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Motility of the Human Digestive Tract under Resting Conditions and After Ingestion of Food

A Study with Endoradiosondes

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ABSTRACT

The motility of the digestive tract in healthy persons was studied by means of pressure-sensitive endoradiosondes, under resting conditions during the night and after ingestion of food. In the stomach, slow pressure waves were observed with a frequency of 3–5 contractions per min and pressures of up to 10 cm H_2O, as well as activity in the form of relatively rapid pressure increases of up to about 25 cm H_2O—so-called type II waves. These waves were observed especially in the antrum. After ingestion of food increased activity was recorded in the form of a higher frequency of type II waves. In the small intestine waves of both type I and type II were recorded. Immediately following ingestion of food the intensity of both type I and type II waves increased. In the colon, waves of types I, III and IV were recorded. After ingestion of food the intensity of the type III and IV waves was increased. Activity during the night was considerably reduced in relation to that during the daytime. However, activity was recorded in all subjects; this was usually of type I, though bursts of type III waves were also recorded.

INTRODUCTION

The motility of the digestive tract under different conditions has been studied by several authors, using various methods. Signs of activity in the intestine have been observed under basal conditions, such as in fasting and sleep. Studies of the conditions during sleep have given rather contradictory results, however. Thus, Cannon (8) found no change in the rate of passage of barium contrast medium through the intestinal tract during sleep in the cat. Neither did Barcroft & Robinson (4) nor Douglas & Mann (12), who studied an exteriorized small-intestinal loop in the dog, find any change in the motility during sleep. The same result was obtained by Hines & Mead (18) and Alvarez (2) in man. However, reduction of the motility during sleep has been observed in man by other authors (17, 29). Increased intestinal activity after a meal has been shown by several authors (3, 4, 5, 12). Bárány & Jacobson (3), in an attempt to ascertain whether there was any correlation between the intraluminal pressure in the intestine and the propulsion of an endoradiosonde, studied the passage of the sonde through the intestine for 5 hours. During this period the effect of food and certain drugs on the pressure conditions and propulsive motility in the small intestine was observed.

The aim of the present investigation was to study the gastrointestinal motility in man during the night, and the effect of ingestion of food on different sections of the gastrointestinal tract.

MATERIAL AND METHODS

The activity in the digestive tract was studied by means of pressure-sensitive endoradiosondes (small wireless transmitters from which information can be conveyed to a radio receiver and a recording unit). Endoradiosondes have been described previously by Jacobson & Nordberg (20). The length of the sonde is 1.65 cm, its diameter is 0.9 cm and its specific weight 2.2 g/cc. The life of the batteries is about 10 days. The sondes were calibrated against a water column at 37.5–38°C. A receiver of the type described by Jacobson & Lindberg (19) was used, and this was connected to one channel of a two-channel recorder.

To enable simultaneous recordings to be made of the pressure changes in the abdomen due to respiration, a breathing indicator for recording the respiratory movements was constructed. This consists of a strain gauge which is incorporated into a belt which is worn around the thorax. The changes occurring in the strain gauge due to thoracic movements on respiration are transmitted electronically to the second channel on the recorder. Fig. 1 shows the wiring diagram of the recorder and Fig. 2 the breathing indicator in position on a subject.

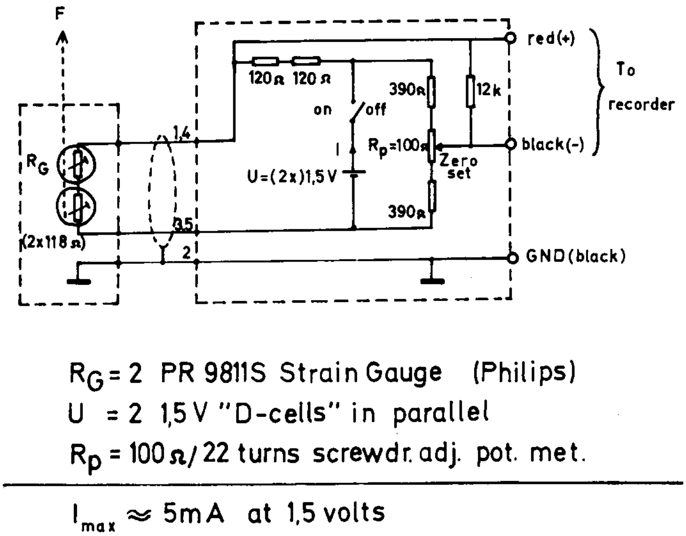

Fig. 1. Wiring diagram for breathing indicator.

