Colonic motor activity and bowel function

Part II Distribution and incidence of motor activity at rest and after food and carbachol

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A number of radiological investigations have shown that motor activity may vary in different parts of the intact human colon, but the significance of this diversity and its effect on bowel function has not been studied.

The earliest observations were those of Schwarz (1911), who made serial tracings of the outline of the bowel on a fluoroscopic screen and showed that haustral movements occurred more commonly in its proximal than in its distal half. It is also evident that almost all the major propulsive movements described by pioneers like Holzkecht (1909), Barclay (1912), and Hertz (or Hurst) and Newton (1913) began in the transverse colon.

Williams (1967), who studied the stripping waves that occurred during barium enema examinations in patients with diverticular disease, found that they might start in any part of the colon and travelled over widely varying distances. However, about two-thirds of the waves that began in the caecum failed to pass beyond the splenic flexure and about two-thirds of those that started at the splenic flexure stopped when they reached the pelvic colon.

Connell, Lennard-Jones, and Madanagopalan (1964) made a study of faecal shadows in the abdomen from plain radiographs of normal subjects, and found that large shadows were most often seen in the right colon; they were never seen in the transverse colon. Faecal shadows of moderate size were commonest in the right colon and in the pelvic colon. Only the lightest shadows were common in the transverse and descending colon.

Eating a meal has long been regarded as a powerful stimulus to propulsion, and this was frequently recorded by Hertz (or Hurst) (1919) and other radiological workers. Ramorino and Colagrande (1964), observing the progress of a radiotelemetering capsule with short spells of cinefluorography, were unable to confirm this; they seem to have begun their cine observations immediately, when the capsule started to record increased pressures after

eating and this may have been before propulsion had had time to develop.

Before any attempts could be made to resolve these apparent contradictions and to relate the movements of the colonic contents to the individual's pattern of bowel function, it was necessary to know what were the different forms of motor activity of which the human colon was capable. Ritchie (1968) made a time-lapse cinefluorographic study of the movements of ingested barium in the colons of 193 ward patients of the Radcliffe Infirmary, Oxford, at rest and after food, and after an injection of carbachol. Films were taken at one-minute intervals for one hour, and the changes that occurred were described and classified.

Non-propulsive segmental activity in some part of the bowel accounted for the only visible movements in 38% of the subjects during the period at rest. Propulsive activity was divided into two complementary forms; there were haustral and multihaustral movements, based on the systolic contraction of segmental units, either singly or in groups, and progressive movements in which a circular constriction of the gut advanced, wave-like, along it without regard to the haustral divisions. In 36% of subjects the simplest form of haustral propulsion transported bowel contents through two or more segments, usually without any sign of coordination between them. As haustral retropulsion was also present in some part of the colon in about 30% of subjects, the overall net aboral transportation derived from this form of activity was limited.

Coordinated propulsion involving multihaustral sections of bowel was less common than haustral propulsion, being present in 8% of subjects during the hour spent at rest, but it transported semiliquid contents over much longer distances. Progressive propulsion, which also required a high degree of intersegmental coordination, was seen in only about 6% of colons under resting conditions; preceded by a zone of relaxation and often followed by tonic

muscular contraction, it formed the basis of peristalsis and made possible the efficient transportation of solids.

Mass propulsion, in which the normal haustral pattern of the colon was replaced by a narrow tubular appearance with relatively rapid advance of the gut contents over 20 cm or more, might develop out of either multihaustral or peristaltic activity. Each form was seen in 2% of subjects, chiefly after food or carbachol.

This paper relates the incidence of motor activity throughout the colon to the frequency of defaecation under resting conditions and after food and carbachol.

EXPERIMENTAL CONDITIONS

One hundred and one of the 193 subjects were kept at rest throughout the period of observation. Sixty-three others were given their ordinary lunch to eat at the start of their hour and 29 were given an intramuscular injection of carbachol instead.

