PERIODIC MOTOR ACTIVITY OF THE STOMACH DURING DIGESTION

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Periodic "hunger" contractions were first studied in detail by V. N. Boldyrev [1], along with the periodic secretion and motor activity of other parts of the alimentary tract. According to Boldyrev, periodic activity of the stomach is absent during digestion. Other conditions that stop periodic function of the stomach are sham and natural feeding, and acid gastric secretion.

If food enters the stomach without passing through the oral cavity, i.e., through a gastric fistula, the "hunger" contractions do not disappear. Moreover, milk, fluid egg albumin, or neutral fat poured into the stomach passes into the intestine in large amounts. On the other hand, these fluids are retained in the stomach for half an hour or so if they are introduced into it in the absence of "hunger" contractions [11]. Although the absence of periodic gastric activity during digestion has since been confirmed by many authors [8, 10, 12], this question still can not be regarded as conclusively settled. First, coordinated periodic activity of various parts of the alimentary tract was observed by V. N. Boldyrev even while food was present in the intestine. Investigators who have studied the periodic motor activity of the stomach have often had to remove a large amount of food from the stomach before an experiment, after which they could immediately record typical periodic contractions. These doubtless occur in the presence of a food mass in small intestine, i.e., under conditions of intensive absorption of food substances into the blood. For that reason, it is essentially incorrect to call periodic gastric contractions "hunger" movements. Secondly, several authors have observed periodic stomach contractions while food residues were present in the stomach cavity, i.e., at the end of gastric digestion [1, 6, 12]. Third, there are some indications that there is no perceptible difference between "hunger" movements and the digestive motor activity of the stomach [9]. In addition, some investigators [2, 5] have seen periodic release of bile from the gall bladder during gastric digestion. Up to two gall-bladder contractions in a 6-hour digestive period were observed in man. In dogs with fistulae of the bile duct it has been found that during the digestive process 2-4 gall-bladder contractions occur after giving milk or meat. The duration of contractions averages 40-80 min, and the duration of the intervals between contractions, when only liver bile is secreted, is 10-80 min. In studying the periodic motor activity of the stomach in dogs after chronic loss of bile, we also observed bile secretion of a periodic character both during digestion and on an empty stomach [7]. In these experiments we noted that when bile is eliminated from the digestive process over long periods of time, the weakening and disordering of the periodic motor activity of the stomach that results is paralleled by a weakening of the emptying function of the stomach. In this connection it is of particular interest to compare Pavlov's conclusion as to the emptying, "throwing-out" character of the movements of the gall bladder, which at that time had not yet been described as periodic [4].

The present paper is a report on experiments concerned with periodic motor activity of the stomach during digestion. The experiments fall into three series: 1) period motor activity of the stomach after removal of chyme through a gastric fistula and rinsing the stomach with warm water; 2) periodic motor actitivy of the stomach with food residues present in it; 3) periodic motor activity of the stomach when the dog was fed mixed food during the experiment.

METHODS

We conducted 46 experiments on six full-grown dogs in which the motor activity of the stomach was recorded for 8-20 hr or more. For these experiments we used the following dogs: Marta (with a fistula at the boundry between the pyloric and fundic portions of the stomach and a gall-bladder fistula with ligation of the common bile duct); Sil'va (having a fistula in the gastric fundus; resection of the pyloric segment with retention of the pyloric sphincter and an end-to-end anastomosis between the fundic and remaining pyloric parts of the stomach); Khitryi (fistula in the gastric fundus, resection of the whole pyloric segment, posterior gastroenteroanastomosis, and gall-bladder fistula with ligated common bile duct); German (fistula at the gastric fundus, and an isolated Pavlov pouch); and Belka and Dzhul'ba (fistula at the boundary between the pyloric and fundic portions of the

stomach). The dogs were kept on a constant mixed diet: bread, meat, and oatmeal. The food was given once a day, usually at noon. In the case of some of the dogs, part of the bread and oatmeal was found to be still in the feeding tray on the following day.

The dogs looked healthy, and their weight remained the same throughout the period of these experiments. The gastric contractions were recorded with the aid of a rubber balloon with a volume of 15-20 ml, connected to a Marey tambour by rubber tubing filled with water and air. The contractions were recorded on kymographs with special clock mechanisms to rotate the drums at a perfectly uniform rate. Two kymographs were used: one made a complete revolution of the drum in six hours, and the other in eight hours. It was not difficult to remove the food from the stomach, on account of the wide lumen of the fistula (2 cm diameter). The stomach was rinsed for 4-7 min with water warmed to 38°. The presence of food in the stomach during the experiment and the ejecting character of the gastric contractions were estimated from the expulsion of chyme through a hole in the stopper placed in the fistula. From time to time the stopper was removed from the fistula and the presence of food in the stomach was checked. In those experiments that ended with food still in the stomach, the chyme was removed through the fistula and weighed. The length of the experiments enabled us to compare the motor function of the empty stomach with its motor activity during digestion.

