On the Action Potential of the Dog's Stomach

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An electrical activity of stomach muscle is one of the important researches in the electrophysiology of the visceral smooth muscle.

In 1912, Stübel (11) verified the rhythmic action potentials in the pigeon's stomach. Afterwards, the electrical activities had been recorded from the stomach of various animals belonging to miscellaneous phyla. In Mammalia, the characteristic cycles of potential changes associated with the rhythmical contraction in this organ have been observed by Alvarez & Mahoney (2), Richter (9), and Niu (7). Bozler (4) demonstrated in 1945 that the action potentials could be obtained constantly from dog's stomachs.

In the present paper, the author clarified the electrical potentials, distinctive from the artifacts caused by respiratory or body movements, in a dog's stomach *in situ*. Its characteristics and the effects of a few autonomic stimulating agents and the vagal stimulation were examined.

METHODS

Healthy hybrid dogs weighing 6～10 Kg were used in this experiment. The animals were anesthetized with sodium thiobarbiturate (Isozol) prior to the laparotomy. As the recording with a glass capillary-electrode goes with the technical difficulties, the electrical activity of the stomach was recorded extracellularly with the bipolar electrodes. The electrodes consisted of two silver or platinum needles which were 0.2 mm in diameter and 1.5～2.0 mm apart. Two needles were insulated with paints and lead-glass leaving the tip exposed. These electrodes were buried in the muscle layer at the ventral wall of the stomach. Sometimes, the kidney-shaped polyethylene plates which were perforated in four places to allow suturing to the outer coats of stomach, were used according to the device by Allen et al. (1). The electrical activity was recorded by means of CR amplifier and ink-writing electromagnetic oscillograph. The time constant was adjusted to 1.5 seconds.

RESULTS and DISCUSSION

It was described by Bozler that there was no remarkable difference between the action potentials recorded by intracellular lead and those by extracellular lead, if the electrode distance was less than the length of excitation wave.

The peristalsis of the dog's stomach was visible with naked eyes in most cases. Its movement was remarkably active at antrum and was lacking at cardiac portion. (On the contrary, the peristalsis of the human stomach can seldom be seen in any part.) Even if the peristaltic waves were not recognized, however, the action potentials were detectable without fail in the stomach, except in the fundus or in the true pylorus.

1. *General characteristics of the action pctential.*

In the record of action potential, we were able to observe the slow spike-like discharges occurring 1.0～1.5 sec ahead of the peristaltic waves. Its duration was about 1 sec. The frequency was the same as peristaltic waves. i.e. 3～6/min. Sometimes the slow fluctuated waves could be seen after slow spike-like discharges. Although these waves seem to be equivalent to the so-called 'T wave' (according to Bozler, 1945), it is difficult to say that the potential is an evident action potential; because it is caused also by the mechanical changes in placing the electrode or by the movement of the animal. According to Bozler, the 'T wave' is related to the muscle tonus.

The magnitude of the spike potential is the largest when the bipolar electrode is arranged longitudinally along the axis of the stomach and is not always proportional to the strength of peristaltic movement. Apparent electrical activity is observed at the lower two-third of the gastric body, but it cannot be obtained from the fundus or the upper one-third of the gastric body. Electrical changes generally consist of two components. The first is a rhythmic or cyclically recurring potential fluctuation (the slow basic electrical rhythm, BER). The second is the bursts of fast or spike-like potentials superimposed on the first. It is generally accepted that the basic electrical rhythm in the duodenum occurs more frequent than in the stomach. Basic electrical rhythms of the stomach and duodenum are independent of each other, while the duodenal basic electrical rhythm often tends to be accompanied with the superimposed spike bursts (Fig. 1). This discrepancy of electrical activity between the stomach and the duodenum could be explained as follows; i.e. ① the interruption of most of the muscle fibers in pylorus (3) may be the cause of that discrepancy or ② both stomach and duodenum may have respective pacemaker. According to Daniel et al. (5) the pacemaker of the duodenum exists near the entrance of the common bile duct. Concerning the stomach, further evidence in favour of this idea has been described by Alvarez et al. as follows; the lesser curvature near the cardia has a faster rate of contraction than that of any other part of the stomach. Therefore, they concluded that the excitation waves are conducted from cardia to pylorus. On the contrary, there is also another experiment (10) which has proven that

