to death of the neurons.

The whole of the pathohistological picture of the residual areas of the brain as thus described proves the considerable functional depression of cortical activity, and sometimes its complete suppression. This presumably accounts for the decline in the digestive conditioned reflex reactions to the sight and smell of food which we observed in our decorticated dogs.

Analysis of the experimental data leads us to conclude that the mechanical factor in gastric secretion retains its physiological importance even after the total anatomical and functional exclusion of the cerebral cortex. Since according to the generally accepted view the power of conditioned reflex activity in decorticated animals is irreversibly lost (which our experiments confirm), it may be suggested that the stimulation and increase of secretion of juice following mechanical stimulation of the stomach in decorticated animals takes place by an unconditioned reflex mechanism, as a result of an increase in the tonus of the subcortical vegetative centers, or in other words by subcortical disinhibition.

The phenomenon of "mechanical secretion," first established by us in decerebrate animals, suggests its unconditioned reflex origin. This in itself provides a positive answer to the problem of the physiological importance of the mechanical factor in gastric secretion.

Thus in seeking to solve the difficult problem posed by I. P. Pavlov on the mechanisms responsible for "mechanical secretion" in the normal animal, we came to the conclusion that the main part in its production is played by an unconditioned reflex, activated from the mechanoreceptors of the stomach through a reflex arc

in the vagus nerve center in the medulla oblongata. These findings confirm once more the correctness of the views of S. I. Chechulin [11, 12] that "mechanical secretion" has an intrinsic physiological importance, appearing and becoming consolidated in the animal in the process of phylogenesis.

However, it would be wrong to think that in normal physiological conditions the cerebral cortex has no regulating influence on "mechanical secretion." Experiments in which mechanical stimulation of the stomach was carried out after unilateral extirpation of the cerebral cortex showed that normalization of the "mechanical secretion" in the majority of cases takes place through a stage of hypersecretion (see Fig. 2). In animals with bilateral extirpation of the cerebral cortex it is not possible to observe normalization of the "mechanical secretion," and they die with a well-marked hypersecretory reaction (see Figs. 1 and 2). Evidently the disturbance of the secretory activity of the stomach may be regarded as the result of depression of the regulatory function of the cortex in relation to the activity of the lower centers of the nervous system. This hypothesis is also confirmed, in our opinion, by the rapid normalization of gastric secretion in partial extirpation of the cerebral cortex.

SUMMARY

The author studied the secretion of the gastric juice in response to mechanical stimulation of the stomach both in normal conditions and in partial and complete extirpation of the cortex of the large cerebral hemispheres. Complete extirpation of the cortex of the large cerebral hemispheres did not arrest the "mechanical secretion."

On the contrary, in a majority of cases it caused a pronounced hypersecretory reaction. The latter is manifested in a sharp decrease of the latent period, rise in the amount of gastric juice, as well as by a certain increase of acidity and the digestive power of the mechanically-induced gastric secretion. This hypersecretion of the gastric juice may be considered to be the result of loss of the controlling cortical function on the activity of the subcortical autonomic centers.

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