# THE MOVEMENTS OF THE STOMACH AND INTESTINES IN SOME SURGICAL CONDITIONS.*

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THERE has been within recent years much physiological investigation of the motor activities of the alimentary canal. The results of this investigation are in some instances of value for their bearings on surgical problems, but usually the relation between the physiological and the surgical conditions is too indefinite to permit exact conclusions to be drawn. On the other hand, a review of the literature of surgical experimentation on the alimentary canal shows that the interest has been largely restricted to such questions as the healing of intestinal sutures and the bounds of possible removal of portions of the large and small intestine without causing death. Relatively little attention has been paid to the behavior of the gastro-intestinal tract after abdominal operations or in conditions demanding surgical interference.

* The results of this investigation were presented before the Boston Society of Medical Sciences, November 21, 1905.

The research here presented is an attempt actually to see how the stomach and intestines move, and how the food is treated by the motor activities of these organs, under various surgical conditions in comparison with normal states. Only certain surgical situations were selected for study. These were: The immediate consequences of operation; the results from different varieties of intestinal suture; the effects of stenosis and obstruction, and of embolus and thrombosis, and the question of postoperative paralysis. The movements of the food in the digestive tract in each of these conditions will be considered in turn in the following pages.

The method employed in this investigation was that used by Cannon and Blake,[1] in an experimental study of gastro-enterostomy and pyloroplasty.

In brief the principles of surgical cleanliness and technique were observed in the operations, and in the preparation and after-care of the animals. To watch the movements of the stomach and intestines, subnitrate of bismuth in small amount was added to the food, and the changes of the shadows of the food, cast upon a fluorescent screen by the Röntgen rays, indicated the activities of the walls of the alimentary canal. Thus the animal was observed, without etherization or drugging, in a quite natural state except for the operation. Any marked deviation from the normal functioning could therefore be regarded as due to operative interference. Because cats are easily observed with the Röntgen rays, and because standards of activity under normal conditions have been established for these animals,[2] they were used in the present investigation. For twenty-four hours previous to operation or observation the animals were given no food.

## MOVEMENTS OF THE STOMACH IMMEDIATELY AFTER INTESTINAL OPERATION.

In order to test the immediate effect of intestinal operation on a definite activity of the alimentary canal, the rate of discharge of food from the stomach was chosen. When cats are given by stomach tube 25 c.c. mashed potato mixed with 5 gms. bismuth subnitrate, gastric peristalsis begins soon after the food is introduced; and usually within ten minutes the pylorus has relaxed and permitted some of the gastric contents to enter the intestine. As pointed out in a previous investigation[3] the *aggregate length* of the shadows of the intestinal contents at different times after feeding, may be taken, in the early stages of intestinal digestion, as evidence of the rate of discharge from the stomach. Potato, for example, ordinarily leaves the stomach rapidly; at the end of a half hour the average aggregate length of the shadows of food-masses in the small intestine is about 10 cm.; at the end of an hour, about 30 cm., and at the end of two hours the amount of food in the small intestine attains its maximum, with the length of the shadows aggregating 43 cm. The question to be settled was the effect of intestinal operation on this rate of discharge from the stomach.

The intestinal operation performed to aid in answering this question was either simple section of the gut or resection of about eight inches, followed by end-to-end union by means of the F. G. Connell suture. The operation in the first cases was done about 18 cm. below the pylorus. The etherization lasted uniformly one half-hour, so that the anæsthesia-factor was fairly constant. Usually within twenty minutes after the etherization is stopped the animals so far recover as to be able to sit up and move about. A half-hour after the stopping of the anæsthesia the animals were given by stomach-tube 25 c.c. mashed potato with 5 gms. bismuth subnitrate. The times of observation—one half-hour, one hour, and every hour thereafter for the first seven hours after the feeding—corresponded to the times of observation adhered to in establishing the standard of activity in normal conditions. A permanent record of the distribution of the food in the alimentary canal was kept by tracing on transparent paper laid over the fluorescent screen, the outlines of the shadows cast by the food. The aggregate length of the shadows of the intestinal contents at the regular times of observation, under normal conditions, and in a typical case after intestinal section about 18 cm. from the pylorus, is presented in the following figures:

| Time in hours | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Normal | 9.0 | 31.0 | 43.0 | 25.0 | 21.0 | 13.5 | 9.0 | 4.0 |
| After section | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.0 | 8.0 |

In Figure 1 is shown graphically a comparison of the amount of food in the small intestine at regular intervals after feeding potato, both under normal conditions and immediately following intestinal section and suture. Under normal conditions this food begins to leave the stomach soon after its ingestion, usually within ten minutes, and the dis-

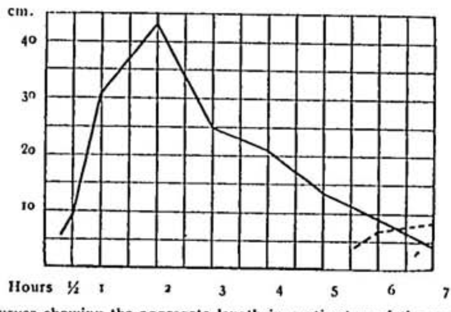


FIG. 1.—Curves showing the aggregate length in centimetres of the masses of potato present in the small intestine at regular intervals for seven hours after feeding. The continuous line represents the normal condition; the dash-line the typical condition immediately following intestinal operation near the pylorus. The delay is due to continuous closure of the pylorus, for gastric peristalsis was seen at every observation after the first half hour.

charge continues so rapid and abundant that the stomach is emptied in about three hours. After high intestinal operation, on the other hand, this food began to emerge from the stomach only after five or six hours. The delay, as will be shown later, was not due to etherization or to section of the abdominal wall.