EXPERIMENTAL VARIATIONS The first 58 of the subjects observed had had ordinary diagnostic barium meals and swallows the previous day and so were examined after an interval of 20 to 24 hours. This proved to be unsatisfactory for a number of reasons. Too many of the subjects had some form of gastrointestinal pathology, and these had often been given more of the barium sulphate suspension than others who had only had barium swallows. The interval before observations began was too long, and could not be shortened because of the intervening night; the barium had almost always left the ileum and thus reduced the scope of any estimate of ileal activity. Barium had sometimes left the colon also, and apart from a few of the most severely constipated subjects some of it had usually reached the rectum.

The remaining 135 subjects were given a uniform dose of 100 ml of Micropaque barium dispersion to drink at bedtime and were studied 12 to 15 hours later.

CLASSIFICATION OF CLINICAL MATERIAL To study the effects of food and of parasympathomimetic stimulation it was necessary to subdivide the colon into four anatomical sections of approximately equal length, in addition to the rectum, and to analyse the altered pattern of behaviour in each. The four divisions were the right colon, consisting of the caecum and ascending colon together, and the transverse, descending and pelvic colon. Changes in the outline of their barium contents as seen, minute by minute, in the cinefluorograms were identified in terms of movement and related to bowel function.

The subjects themselves were placed in subgroups, for example, by sex, age, clinical diagnosis, and by various aspects of colonic activity, to see what effects these different factors had on the movements of the colonic contents.

Sex did not appear to affect function in the 110 (57%) male subjects or in the 83 females, and need not be further considered.

Age distribution of the subjects composing the study is shown in Fig. 1; the mean figure was 54 years. The four age groups showed no significant differences in propulsive activity either at rest or after food or carbachol, but there was a decrease in the frequency of bowel actions among the 29 subjects over the age of 70.

Clinical distinctions, as between the 73 subjects in whom there was some kind of gastrointestinal pathology and those with disease elsewhere, in general provided no outstanding differences. A few clinical conditions like ulcerative colitis did appear to have an effect on function, but only 19 (10%) of the subjects observed were known to have any colonic disease. The clinical subgroups were too small to allow any statistical significance to comparisons.

Colonic activity was examined from three different aspects. These were, first, individual frequency of defaecation, secondly the distribution of barium at the start of observations, and thirdly the nature and incidence of movements imparted to the barium by the gut wall in each of the five sections.

RESULTS

FREQUENCY OF DEFAECATION To simplify comparisons, the subjects were divided into three functional groups, those in whom bowel actions usually took place at daily intervals, or more often, or seldom. The 'normal' group among the 101 subjects observed at rest was made up of 66 (65%) who, over a 48-hour period centred on the actual hour of observation, had their bowels open at least once and not more than three times. The 26 subjects who had two or more motions per day were, for simplicity, designated the 'diarrhoeic' group and the nine whose bowel actions were delayed by more than 24 hours were regarded as being 'constipated'.

Among the subjects given lunch, 39 (62%) were classed as having normal bowel function, 18 (28%) were diarrhoeic, and six constipated. The number of subjects given carbachol, of whom 19 (65%) were normal, five diarrhoeic, and five constipated, was too small to allow any valid comparisons between the three functional groups. In all there were 124 subjects (64%) with normal bowel function, 49 (26%) had more frequent bowel actions, and 20 (10%) were inclined to constipation. A similar proportion of the group of 29 subjects over the age of 70 had normal function as of the subjects under 70, but constipation was relatively more common over 70 (Fig. 1). It was present in eight (28%) of that group, compared with only 7% of younger subjects.

DISTRIBUTION OF COLONIC BARIUM The 193 subjects represented between them a total of 965 bowel sections. Of these, 220 sections (23%) were not outlined by barium at the start of observations, either because it had not yet reached them or because

FIG. 1. Number of subjects and their comparative bowel function in each age group.

they had already expelled it, or because that section was outside the field of the image intensifier.

This proportion of bowel sections lost was the same in the group of subjects who were studied at rest as it was in subjects who were given lunch or injected with carbachol (Table I). In the normal and diarrhoeic groups, it was equivalent to eliminating one of the five sections from each subject; among the 20 who were constipated the proportion of sections lost in this way increased to 42%, almost all in the distal half of the colon.

