Colorectal and rectocolonic reflexes in canines: involvement of tone, compliance, and anal sphincter relaxation

Ji-Hong Chen,1,2 Hanaa S. Sallam,1 Lin Lin,1 and Jiande D. Z. Chen1,3

1Division of Gastroenterology, University of Texas Medical Branch, Galveston, Texas; 2Division of Gastroenterology, Renmin Hospital of Wuhan University, Wuhan, People’s Republic of China; and 3Veterans Research and Education Foundation, Veterans Affairs Medical Center, Oklahoma City, Oklahoma

Submitted 22 July 2009; accepted in final form 9 June 2010

Chen JH, Sallam HS, Lin L, Chen JDZ. Colorectal and rectocolonic reflexes in canines: involvement of tone, compliance, and anal sphincter relaxation. Am J Physiol Regul Integr Comp Physiol 299: R953–R959, 2010. First published June 16, 2010; doi:10.1152/ajpregu.00439.2009.—Distention of the proximal colon may have inhibitory or excitatory effects on the rectum and vice versa. The reflexes between the proximal colon and the rectum have not been well studied due to difficulties in accessing the proximal colon. The aim of this study was to investigate the reflex responses and their mechanisms between the proximal colon and the rectum in consideration of distention-related changes in tone and compliance of these regions as well as anal sphincter relaxation in a canine model. Proximal colon/rectal tone, compliance, and anal sphincter relaxation were investigated in six dogs chronically implanted with a proximal colon cannula while in the fasting state and during proximal colon distention or rectal distention. It was found that: 1) both rectal distention and proximal colon distention significantly and substantially decreased the compliance of the opposite regions, and guanethidine abolished proximal colon distention-induced changes in rectal compliance; 2) rectal/proximal colon distention decreased proximal colonic/rectal tone, and guanethidine abolished both of these inhibitory effects; 3) the anal sphincter was more sensitive to rectal distention than proximal colon distention; and 4) the minimal distention pressure required to induce anal inhibitory reflex was lower for rectal distention than proximal colon distention. It was concluded that distention-related changes in tone and compliance suggest the long inhibitory reflexes between the proximal colon and the rectum with the sympathetic involvement in rectal responses. The anal sphincter is more sensitive to the distention of the rectum than that of the proximal colon.

The aim of this study was, therefore, to investigate reflex responses and their sympathetic mechanisms between the proximal colon and the rectum by assessing the tone and compliance of these regions as well as anal sphincter relaxation in dogs chronically equipped with a cannula in the proximal colon. These may have significant implications for the pathophysiology and therapy of functional gastrointestinal disorders. We hypothesize that there exist inhibitory reflexes between the proximal colon and the rectum, similar to those between the descending colon and the rectum, and these reflexes are mediated via the sympathetic pathway. Furthermore, we anticipate that the anal sphincter is more sensitive to rectal distention than proximal colon distension.

MATERIALS AND METHODS

Animals. Six healthy female hound dogs (20–28 kg) were used in the study. After an overnight fast, the dogs were anaesthetized with an initial intravenous infusion of sodium thiopental (5 mg/kg; Abbott Laboratories, North Chicago, IL) and maintained on IsoFlo (1.5% isoflurane, Abbott Laboratories) in oxygen-nitrous oxide (1:1) carrier gases delivered from a ventilator following endotracheal intubation. After a midline incision on the lower abdomen, a plastic cannula (length of 5 cm, inner diameter of 1.0 cm) was placed in the proximal colon 6 cm distal to the cecum through the colon and abdominal wall with one opening in the inner wall of the colon and the other opening at the abdomen (Fig. 1). One end of the cannula that was oval shaped was placed in the lumen of the colon and secured with sutures. The other end of the cannula was round shaped with a diameter of 3 cm and was externalized on the middle (slightly to the right) of the lower abdomen (above the ascending colon). The cannula was used for the
insertion of a barostat balloon into the proximal colon for distention or the measurement of colon tone. Initially, a canine jacket was used to protect the cannula, and later, it was found to be unnecessary as the dog occasionally licked the cannula but never tried to pull it out the cannula. The dogs were transferred to recovery cages after receiving medications for postoperative pain control, and the study was initiated after a 2-wk recovery. All experiments were performed with the animals in the conscious state. The study was approved by the Institutional Animal Care and Use Committee of the University of Texas Medical Branch (UTMB) at Galveston and performed at UTMB.