RESULTS

Removing food from the stomach and rinsing it with water causes the tone of the gastric musculature to be elevated for 1-2 hr. But the periodic activity of the stomach in this case is not noticeably different from the typical periodic motor activity that occurs when all food passes into the intestine. Since various amounts of half-digested food (from 100 to 800 g) were removed from the stomach in these experiments, there is reason to suppose that clear-cut periodic motor activity of the stomach was occurring in the presence of active intestinal digestion.

In experiments where the stomach was not rinsed, 100-400 g of chyme was pushed out through the opening in the fistula stopped by the gastric contractions. At the end of some experiments, up to 200 g of chyme was extracted from the stomach. In the course of these experiments it became clear that the presence of food in the stomach has a marked effect on the motor activity of the stomach, without disturbing its periodicity. A distinctive feature of such "digestive" periods, as compared to so-called "hunger" periods, is that they are thoroughly saturated with contractions during the phase of relative rest. In the empty stomach, after the end of a period of activity there follows a distinct period of rest for the gastric musculature for 1-2 hours, but during gastric digestion the resting phase is completely replaced by stomach contractions. The latter gradually become stronger and pass directly into contractions of the active period.

Figure 1 shows that the periodic changes in tone and the periodic development of strong contractions characteristic for the empty stomach (second half of the experiment) are also observed when food residues are present in the stomach (first half of the experiment). It can be seen from Fig. 1 that the clear-cut division of the motor activity of the stomach into periods of work and rest, which characterized the empty stomach of the dog, is largely masked during gastric digestion by contractions in the "resting" phase. In addition, we note some variability in the length of the "digestive" cycles which is less characteristic of the periodic activity of the empty stomach. Whereas the length of the "hunger" cycles was $1\frac{1}{2}$ hr, on the average, that of the "digestive" cycles varied during a single experiment from an hour and twenty minutes to two hours and ten minutes. The periods of activity during gastric digestion were generally far longer than those of the empty stomach; the former usually lasted about an hour, in which time up to fifty contractions occurred. It was also noted that an individual periodic contraction, either during digestion or while the stomach is empty, is a complex peristaltic wave consisting of several component movements. Although contractions occur continually in the period of "rest" during digestion, the expression of food through the opening in

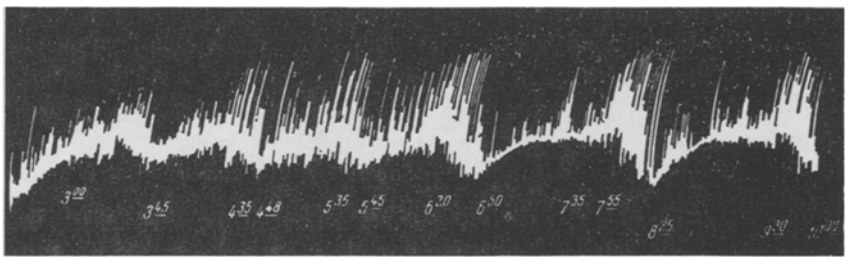

Fig. 1. Comparison of the periodic motor activity of the stomach when food is present in the stomach (first half of the experiment, up to 6 hours 50 minutes) and when the chyme has all moved into the intestine (second half of the experiment). Dog German. Experiment of November 2, 1952.

the fistula stopper occurs primarily during the period of activity.

Experiments with food present in the stomach also showed that the characteristics of the motor activity during digestion are similar to those of the empty stomach.

Thus, in one of the dogs the periodic motor activity of the empty stomach was irregular. During digestion the periodic motor activity of this dog's stomach had the same characteristics.