This striking difference between the normal and post-operative discharge of carbohydrate food from the stomach is due to an altered functioning of the pyloric sphincter. The gastric peristaltic waves under normal conditions are seen running continuously, so long as food remains in the stomach.[4] In these postoperative cases, likewise, at every observation after the first half-hour of digestion, peristaltic waves were seen coursing regularly over the stomach to the pylorus. And under normal conditions, as already stated, the pylorus relaxes usually within ten minutes after the ingestion of such food as potato, whereupon the peristaltic waves begin the discharge into the intestine. But in these postoperative cases, in spite of peristaltic rings pushing the food up to the pylorus about five times a minute for more than five hours, the sphincter held perfectly tight against this repeated recurrence of pressure and did not permit the food to pass on into the injured gut.

The remarkable character of this protective mechanism of the pylorus appears in comparing the time required for primary cementing of intestinal wounds with the time during which the food is retained in the gastric reservoir. "Under favorable circumstances a firm lymph or gluey exudate, which is a natural means of repair, is promptly thrown out and spread around and upon any wound of the peritoneum, either visceral or parietal. It often begins to appear firm and available to hold surfaces together within two hours. The usual time, however, when it may be expected to afford efficient support is after at least six hours have elapsed."[5] It is certainly very striking that the period of primary repair and the period during which the food is prevented from entering the injured intestine should so closely coincide.

From evidence which is to be presented later, as to the paralyzing effect of handling, it seems probable that the immediate region of intestinal suture is protected from any demand for normal functioning by the manipulation incident to the operation. Some evidence on this point was secured by making an intestinal section and suture (end-to-end) about 3 cm. above the ileocæcal valve. The animal was fed as previously described. Food was first seen to have left the stomach at the end of two hours; and during the remainder of the seven hours of observation it continued to accumulate in the small intestine. In normal conditions mashed potato reaches the colon in two or three hours after it is fed; but in this case at the end of seven hours nothing had yet appeared in the large intestine. There was no evidence of obstruction, such as bulging of the gut and powerful and repeated peristalsis in the region of stasis. The intestinal masses merely accumulated and remained unmoved. It may be that at any point along the alimentary canal injury produces a functional blocking effect which saves the injured part from activity until a certain degree of repair has taken place.

In all cases observed there was no question of the patency of the lumen of the gut. The day after the operation and the feeding the total remnant of the food was invariably found in the large intestine, and the animal was in the best of spirits.

The mechanism causing the pylorus to remain closed for so many hours while gastric peristalsis continues active is left undetermined. Whether the injured intestine is the origin of a reflex effect on the pylorus, which is mediated through the central nervous system or through the local nervous mechanisms of the intestinal wall, is a matter for further investigation.

## THE EFFECTS OF END-TO-END AND LATERAL INTESTINAL JUNCTION.

In resecting the intestine to remove stricture, in getting rid of gangrene, lacerations and large perforations, intestinal union must be employed. Clinical experience has not yet determined whether end-to-end or lateral methods of uniting the divided intestine are preferable. In favor of the lateral junction the argument has been urged [6] that it permits conveniently a desirable large contact of serous surfaces—a condition said not to be possible in the end-to-end union without dangerously narrowing the lumen of the canal and without liability of producing ischæmic necrosis from pressure on mesenteric vessels involved in the suture. It has also been claimed for the lateral anastomosis that it can be used without regard to the size of the intestinal parts to be united, and that with it the opening between the two intestinal ends can be made as extensive as may be wished. On the other hand the tendency of all lateral unions of the parts of the alimentary canal to undergo cicatricial stenosis has been repeatedly recognized. And studies on animals have shown that indigestible substances, such as straw and hair, may accumulate at the point of lateral union and block the passage.[7] It is stated, however, that such a condition has never been cited as true of man whose diet must be and is carefully watched after operation.

From theoretical considerations there are possibilities of functional disturbance both in the end-to-end and in the lateral union. There exists in the intestinal wall a reflex mechanism such that a stimulus at any point causes contraction above and relaxation below that point.[8] It is thus that masses of food are pushed through the alimentary canal. In the end-to-end junction two severed ends of the intestine are sewed together. It is conceivable that the transverse cutting of the gut destroys locally the nervous mechanism governing peristalsis, and that under these conditions there is a stasis of the food in the region of the union. In lateral anastomosis the circular muscle-fibres of the canal are cut—the fibres which force the food onward. Contraction of the circular muscle singly in either one or the other of the overlapping intestinal ends could not force the food onward, but must simply shift the food over into the inactive part. In order that there shall be propulsion of the contents of this region there must be a coördinated, advancing contraction of the circular fibres simultaneously in the two apposed loops. As already noted undigested material has been found as a remnant in the region of lateral junction. Is there in this region a stasis of the normal food material?