Barium was seen in the rectum within 12 to 15 hours in 48 (56%) of 86 subjects with normal bowel function (Fig. 2). The proportion rose to 80% among the 34 diarrhoeic subjects and fell to 33% in the group of 15 who were constipated. In the smaller group of 58 subjects examined 24 hours after swallowing the barium, it had reached the rectum in 81% of normal subjects and in 87% of those with diarrhoea; five of the six who were constipated had their barium held up in the transverse colon and the other in the descending colon.

MOVEMENT OF COLONIC BARIUM IN INACTIVE SECTIONS

Out of 389 bowel sections visualized at rest, one-

third remained immobile over the whole hour of the study (Table I). This proportion was reduced to one section in five among the subjects observed after lunch and to one in eight in the group who were given carbachol. The figures did not differ significantly between one functional group and another.

Inactivity covering the whole period of observation at rest was most frequently seen at the extremities of the colon; it occurred almost twice as often in the rectum as it did over the bowel as a whole. Inactivity was relatively rare in the transverse colon (Fig. 3). The incidence of inactivity was reduced after eating lunch to a third of the resting level in the proximal half of the bowel, though the difference diminished progressively towards the rectum. Carbachol reduced the number of inactive sections still further and there was a more uniform distribution over the whole colon apart from the rectum, which was once again little affected.

NON-PROPULSIVE SEGMENTAL ACTIVITY Non-propulsive activity involving barium in the colonic haustra was seen at some time during the hour spent at rest in two-thirds of all bowel sections; in half of these, if gas were ignored, it was the only form of

TABLE I

PROPORTION OF COLON SECTIONS ENGAGED IN DIFFERENT ACTIVITIES AT REST AND AFTER FOOD AND CARBACHOL

	Subjects at Rest	Subjects Given Lunch	Subjects Given Carbachol
Colon sections not visualized	116/505 = 23%	71/315 = 23%	32/145 = 22%
Number of sections outlined	389	244	113
Colon sections remaining inactive	134/389 = 34%	50/244 = 20%	14/113 = 12%
Colon sections showing non-propulsive activity	134/389 = 34%	66/244 = 27%	32/113 = 28%
Colon sections involved in transportation	121/389 = 32%	128/244 = 53%	67/113 = 60%
Colon sections showing haustral propulsion	67/389 = 17%	68/244 = 28%	19/113 = 17%
Colon sections showing retropulsion	43/389 = 11% ¹	53/244 = 22% ¹	15/113 = 13% ¹
Colon sections showing coordinated propulsion	24/389 = 6%	29/244 = 12%	39/113 = 35%

¹Some sections showed both propulsive and retropulsive movements during the hour and are included under both headings.

FIG. 2. Proportion of subjects in each functional group with barium in the rectum after 12 to 15 hours and 24 hours.

FIG. 3. Proportion of colon sections inactive at rest and after food and carbachol.

FIG. 4. *Proportion of colon sections showing non-propulsive segmental activity only at rest and after food and carbachol.*

movement (Table I). It was commonest in the proximal half of the colon (Fig. 4). The incidence of non-propulsive activity in the transverse and proximal descending colon was reduced after food, and that in the transverse colon after carbachol. In each case, the deficit was made up by an increase in haustral propulsion.

COLONIC TRANSPORTATION In the remaining third of all the bowel sections observed at rest, non-propulsive segmental activity was combined with propulsive and retropropulsive movements (Table I). After food and carbachol the proportion of sections involved in some form of transportation increased to 53% and 60% respectively, almost double the resting figure. A number of bowel sections showed both propulsion and retropropulsion during the hour of observation. The average hourly aboral net displacement of colonic contents in the different functional groups, calculated from the distances covered by haustral and coordinated propulsion less the distance lost through retropropulsion, is set out in Figure 5.

