Rectal and colonic distension elicit viscerovisceral reflexes in humans

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Law, Ngai-Moh, Adil E. Bharucha, and Alan R. Zinsmeister. Rectal and colonic distension elicit viscerovisceral reflexes in humans. Am J Physiol Gastrointest Liver Physiol 283: G384–G389, 2002. First published April 10, 2002; 10.1152/ajpgi.00359.2001.—Colonic transit is slowed in patients with disordered rectal evacuation, but the mechanism of this phenomenon is unclear. Our objective was to investigate rectocolonic inhibitory reflexes in humans to provide potential insight into patients with obstructed defecation. In 30 healthy subjects, a barostat-manometric assembly recorded colonic tone and phasic activity in the descending colon during rectal distension and recorded rectal tone during colonic distension. Phasic distensions were 8, 16, and 32 mmHg above balloon operating pressure, and staircase inflations were comprised of balloon inflation then deflation in 2-mmHg increments at 30-s intervals from 0 to 36 mmHg. Colonic balloon volumes increased to a similar extent during phasic rectal distensions 8, 16, and 32 mmHg above operating pressure, reflecting reduced colonic tone; balloon volumes also increased and phasic pressure activity decreased during staircase rectal distensions. In contrast, rectal balloon volume declined, reflecting increased tone during phasic and staircase colonic distensions. Thus rectal distension inhibited colonic motor activity, indicative of a viscerovisceral inhibitory reflex.

THE RECTUM SERVES AS A RESERVOIR for feces until defecation becomes socially convenient. Whereas defecation can be postponed, habitual suppression of the urge to defecate is thought to cause chronic constipation in humans (15). Voluntary suppression of defecation in healthy subjects markedly reduced the frequency of defecation and stool weight and prolonged total rectosigmoid and right colonic transit times (8). Moreover, patients with obstructed defecation due to pelvic floor dysfunction had delayed colonic transit (14) and abnormal motor function (11, 13). Whether the delay in colonic transit is attributable to obstruction of luminal contents by retained stool, colonic motor dysfunction unrelated to obstructed defecation, or a rectocolonic inhibitory reflex is unknown. Although the general concept that motor activity in the gastrointestinal tract can be inhibited reflexly by stimulation of a distant portion of the gut has been established by studies in animal models (9), the effect of rectal distension on colonic motor activity in humans is unclear. Our aims were to address the hypotheses that rectal distension would reduce motor activity in the descending colon, whereas colonic distension would not significantly influence rectal motor activity.

MATERIALS AND METHODS

Healthy Volunteers

All participants signed informed consent to participate in the studies approved by the Institutional Review Board at the Mayo Clinic. We recruited 30 healthy volunteers, aged 18–51 yr (mean ± SE 33 ± 1.1; 14 men and 16 women) by public advertisement. A clinical interview and physical examination were performed to exclude significant cardiovascular, respiratory, neurologic, psychiatric, or endocrine disease. No participant had previously undergone abdominal surgery (other than an appendectomy and/or cholecystectomy) or were taking medications with the exception of oral contraceptives. Validated screening questionnaires [a Bowel Disease Questionnaire (17) and the Hospital Anxiety and Depression Inventory (20)] were used to exclude subjects with irritable bowel syndrome based on Rome I criteria (3) and to determine anxiety and depression scores.