Experimental procedure. The study was composed of four experiments in six randomized sessions to investigate: 1) effects and mechanisms of rectal distention on proximal colon tone and compliance (2 sessions, 1 for tone and the other for compliance); 2) effects and mechanisms of proximal colon distension on rectal tone and compliance (2 sessions, 1 for tone and the other for compliance); 3) colonic anal inhibitory reflex (CAIR) (1 session); and 4) rectal anal inhibitory reflex (1 session). Each session was performed on a separate day at an interval of 3 days or more. All sessions were performed in an overnight-fasted state with the rectum of the animal cleaned with a 133-ml enema (C. B. Fleet) 2 h prior to each experiment. To be consistent, all sessions were performed at the same time of the day. To reduce the effect of fecal load, the animals were fed with liquid food 1 day before each session.

Assessment of colonic and rectal minimal distending pressure. At the beginning of the first session for each dog, the minimal distending pressure (MDP) for the proximal colon and the rectum was measured by a barostat system (Distender Series II; G & J Electronics, Toronto, Canada). A barostat balloon was inserted into the proximal colon via the colon cannula or into the rectum via the anus and connected to the barostat device. The MDP was determined by inflating the intralumen balloon in 1-mmHg steps until a pressure at which evident exertions related to the intralumen pressure were recorded and a proper balloon volume achieved (>30 ml). The pressure that was 2 mmHg above the MDP was defined as the individual operating pressure (IOP). The IOP was individualized among animals and maintained the same in each dog in different sessions since the MDP was found consistent on different days in preliminary testing. The distention pressure was applied on top of this IOP.

Experiment 1: effects and mechanisms of rectal distention on proximal colon tone and compliance. The experimental protocol for the study of proximal colon compliance during rectal distention was composed of three sequential procedures: 1) a compliance test without rectal distention, 2) a compliance test with rectal distention (10 mmHg above IOP) after administration of saline (50 ml iv within 5 min), and 3) a compliance test with rectal distention (at same pressure as in procedure 2) 15 min after administration of guanethidine.

In the colon compliance test, the colon cannula was opened (it was closed with a metal screw with a diameter of 1 cm), and a double-lumen catheter with a finely folded adherent plastic bag (600-ml capacity, maximal diameter of 15 cm when inflated; MUI Scientific, Mississauga, ON, Canada) attached to its distal end was inserted into the proximal colon through the cannula. The balloon was placed in the ascending colon with its proximal end 3 cm distal to the colon cannula (or 9 cm distal to the cecum). Two measures were used to ensure that the barostat balloon was placed in the right direction and position: 1) during placement of the cannula, a mark was made on the external end of the cannula to indicate the direction of the distal colon; 2) before the formal experiment, a long polyethylene catheter was inserted into the colon through the cannula to validate the direction of the distal colon; if the catheter was placed in the distal direction, its distal end came out from the anus (the length of the canine colon is ~50–60 cm). The catheter was snared at the desired position of the balloon was reached and connected to the barostat system. The folded balloon was first fully opened by briefly inflating the balloon and then deflated. Stepwise distention was performed at pressures from 2 to 26 mmHg above IOP with a step size of 2 mmHg; each distention was maintained for 1 min with 1-min deflation in between. The deflation period was used to ensure the tolerance of the animals for the procedure. The volume for each distention pressure was measured by averaging the last 20 s of the distention period. Rectal distention was applied by inserting a noncompliant balloon to the rectum with the distal end of the balloon 5 cm from the anal verge. The balloon was connected to a blood pressure meter (Medtronic, Minneapolis, MN), and the pressure was maintained at 10 mmHg above the rectal IOP. Guanethidine was infused intravenously within 5 min at a dose of 3 mg/kg (Sigma, St. Louis, MO) that was previously proven effective (4).