Ten subjects were studied. All were subjectively free from gastrointestinal symtoms.

The studies were usually started in the morning. The subject swallowed the endoradiosonde with a drink of water, after which the recording was started immediately and continued uninterruptedly for 12–36 hours. At the end of the study the sonde usually lay somewhere in the colon.

The curves were analysed qualitatively and quantitatively. The stomach, small intestine and colon were studied separately. The classification of pressure waves in the digestive tract first suggested by Templeton & Lawson (28) was used. The quantitative analysis was performed in the same way as described by Bárány & Jacobson (3). The curves for each hour before and after a meal were divided into 15-min periods. For each period the sum of the amplitude in cm H_2O of all type I waves was calculated. The increase of the basal pressure with type III waves was measured by planimetry of the total area formed by the base line and the pressure curve. The sum of all areas during all 15-min periods was then calculated.

The propulsive motility was estimated approximately by attempting the whole time to keep the antenna at the position on the abdomen where the strongest signal was recorded. The antenna was thus moved according to the propagation of the sonde in the analward direction.

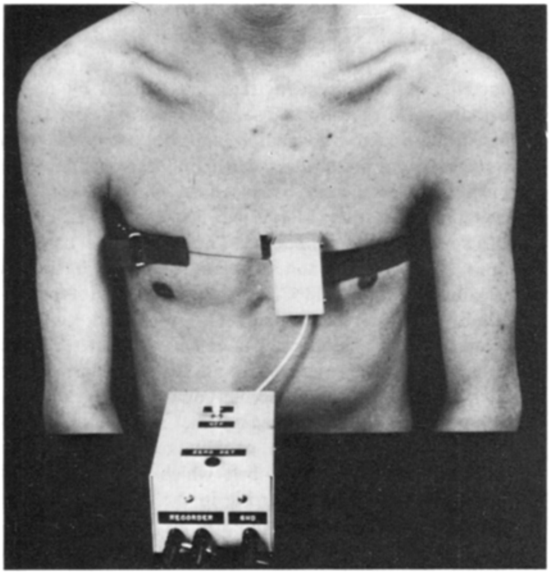

Fig. 2. Breathing indicator in use.

RESULTS

When the sonde lay in the stomach, two different types of pressure waves were observed. When the strongest signal was recorded high up to the left in the epigastrium, the sonde was estimated to lie in the corpus of the stomach. At that time a slow pressure wave with a frequency of 3–5 contractions/min and a pressure of up to 10 cm H_2O was recorded. This pressure wave was seen especially under fasting conditions (Fig. 3). When the strongest activity was recorded to the right of the midline and the sonde could thus be estimated to lie in the antrum, a different type of activity was observed in the form of relatively rapid pressure increase usually to about 25 cm H_2O but sometimes rising to about 60 cm H_2O (Fig. 4). In the literature this latter type of wave has been called type II. When the sonde lay in the antrum in

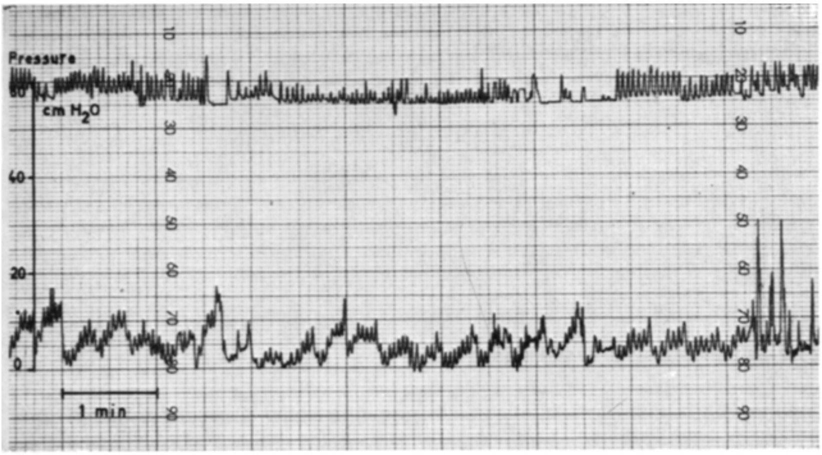

Fig. 3. Pressure activity in gastric corpus between meals.

cases where a meal had been taken, a marked increase in frequency of type II waves was noted (Fig. 5).

