J. Physiol. (1941) 107, 472–478 612.337

THE ACTIVITY OF THE DUODENUM

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(*Received* 15 *November* 1947)

This investigation of the activity of the duodenum was undertaken first to find out if the motor response, which appears in the jejunum, ileum and colon after feeding, also appears in the duodenum; and secondly to determine the frequency of the rhythmic contractions of the duodenum. Observations were made on trained dogs, in whom the duodenum had been exteriorized and enclosed in a tube of skin, a preparation originally applied to the small intestine by Biebl (1930), and later to the colon by Douglas & Mann (1940). It has the advantage over the Thiry and Thiry-Vella loops that, being in continuity, it is functionally active and takes its full share in the digestion and transport of food.

METHODS

Three suitably docile animals were selected, trained to lie on an observation table for periods of 2 hr. and to eat a standard meal of boiled dried meat, vegetables and biscuits in that position. Under general anaesthesia with intravenous pento-barbital and with full aseptic precautions, the duodenum was then exteriorized by the following operation.

Two parallel incisions were made in the abdominal wall immediately lateral to the mammary lines and the skin flap thus outlined was dissected up. The peritoneal cavity was opened in the mid-line and the duodenum delivered into the wound (Fig. 1A). After ligation of the branches reaching it from the superior and inferior pancreatico-duodenal vessels, the uncinate process of the pancreas was freed from the duodenum. The pancreas, as far as the main pancreatic duct, was then detached by blunt dissection and swung upwards to the greater curvature of the stomach (Fig. 1B). An incision was made in the mesentery of the duodenum, care being taken to avoid damage to the vessels. The pancreas, stomach and first part of the duodenum having been returned to the peritoneal cavity, the remainder of the duodenum was exteriorized by suturing the peritoneal and muscular layers of the abdominal wall through the gap in its mesentery (Fig. 1C). Experience has shown that at this stage it is necessary to divide the muscles for a distance of 1 cm. at right angles to their fibres on each side of the gaps through which the ends of the loop leave and re-enter the peritoneal cavity. If this is not done, stenosis of these openings eventually causes intestinal obstruction. Finally, the exteriorized gut is enclosed in the bi-pedicled skin flap already prepared (Fig. 1D).

After recovery from the operation, the animals remained in good health, and as in the case of other animals in which this technique has been used at lower levels of the intestine, they appear to suffer no inconvenience from the exteriorized duodenum. Indeed, one of the bitches whelped

and successfully reared four pups after this operation, and 14 months later is still in excellent condition.

Tracings of the activity of the loop were taken by an air displacement system described elsewhere (Douglas & Mann, 1941). Information was also obtained by manual palpation and by inspection of the exteriorized viscus. Before an observation was made, the animal was fasted for 24 hr.; it was then placed on the observation table and a continuous tracing, lasting about 90 min., was taken before, during and after the administration of the standard meal.

The necessary ligature of some vessels probably interferes to some extent with the extrinsic nerve supply of the duodenum, but since the main blood supply is intact it is likely that this interference is minimal. Moreover, since the animals maintained a high standard of health it is likely that the exteriorized duodenum was functioning in a fairly normal manner.

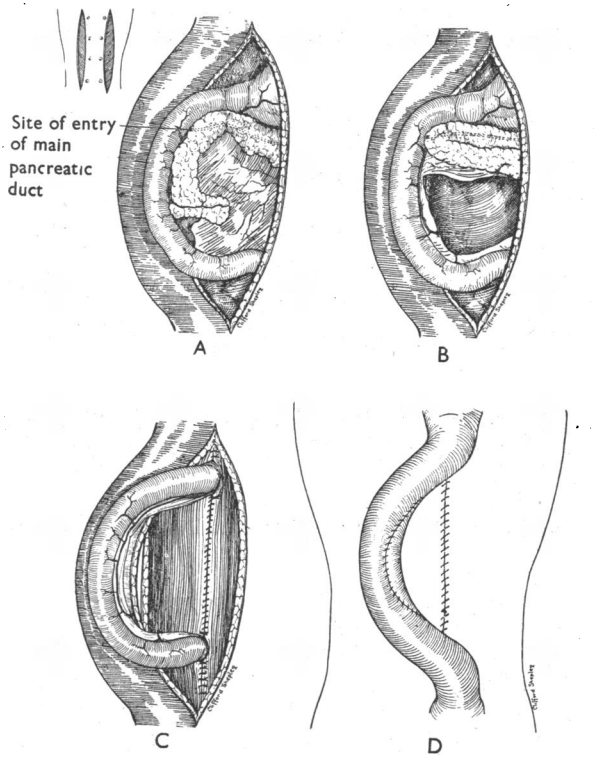

Fig. 1. Technique of preparation of an exteriorized loop of duodenum in continuity.

