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Since Alvarez\(^1\)\(^2\) first drew attention to the intestinal action currents, this problem has been studied further by Puestow,\(^3\) Berkson\(^4\) and other authorities in America. But in Japan, so far as I know, only Okuda and Maeda\(^5\)\(^6\) published their reports on the problem in 1925.

In our laboratory, in 1943 Ito succeeded in obtaining the action currents from the bowel of a dog, and thereafter using rabbits chiefly, we made researches of the intestinal action currents which were influenced by drugs and which changed in pathologic situation.

Now I have studied the relation of extrinsic nervous system to the intestinal action currents and I have made experiments of the effects of several drugs upon the action currents from an excised piece of intestine, using rabbits to inquire into the action currents of the gut from which the influences of the extrinsic nerves were absolutely excluded, namely which was disconnected with the central nervous system.

A) The influence of the extrinsic nervous system.

Apparatus and experimental technique:

The abdomen of animals, which were kept from food for about 15 hours before the experiments and which 25 per cent. urethan anaesthetized, was opened and the lower ileum was exposed. Unipolar electrographic records were obtained by applying the zinc-zinc-sulfate moist thread electrodes attached to a string galvanometer. One of electrodes was attached to the serosal surface of the bowel and the other to the subcutaneous tissue, which had no potential change. The sensitivity of the galvanometer is \(2.1 \times 10^{-8} \text{ A.} \) and periods of 4 seconds.
Results of experiments:

1) Effects of spinal anaesthesia.

5 rabbits were used. The upper part of the animal was fixed lying on its back and the lower sideways. The abdomen was opened and at first the electric records of the normal stage of the intestine were taken. Next, the changes of electric waves after the injection of 2 per cent. novocain-solution 0.5 cc. pro kilogram of the body weights were observed. A needle was inserted between the second and the third lumbar vertebrae after the removing of their transverse process and soon after the injection, the caudal part of the body was raised up and the inclination of about 30° was made. Iwashima7) stated that by means of this method, the splanchnic nerves, which control the small intestine, were completely paralysed.

The electric waves in all cases did not change in their period, but grew larger in their amplitude obviously in a few minutes after the injection and this condition continued about an hour (Fig. 1).

Fig. 1

Fig. 2

Fig. 1. The effect of the spinal anaesthesia; a) Before the injection. b) 5 minutes after the injection, large amplitude is seen. c) An hour after, that condition continues. d) One hundred minutes later, returned to normal. The time interval 5 seconds.

Fig. 2. The effect of cutting off the splanchnic nerves; a) Before the cutting. b) 40 minutes after the cutting. c) An hour later. d) 18 hours later. After the cutting, large amplitude is seen. e) 20 hours later, that condition returned to normal. The time interval 5 seconds.
2) **Effects of cutting off the splanchnic nerves.**

5 rabbits were used. The animal was fixed sideways and the abdomen was opened by upper midline incision. The normal records were obtained at first and next the both side splanchnic nerves were cut off extraperitoneally and thereafter the changes of the electric waves were observed.

The waves became regular and grew larger in their amplitude, but did not change in their period. This condition continued several hours. In one case, this change was noted to return to the normal condition after about 20 hours (Fig. 2).

3) **Effects of cutting off the vagus nerve.**

5 rabbits were used. The abdomen was opened with upper midline incision, the normal electric waves were obtained and then the change of the electric waves after cutting off the both side vagi right below diaphragma were observed.

The electric waves became larger in their period and smaller in their amplitude, but in one case the waves enlarged obviously, namely the results were indefinite (Fig. 3).

![Fig. 3](image-url)  
**Fig. 3.** The effect of cutting off the vagal nerves; a) Before the cutting. b) 40 minutes after the cutting, amplitude became smaller and period larger. In the other case: a') Before the cutting. b') 25 minutes after the cutting, both amplitude and period became larger. c') 40 minutes after, that condition continued. The time interval 5 seconds.

![Fig. 4](image-url)  
**Fig. 4.** Circuit of the apparatus. G: Galvanometer. K: Kymographion. I: Intestine. T: Tyrode's solution. e, e': Electrodes.
B) The effects of several drugs upon the excised intestine.

Apparatus and experimental technique:

A piece of intestine about 3 cm. long was excised from the lower ileum of a rabbit. It was allowed to contract rhythmically in Tyrode's solution 200 cc., kept at about 38°C. Namely by Magnus' method the mechanical records were made on a soot-paper and simultaneously the electric ones were made on a bromide paper by unipolar method, in which one electrode was attached to the serosal surface of the intestine and the other to the surface of the solution as shown in Figure 4. I used the same galvanometer as in the experiments on an intact intestine.

Results of experiments:

1) Normal records. I observed the more regular wave than in the case of an intact intestine. Its period corresponded to the mechanical wave clearly, but its amplitude, namely the potential change, did not always coincide with the intensity of intestinal activity (Fig. 5).

Fig. 5. Normal waves. A simultaneous electrical (above) and mechanical record (below) from the excised intestine. The time interval 5 seconds.

2) When 0.1 per cent. adrenaline 0.2 cc. was added to the solution, the electric records showed that the wave became smaller in an average of its amplitude and period, and about 10 minutes after it returned to the normal condition and then 20 minutes after grew gradually greater than before. The mechanical movement stopped completely soon after the addition, about 10 minutes later began to move and 30 minutes later enlarged rather than before (Fig. 6).