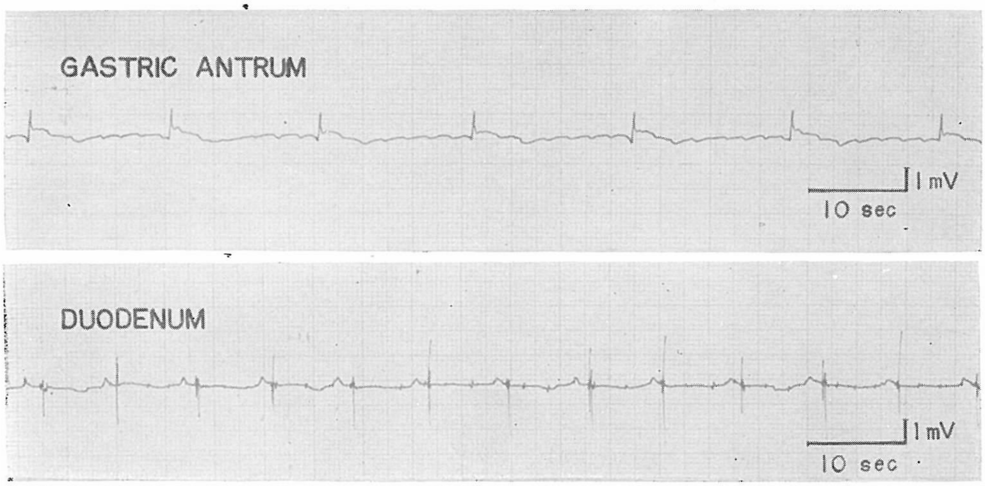

Fig. 1. The basic electrical rhythms (BER) of the antrum and duodenum are shown. The rate of this rhythmic activity is more frequent in the duodenum than in the antrum. The fast activity is often seen superimposing on, or occurring after the duodenal BER.

the potential gradient from greater to lesser curvature was demonstrated on the transverse line in toad's stomach. In other words, the amplitude of the action potential was higher in the greater curvature than in any other part on the same transverse level by the intracellular lead. From these facts it is conceivable that the pacemaker, in the meaning of the site of origin of the excitation wave, locates predominantly in the cardiac portion when the excitation wave is conducted longitudinally, and in the greater curvature when it is conducted transversely.

In the present experiment, however, it must be emphasized that the differences between the discharge frequency of the gastric body and the pyloric antrum were not obtained, and also that the difference between the amplitudes from the lesser curvature and that from the greater curvature was not found.

On the other hand, Ichikawa and Bozler (6) recorded the action potentials in the longitudinal muscle separated from the circular muscle and obtained the similar configuration of the action potentials from both fibers. They ascertained also that, in the circular muscle, the amplitude was the largest when the bipolar electrodes were arranged transversely to the muscle fiber. It is reasonable to suppose that these results are related with the fact that the contraction waves are mainly conducted along the longitudinal axis of the stomach.

As for the differences among the magnitudes or the durations of the action potentials in various parts, extending from the cardia to the pylorus, the strength of motility, the difference of the anatomical structure and/or the developmental grade of the muscle (8) are considered to be the cause.