RESULTS

General character of duodenal motility. Tracings of duodenal motility resemble those from lower levels of the small intestine; the same long periods of quiescence are observed in the fasting animal, and the same motor response follows the ingestion of food (Fig. 2). However, regular contractions are more common in the duodenum than in the ileum, and consist of serial waves of contractions which pass rhythmically down the loop propelling the food towards the jejunum. These waves differ from the rhythmic segmentation

seen in loops at lower levels in that contraction and relaxation of adjacent intestinal segments cannot be discerned. It may be noted that a similar type of propulsive activity in the human duodenum can be demonstrated by X-ray after the ingestion of an opaque meal; this suggests that, both in the human

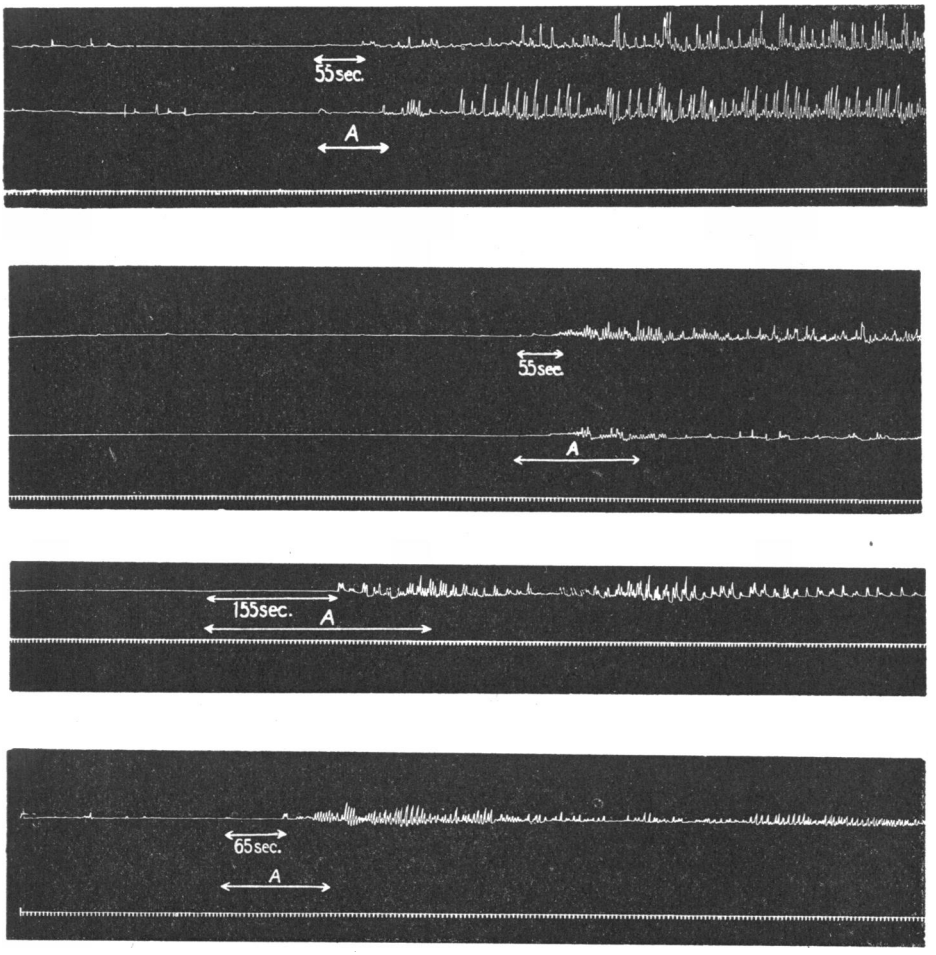

Fig. 2. Tracings of post-prandial excitation of the duodenum. Time in 5 sec. intervals. At *A* the animal is fed. In the upper two tracings records have been taken from the upper and lower ends of the loop simultaneously. The onset of the excitation varies from 55 to 155 sec. after the beginning of the meal.

and in the canine duodenum, transport rather than trituration is the main function of the duodenal muscle coat.

