Differential regional effects of octreotide on human gastrointestinal motor function

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Abstract
The effects of octreotide on regional motor function in the human gut are unclear. In a randomised, blinded study the effects of octreotide (50 μg, subcutaneously, three times daily) and placebo on gastric, small bowel, and colonic transit, and colonic motility and tone were assessed in 12 healthy volunteers whose colon had been cleansed. Octreotide accelerated initial gastric emptying (p<0.05), inhibited small bowel transit (p<0.01), and reduced ileocolonic bolus transfers (p<0.05). Colonic transit was unaltered by octreotide; the postprandial colonic tonic response was inhibited (p<0.05 v placebo), whereas colonic phasic pressure activity was increased by octreotide (p<0.05 v placebo). These data support the use of octreotide in diarrhoeal states but not in diseases that cause small bowel stasis and bacterial overgrowth. Simultaneous measurements of colonic transit, tone, and phasic contractility are valid in studying the effects of pharmacological changes and may be applicable to the study of the human colon in health and disease.

Figure 1: Experimental design. (Drug=octreotide (50 μg subcutaneously) or placebo.)

Methods
HEALTHY CONTROLS
We studied 12 healthy control subjects, whose ages ranged from 20 to 54 years (mean: 34 years; four women and eight men). All women participating in the study who were of childbearing potential had a negative plasma (βHCG) pregnancy test within 48 hours of the study. The research protocol was approved by the Mayo Institutional Review Board and all participants provided written informed consent.
GASTROINTESTINAL TRANSIT STUDY

We quantitated gastric, small bowel, and regional colonic transit by means of a validated scintigraphic method14-17 that utilises a delayed release capsule containing 111In-radiolabelled Amberlite-IR 120 ion exchange pellets (Sigma Chemical Co, St Louis, MO) to assess colonic transit, and 99mTc radiolabelled pellets (Amberlite 410, Sigma Chemical Co, St Louis, MO) in an egg meal to assess gastric and small bowel transit. The preparation, conduct, and analysis of these studies have been previously published.14-17

COLONIC TONE AND PHASIC PRESSURE ACTIVITY

After placement of a soft tipped guidewire (Microvasive, Hobbs Medical Inc, Stafford Springs, CT) in the transverse colon via colonoscopy, a combined barostat-manometric assembly was inserted into the descending colon so that the tip of the multilumen tube was located at the splenic flexure in all subjects. The barostat balloon was 10 cm in length, and the method used for measuring and calculating tone in the colon followed the studies previously reported.18-20 Manometric side holes were located 2 cm proximal, as well as 2, 7, and 12 cm distal to the barostat balloon. Briefly, an infinitely compliant bag was inflated with air and kept under a constant operating pressure throughout the studies; changes in the volume within this bag were used as estimates of changes in colonic tone. The barostat tracing was separated (by means of a computer program (Modified VAX LAB

**TABLE 1  Effect of octreotide on gastric emptying**

<table>
<thead>
<tr>
<th></th>
<th>Lag time (min)</th>
<th>Post-lag fractional emptying rate (%min-1)</th>
<th>β</th>
<th>ω×10^-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo (n=6)</td>
<td>92 (17)</td>
<td>0.28 (0.04)</td>
<td>2.15 (0.34)</td>
<td>44 (6)</td>
</tr>
<tr>
<td>Octreotide (n=6)</td>
<td>40 (17)</td>
<td>0.46 (0.25)</td>
<td>1.26 (0.21)</td>
<td>89 (45)</td>
</tr>
<tr>
<td>p Value (placebo vs octreotide)</td>
<td>0.09 &gt;0.1</td>
<td>0.048 &gt;0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data show mean (SEM).

consent. All subjects received 1·5 l of an oral colonic lavage solution (OLS, Abbott Laboratories, Chicago, IL) on the evening before the study.