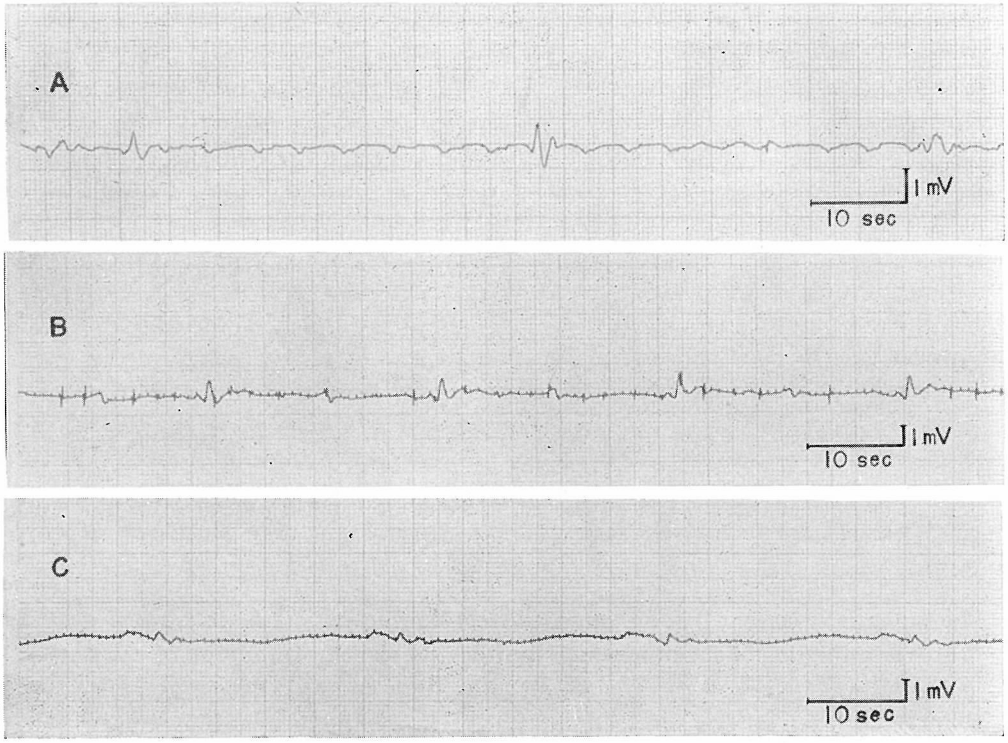

Fig. 2. The action potentials recorded from the antral portion. A: The electrode distance 2 cm. The small fluctuations due to the respiratory movements are seen. The duration of the action potentials tend to broaden. B: The electrode distance 3 cm. The artifacts due to the respiratory movements and electrocardiograms mix in the electrical activities of the stomach. C: The electrode distance 6 cm. Electrocardiograms mix in and the shape of the action potentials is distorted.

Examining the changes of the electrical activities due to the increase of the electrode distance, it seemed that the unexpectable noises were more liable to mix in the records when the electrode distance of the bipolar electrodes was larger (Fig. 2). The necessity to minimize the noises would be the experimental condition that the electrode distance is less than the wave length of the activity.

It is interesting that the potential changes could not be recorded at the true pyloric region (hypomuscular segment). In the resting state, the pyloric sphincter remained constricted because of the continuous activity of the muscle, and the changes of contractile activity might be considered too slow to render the electrical activity measurable. As a rule, no peristalsis can be observed where the electrical activity is not substantiated.

2. *Effects of drugs or vagal stimulation.*

(1) ADRENALINE (epinephrine hydrochloride).

When adrenaline was injected intravenously by 0.1 mg/Kg, the discharge intervals of stomach action potentials prolonged and became transiently irregular (2 min after adrenaline administration), and in about 10 minutes after the injection the frequency of the discharges returned to the previous one. The shape and the magnitude of action potential were not changed by the adrenaline administration.

(2) BESACHOLINE (Bethanechol chloride)

Intramuscular administration of besacholine (0.25 mg/Kg) gave to the visible contraction-wave a strong reaction, the peristaltic waves became larger, while the frequency of peristalsis decreased. The discharge interval of the recorded action potential prolonged but the amplitude did not alter. In addition, the potential fluctuation appeared following the BER (Fig. 3). These phenomena might be interpreted as the results of the increased tonus of the muscle.