In experiments in which the dogs were fed mixed food during periodic activity of the empty stomach, the same results were obtained, in the main, as in those experiments where food remained in the stomach (Fig. 2). The act of eating itself, during the period of gastric "rest", brings on small contractions lasting 10-40 min. The elevation of "tone", which was almost always seen under these circumstances, was probably caused by mechanical pressure of the food on the balloon. The stomach contractions began during the very first minute of eating, and lasted for 5-7 min. The entrance of food into the stomach was accompanied by periodic motor activity, which lasted from five to ten hours, until all the food had moved into the intestine. Periodic motor activity then continued in the empty stomach. The first period of work during digestion came 1-3 hours after eating. During this 1-3 hours the stomach gave continual weak contractions, which gradually became stronger toward the beginning of the period of work. In the case where the dog ate 300 g of food (150 g of cooked meat and 150 g of thin oatmeal), the first period of work began 3-4 hr after the meal; it continued about an hour and was sometimes the only period of gastric work during the time of digestion. If the dog ate 600 g of food (150 g of meat, 100 g of bread, and 350 g of thin oatmeal), the first period of work more often began an hour after eating, and during gastric digestion 3-5 periods of stomach work were noted.

Thus, our experiments showed that during intestinal and gastric digestion periodic motor activity of the stomach occurs in dogs. There is no essential difference between periodic motor activity of the stomach during digestion and in the absence of gastric contents. A distinctive feature of the periodic motor activity of the stomach during digestion is a work period that is more prolonged than with the empty stomach, and a less marked period of relative rest.

The conditions that have permitted us to observe distinct periodic motor activity in the stomach during digestion are apparently the relatively long duration of our experiments under continuous-recording conditions, the method of slow recording of gastric activity, the maintenance of the dogs on a mixed diet, and the feeding of a mixture of foods during the experiment. These conditions distinguish our experiments from earlier ones.

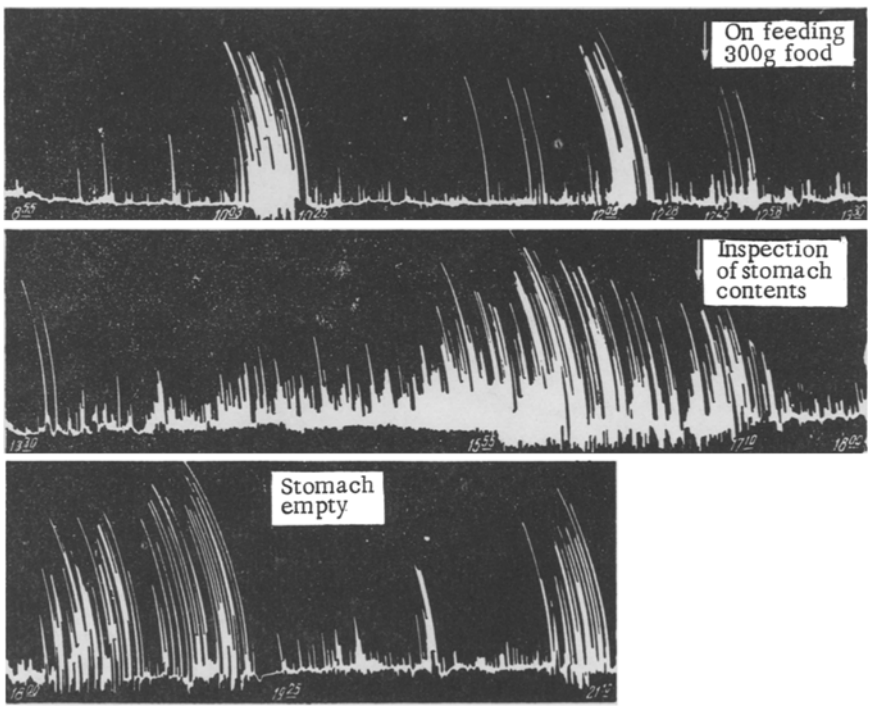

Fig. 2. The effect of eating a mixed meal on the periodic motor activity of the stomach. Small degree of excitation of gastric contractions in connection with eating. Three hours after meal, development of strong, prolonged period of gastric work, during which not all the food entered the intestine. After a second, also prolonged, period of work the stomach was free of food. Dog Dzhul'ba. Experiment of May 11, 1952.

In addition, our experiments give us reason to suppose that periodic motor activity of the stomach probably plays an important role in the natural transfer of food from the stomach into the intestine.

SUMMARY

A method of prolonged constant recording of the periodic motor activity of the stomach was used in chronic experiments on dogs with fistulae of various portions of the digestive tract. The existence of periodic gastric motor activity during intestinal and gastric digestion was revealed. This type of motor activity was recorded in dogs on mixed diets; these dogs also received a mixture of foods during the experiment. On the basis of these experiments it is suggested that periodic motor activity plays an important role in the natural passage of food from the stomach into the intestine. Stimulation of gastric motor function for 10-40 minutes in connection with the act of eating was also noted.

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