Haustral propulsion accounted for approximately half the length of all colonic transportation under resting conditions, being present in 17% of 389

bowel sections. In many of the 36 subjects in whom it was seen, it occurred in two or more sections independently during the hour. The aggregate distance covered by the 67 movements was 472 cm, representing a mean advance of 7 cm for each propulsive movement. Over the whole group of 101 subjects observed at rest this represents an average of 0.66 propulsive movements each, equivalent to an overall displacement of colonic contents of 4.7 cm/subject/hr.

Separate analyses of transportation in each section of the colon at rest and after food are illustrated in Figure 6. This shows that in subjects with normal bowel function, under resting conditions, haustral propulsion was most active in the transverse, descending, and pelvic sections, where it averaged about 1.5 cm/hr. Amongst the diarrhoeic group of subjects, haustral propulsive movements were of almost the same average length as in the normal group and, as they occurred slightly more often, the mean rate of haustral propulsion was greater. The movements travelled fastest in the transverse colon, where they covered 3.3 cm/hr, an increase of more than three and a half times compared with the figure for the right colon of less than 1 cm.

FIG. 5. Mean rates of propulsion and retro-pulsion in cm/subject/hr by functional groups over the whole colon at rest, after food (F) and carbachol (C).

FIG. 6. Mean rates of propulsion and retro-pulsion (cm/subject/hr) in different colon sections by functional groups at rest and after food.

After lunch, the 63 subjects shared 68 haustral propulsive movements with a total length of 487 cm, increasing the overall rate of haustral propulsion by two-thirds to 7.7 cm/subject/hr (Fig. 5). In subjects with normal bowel function the speed-up was confined to the ascending and transverse colon. Amongst the diarrhoeic group, the increase in the rate of haustral propulsion after food was maximal in the ascending colon and it continued to be greater than normal right through to the rectum. The few constipated subjects who were examined after lunch also showed more haustral propulsion in the transverse and descending colon.

Injection of carbachol was followed by a similar rise in the rate of haustral propulsion in normal

subjects; in those with abnormal bowel function there was instead a big increase in multihaustral propulsion and peristalsis, and haustral propulsion was diminished.

Retro-pulsion was seen in 11% of all the bowel sections observed under resting conditions (Table I). It was usually a product of uncoordinated haustral activity and in all three functional groups the mean distance each retro-pulsive movement travelled was 6.3 cm. No retro-pulsion was seen in the right colon at rest.

Among normal subjects the mean reflux of colonic contents over the whole bowel amounted to about 2.3 cm/hr (Fig. 5). This was approximately half the aboral transit rate of haustral propulsion and was

more or less the same in all sections. Retropulsion nullified a similar fraction of haustral propulsion in diarrhoeic subjects, but not so uniformly. In this group, there was a progressive increase in the proportion of reflux to propulsive movements from about one to six in the transverse colon to approximately twelve to one in the rectum (Fig. 6).

In the group of 20 constipated subjects observed at rest, haustral propulsion and retropulsion over the whole length of the bowel, amounting to about 4.1 cm/hr, were effectively the same. In three subjects out of nine there was retropulsion in the transverse colon, though none was seen in either the ascending or descending sections. Half the reflux that was seen at rest occurred in the distal part of the bowel in sections where there was no aboral transportation during the hour of observation. Unfortunately there were only two members of this group in whom barium was visible beyond the descending colon, so that these observations are of little value.

Eating lunch doubled the overall rate of colonic retropulsion from 2.7 cm to 5.5 cm/subject hour. This increase was most clearly seen in the transverse and descending colon in the normal group of subjects, and in the descending and pelvic colon in the diarrhoeic group. In both groups, the mean distance covered by retropulsion distal to the splenic flexure exceeded that of haustral propulsion, leaving the balance of aboral movement, if there were any, to be made up by multihaustral and peristaltic activity.

Carbachol caused no comparable increase in retropulsion.

Coordinated propulsion, either multihaustral or peristaltic, was present in only about 6% of all the bowel sections observed at rest (Table I), and the mean distance travelled by each propulsive movement in any one section was 15 cm. Under resting conditions, over the whole study, coordinated propulsion amounted on average to 3.1 cm/subject/hr (Fig. 5).