In order to try these possibilities of functional disturbance, intestinal sections and resections were made in animals and the severed gut then united either end-to-end or laterally. The operation was performed as near as possible beyond the delicate fold of mesentery which holds the end of the duodenum in place. There are two advantages in having the operation at this point: The point is fixed so that the position of the suture can be recognized fairly accurately in observations with the X-rays; and also, the point is so near the stomach that the observer does not have to wait long after feeding the animal before the food reaches the region he wishes to study.

Observations were made on different animals one, four, seven, and ten days after end-to-end union of the intestine. In no case was the slightest evidence of stasis of the food in the region of operation to be observed. The food was passed along that part of the intestine as it was passed along other parts.

The results were quite different with lateral anastomosis. Animals permitted to live ten days or two weeks showed usually the condition already mentioned as observed by Senn and Reichel—a more or less complete blocking of the canal by accumulated hair and undigested detritus at the opening between the apposed loops. In order to see whether there was a stoppage of the normal food at the anastomosis, animals were operated upon and carefully fed for four days on food with little waste. Then they were given a rather thin boiled starch (4 gms. starch : 100 water) with an admixture of subnitrate of bismuth. As long as this food was passing through the intestine some of it was always present at the junction. And when almost all the unabsorbed material was in the colon there still remained a large mass filling the widened lumen where the coils were laterally joined. Observation the next day showed the mass still at the anastomosis. Autopsies on these animals proved that the stasis of the food was not due to previous accumulation of indigestible waste. The region of junction was filled, not with hard material but with a pasty stuff, in physical characteristics much like that seen ordinarily in the small intestine, and certainly capable of easy transmission through the gut by peristalsis. It is evident that in these cases the two apposed coils did not act together to propel the enclosed food. The food was forced through the region of the union by a push from behind, a push exerted by the peristalsis of the intact wall driving new particles of food from time to time into the accumulation at the junction. And when no food remained to act as an intermedium between the accumulated mass in the widened lumen and the pressing peristalsis of the intact gut there was nothing to continue the propulsion of the food through the chamber formed by the united loops, and the mass was left unmoved.

Inasmuch as stasis of the food was not observed at any time after end-to-end union of the severed gut, while after lateral anastomosis the ordinary food was stagnant in the region of junction, it is clear that, other things being equal, the end-to-end union is to be preferred to the lateral for rapid resumption of the normal functioning of the canal. It is known that in some cases at least after lateral union the canal may become changed from a crooked to an almost straight tube.[9] Possibly as such an alteration takes place there may be a restitution of the functional efficiency of the joined parts. It must be admitted, however, that the absence of this functional efficiency, for some days certainly and probably for weeks after the operation, renders lateral anastomosis not an ideal procedure. And on the other hand, the dangers of the end-to-end union have been largely obviated by recent improvements in the technique of intestinal surgery. The use of the F. G. Connell suture has permitted us to join the ends of the cat's severed intestine, an intestine with a thick wall and a relatively small lumen, a large number of times with never a sign of obstructive narrowing of the lumen, and with so little of the intestinal wall turned in as to make compression of mesenteric vessels and ischæmic necrosis highly improbable contingencies, yet such firmness of union that there was never doubt that the junction would be strong and tight. As to the claim made for lateral anastomosis that it permits the opening between the two intestinal ends to be as large as one may wish, it may be stated that this can be done only by more extensive cutting of the circular muscle of the intestine, thereby still further interfering with peristaltic activity; and also, that the condition to be desired is not so much a large opening as an opening that functions satisfactorily.

Although our experiments have led us to differ from the opinions of Ashton and Baldy [10] as to the universal desirability of lateral approximation, we agree with them as to the danger of allowing the blind ends of the intestinal loops in lateral union to extend beyond the anastomotic opening. If they each extend beyond the opening, the proximal closed loop, in our experience, is in danger of becoming packed with hardened waste; and the end of the distal loop is likely to invaginate until the invaginated portion fills the lumen in the region of the anastomosis and produces obstruction.

## THE EFFECTS OF INTESTINAL OBSTRUCTION.

The manner in which food was treated when the lateral anastomotic opening became completely closed by accumulated detritus, led to further observation on intestinal obstruction. For this purpose stenosis was produced by tying a coarse linen ligature tightly around the gut near the duodenal band. When animals were treated in this manner we found it necessary to make observations upon them within a day or two after the operation; if the interval was longer, the ligature sank so deeply into the intestinal wall as to be entirely covered by peritoneum. Under these circumstances the narrowing effect of the ligature naturally became less and less with the lapse of time.[11] Animals in which a part of the intestine had been reversed, and cases of operative kink, served also for observation on the effects of intestinal obstruction.