The experiment for the measurement of proximal colon tone during isobaric rectal distention (rectocolonic reflexes) was performed on a separate day using the following protocol: 1) a baseline recording of proximal colon tone was made for 20 min or more (to ensure the recording was stable) with the rectal balloon deflated; 2) a 2-min recording of proximal colon tone with rectal distention at a pressure of 10 mmHg above the rectal IOP, followed with a 10-min or more recovery period to ensure the recovery of colon tone; 3) repetition of procedure 2 two times with rectal distention at pressures of 20 mmHg and 30 mmHg, respectively; 4) administration of guanethidine (3 mg/kg iv within 5 min); and 5) 15 min after guanethidine, procedures 2 and 3 were repeated. The tone of the proximal colon was measured during the entire experiment using the barostat system under the colonic IOP. The rectal distention was applied using the same method as described in the compliance test. The rectocolonic reflex (alterations in proximal colonic tone upon rectal distention) was assessed by averaging the intracolonic balloon volume during the second minute of each 2-min isobaric rectal distention.

Experiment 2: effects and mechanisms of proximal colon distention on rectal tone and compliance. The experimental procedures for the assessment of rectal tone and compliance were the same as those described in experiment 1 except that 1) the barostat balloon was inserted into the rectum with its proximal edge 5 cm from the anal verge, instead of the proximal colon; and 2) the distention was performed in the proximal colon instead of the rectum.

The experiment was also performed in two sessions on two separate days, one for the compliance test and the other for the assessment of colorectal reflexes (rectal tone changes with proximal colon distention).

Experiment 3: CAIR. This experiment was performed in the fasting state in two series on the same day: a control CAIR test and a CAIR test 15 min after administration of guanethidine.
estimated only for the last 10 min to ensure the stability. The intraballoon versa. For the baseline recording, the balloon volume was averaged increase in the volume was indicative of a reduced tone and vice determined by the measurement of the intraballoon volume. An compliance.

(P 1/2); values of P 1/2 were considered the primary endpoint for corresponding to half-maximal volume on the pressure-volume curve

Fig. 2. Colon compliance (1 dog). A: compliance curve in 1 individual dog (dog No. 7805). B: power exponential transformation of same data with volume expressed as a proportion of the maximum volume on the y-axis and reciprocal of pressure on the x-axis. BSL, baseline; Gua, guanethidine; Gua+RD, RD with Gua administration.

A water-perfused manometric system (PC Polygraf; Medtronic) was used for the measurement of the anal sphincter pressure. An anorectal manometric catheter with four side holes at an interval of 1 cm was inserted into the anorectum. Once the high-pressure zone was identified and the recording was stable for at least a period of 15 min, graded distention of the proximal colon was applied, each step lasting 10 s. The distention pressure was from 5 mmHg above the IOP until the observation of an anal inhibitory reflex with a step size of 3 mmHg. The minimal distention pressure to induce CAIR was defined as the pressure at which a reduction of anal sphincter pressure by 10 mmHg or more was noted. There was a 2-min interval between two consecutive periods of colonic distention. To study possible mechanisms involving the sympathetic pathway, the procedure was repeated 10 min after administration of guanethidine (3 mg/kg iv in 5 min). The distention of the proximal colon was applied using the same method as described in experiments 1 and 2.

Experiment 4: rectal anal inhibitory reflex. The procedure of experiment 4 was the same as experiment 3, except that the distention was applied to the rectum instead of the proximal colon.

Data analysis. For the analysis of compliance, a power exponential model was used to fit the nonlinear compliance curve, $Vol = V_{\text{max}} \times \exp[-(\kappa \times \text{RelP})^{\beta}]$, with parameter $\beta$ representing the overall shape of the curve and $\kappa$ representing the change in volume as a function of $1/P$ at any given point. $V_{\text{max}}$ represented the maximum volume, and RelP represented the relative pressure, $\text{RelP} = (1/P - 1/P_{\text{max}})$. The estimated $\kappa$ and $\beta$ for each animal were used to calculate the pressure corresponding to half-maximal volume on the pressure-volume curve (P 1/2); values of P 1/2 were considered the primary endpoint for compliance.

For rectocolonic and colorectal reflexes, colon or rectal tone was decreased by rectal distention without the involvement of the sympathetic pathway (Figs. 2, 3, and Table 1). $P_{1/2}$ was 12.42

RESULTS

The mean MDP was $4.5 \pm 1.1$ mmHg for the proximal colon and 4.4 $\pm 0.24$ mmHg for the rectum; no difference was noted between the rectum and the proximal colon. Accordingly, the IOPs for the rectum and colon were similar.