Less than a second elapses between the appearance of the wave at the top of the loop and its disappearance at the lower end some 15 cm. distant; the wave

thus travels between 15 and 30 cm./sec. This is much faster than the rate of peristaltic waves originally described for the small intestine of the dog by Bayliss & Starling (1901). They described a slow wave progressing down the intestine at the rate of 2 cm./min. The rate of 30 cm./sec. is much closer to that described by Alvarez (1924) in the small intestine of the rabbit, and termed by him the 'peristaltic rush'; he described peristaltic rushes with rates as fast as 25 cm./sec. Though antiperistalsis is commonly described in the human duodenum, evidence that it occurs in the dog was not obtained in this study.

The effect of the ingestion of food. If after a 24 hr. fast the duodenum was quiescent, the eating of a meal was followed by a rapid increase in activity (Fig. 2). If, on the other hand, the duodenum was still active after this period of fasting, no additional activity could be detected. The time of appearance of the motor response in the duodenum varied somewhat from animal to animal (Table 1). In dogs 1 and 3 the response appeared within 60 sec. of the beginning

TABLE 1. Time from feeding to appearance of motor response in the exteriorized duodenum of the dog

Dog	Mean time in sec.
1	53± 5·8 (6)
2	138±30·2 (5)
3	65±13·1 (6)

of the meal, whereas sometimes in dog 2 it did not appear for 175 sec. It may be noted in passing that dog 2 was rather more difficult to train than the other two animals; it was necessary to feed it by hand, and this resulted in a much slower rate of consumption of the meal. It may be that this is the explanation for the delay in the appearance of the motor response in this animal.

The frequency of rhythmic contractions. In a previous study (Douglas & Mann, 1939) it has been found that in the jejunum and the ileum of the dog the frequency of rhythmic contractions is constant within narrow limits for any given segment of the intestine. In the present study the same was found to hold true for the duodenum (Table 2). In one dog the frequency of rhythmic

TABLE 2. The frequency of rhythmic contractions in the exteriorized duodenum of the dog

Dog	Mean number of rhythmic contractions per min.	Period of observation in weeks
1	17·7±0·71 (336)	17
2	17·9±0·67 (129)	7
3	17·3±0·61 (69)	5

contractions was between 17 and 19 contractions per min. in over 300 readings during a period of 17 consecutive weeks of observations, and the mean frequencies in the three dogs were 17·7, 17·9 and 17·3.

DISCUSSION

Though much work has been done on the activity of the first part of the duodenum proximal to the entry of the common bile duct, much less is known of the activity of the duodenum beyond that point. This is because it is difficult to prepare a Thiry-Vella loop at this level. If the animal were to be kept in reasonable health, it would be necessary to transplant both the common bile duct and the pancreatic duct.

From radiographic studies, the first part of the duodenum in man and in the dog appears to act in a different way from the remainder of the small intestine. Its movements are reasonably comparable to those of a chamber of the heart. It shows a period of diastole during which it receives barium from the pyloric antrum, succeeded by a period of systole during which the barium is ejected into the remaining portion of the duodenum. The frequency of this cycle does not appear to have been studied accurately. During the diastolic phase the characteristic 'duodenal cap' is seen. As the barium passes into the remaining portion of the duodenum, it is rapidly whisked round to the duodeno-jejunal flexure and radiologists agree as to the considerable speed of this wave. Segmentation is not normally observed radiographically in the human duodenum. Antiperistalsis in the human duodenum is said to be seen in the condition of duodenal ileus when the barium can be observed to pass round to the obstruction and subsequently to return to the duodenal bulb. It is doubtful if this appearance proves the existence of reverse peristalsis. It is easy to postulate that forcible propulsion of barium against an obstruction would result in its rebound in a reverse direction. However that may be, it is difficult to find reliable evidence that under normal conditions antiperistalsis takes place, and although particular attention was paid to the point in this study, evidence of its occurrence was not obtained. The rapid propulsive type of wave which appears to be the common type of activity in these loops is perhaps comparable with the whisking wave seen by radiologists in the human duodenum, and it is reasonable to suppose that its function is to propel the mixture of food and enzymes to the more absorptive reaches of the small intestine.