The presence of obstruction in the intestine even within

25 cm. of the pylorus did not retard the discharge of food from the stomach. As the food collected in the obstructed gut there was seen in every instance a remarkable exhibition of intestinal activity. Ordinarily in the small intestine a repeated segmentation of the food into small masses is a much more common activity than peristalsis. Peristalsis is only an occasional occurrence.[12] But in these cases of obstruction the food was over and over again pushed toward the obstruction by repeated waves of peristalsis. And the moving constrictions were evidently powerful, for as they advanced, the walls of the canal in front were bulged widely by the compressed contents; and when the peristaltic ring could no longer withstand the pressure it was causing as it moved, the

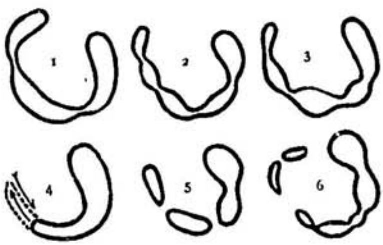


FIG. 2.—Tracings of the shadows of the contents of an obstructed loop of intestine, showing the sequence of changes through segmentation and peristalsis during a few moments of observation about an hour and a half after feeding. In the condition represented by No. 4, there was repeated peristalsis with regurgitation of the food through each advancing peristaltic ring.

contents squirted back through the moving ring for some distance along the gut. No sooner had one wave passed over the accumulated food to the point of blocking than another would start and go over the same course again, or a series of rhythmic contractions would occur, dividing the contents into large segments and sometimes separating them widely from one another. The numbered parts in Fig. 2 are tracings of the sequence of changes in the shadows of the food during a few moments of observation about an hour and a half after feeding boiled gluten-flour. Similar activities, though not so violent, were seen taking place an hour previous. Other cases, observed during a longer period, showed this same vigorous squeezing and churning of the accumulated food, alternating, however, with periods of rest.

It is clear from the observations above recorded that in the presence of intestinal obstruction there is aroused an activity of the circular musculature which must tend to compensate for the obstruction, and work to obviate it. These results support a contention made in an earlier investigation [13] that under normal conditions kinks and sharp bends in the intestine must have food forced through them by peristalsis. A kink was artificially produced by turning a loop back on itself for about 4 cm. and sewing together the surfaces in contact. Observation five days later proved that the food was pushed around the very sharp bend of the tube by the vigor of the peristaltic waves.

In order to test whether functional intestinal obstruction could be caused by opposing the directions of peristalsis, various lengths of the small intestine were in several animals resected and sutured end-to-end but with the direction reversed. Our results in the main confirm those of Mall and others [14] who have experimented on intestinal reversal. Although food was driven through when the reversed portion was relatively short—about 20 cm. in length,—there was in all cases an enlargement of the tube and a stasis of undigested waste in the region of the upper suture. These observations are generally interpreted as proof that antiperistalsis of the small intestine, a reversal of the direction of its motor function, does not occur. Opposed to this conclusion is the clinical evidence that in cases of intestinal obstruction there may be continued vomiting of offensive decomposed material after the stomach has been repeatedly washed—the so-called "fecal vomiting."

In relation to this conflict of evidence, observation made on an animal with a reversal of about 20 cm. of the intestine just beyond the duodenal band is of interest. The observation was made six days after the operation. At the autopsy soon after the observation a heap of indigestible stuff was found obstructing the canal at the upper suture. With the X-rays the food had been seen again and again to leave the stomach; as it collected in the duodenum it moved onward, with occasional segmentation, through a definite course which was traced on transparent paper; finally it began to accumulate in the region of the upper suture. About a half hour after the feeding the whole mass begaft to be tossed about by the alternating periods of segmentation and peristalsis already described as characteristic of the state of obstruction. Suddenly the mass was seen to be divided near the enlargement of the upper suture; then the proximal part of the mass was moved rapidly back along the course which had been traced, even up to the pylorus. This reversed movement of the food has been seen repeatedly with perfect distinctness. The method used does not permit seeing the contractions of the intestinal wall; only the effects of such movements on the food can be observed. But if food had been moved forward as in this instance it was certainly moved backward, the movement must assuredly have been attributed to peristalsis. It seems to us probable that a direct study of peristalsis in animals in which obstruction and stasis of food have been caused may prove that in such conditions reversal of the normal direction of peristalsis readily occurs.

## THE EFFECTS OF THROMBOSIS AND EMBOLISM.

In testing the effects of thrombosis and embolism, either the veins or the arteries supplying more or less extensive areas (varying from 10 cm. to most of the small intestine) were tied, and the connecting arches in the mesenteries were also tied to prevent collateral circulation. Care was always taken to avoid including nerves in the ligatures. In both conditions there was a sudden stoppage of a continuous supply of nutriment and oxygen to the parts involved. It was perhaps to be expected, therefore, that there would be, as in human beings, a similarity of effects in the two conditions.[15]

The operation was performed in every case during a uniform period of etherization—one half-hour; and about an hour and a half after the operation the animals were fed 25 c.c. mashed potato mixed with 5 gms. bismuth subnitrate. Three animals were taken for each condition. In only one of the six there was any activity of the stomach and intestines. In that one (a case of embolism) food passed out from the stomach for a time; then the pylorus closed and, although gastric peristalsis continued for about four hours, there was no further accumulation of food in the intestine. At the autopsy the gut just above the affected part was found somewhat dilated with food, but the gut below was wholly clean and free from contents. In the other five animals there was no gastric peristalsis and no discharge of food into the intestine.