In subjects with normal bowel function, coordinated propulsion was approximately as effective a form of transport under resting conditions as haustral propulsion; although individual movements occurred less than half as often, each of them travelled more than twice as far. Coordinated propulsion was relatively less important at rest in diarrhoeic and constipated subjects, in whom it accounted for only about a quarter of their aboral movement.

Eating lunch increased the rate of coordinated propulsion in the proximal half of the colon in normal subjects, but over the whole length of the bowel the stimulant effect was negligible. Amongst the diarrhoeic group of subjects eating was much more effective in evoking coordinated propulsion and increased it from 2.2 cm/subject/hr at rest to 13.1 cm.

All sections of the bowel were affected, down to the pelvic colon.

Carbachol increased coordinated propulsion four-fold in the normal group of subjects, to about the levels that were reached by diarrhoeic subjects after lunch, and it made up almost three-quarters of all their propulsive activity. In those with abnormal bowel function, whether diarrhoeic or constipated, the increase in coordinated propulsion after carbachol injection was more than tenfold.

INCIDENCE OF COORDINATED PROPULSION Recording coordinated propulsion in all the bowel section in which it was seen was in some respects confusing, as 25 of the 53 separate propulsive movements observed in the present study extended over two or more sections; on four occasions a mass propulsion passed through four sections in succession. For simplicity, in estimating incidence, the different forms of coordinated propulsion were classified as either multihaustral or peristaltic movements and related to the sections in which the movement began. No coordinated propulsion started in the rectum, so only four sections were involved in this part of the study (Fig. 7).

At rest the 101 subjects of all three functional groups produced nine propulsive movements involving multihaustral or mass activity, seven of which began in the transverse and the other two in the ascending colon. There were also six peristaltic movements, all beginning in the transverse, descending, and pelvic colon.

The 63 subjects who had eaten lunch provided 10 (16%) multihaustral propulsive movements, but only two of them started in the transverse colon. The other eight began in the ascending colon, and this represented a significant increase over the incidence of segmental propulsion in that section at rest. Another five (8%) of the subjects showed peristalsis after eating, which once again began in the three distal bowel sections, so there was no change from the incidence observed under resting conditions. The greatest proportion of coordinated propulsive movements in any single functional group after food occurred in the ascending colon among the diarrhoeic subjects. Four of the 16 members of that group in whom this section was visible began systolic multihaustral or mass activity during the hour of observation, compared with none in the same group at rest. However, this difference was not statistically significant.

After carbachol in 29 subjects, the relative distribution of individual propulsive movements between bowel sections was much like that after food, but they had trebled in numbers and also extended their range. Among the 12 instances of multihaustral

FIG. 7. Incidence of coordinated propulsion at rest and after food and carbachol in different colon sections.

propulsion (41%), movement was seen to start as far distally as the descending colon in two subjects; peristalsis occurred 10 times (35%) and once began in the ascending colon.

DISCUSSION

SELECTION OF FUNCTIONAL GROUPS The criteria chosen to differentiate the 64% of normal, 26% of diarrhoeic, and 10% of constipated subjects were entirely arbitrary and 19 of the 193 subjects taking part in the study had known colonic disease. In spite of this, the proportions making up each functional group are comparable to those of Connell, Hilton, Irvine, Lennard-Jones, and Misiewicz (1965) for a group of 1,055 factory workers, of whom 27% had their bowels act more than once a day and 5% less than four times a week. This population sample naturally included few older subjects and none over 70. In the present study that age group alone accounted for almost half the total of constipated subjects. If these were to be excluded, the two sets of figures would be closely similar, and in fact 9% of a parallel sample of 400 patients without gastrointestinal symptoms, seen in general practice, were equally constipated. In terms of bowel function, therefore, the subjects making up the material for the present study are probably the same as a cross-section of the general population.