(3) ACETYLCHOLINE (Trimethyl acetoxy-ethyl-ammonium chloride)

To the electrical activity of the stomach, acetylcholine gave the similar effects as the besacholine. The visible peristalsis became larger and frequent immediately after the administration of acetylcholine. The frequency, however,

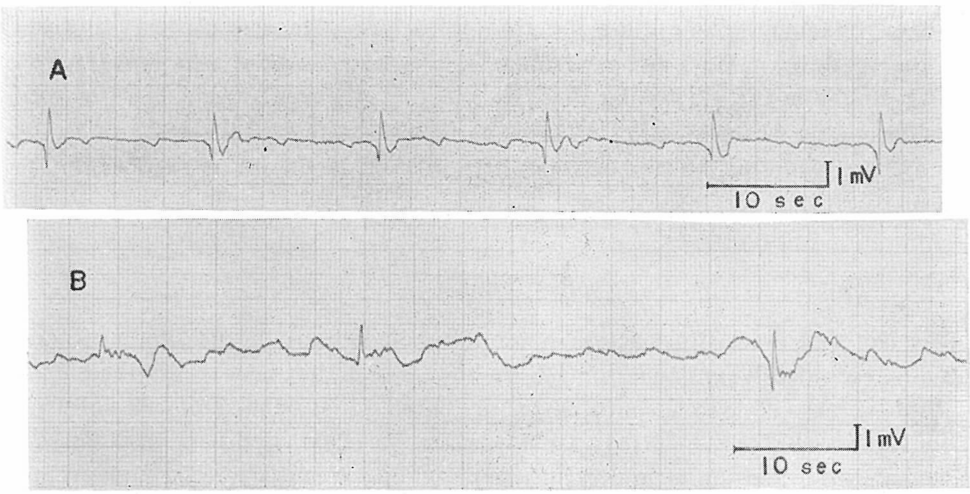

Fig. 3. The effects of besacholine are shown. A: The electrical activity of the stomach (antral portion) before the besacholine is injected. B: The electrical activity of the stomach in 2 minutes after the administration of besacholine. The frequency of the discharges decreases, and slower fluctuations are observed.

was decreased soon after the administration, and about ten minutes later it recovered to the previous frequency before the administration.

Except the frequency, there were no remarkable changes in the action potential, but sometimes the reverse of diphasic polarity was observed.

(4) ATROPINE (Atropine sulfate)

The heart rate increased under atropine administration (0.05 mg/Kg) without any remarkable change in the stomach's electrical activities; i.e. no changes in the amplitude, the frequency or the configuration of the recorded action potentials were observed.

(5) VAGAL STIMULATION

The left vagus nerve which is said to innervate the anterior wall of the stomach, was stimulated in the neck level with rectangular electric pulses of 1 msec duration and 10/sec frequency.

The period of the stimulation was 3～5 seconds. Though the effect of stimulation was enough to produce slowing or stopping of the heart beat during its performance, the definite influences to the electrical activity of the stomach could not be observed. There is an experiment (12) which records that, a week after the vagotomy of both anterior and posterior branches was made at the level of abdominoesophagus, antiperistaltic activity was recorded, but the author of this paper could not record results. Beside the direct effects of vagal stimulation to the electrical activity of the stomach muscle, other factors such as the decrease of gastric secretion may be responsible for initiating the antiperistaltic waves or reducing the amplitude of action potentials. These results may suggest that the vagus nerve does not participate in initiating the peristaltic movements itself. But from the view point that the effect of the vagal stimulation for the stomach muscle was not major in this experiment, it can be considered that the vagus nerve regulates the stomach motility, in cases when the normal rhythms and/or peristalsis were disordered.

SUMMARY

The fact that the distinct action potential excluding all the possible artifacts could be recorded from dog's stomach by bipolar lead, has been established.

1) It is reasonable to accept that the action potential of the stomach consists of two components. The first is the slow basic electrical rhythm or slow potential fluctuation, and the second is the bursts of fast potentials superimposed on the former.

2) There is no relationship between the electrical activities of the stomach and that of the duodenum.

3) The effects of autonomic stimulating agents such as adrenaline, besacholine, acetylcholine, atropine on the electrical activities of the stomach were observed.

4) The changes in the electrical activity resulted by the repeated stimulation of the vagus nerve or by the vagotomy were discussed.

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