The absence of gastric peristalsis in these cases of embolism and thrombosis of the intestine notably distinguishes them from the cases of high intestinal operation. Usually within an hour the animal vomited, and if the gastric contents were not at that time mostly ejected the animal ordinarily vomited again. And within three or four hours the animals usually began to exhibit a condition of lethargy and tonelessness, which increased as time passed. The extent of the intestine involved in the disturbance of circulation seemed to make little difference in the effects.

Autopsy of the animals with veins tied revealed the typical anatomical changes described by investigators who have studied experimentally hæmorrhagic infarcts of the intestine.[10] In the involved portion of the gut, the wall was thick and tense with infiltration, the lumen contained a thick bloody mass resembling clot, and a free sanguinous fluid was present in the peritoneal cavity. The involved portion of the intestine in the cases of artificial embolism was not so greatly altered as in the thrombosis cases, but it was red and injected, was moderately distended, and contained a foul grumous stuff slightly reddened.

The inactivity of the bowel, after food had entered it, in the case of artificial embolus above reported, illustrates one of the three types of dynamic ileus in Nothnagel's classification [17] —the type attended by anatomic lesions, such as embolism and acute general peritonitis. Of the other two types—toxic entero-paralysis, and functional nervous paralysis of the gut—the latter is of special surgical interest, since probably to that type belongs the intestinal paresis occasionally following laparotomy.

## THE QUESTION OF POST OPERATIVE PARALYSIS OF THE INTESTINE.

According to Kocher [18] the non-inflammatory dynamic ileus after abdominal operations depends upon a slight adhesion of the intestinal coils due to injury to the serosa, either circumscribed or extensive, and he thinks it probable that the circulatory disturbances following laparotomy exert an important influence on the contractility of the intestine. Scant credit is given to the idea that dynamic ileus is a purely functional disturbance—" little mechanical obstacles lie at the bottom of it." Nothnagel [19] on the other hand, reported a case of pure *ileus paralyticus,* with tympanites and other symptoms of obstruction, but showing at autopsy no cause of intestinal inactivity. Similar cases are seen after contusion of the testicle, after abdominal injury with a blunt instrument, after the relief of strangulated hernia, and during severe attacks of renal or biliary colic.

It is evident that postoperative paralysis of the alimentary canal must arise from the general condition of the patient, from alterations produced by the operation, or from a combination of the two. If the general condition of the patient is good, the trouble following operation may be due to the nature of the surgical interference or to the factors attending the surgical procedure. The character of the disorder to be attacked may leave little choice as to the nature of the surgical operation, but the manner of operating is to an important degree under control. And if the duration of the etherization, or the exposure of the stomach and intestines to the air, or the cooling or the handling of them, tends to produce functional disorder, it should be known. With the object of learning the action of these factors attending abdominal operation, they have been studied in their effects on the discharge of food from the stomach and its passage through the small intestine.

1. *The Effect of Etherization.*—In order to test the effect of etherization animals were etherized one half hour or one hour and a half; and about a half-hour after the etherization had been stopped 25 c.c. mashed potato mixed with 5 gms. bismuth subnitrate were given. As in the standard normal

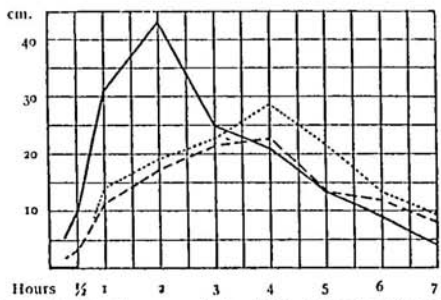


FIG. 3.—Curves showing the aggregate length in centimetres of the masses of potato present in the small intestine at regular intervals for seven hours after feeding. The continuous line represents the normal condition, the dash-line the typical condition after etherization for a half hour, and the dotted line the typical condition after etherization for an hour and a half.

cases, tracings of the shadows of the food in the stomach and intestine were made at the end of the first half hour after the feeding and then every hour for seven hours. The following figures show in centimetres the aggregate length of the food masses in the small intestine at the regular times of observation, in the normal condition and after etherization:

| Time in hours | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Normal | 9.5 | 31.0 | 43.0 | 25.0 | 21.0 | 13.5 | 9.0 | 4.0 |
| Etherized ½ hr. | 3.0 | 11.0 | 17.0 | 21.5 | 22.5 | 13.5 | 12.0 | 8.0 |
| Etherized 1-½ hrs. | 0.0 | 14.0 | 19.0 | 22.5 | 28.5 | 21.5 | 13.0 | 9.0 |