Colonic and Rectal Motor Function

A polyethylene balloon barostat-manometric assembly was placed into the prepared upper descending colon using flexible sigmoidoscopy and fluoroscopy (2). The assembly was comprised of an infinitely compliant 10-cm-long balloon with a maximum volume of 600 ml (Hefty Baggies; Mobil Chemical, Pittsford, NY) linked to an electronic rigid-piston barostat (Mayo Rigid Barostat, Engineering Department, Mayo Clinic, Rochester, MN) by a double-lumen tubing with a larger lumen (3.2 mm inner diameter) for balloon distension and a smaller lumen (2 mm diameter) for measuring pressure (18). The manometric portion of the assembly was comprised of six water-perfused (0.4 ml/min) pneumohydraulic transducers 5 cm apart. The first and second transducers were 5 cm oral and caudal to the balloon, respectively. Rectal motor activity was recorded with a 7-cm-long polyethylene balloon in the rectum with the distal site 5 cm from the anal verge connected to a separate barostat that recorded rectal motor activity. Intraballloon pressures were set to op-
erating pressure as described in detail previously (2). Intraballoons were used to monitor wall contractions and relaxation pressures in response to wall contractions and relaxation. The experimental protocol is illustrated in Fig. 1. During the conditioning distension, intraballons were inflated with 0 to 36 mmHg in 4-mmHg steps at 30-s intervals. After the colon and rectum were distended separately by staircase and phasic distensions in randomized order. During staircase distensions, the barostat balloon was inflated in 2-mmHg increments at 30-s intervals from 0 to 36 mmHg and was subsequently deflated in similar steps to 0 mmHg. Phasic distensions were 8, 16, and 32 mmHg above operating pressure, administered in random order, and lasted 1 min with an interstimulus interval of 1 min. We measured the effects of rectal distension on colonic barostat balloon volume and manometrically recorded phasic motor activity and the effect of colonic distension on rectal barostat balloon volume.

**Experimental Procedure**

All subjects were admitted to the General Clinical Research Center at St. Mary's Hospital on the evening before the study for bowel preparation. Subjects drank 2–5 liters of polyethylene glycol-3350 and electrolyte solution (OCL; Abbott Laboratories, Chicago, IL) until their fecal effluent became a clear liquid. All subjects had a screening electrocardiogram to exclude significant rhythm disturbances or ischemia. Women of childbearing potential underwent a plasma β-human chorionic gonadotropin pregnancy test before (121 ± 12 ml) and after (118 ± 10 ml) the staircase distension sequence. Barostat volumes were sampled as analog signals at 8 Hz and converted to digital form before entry into a computer (2). All barostat balloon data were quantified using a computer program identical to that employed in previous studies (2). We studied the effect of rectal distension on colonic balloon volume and phasic activity and of colonic distension on rectal balloon volume. For phasic distensions, we compared the balloon volume at operating pressure before distension (predistension), to the balloon volume during distensions at 8, 16, and 32 mmHg above operating pressure. Three separate paired t-tests at an adjusted two-sided alpha level of 0.0167 (Bonferroni correction for three tests) were used.

Each staircase distension sequence was broken down into ascending and descending limbs for analysis (Fig. 1). In each limb, the low portion included pressures from 0–18 mmHg and the high portion included pressures from 20–36 mmHg. Differences within subjects during staircase distensions (high ascending-before and high ascending-after) were assessed by a paired t-test or corresponding nonparametric signed-rank test. The adjusted two-sided alpha level for these comparisons was 0.025 (Bonferroni adjustment for 2 comparisons). The effects of rectal staircase distension on manometric motor activity were analyzed by estimating the mean and 95% confidence intervals of the differences between the same epochs (i.e., high ascending-before and high ascending-after). Data are expressed as means ± SE unless stated differently.

**RESULTS**

Barostat operating pressures in the colon (9.1 ± 0.4 mmHg) were similar to those in the rectum (10.4 ± 0.4 mmHg, P > 0.05).

**Effect of Rectal Distension on Colonic Tone**

Phasic rectal distension was accompanied by increased colonic balloon volume (P ≤ 0.017 vs. predistension) (Figs. 2A and 3) reflecting reduced colonic tone. The colonic balloon volume increased from 102 ± 10 ml before rectal distension to 118 ± 10 ml, 120 ± 12 ml, and 120 ± 13 ml during rectal distension 8, 16, and 32 mmHg above operating pressure, respectively.