EXPERIMENTAL DESIGN (FIG 1)

After bowel preparation on the preceding evening and an overnight fast, subjects ingested the methacrylate coated capsule containing 111In pellets and underwent partial colonoscopy without sedation. The combined barostat-manometry assembly was introduced into the descending colon under fluoroscopic control. Subjects were then transferred to a gamma camera, laboratory and placed in a chair with the back at an angle of 30° to the horizontal. When the methacrylate coated capsule was shown to have emptied from the stomach on the gamma camera image (that is, below markers placed on the anterior superior iliac spines and to the right of the midline), barostat and manometry recordings were obtained for 40 minutes in the fasting period. Octreotide, 50 μg, or an equal volume of saline (0·5 ml) was administered subcutaneously and colonic recordings were then obtained for a further 10 minutes. Subjects next ingested a 1000 kcal meal which included 300 kcal of egg (radiolabelled with 99mTc pellets), brown bread, and a chocolate malt (protein 15%, carbohydrate 35%, and fat 50%). After the meal was ingested, regular monitoring of gastrointestinal transit was obtained with a dual headed gamma camera, continuous recordings of colonic motility were obtained by multilumen manometry and the barostat balloon, and blood samples to measure gut hormones were obtained at 10 minute intervals during the first two hours postprandially.

DATA ANALYSIS

The transit profiles were summarised by the following parameters, as in previous studies from our group14-17 and others.22 We evaluated gastric emptying by the log time (defined as the time for 10% of the isotope to empty from the stomach,14 21 post-lag gastric fractional emptying rate, and by power exponential analysis [Prog=αexp(-κt)]21 Briefly, prog, is the proportion remaining in the stomach at time t, α is the proportion at time 0, β describes the shape of the initial part of the curve, and κ is an expression of the rate constant of the emptying curve. Small bowel transit time (expressed as the time for 10% of isotope to reach the colon, minus time for the same proportion to empty from the stomach, or t10%), proximal colonic emptying rate, and colonic geometric centre (weighted average of counts in five regions of interest: ascending, transverse, descending, sigmoid/rectum, and stool) at two, eight, and 24 hours were also measured. Ileocolonic transit and ascending
Colon emptying were plotted for 11 of the 12 participants, since in one patient taking octreotide, the methacrylate coated capsule did not dissolve until it reached the distal transverse colon. Ileocolonic bolus transfers were defined by a rate of flow \( \geq 10\% \) of \( 1\mathrm{I} \) in over 15 minutes, as in previous studies.\(^4\)\(^-\)\(^23\)

Colonic tone was calculated by the baseline volume of the barostat balloon. Since the baseline volume depends on the dimensions, shape, as well as the elasticity and muscular function of the vescus, which differ between individuals, we calculated the percentage change in volume relative to the fasting period, thereby normalising for interindividual differences before octreotide or placebo. Colonic manometric phasic pressure activity was averaged for the three tracings, 2, 7, and 12 cm distal to the barostat balloon and expressed as a motility index:

\[
[M=2 \times \text{amplitude} \times \text{no of contractions} + 1] \text{ per hour.}
\]

**Statistical Analysis**

Student’s \( t \) test (two tailed) was used to compare summaries of transit in the octreotide and placebo treated group. When parameters did not show a Gaussian distribution, a Wilcoxon rank sum test was used. The occurrence of ileocolonic bolus transfers in the two treatment groups was compared by \( \chi^2 \) test. Data in this paper are expressed as mean (SEM).

**Results**

**Gastrointestinal Transit**

Octreotide resulted in a faster initial emptying from the stomach (Table I) as shown by the lag time (\( p=0.09 \)) and by estimates of \( \beta \), the initial shape of the gastric emptying curve (\( p=0.048 \)). Figure 2 shows gastric emptying plots derived from the median data for the two groups. Note the difference in the shape of the initial part of the gastric emptying curve; in contrast, the remainder of the curves look similar. Thus, the post-lag fractional gastric emptying rate and \( \kappa \) were not significantly different in the two groups (Table I).

Octreotide prolonged small bowel transit time (Fig 3). There was also a reduction in the number of bolus transfers (Fig 4) across the ileocolonic junction in subjects treated with octreotide (five bolus transfers in the placebo group, while only one of the octreotide treated subjects had a bolus transfer; \( p<0.05 \) by Pearson’s \( \chi^2 \) analysis).

Ascending colon emptying rate, as well as the geometric centre (weighted average of counts in the colon) at two, eight, and 24 hours (estimates of total colonic transit) were similar in the two treatment groups (Table II). Figure 5 shows the profiles of ascending colon transit corrected for the time of onset of colonic transit, identified by appearance of \( 100\% \) of the \( 11\mathrm{I} \) counts in the ascending colon. Two subjects given placebo seemed to have very rapid emptying of the isotope from the ascending colon; however, the remainder of the subjects had very similar profiles of ascending colon emptying characterised by linear phases and plateaux. The geometric centres at two, eight, and 24 hours were similar in the two groups, suggesting no overall effect of octreotide on transit through the prepared colon.