This increased activity after a meal was not observed so regularly in the stomach as in the small intestine. Fig. 6 shows the results of quantitative analysis of the conditions 1 hour before and after a meal in a representative case where the sonde lay in the antrum when the meal was ingested. Motility was observed in the stomach even during the night, but to a considerably smaller extent than by day. A particular finding was that the frequency of type II waves in the antrum was lower during the night.

Like other authors, we recorded activity of types I and III in the small intestine. Type I consists of regular, almost identical waves with no appreciable elevation of the base line and with a pressure of up to 10–20 cm H_2O. Type III consists of an elevation of the base line, superimposed by waves of type I or type II. Waves of types I and III were identified under fasting conditions, after a meal, and during the night with the patient at rest. During the night the frequency of pressure waves was considerably reduced compared with the conditions during the daytime. However, bursts of marked pressure increase were also observed during the night (Fig. 7).

The gastro-jejunal or gastro-ileal reflex was noted very regularly. Very soon after a meal had been taken, sometimes almost immediately after the first food had been swallowed, lively activity was recorded in the intestinal tract. These recordings comprised waves of both type I and type III, where both the frequency and amplitude were increased. This increased activity (Fig. 8) persisted for ½–2 hours. Fig. 9 shows the results of quantitative analysis in a typical case 1 hour before and 1 hour after a meal.

The intensity of the motility changes after the meal varied between different subjects. The reflex was sometimes very well developed and in other cases only weakly discernible. On the whole, the different recordings varied in appearance, but the

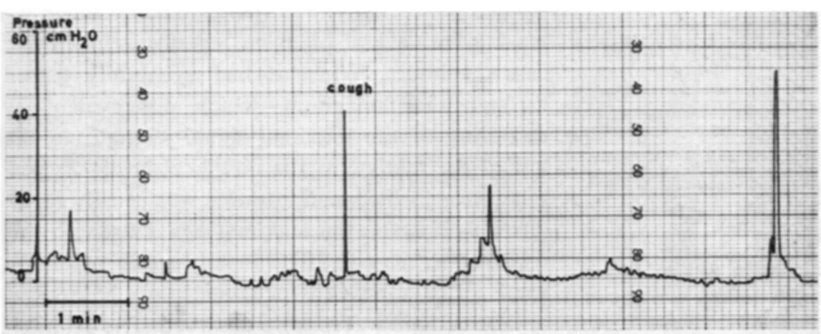

Fig. 4. Pressure activity in gastric antrum between meals.

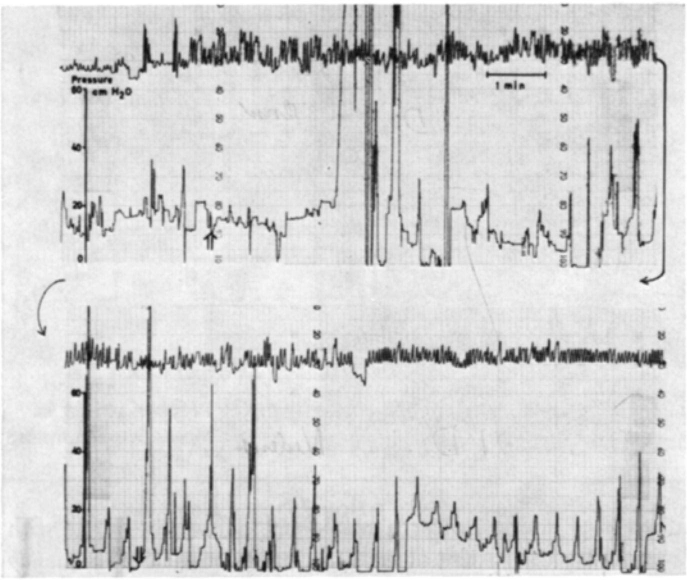

Fig. 5. Pressure activity in antrum before, during and after a meal. Arrows indicate beginning and end of meal.

pattern mentioned above could be distinguished in all cases.