The appearance in the duodenum of a motor response to feeding is of interest since a similar response has been observed at other levels of the small intestine and colon (Douglas & Mann, 1940). It provides further evidence that a wave of activity passes down the whole length of the bowel when food is first taken after a fast. Its appearance in the ileum has been termed by Hurst (1913) the gastro-ileal reflex, and in the colon the gastro-colic reflex. It is doubtful, however, whether such terms are justified since the reflex is not abolished by section of the extrinsic nerves of the intestine, and the waves can traverse a recent anastomosis. The time of the appearance of the response in the duodenum is very similar to that of its appearance in the jejunum where in

two animals it appeared 72 and 84 sec. from the beginning of the meal. In all likelihood the function of this post-prandial wave is to empty the intestine before more food arrives from the stomach. When the wave reaches the rectum, defaecation may take place. Thus the function may be an excretory one, analogous to the act of micturition; but whereas in the latter the stretching of the muscle fibres in the wall of the bladder is the adequate stimulus, in the former it is possibly the stretching of the muscle fibres in the stomach. It is difficult to find a suitable term for this physiological phenomenon, but 'post-prandial excitation of the intestine' seems to be the most suitable.

The uniform frequency of the rhythmic contractions in the duodenum is similar to that in the remaining portion of the small intestine. It should be emphasized that the constancy relates only to frequency and not to amplitude of contraction. On many occasions contractions are absent altogether and when they are present great variations in amplitude can be seen (Fig. 3). The

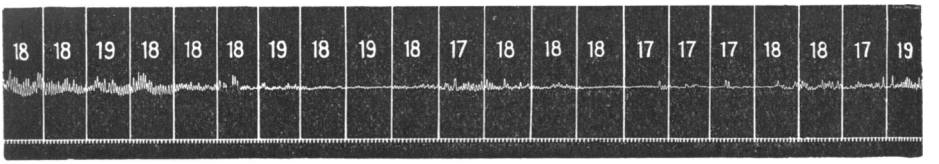

Fig. 3. Tracings of the activity of the duodenum of the dog. Time in 5 sec. intervals. Tracing ruled off at 1 min. intervals and number of contractions entered. Note that the amplitude of contractions varies while the frequency remains constant.

explanation for this observation is difficult to find. It may be suggested that the frequency of rhythmic contractions is fundamental to the caudal progress of food residues as suggested by Alvarez (1915). There is no doubt that the frequency of rhythmic contractions falls at successive levels of the small intestine (Table 3). It will be noted from this table, which has been prepared

TABLE 3. Frequency of rhythmic contractions in the small intestine of the dog

Dog	Site of loop	Mean frequency of rhythmic contractions per min.
1	Duodenum	17·7±0·71 (336)
2	Duodenum	17·9±0·67 (129)
3	Duodenum	17·3±0·61 (69)
4	Jejunum, 15 cm. from lig. of Treitz	18·0*
5	Jejunum, 30 cm. from lig. of Treitz	17·6±0·77 (45)
6	Jejunum, 30 cm. from lig. of Treitz	17·1±0·93 (46)
7	Ileum, 75 cm. above caecum	13·9±0·72 (118)
8	Ileum, 60 cm. above caecum	13·8*
9	Ileum, 30 cm. above caecum	11·8±0·82 (58)
10	Ileum, 25 cm. above caecum	13·4±0·71 (107)
11	Ileum, 10 cm. above caecum	12·5*

* Necessary detailed data to calculate the standard deviation are not available for these animals in which the observations were made in 1938–9. In the recollection of the writer, however, the readings did not vary more than in the present study.

from the present study and from previous work, that there appear to be two distinct zones of rhythmic frequency in the small intestine of the dog, an upper zone in which the rate is between 17 and 19 contractions per min., and a lower zone in which it is between 11 and 14 contractions per min.

SUMMARY

1. The duodenum below the entrance of the common bile duct has been exteriorized in continuity in the dog.

2. A study of its motility has been made visually, by palpation and by mechanical recording.

3. The common type of activity observed was a rapid propulsive wave of a uniform frequency of between 17 and 19 per min.

4. Fasting usually produced quiescence of the loop, and subsequent feeding a rapid motor response. The onset of this response varied between 50 and 140 sec. after the beginning of the meal.

5. This evidence, together with evidence presented in previous publications, is taken to suggest that (*a*) after the taking of food in the fasting animal a wave of excitation passes down the whole length of the small intestine from duodenum to ileum, and (*b*) there appear to be two zones of rhythmic frequency in the small intestine of the dog, an upper zone consisting of duodenum and jejunum in which the frequency is of the order of 17 to 19 contractions per min. and a lower zone in which the frequency is between 11 and 14 contractions per min.

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