In Fig. 3 is shown graphically the differences between the aggregate length of the food masses in the intestine under normal conditions and after etherization. It is clear that the anæsthesia alone,—in distinction, for example, from high intestinal operation or thrombosis and embolism accompanied by anæsthesia during the operation,—has a relatively slight effect on the rate of discharge from the stomach. When an animal has been etherized an hour and a half, the chances are that the initial passage of food from the stomach will be for a short time delayed. But whether the anæsthetic has been administered a half-hour or triple that time, the most marked alteration in the passage of the food from the stomach is the slowing of the rate of discharge. The curve rises slowly instead of abruptly. And corresponding to the slow rate of gastric discharge, is a slow passage through the small intestine; the food appeared first in the large intestine, not at the end of two or three hours, as was the case when potato was fed to normal animals, but at the end of four, five and six hours after the feeding—a slightly greater retardation in the cases of etherization for an hour and a half than in the cases of etherization for thirty minutes.

The etherization therefore does not cause an inactivity of the alimentary canal; it seems merely to produce a slowing of the movement of the food through the canal.

2. *The Effect of Exposure to the Air.*—In testing the effect of exposure to the air, the anæsthetic was given for a few minutes over a half hour. As soon as complete anæsthesia was reached a long median abdominal section was made, the abdominal flaps were held widely apart, and the omentum drawn close to the stomach, so as to expose the small intestine and stomach as much as possible. Care was taken not to touch the viscera during these manipulations. Thus the visible surface of the stomach and intestine was exposed to the air, and was kept exposed for thirty minutes. During this time the serosa became dry and lost its glisten. Then the abdomen was closed. After recovery from ether the animals received the usual amount of potato with subnitrate of bismuth. The

following figures represent the aggregate length of the food masses in the small intestine at the regular times of observation, in the normal condition, and after etherization with exposure of the alimentary canal to the air for half an hour:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time in hours | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Normal | 9.5 | 31.0 | 43.0 | 25.0 | 21.0 | 13.5 | 9.0 | 4.0 |
| After exposure | 8.0 | 13.5 | 22.0 | 29.5 | 33.5 | 23.5 | 17.0 | 12.0 |

In Fig. 4 these figures are represented to show graphically the differences between the normal condition and the condition following exposure. It will be seen that the discharge from the stomach is not delayed,—the food begins to pass into the intestine within the first half-hour. The outgo is slow,

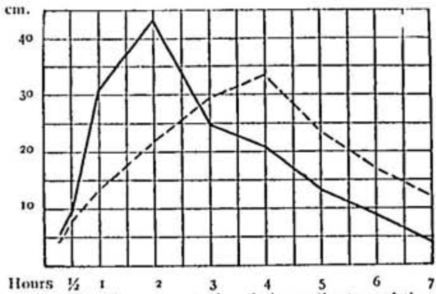


FIG. 4.—Curves showing the aggregate length in centimetres of the masses of potato present in the small intestine at regular intervals for seven hours after feeding. The continuous line represents the normal condition; the dash-line the typical condition following etherization with exposure of the stomach and intestines to the air for a half-hour.

but, curiously enough, not so slow as in the cases of etherization alone. Nothing was seen in the large intestine until the end of six hours—an interval not exceeding that observed when the animals were merely etherized.

As long ago as 1872 Von Braam Houckgeest noted the disturbing effects of drying on the action of the intestines,[20] and, in order to study the natural activity made use of a bath of warm normal salt solution. It might be supposed that if gastro-intestinal movements are inhibited during exposure to the air, they might be considerably altered after exposure. Such seems, however, not to be the case. The activities are not checked; the slowing of the passage of the food through the canal is explained as the normal effects of the anæsthetic.

3. *The Effect of Cooling.*—Not only does drying the surface of the alimentary canal cause a cessation of its movements; cooling the body has the same effect.[21] Does a temporary cooling of the stomach and intestines, without drying, stop the movements of these organs? In order to answer this question, ether was administered as usual for a half hour, and within that time, for ten minutes, sterile normal salt solution with a temperature of 20° C. was poured at intervals into the opened abdominal cavity. The body temperature, by rectum, was thus reduced to nearly 33° C. About forty minutes after the abdomen had been closed and the etherization discontinued, the animal was given the usual food. In the following figures may be seen the differences between the aggregate length of the food-masses in the small intestine at the regular times of observation, in normal conditions and in a typical case after cooling the alimentary canal:

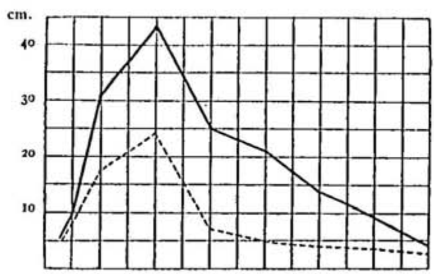


FIG. 5.—Curves showing the aggregate length in centimetres of the masses of potato present in the small intestine at regular intervals for seven hours after feeding. The continuous line represents the normal condition; the dash-line the typical condition after etherization, and cooling of the abdominal cavity with sterile normal salt solution at 20° C. The early drop in the dash-line is due to the rapid passage of the food into the large intestine.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time in hours | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Normal | 9.5 | 31 | 43 | 25 | 21 | 13.5 | 9.0 | 4.0 |
| After cooling | 8.0 | 17 | 24 | 7 | 5 | 4.0 | 3.5 | 2.5 |