Recordings were also made with the sonde lying in the colon. Colonic activity was also observed during the night, but this was reduced compared with that in the daytime. Spontaneous contraction waves of types I, III and IV were seen. Type IV has usually been defined as a wave with a duration of over 1 min, with a high or low amplitude. As a rule, the rise of the wave was rapid and its fall slow (Fig. 10). The amplitudes of the waves in the colon were often greater than those of waves in the rest of the gastrointestinal tract, with the possible exception of the stomach, and corresponded in some cases to a pressure of about 40–70 cm H_2O. The gastrocolic reflex was also observed. This reflex was very active and in some cases started simultaneously with the start of food ingestion. In such cases series of strong contractions of types III and IV, with high amplitudes, were observed. The amplitude sometimes corresponded to a pressure of up to 60–70 cm H_2O (Fig. 11).

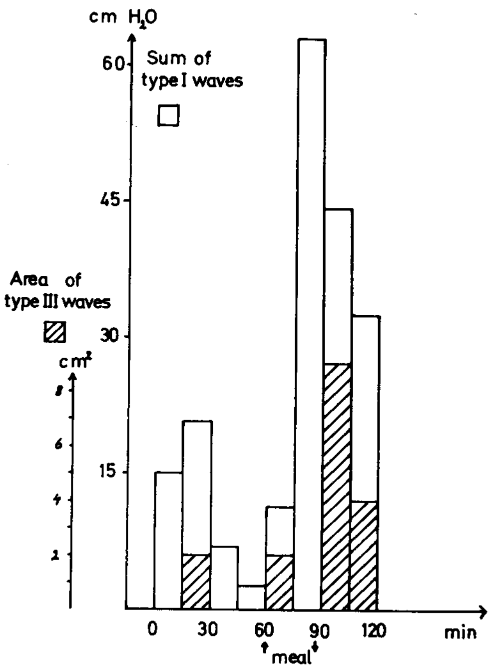

Fig. 6. Diagram of pressure conditions in antrum during 15-minute periods in a healthy subject before, during and after a meal.

Regarding the propulsive motility, which was studied indirectly, it was found that the sonde often lay for several hours in the stomach—in one case 21 hours. When it had eventually passed through the duodenum—which was evident by recording of the maximal signal strength to the left of the midline at the umbilical level—its passage through the small intestine was usually rapid. After 6–10 hours the maximal signal strength was recorded at the right iliac fossa. In this region the sonde often remained for some hours before the typical colonic waves were observed. The relation-

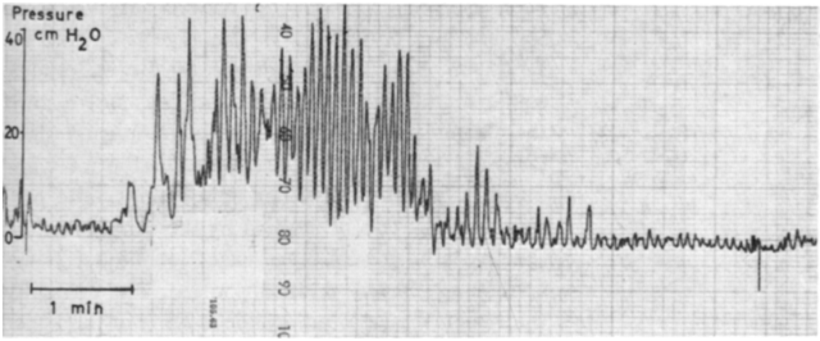

Fig. 7. Contraction waves of types I and III in small intestine during sleep.

ship between pressure wave and propulsion could not be elucidated by this method, however, since the propulsion was only studied indirectly.

It was sometimes observed that the sonde was propelled in an analward direction without any noteworthy pressure changes occurring. In other cases considerable activity was recorded while the sonde remained relatively still.

DISCUSSION

Gastrointestinal motility has been studied previously by several methods. In animal experiments, Brandberg (6), Parkkulainen (23) and Rödén (26), among others, used a window produced operatively in the abdominal wall. Puestow (24) brought forward an intestinal loop and sutured it to the abdominal wall, and studied the motility there. Ehle & Foltz (13) and Rinecker et al. (25) used a method in which a strain gauge was sutured into the intestinal wall. The gastrointestinal propulsion has been studied in experimental animals with isotope techniques by Nylander & Wikström (22) and other investigators.