TRANSIT RATE OF BARIUM Manousos, Truelove, and Lumsden (1967) found that in 61% of 88 healthy volunteers of average age 52, who had previously swallowed 1-oz portions of barium sulphate suspension with each of four meals in one day, it had reached the rectum within 24 hours. In a group of 75 patients with the irritable colon syndrome, the corresponding proportion was 84%. In the present study barium was present in the rectum 12-15 hours after ingestion in 56% of normal subjects and in 80% of those with more frequent motions. The apparent speed-up on the transit rate of these subjects' barium was probably due to their having swallowed single 4-oz portions; its relative slowness in the six constipated subjects observed after 24 hours is likely to have been a chance variation.

COLONIC ACTIVITY AND BOWEL FUNCTION In subjects with a normal frequency of bowel function, as Fig. 5 shows, the mean rate of transportation in the right colon under resting conditions was 1 cm per hour. Net propulsive activity, the surplus of combined propulsive movements over retropulsion, increased nearly two and a half times in the transverse colon, entirely due to the extra coordinated propulsion, and it increased still further in the descending colon. Propulsion decelerated rapidly in the pelvic colon, partly because of increased retropulsion in that section, and there was very little effective

propulsion in the rectum. This would explain the relative absence of faecal shadows in the transverse colon reported by Connell *et al* (1964) and their accumulation in the right colon and in the pelvic colon.

The acceleration of contents in the transverse and descending colon, in spite of a diminution in their volume by water absorption, is probably due to the bowel becoming progressively narrower. The deceleration in the proximal pelvic colon may be caused by absorption reducing the amount of contents to be moved, or by a lessening of motor activity. However, the slowing is accentuated in diarrhoeic subjects and is accompanied by an increase in retropulsion; it may be related to some mechanism controlling the distribution of gas in the sigmoid loop.

The density of the normal bowel contents differs so little from that of water or of the surrounding viscera that even when they include a small proportion of barium they are relatively weightless in the abdominal cavity. Gas is very much lighter. One has only to try dragging a child's balloon beneath the surface in a bath of water to see how strong is the tendency for a few inches water pressure to collapse the lower part of it, and for the gas inside to distend the upper part. The gut wall tension that is needed to maintain a given intraluminal pressure increases with its diameter and, for this reason, a distended section of gut becomes increasingly liable to further distension.

If the diameter of a partially gas-filled bowel is to remain uniform under the conditions existing within the abdomen, there must be a relative increase of muscle tone in the gut wall in the upper part of any loops or flexures in which gas can be trapped. The sigmoid loop, with any gas that may be in it, is free to float upwards on its mesentery in any position of the body, and it is postulated that this creates a zone of hypertonus there. The resulting aboral tonic gradient in the proximal half of the pelvic colon cannot obstruct gas movements because the whole gas-filled section tends to be isobaric, but it may hinder the propulsion of solid or liquid contents, or assist in their retropulsion.

Over the whole length of the colon, the net rate of advance during the hour after lunch was reduced in subjects with normal bowel function. This was partly because any increase in the level of propulsion was offset by more effective retropulsion. At the same time, the contractile activity of the colon may have been inhibited by the distension of the terminal ileum that occurs after food; Hukuhara and Miyake (1959) showed that stimulation at this point could cause a reduction of colonic muscular movements.

Amongst the diarrhoeic group of subjects under

resting conditions, there was no visible increase in the rate of propulsion in the right colon, although the emptying of the ileum into it was usually accelerated; in six out of seven instances in which segmental propulsion was seen at rest in the transverse colon of a diarrhoeic subject there was already clear ileal effluent in the ascending colon at the start of observations. By contrast, in only one of the 12 subjects with normal function, who also showed segmental propulsion in the transverse colon, was there similar evidence of an accelerated ileal outflow; in three of them, barium was still visible in the small intestine after 12 to 15 hours and ileal emptying may have been delayed.