Colonic balloon volume also increased during the high ascending phase of the staircase distension sequence (P < 0.001 for high ascending (133 ± 10 ml) vs. before (121 ± 11 ml)); this finding reflected colonic relaxation during rectal distension by pressures ≥20 mmHg (Figs. 2A and 4A). When the rectal balloon was returned to operating pressure after the staircase distension sequence, colonic barostat balloon volumes returned to baseline [P ≤ 0.001 for high ascending vs. after (113 ± 9 ml)].

Effects of rectal staircase distension on colonic phasic motor activity are depicted in Table 1. Mean differences for the epochs (high ascending-before and high ascending-after) were consistently negative, although
not statistically significant at the 0.05 level, indicating a reduction in phasic motor activity during the high ascending phase of the ramp distension sequence.

**Effect of Colonic Distension on Rectal Tone**

Rectal balloon volume changed from $169 \pm 17$ ml at baseline to $162 \pm 17$, $162 \pm 17$, and $159 \pm 17$ ml during colonic distension by pressures at 8, 16, and 32 mmHg above operating pressure, respectively. The reduction in rectal balloon volume during colonic phasic distension was only significant (i.e., $P < 0.017$) at a distending pressure of 32 mmHg. Staircase distension of the colon had similar effects on rectal tone. Rectal balloon volume declined at higher distending pressures during

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Fig. 2. Effect of rectal distensions on colonic motor activity in a typical subject. **A**: colonic balloon volume increased and colonic phase pressure activity was reduced during staircase and phasic rectal distensions. **B**: in the same subject, rectal balloon volume declined during staircase colonic distension, returning to baseline after distension.
the staircase distension sequence ($P = 0.005$ for high ascending vs. before) and returned to baseline when the colonic balloon was deflated to operating pressure ($P = 0.02$ for high ascending vs. after) (Fig. 4B).

**DISCUSSION**

We have demonstrated that acute rapid intermittent (phasic) and staircase rectal distensions reduced both colonic tone and phasic motor activity in humans. Conversely, acute distensions of the descending colon were associated only with a subtle increase in rectal tone. These observations support the hypothesis that rectal distension reflexly inhibits colonic motor activity. We suggest the increase in colonic balloon volume and reduced phasic activity during rectal balloon distension represents colonic relaxation and is not an artifact induced by balloon distension; thus the colonic barostat balloon was located at least 30 cm proximal to the rectal balloon, and rectal distension did not have physical effects on the descending colon. Moreover, the responses to staircase and phasic rectal distension were qualitatively similar and recorded by two separate measurement techniques, i.e., barostat balloon and manometric sensors. In contrast, only marked colonic distension (to 32 mmHg) induced a relatively subtle increase in rectal contractility, not relaxation.

Colonic tone was reduced to a similar extent during rectal distensions of 8, 16, and 32 mmHg above operating pressure, akin to an all-or-none physiological response. Because colonic relaxation was observed even during rectal distension by a relatively low pressure, i.e., 8 mmHg above operating pressure, it appears that the stimulus for this reflex need not be noxious. Colonic tone and phasic motor activity also decreased during rectal staircase distension, albeit only during distension by higher pressures (i.e., ≥20 mmHg). This suggests that the threshold for colonic relaxation is lower during rapid, compared with slow rectal distension. Rectal distension has been demonstrated to reduce colonic myoelectrical activity, both before and after ingestion of a meal (4). Perhaps rectocolonic inhibitory reflexes serve to retard the delivery of feces when the rectum is suddenly filled with stool.

Bayliss and Starling (1) were the first to demonstrate that pinching or distension of the small intestine, but not of the colon, inhibited contractions in the gastrointestinal tract. The role of descending reflex loops, traveling from the distal to the proximal gut via prevertebral ganglia and independent of the central nervous system, was highlighted in the guinea pig by Kreulen and Szurszewski (9). Distension activated afferent mechanosensory fibers that project to the prevertebral ganglia wherein the mechanosensory afferent synaptic input was integrated with central synaptic input and then conveyed to the superior mesenteric and celiac ganglia via intermesenteric nerves. Thus afferent input activates sympathetic neurons in the prevertebral ganglia and inhibits motor activity in the colonic segment proximal to the site of distension. Transmission is primarily by a direct inhibitory effect of norepinephrine at $\alpha_2$-receptors on cholinergic neurons. Indeed, the $\alpha_2$-antagonist yohimbine abolished colocolonic inhibitory reflexes in dogs (6).