In man, several authors have used catheters with balloons or open lumina in order to study motility. To measure both the changes in pressure in the intestine and the propulsive motility,

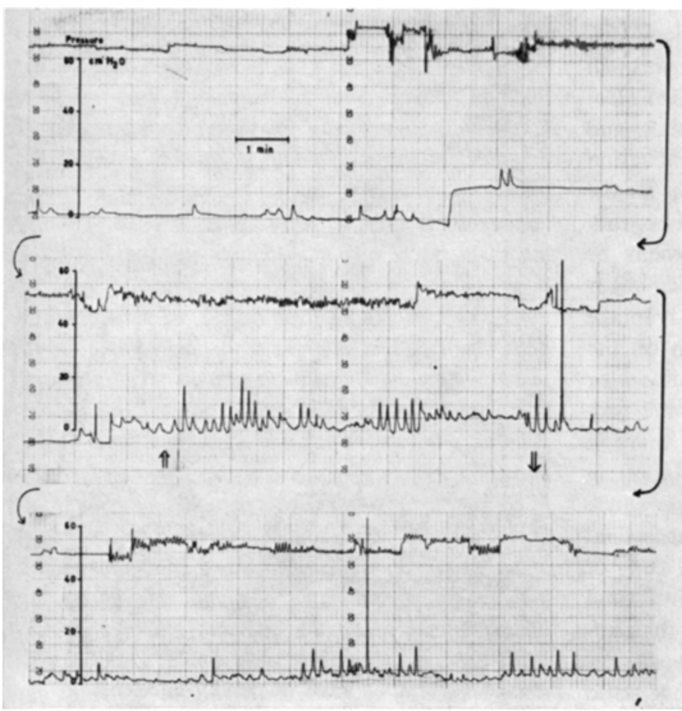

Fig. 8. Pressure conditions in small intestine before, during and after a meal. Arrows indicate beginning and end of meal.

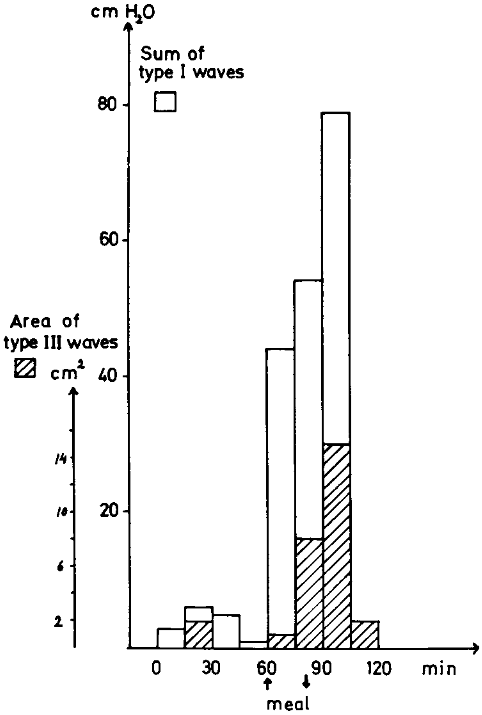

Fig. 9. Diagram of pressure conditions in small intestine during 15-minute periods in a healthy subject before, during and after a meal.

Deller & Wangel (11) combined pressure measurement via catheters with cinéradiography. The propulsion has also been studied roentgenologically, whereby the passage of contrast medium through the intestinal tract has been followed (16). Isotope technique have also been used in man, and especially Brömster (7) studied gastric evacuation by this means. The pressure conditions in the human digestive tract have most often been studied with the aid of catheters with balloons or open lumina introduced orally into the oesophagus and stomach, a method which has the advantage of giving more or less direct information on the changes in pressure exerted on the balloon or catheter tip. It gives no information on the propulsive motility, however. Furthermore, there is a risk that the catheter, by causing irritation in the mouth, oesophagus or stomach, may produce changes in the motility of the gastrointestinal tract. A window in the abdominal wall can, of course, give a good picture of the intestinal motility but has a similar disadvantage that unphysiological conditions may be produced.

Pressure-sensitive endoradiosondes have also been used in different connections for studies of the pressure conditions in the digestive tract (3, 9, 14, 15, 27). The advantage of the endoradiosonde method is that the sonde does not disturb the normal physiological course of events, since it passes through the gastrointestinal tract without any catheters or other connections. The propulsion, also, can be studied by the simple method that we used, or by more exact technique, as described by Bárány & Jacobson (3). The difficulty that when the endoradiosonde is lying in the upper part of the abdomen it also records pressure changes due to respiratory movements, has been overcome essentially by means of the breathing indicator which we have constructed. The finding that the sonde sometimes seems to move distally without any noteworthy pressure changes being recorded, may possibly be due to the fact that the sonde, with its pressure-recording membrane, has moved at exactly the same velocity as the pressure wave for a short distance. The sonde thus "rides" on the pressure wave, which means that no change in the pressure over the membrane