**Colonic Motor Function**

Representative examples of tracings of colonic motility are shown in Figure 6(A) (placebo) and (B) (octreotide).

**Colonic Motility**

The fasting baseline barostat volumes in the two groups were not significantly different, and after the meal both groups showed a gastrointestinal response which was significantly increased in the placebo group (\( p<0.05 \)) and was less marked, although still showing a trend toward significance (\( p=0.09 \)) in the octreotide group (Fig 7). The magnitude of the tonic response to the meal is best summarised by the fractional decrease in the balloon volume after the meal, and was significantly lower in the octreotide group 13 (5\%) compared with the placebo group 28 (4\%) (\( p<0.05 \)).
both groups showed a significant increase in the motility index (Fig 8). However, the increment in phasic pressure activity in the octreotide group showed a trend to being greater than in the placebo group (p = 0.09).

**Discussion**

This study has shown the regional effects of octreotide on the motor function of the stomach, small intestine, and colon. The predominant effects seem to be on initial emptying from the stomach and on small bowel transit. Important but opposite effects on colonic tone and phasic pressure activity were noted. The effects of octreotide on gastric emptying of solids are unclear. O'Donnell et al. showed prolongation of oro-caecal transit time, but whether this prolongation was the result of impaired gastric or small bowel transit was unknown. There is some evidence that somatostatin and octreotide inhibit gastric emptying, and in a previous perfusion study of the jejunum, transit time over a 30 cm segment was prolonged by octreotide. Previous reports did not, however, clearly evaluate octreotide's effect on transit of solid residue through the entire small bowel.

A novel finding in our study was a significant difference in the shape of the initial part of the gastric emptying of solids (B factor), consistent with quicker initial emptying with octreotide compared with placebo. However, no effect was shown on the subsequent rate of gastric emptying. These observations on gastric emptying may be, at least partly, explained by the inhibitory effects of the somatostatin analogue on gastric secretion. Thus, since the total intragastric volume (standard meal plus endogenous secretion) was probably smaller in the subjects taking octreotide, the more rapid initial emptying rate may reflect either the reduced volume load or a change in the motor function of the stomach. Previous studies have shown that the same dose of octreotide inhibits distal antral motility, which is usually associated with slower gastric emptying of solids.

Hence, any effect of octreotide on gastric motility to account for accelerated emptying would have to be explained on the basis of a change in an alternative motor function, such as pyloric resistance, fundic tone, or a reduction in the intestinal resistance to flow by induction of a migrating motor complex. Shortening of the phase III lag phase is typically seen after vagotomy, presumably as a result of the abolition of the stomach's accommodation and inhibition of fundic tone, or by stimulation of highly propulsive gastric contractions by erythromycin. Further studies of these motor functions will be necessary to demonstrate conclusively the mechanism whereby octreotide reduces the lag phase for solid emptying.

The similarity in the second phase of gastric emptying in the two groups may suggest that since the gastric volume load was likely smaller with octreotide, the latter may actually have slowed gastric emptying during this period. The precise or relative contributions of volume load and emptying rate cannot be resolved by our methodology, but alternative approaches, such as magnetic resonance imaging, may be more useful.

The overall inhibition in the small bowel transit of solid residue measured accurately by scintigraphic method clarifies the observations of previous studies evaluating oro-caecal transit time which was appreciably delayed by octreotide in both health and in disease states. Our results have also been confirmed in a preliminary report by Vecht et al. These specific observations on small bowel transit are important because of the previous suggestion that octreotide might be used to stimulate propulsive activity fronts and, hopefully, accelerate transit through the small intestine of patients who have intestinal involvement by progressive systemic sclerosis. Our data show the importance of not trying to predict transit times on the basis of manometric recordings. Peeters et al. have shown in the dog that octreotide induced phase III like interdigestive activity, while reducing the intermittent pressure activity of phase II. The slowing of small bowel transit may result from the inhibition of phase II contractile activity reported in dogs or of the fed motor pattern reported in healthy subjects. We have also previously shown that octreotide (50 μg subcutaneously) invariably induces a migrating motor complex or activity front in the small intestine in functional or organic dysmotilities; however, this form of motor stimulation is not necessarily associated with acceleration of overall small bowel transit. Thus, for example, it is known that morphine, a μ-opioid agonist, frequently stimulates phase III like activity in the small intestine, but it is well known that such agonists delay small bowel transit. Our observations suggest that octreotide significantly prolongs small bowel transit time in healthy subjects to levels.