Fig. 5 is a graphic representation of the content of the small intestine in the normal condition and after cooling. The discharge again is somewhat slow, but the passage through the small intestine is surprisingly rapid. The first appearance of food in the large intestine in this case was at the end of three hours, and at the end of four hours almost all of the remnant of the food was in the colon. The rapid drop in the curve between the second and third hours is thus explained. It must be admitted that the degree of cooling—to a body temperature of about 33° C.—was excessive. Nevertheless, the departure of food from the stomach was not slower than when the abdominal contents were merely exposed to drying; and certainly the rapid passage of the food through the small intestine lends no support to the supposition that cooling in itself causes enteric paresis.

4. *The Effect of Handling.*—In studying the effect of handling on the functioning of the stomach and intestines, it is desirable to consider different degrees of manipulation. Unfortunately an exact standard of severity of handling is difficult to establish. The experimenter can know that he has taken hold of the gut more or less harshly, and he has to be content with such general characterizations in reporting his results.

In all cases the animals were etherized one half hour, within which the abdomen was opened and the stomach and intestines manipulated. In the most severe treatment of these organs they were stripped between the thumb and first finger with considerable pressure, as would be done in forcing out the contents; in the less severe treatment these organs were fingered gently in air, or in a trickling stream of warm normal salt solution, with the parts protected from the fingers by absorbent cotton wet with the solution; or run through the bare fingers, but wholly within the peritoneal cavity. About an hour after stopping the anæsthetic the animals were fed as in former experiments and the observations were taken at the usual intervals. In the following figures is shown at regular periods of observation the content of the small intestine, in total lengths of the food-masses in centimetres, under normal conditions and after various manipulations:

| Time in hours | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Normal | 9.5 | 31.0 | 43.0 | 25.0 | 21.0 | 13.5 | 9.0 | 4.0 |
| Under warm salt solution | 0.0 | 0.0 | 0.0 | 11.0 | 21.0 | 29.5 | 24.5 | 13.5 |
| Gently, in peritoneal cavity | 0.0 | 0.0 | 0.0 | 8.5 | 9.5 | 15.5 | 26.0 | 23.5 |
| Gently, in air | 0.0 | 0.0 | 0.0 | 4.5 | 8.5 | 11.0 | 12.5 | 13.4 |
| Severely, in air | 0.0 | 0.0 | 0.0 | 0.0 | 3.5 | 5.5 | 6.5 | 9.5 |

The relation of these typical cases to the normal condition is shown graphically in Fig. 6. In examining the figures and the curves, it should be kept in mind that since neither the etherization alone, nor such cooling and drying

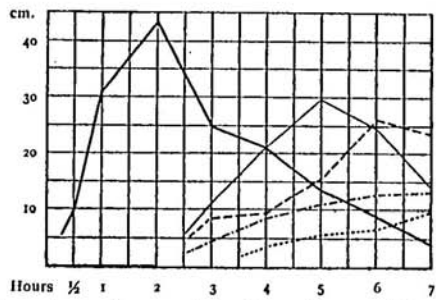


FIG. 6.—Curves showing the aggregate length in centimetres of the masses of potato present in the small intestine for seven hours after feeding. The heavy continuous line represents the normal condition; the light continuous line the typical condition after handling the stomach and intestine gently under warm normal salt solution; the dash-line the typical condition after handling the organs gently in the peritoneal cavity; the dash-and-dot line after handling them gently in the air; and the dotted line after handling them severely in the air.

as the viscera in some cases suffered, cause a delay in the escape of food from the stomach, the delay must have been due to the manipulation. Even when the stomach and intestines were handled most gently, either under warm normal salt solution or within the peritoneal cavity, no movements of the stomach were seen, and no discharge into the intestine, for three full hours after the feeding. Even after the first departure of food from the stomach the discharge continued very slowly as shown by the sloping of the curve; and the passage through the small intestine was also retarded. In only one case did food appear in the large intestine before the end of the seven hours of observation.

When the organs were removed from the abdomen and handled gently in air the movement of the food was retarded to a greater degree than when they were fingered in the peritoneal cavity or under warm normal salt solution. So great was the retardation that in the case recorded on the above table not all the food had passed into the large intestine from the ileum even twenty-six hours after the feeding. Indeed, the condition then was that reached under normal conditions in about five hours.

With rougher treatment in air food was first passed from the stomach only after four hours. Thenceforward it departed very slowly and, as shown by the permanence of position from observation to observation, was carried through the small intestine with extreme sluggishness. In one case of severe manipulation no food had left the stomach at the end of seven hours. And in another case the food had not yet reached the large intestine twenty-four hours after the feeding (the food used begins to appear there normally at the end of two or three hours); only a slight amount of food was in the small intestine, and the stomach was still well filled.