The extra ileal outflow in diarrhoeic subjects was frequently retained in the right colon, causing its distension. Nevertheless, the mean rate of haustral propulsion in the transverse colon at rest was more than double, and that of retropulsion there little more than half, those found in the normal group. These conflicting observations can best be reconciled by assuming that there had been further narrowing of the transverse colon, and perhaps an increase of gut wall tone, to account for the increased rate of propulsion. There would also probably have been a substantial aboral gradient of intraluminal pressures between the distended right colon and the splenic flexure. Wangel and Deller (1965) found pressures in the ascending colon consistently higher at rest than those in the sigmoid region in one of their patients with diarrhoea.

Although the net rate of transport in the transverse colon was increased fourfold, propulsion diminished rapidly in the distal half of the bowel under resting conditions and, as retropulsion increased at the same time, the overall level of colonic propulsion in diarrhoeic subjects was normal. The cause of the abrupt deceleration in the descending and pelvic colon remains uncertain. A progressive narrowing of the transverse and more distal bowel sections, compared with their diameter in normal subjects, appears to have been a characteristic feature of the group, but their propulsive activity is unlikely to have been reduced by segmental obstruction resulting from it; the observations of Chaudhary and Truelove (1961), Connell (1962), and others have shown that intraluminal pressures are diminished in diarrhoea, and obstruction would have raised them. The relative increase in retropulsion suggests an enhanced aboral tonic gradient in the narrowed pelvic colon and rectum.

After lunch, the net increase of propulsion over the whole length of the bowel in diarrhoeic subjects was more than threefold, and after carbachol it was fivefold; part of this was probably due to the extra ileal outflow. There appeared also to have been a big

increase of tone and activity in the caecum and ascending colon, which often started multihaustral or mass propulsion in the liquid contents of the transverse colon with increasing acceleration distally; only one of the propulsive movements seen in diarrhoeic subjects was peristaltic.

In the transverse colon, among diarrhoeic subjects, eating lunch more than doubled the resting mean rate of propulsion, especially that due to coordinated activity. In the descending colon, instead of the deceleration seen at rest, the net rate of advance was trebled after lunch in spite of extra retropropulsion, and in the pelvic colon it was increased to more than eight times the mean resting rate. It was evidently the effect of food and parasympathetic stimulation on a gut with reduced capacity and increased resistance to distension that caused this progressive acceleration. The absence of any gross hyperactivity reflected in the pressure records of Misiewicz, Connell, and Pontes (1966) from diarrhoeic subjects after food may indicate a degree of interhaustral relaxation; their telemetering capsules continued to advance in a liquid medium with only minimal pressures behind them. The combination of excessive liquid contents in a narrow bowel with haustration that was partially relaxed would almost amount to mass propulsion, and without resistance a capsule or any other form of contents would need little phasic contractile activity to transport it.

SUMMARY

One hundred and ninety-three volunteers, given barium sulphate suspension by mouth 12 to 24 hours earlier, were examined by time-lapse cine-fluorography for colonic motor activity at rest, and after food and carbachol. Functionally, 64% were said to be normal with one daily bowel action, 26% were inclined to diarrhoea, and 10% to constipation. Barium had reached the rectum within 12 to 15 hours in 56% of normal subjects.

For comparative purposes, the bowel was divided into five sections. One third of the bowel sections visualized remained inactive throughout the hour of observation, and another third showed non-propulsive segmental activity only. The remaining third of the sections showed in addition propulsive and retropropulsive activity. The chief sites of haustral and coordinated movements in each of the three functional groups were recorded, together with the different actions on them of food and carbachol, and the net rates of propulsion of contents in each section have

been compared. These findings are considered in relation to previous work, and their mechanisms discussed.

The average net propulsion of colonic contents in normal subjects amounted to 5.8 cm/subject/hr under resting conditions and was slightly diminished after lunch. In constipated subjects net propulsion at rest was 0.9 cm/subject/hr; there were too few of them with barium visible in the distal colon to assess the effect of food. Net colonic propulsion in diarrhoeic subjects under resting conditions was 4.9 cm/subject/hr and it increased after lunch to 16.6 cm. The effect of carbachol was consistently to increase coordinated propulsion.

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