3) Immediately after 1 per cent. atropine 0.5 cc. was added to the solution, I observed that the electric wave became a very irregular one, that is, the small waves were piled up over. About 5 minutes later a special wave appeared: one electric wave corresponds to two mechanical ones.
Fig. 6. The effect of adrenaline; Adrenaline was added to Tyrode’s solution (1:1,000,000). a) The electric wave (above) became small only in an average of its period and amplitude, while the movement (below) stopped immediately after the addition. b) 12 minutes after, the electric wave returned to normal and the intestine began to move. c) 30 minutes after, amplitude of the both waves enlarged rather than before the addition. The time interval 5 seconds.

Fig. 7. The effect of atropine; Atropine was added to the solution (1:40,000). a) Electrical record (above) soon after the addition showed that the waves were very irregular, in which small ones were piled up over. The movement (below) became very weak. b) 5 minutes after, one electric wave corresponded to two mechanical ones. The mechanical wave began to move. c) 35 minutes later, special waves (left) above mentioned continued. Mechanical ones (right) returned gradually to normal. The time interval 5 seconds.

This change continued about 30 minutes. The intestinal movement were clearly inhibited: the mechanical wave almost disappeared or became very weak, and about 5 minutes later it returned gradually to normal (Fig. 7).

4) When 0.1 per cent. pilocarpine 0.5 cc. was added to the solution, I could observe that very great oscillation occurred soon after the addition, a few minutes later the electric waves became larger in their amplitude and relatively more regular. And then about 30 minutes later, they returned to normal.

The mechanical records showed that the tetanic-like contraction occurred soon after the addition, after a few minutes very vigorous and
irregular movements began and continued about 30 minutes. Thereafter these movements became gradually regular and normal (Fig. 8).

![Fig. 8](image)

Fig. 8. The effect of pilocarpine; Pilocarpine was added to the solution (1:400,000). a) Before the addition. b) Very great oscillation (above) occurred soon after the addition. The mechanical movement (below) showed the tetanic-like contraction. c) 10 minutes after, the electric waves became larger in amplitude and relatively regular (above). Very vigorous and irregular movements began (below). d) 30 minutes after, both records returned gradually to normal. The time interval 5 seconds.

**Comment.**

It is generally recognized that effects of the splanchnic nerves are inhibitory on intestinal movements and if these nerves are paralysed, the intestinal movements are excited. And it is ascribed to the paralysis of the splanchnicus that the intestinal movements increase, when spinal anaesthesia is performed. And it is quite well known that when the vagal nerves are stimulated, the intestinal movements increase, but recently Kure⁹) and his fellow-workers have suggested that the vagal nerves have something to do only with the stomach and the upper part of the small intestine and the greater part of it is innerved by the spinal parasympathicus. Their investigations have aroused general interest. Namely the influences of the vagus on the lower part of the small intestine are indefinite. In any case, it is recognized that the splanchnicus and the vagus give each other the opposite effects on the intestinal movements.

In my experiments, I have observed that the intestinal action currents either by the section of the splanchnicus or by spinal anaesthesia showed the identical changes, in which the electric waves increased in their regularity and grew greater in their amplitude. On the other hand, when
the vagus was cut off, the electrical records showed that the electrical changes were almost inhibited, but in one case the electric waves became rather greater. From these results it was clear that the intestinal action currents were so influenced by the extrinsic nerves as the intestinal movements. And in the experiments, using the excised intestine which was completely separated from the central nervous system, I found the electrical and the mechanical curves changed almost parallel with each other and more regularly than in the case of intact intestine, but I also found the fact that two curves were dissociated by adding certain drugs, as described by Berkson10) and other physicians. So it may be assumed that the intestinal action currents have intimate relations to the movements but the former differ from the latter in their origin. In other words, the obtained electrogram may be the one that was made by combination of the action currents from nervous cell itself of the local nervous system (Auerbach's and Meiszner's plexus) with the action currents following the intestinal movements. According to this hypothesis, it may be attributed to the myenteric plexus that the potential changes are able to occur without the intestinal movements.

CONCLUSION.

1. After spinal anaesthesia and in the case of cutting off the splanchnicus, the electric waves increased their regularity and grew larger in their amplitude, and they were inhibited in most cases of cutting off the vagus, except in one case of the experiments.

2. When I obtained the electrical records from the excised intestine of rabbits, which was disconnected with the central nervous system, it was found that the electric waves became more regular than in the case of the intact intestine, which was controlled through the extrinsic nerves by the central nervous system. Therefore I think that the essential intestinal action currents show the rhythmical impulse occurring from the local nervous system and having nothing to do with the extrinsic nerves.

3. I investigated, using the excised intestine, the effects of some drugs on the intestinal action currents and its movements. The electrical and mechanical curve changed almost parallel with each other, but it was found that two curves were dissociated when the certain drugs were applied.

4. Hence it was assumed that the extrinsic nervous system had some effects on the intestinal action currents, but Auerbach's and Meiszner's plexus played a leading role of the occurrence of the intestinal action currents.

References.

(1) Alvarez and Mahoney; Amer. J. Physiol., 1921–1922, 58, 476.
(2) The Same; Ibid., 1924, 69, 226.
(5) Okuda and Maeda; Nagasaki Igk. Z., 1923, 3, 537.
(6) The Same; Ibid., 1926, 4, 648.
(10) Berkson, J.; Amer. J. Physiol., 1933, 106, 682.