Manipulation of the stomach and intestine, even gently and under most favorable circumstances, produced in our experiments much greater effect in the direction of postoperative inactivity than any other of the factors concerned in the manner of operating. Whether the manipulation produces its effects directly on the mechanisms in the wall of the alimentary canal, or indirectly through reflex inhibitions from the central nervous system, remains to be determined. Goltz's success in stopping the frog's heart by tapping on the intestines [22] suggests that the intestine may be sensitive to mechanical treatment to a degree not commonly realized; and this sensitiveness might very readily result in the same sort of reflex inhibition that occurs when a testicle is crushed.

It should be kept clearly in mind that the animals used in these observations were vigorous normal specimens. Furthermore it may well be that the intestine of these animals is normally less sensitive to stimulation than the human intestine. It seems probable therefore that what is true of these experimental animals is also true of man, but to a greater degree. And when the strength has been sapped and the bodily vigor lost, the factors which operate to check the activities of the alimentary canal must have a greatly increased effect. During the course of other researches on the movements of the food in the stomach and intestines one of us (C.) has had repeated opportunity to observe animals in conditions of asthenia, animals suffering from distemper, with purulent inflammation of nose and eyes, with soft toneless muscles, and every appearance of debility. Nothing is more remarkable than the responsiveness of the alimentary canal to such a condition. All day long food will lie in the stomach without the slightest sign of a peristaltic wave passing over it. There is a total stoppage of the motor activity of the digestive organs. In asthenic states leading to such conditions the handling of the alimentary canal, which we find produces the most marked paralyzing action, can only cause an intensification of the effect of the general bodily weakness, a deepening of the state of inactivity.

## SUMMARY

In studying the movements of the stomach and intestines in some surgical conditions, animals were etherized usually one half-hour, operated upon, and subsequently fed food mixed with a small amount of subnitrate of bismuth. Fluoroscopic observations of the changes in the contents of the alimentary canal were then made by means of the Röntgen rays.

After high intestinal section and suture, gastric peristalsis is not interfered with. But for almost six hours after recovery from the ether the pylorus remains tightly closed against the peristaltic pressure and does not permit the food to pass into the injured gut. There is a striking coincidence between the duration of the delay of the discharge from the stomach and the period of primary cementing of intestinal wounds.

After end-to-end suture of the severed intestine no inefficiency of the gut in the region of suture was observed. But after lateral anastomosis there was always an accumulation of food in the chamber formed by the apposed loops. The cutting of the circular fibres in this operation destroys efficient peristalsis at the junction unless the circular muscles of both loops work in coördination. As they do not so act, at least for days and probably for weeks, following operation, lateral anastomosis is not so ideal an operation as the end-to-end union.

In case of intestinal obstruction, food leaves the stomach without delay. As it accumulates above the obstruction violent peristalsis repeatedly occurs, tending to force the food past the obstacle. The peristalsis alternates with vigorous segmenting movements. After such turbulent treatment the food has been observed moving swiftly *backward* to the stomach along the course traversed in its passage from the stomach to the region of obstruction.

After thrombosis and embolism there is usually no movement of stomach or intestine; the food lies quiet in the stomach until discharged by emesis. In one case gastric peristalsis was observed for some hours and a slight amount of food was discharged into the intestine, but it gathered above the infarcted region and was not advanced further.

In studying the conditions attending operation as possible causes of postoperative paralysis of the alimentary canal, etherization, one half or one and a-half hours, was found not to delay to any marked degree the discharge of food from the stomach; exposure to the air and unusual cooling of the gut likewise caused no noteworthy delay; but by far the most striking effects were seen after handling the digestive organs. Even with most gentle handling, within the peritoneal cavity or under warm salt solution, no gastric peristalsis was seen and no food left the stomach for three hours. Fingering gently in the air caused still greater retardation of the movement of the food.

And with rough handling in air no food passed from the stomach for four hours, and then it emerged very slowly and was moved onward with every evidence of extreme sluggishness of the intestine.

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[4] Cannon. American Journal of Physiology, 1898, i, p. 367.

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[6] Küttner. Beiträge zur klinischen Chirurgie, Tübingen, 1896, xvii, p. 505.

[7] Senn. ANNALS OF SURGERY, 1888, vii, p. 265, and Reichel; Münchener medicinische Wochenschrift, 1890, xxxvii, p. 197.

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[9] Edmunds and Ballance. Medico-chirurgical Transactions, London, 1896, p. 263.

[10] Ashton and Baldy. Medical News, 1891, lviii, p. 235.

[11] Although it has been known since the time of Sir Astley Cooper (Lectures on the principles and practice of surgery, London, 1824-27) that a thread tied about a lifted piece of the intestinal wall would sink into the tissue and later reach the lumen, the fact that in gastroenterostomy wires are sometimes applied about the gut to close the lumen and require the food to take a desired course, indicates that the lesson of Cooper's observation has not been well learned.

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[13] Cannon and Blake. ANNALS OF SURGERY, 1905, xli, p. 703.

[14] See Mall. Johns Hopkins Hospital Reports, 1892, i, p. 93; and Prutz and Ellinger. Archiv für klinischen Chirurgie, 1902, lxvii, p.

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