Prior in vivo observations in animals and humans have also demonstrated viscerovisceral inhibitory reflexes. Rectal distension reduced gastric emptying (19) and phasic contractility of the jejunum (7). Aside from balloon distension, instillation of a chemical irritant in the rectum, such as glycerol, also evoked a rectocolonic reflex in humans (10). Whereas glycerol infused into
the rectum increased rectal and reduced colonic tone, it also induced colonic high amplitude propagated contractions, which could induce mass evacuation of colonic contents. In contrast to the long colocolonic reflexes described in our study, Sims et al. (16) demonstrated that descending colonic distension triggered the equivalent of a peristaltic reflex with proximal contraction and distal relaxation in humans. However, the proximal and distal recording balloons were closer to the distending balloon than in our study.

Rectocolonic inhibitory reflexes may partly explain colonic motor dysfunction, as evidenced by delayed colonic transit (14) and an impaired colonic contractile response to a meal in patients with obstructed defecation (11). An improvement in rectal evacuation after biofeedback therapy is accompanied by an improvement in the colonic contractile response to a meal, suggesting that the colonic motor abnormality was secondary to impaired rectal evacuation. Whereas our study assessed the effects of acute rectal distension on colonic motor activity, Musial and Crowell (12) demonstrated that prolonged continuous rectal distension delayed colonic transit and tended to inhibit the colonic motor response to a meal in pigs.

In summary, our observations suggest that acute rectal distension inhibits colonic motor activity, whereas acute colonic distension may increase rectal tone. From a physiological standpoint, phasic distensions may be preferable to staircase distensions for assessing rectocolonic inhibitory reflexes in humans. Because rectocolonic inhibitory reflexes are mediated by reflex loops integrated in the prevertebral ganglia, they provide a means to document activation of extrinsic afferents during bowel distension. The effects of rectal distension on colonic transit, threshold pressures necessary for eliciting the reflex, and the role of sympathetic pathways in modulating these reflexes in healthy subjects and patients with obstructed defecation deserve further study.

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Table 1. Effect of rectal staircase distension on colonic phasic pressure activity

<table>
<thead>
<tr>
<th>Manometric Sensor</th>
<th>Difference in Phasic Pressure Activity (high ascending-before)</th>
<th>Difference in Phasic Pressure Activity (high ascending-after)</th>
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<tr>
<td>1</td>
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<td>-0.7 (-1.6, 0.2)</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<td>4</td>
<td>-1.1 (-2.1, 0.0)</td>
<td>-1.7 (-2.6, 0.8)</td>
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<tr>
<td>5</td>
<td>-0.4 (-1.5, 0.7)</td>
<td>-1.0 (-2.2, 0.1)</td>
</tr>
<tr>
<td>6</td>
<td>-0.3 (-1.5, 1.0)</td>
<td>-0.9 (-2.0, 0.1)</td>
</tr>
</tbody>
</table>

All figures are means ± (95% CI) in mmHg/s. Negative values reflect a reduction in colonic phasic pressure activity during rectal distension. Ascending refers to inflation limbs of the staircase distension sequence.

Fig. 4. Effect of staircase rectal distension on colonic barostat balloon volume (A) and staircase colonic distension on rectal balloon volume (B). Low and high refer to rectal intraballoon pressures ranging from 0–18 and 20–36 mmHg, respectively. Ascending and descending refer to the segment of the compliance curve during which pressures were gradually increased (0–36 mmHg) or decreased (36–0 mmHg), respectively. Each symbol represents the colonic balloon volume before and during rectal distension in a given subject. *P < 0.02 for high ascending vs. before and after.