**Table II**

<table>
<thead>
<tr>
<th></th>
<th>GC&lt;sub&gt;2&lt;/sub&gt;</th>
<th>GC&lt;sub&gt;3&lt;/sub&gt;</th>
<th>GC&lt;sub&gt;4&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placebo (n=6)</td>
<td>2.0 (0.8)</td>
<td>2.8 (0.6)</td>
<td>3.4 (0.6)</td>
</tr>
<tr>
<td>Octreotide (n=6)</td>
<td>1.3 (0.08)</td>
<td>2.5 (0.4)</td>
<td>4.3 (0.4)</td>
</tr>
<tr>
<td>p Value (placebo vs octreotide)</td>
<td>0.21</td>
<td>0.69</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Data show mean (SEM).

GC = geometric centre at 2, 8, and 24 hours.
observed in patients with myopathic pseudo-obstruction\textsuperscript{23} studied using identical methods in our laboratory. The use of octreotide in disorders associated with small bowel stasis requires further detailed study of its effects on objective and subjective parameters in disease states, as well as placebo controlled rather than open trials.\textsuperscript{10}

The pattern of delayed overall small bowel transit in the octreotide treated patients is associated with a reduction in the number of bolus transfers\textsuperscript{44} across the ileocaecal junction. In the one patient receiving octreotide who showed a bolus transfer, its magnitude (15\%) was identical to the mean magnitude of the transfers in the placebo group (14\%). Thus, although the pattern of motor mechanisms that result in bolus transfers across the ileocaecal junction is unclear,\textsuperscript{38} octreotide seems to inhibit this propulsive event in most individuals and this may contribute further to the overall retardation of small bowel transit. The presumably reduced pancreaticobiliary and intestinal secretion in the presence of octreotide may result in a lower ileal volume load and, hence, a lower contractile response by the distal ileum with the attendant reduction in the size of bolus transfers.

We were unable to show any change in overall colonic transit or in the emptying rate of the ascending region of the prepared colon.

We were impressed by the rapidity with which the ascending colon and the remainder of the colon emptied in comparison with transit profiles in our previous studies\textsuperscript{15,17} which were performed with the colon unprepared. Preparation of the colon results in an increase in colonic motor activity measured manometrically.\textsuperscript{39} Future studies will need to appraise whether octreotide significantly alters transit in the unprepared colon.

The effects of octreotide on colonic motor function are intriguing. Octreotide caused a reduction in the tonic response to a standardised meal. It is possible that beneficial therapeutic effects of octreotide in patients with carcinoid diarrhoea who have increased postprandial colonic tone\textsuperscript{13} are to restore normal colonic tone and facilitate greater storage in the colon, thereby enhancing its

Figure 7: (A) Summary of colonic tone measured as baseline barostat volumes. Note the similarity of fasting baseline barostat volume and the decrease in volume (= increase in tone) observed in both groups postprandially (\textit{p}=0.05 for placebo, \textit{p}=0.09 for octreotide). (B) Although the absolute volumes measured postprandially in the two groups are similar, the increase in tone (fractional decrease in volume) was significantly greater with placebo than with octreotide.

Figure 8: Fasting and postprandial colonic motility index. Note the similar fasting value in the two groups and the greater increment postprandially in the octreotide group.
normal absorptive functions. Future studies will need to explore the hypothesis that decreasing colonic tone retards overall colonic transit. The concomitant increase in colonic pressure and phasic activity induced by octreotide confirms previous data in the rectum, and may have counteracted the potential effect on transit of reducing colonic tone. Thus, overall colonic transit was unaltered by octreotide, suggesting that the major beneficial effect in diarrhoeal disorders may be due to the retardation of small bowel transit and inhibition of small bowel secretion.26

In summary, our study has characterised in detail the regional motor effects of octreotide in the healthy gastrointestinal tract. Data from these studies support the use of octreotide in the treatment of diarrhoea predominant IBS. The current studies do not provide a rationale for using octreotide to treat small bowel stasis syndromes. Approaches using specific antagonists will be necessary to understand the mechanisms whereby octreotide alters motor function in the whole animal. From a methodological standpoint, our studies have proved that it is feasible to study the colon's motor function using simultaneous measurements of transit, tone, and phasic contractility. This approach seems to be advantageous as it provides a means of assessing simultaneously the functional significance of contractile activity, and may allow a clearer understanding of the processes that result in colonic propulsion in health, pharmacological perturbations, and disease.

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