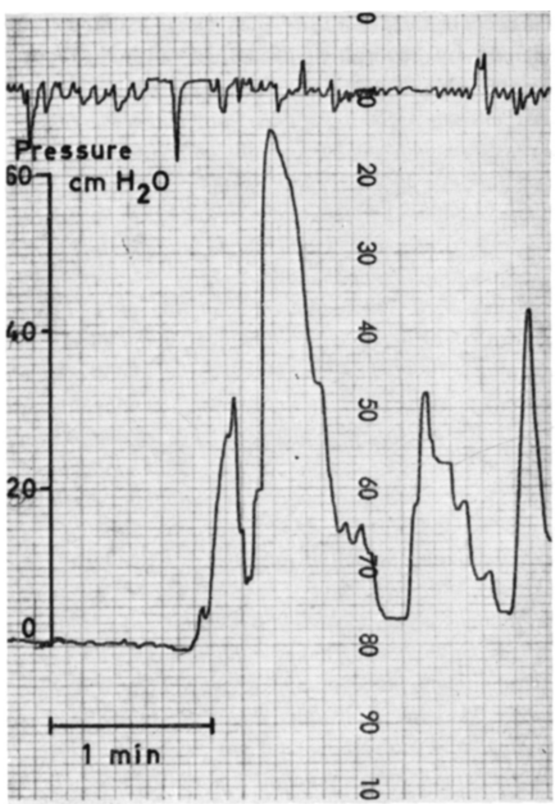

Fig. 10. Contraction waves of type IV in colon.

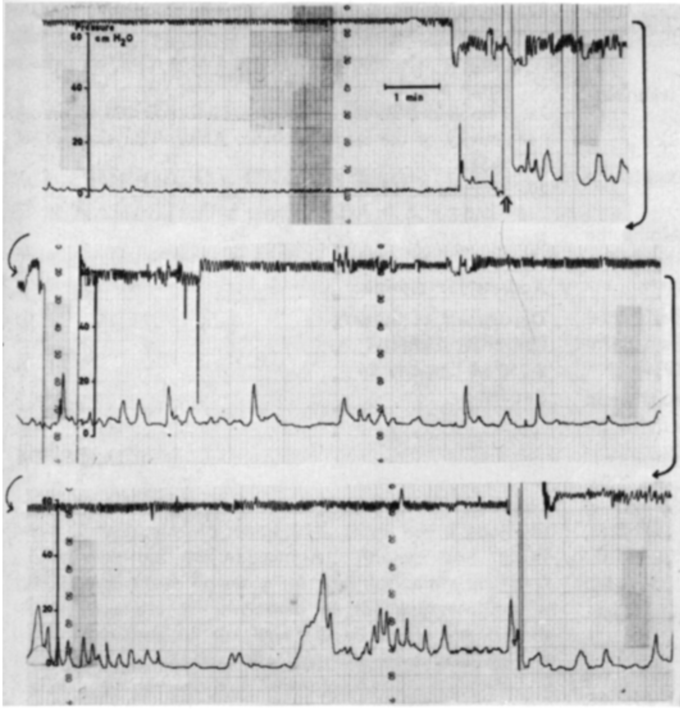

Fig. 11. Pressure conditions in colon before, during and after a meal. Arrow indicates beginning of meal.

takes place as long as its propagation rate is equal to that of the pressure wave. Usually, however, the sonde has a different velocity from the propulsive motility and therefore registers the pressure changes adequately.

The resting activity during the night was found to be somewhat lower than that during the day. On ingestion of food the entire gastrointestinal tract seemed to enter a phase of increased activity from the stomach down to, and including, the colon. These results agree well with the findings of several authors concerning the small intestine (3, 21). The gastro-colic reflex has also been demonstrated by other authors (1, 10, 11). The effect on the stomach is perhaps not so well documented as that on the intestine, but it seems reasonable to assume that when food enters the fundus of the stomach the motility of the antrum increases in order to propel forwards the contents that have lain there previously, thereby preparing room for the newly ingested food.

The conditions during the night obviously vary, but some diminution of the intestinal activity seems to occur. However, bursts of increased activity do take place even during sleep. The findings in these long-term studies in man may explain why in short-term studies in different species, controversial results have been obtained.

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