Effects and mechanisms of rectal distention on proximal colon compliance. The compliance of the proximal colon was decreased by rectal distention without the involvement of the sympathetic pathway (Figs. 2, 3, and Table 1). $P_{1/2}$ was 12.42

Statistical analysis. Data on the volume of the rectum/colon and the percentage of anal sphincter relaxation are expressed as means $\pm$ SE. ANOVA was applied to assess the difference in rectal/colon tone among baseline, distention, guanethidine, and guanethidine plus distention. Student’s paired $t$-test was used to determine the differences between any pairs.

Data on the compliance parameters are expressed as median with range values. A nonparametric Wilcoxon signed-rank test was used to compare compliance variables between the resting state and each distention period. $P < 0.05$ was considered to be significant.
mmHg at baseline and was reduced to 7.41 mmHg during rectal distention at the pressure of rectal IOP + 10 mmHg (P = 0.03 vs. baseline), suggesting the inhibitory effects of rectal distention on proximal colon compliance. The proximal colon compliance was also decreased by rectal distention after the administration of guanethidine (8.25 mmHg, P = 0.04 vs. baseline); however, administration of guanethidine alone did not alter proximal colon compliance (P = 0.12 vs. baseline), suggesting the insignificant involvement of the sympathetic pathway in proximal colon compliance.

Effects and mechanisms of proximal colon distention on rectal compliance. The compliance of the rectum was decreased by proximal colon distention with the involvement of the sympathetic pathway (Figs. 4, 5, Table 2). The rectal compliance (P 1/2) was decreased from 9.71 mmHg at baseline to 4.31 mmHg with proximal colon distention (P = 0.03 vs. baseline), and this effect was blocked by the administration of guanethidine (P 1/2 = 8.54 mmHg, P = 0.18 vs. baseline), suggesting the involvement of the sympathetic pathway. Interestingly, under the normal condition (with no colon distention), the administration of guanethidine showed an inhibitory effect on rectal compliance (P 1/2 = 5.64 mmHg, P = 0.04 vs. baseline).

Effects and mechanisms of rectal distention on proximal colon tone. Isobaric rectal distension reduced proximal colon tone, reflected as an increase in the volume of the proximal colon, and the inhibitory effect was mediated through the sympathetic pathway (Fig. 6). The proximal colon volume was increased from 140.0 ± 21.5 ml at baseline to 170.0 ± 16.3 ml at a distention pressure of 10 mmHg above the IOP level (P = 0.02 vs. baseline), 167.5 ± 18.2 ml at a distention pressure of 20 mmHg above the IOP level (P = 0.04 vs. baseline), and 171 ± 20.3 ml at a distention pressure of 30 mmHg above the IOP level (P = 0.02 vs. baseline), indicative of reduced proximal colon tone with rectal distention. No differences were noted in the inhibitory effects of the rectal distention among different distention pressures (P > 0.05, ANOVA).

In the presence of guanethidine, the rectal distention-induced increase in colon volume was reduced at all distention pressures.

Table 1. Comparison of proximal colon compliance variables among different conditions

<table>
<thead>
<tr>
<th></th>
<th>κ</th>
<th>β</th>
<th>P 1/2, mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>9.13 (6.23–12.40)</td>
<td>0.69 (0.45–0.93)</td>
<td>12.42 (8.31–14.65)</td>
</tr>
<tr>
<td>RD</td>
<td>1.31 (0.58–2.61)*</td>
<td>0.65 (0.33–0.82)</td>
<td>7.41 (5.22–9.41)*</td>
</tr>
<tr>
<td>Gua</td>
<td>2.02 (0.95–2.76)*</td>
<td>0.59 (0.41–0.73)</td>
<td>10.23 (7.54–11.77)</td>
</tr>
<tr>
<td>RD+Gua</td>
<td>2.90 (0.83–3.52)*</td>
<td>0.83 (0.49–1.06)</td>
<td>8.25 (7.24–9.17)*</td>
</tr>
</tbody>
</table>

Values are presented as medians with interquartile range (25–75th percentiles) in parentheses. RD, rectal distention; Gua, guanethidine. *P < 0.05 vs. baseline.

Table 2. Comparison of rectal compliance variables among different conditions

<table>
<thead>
<tr>
<th></th>
<th>κ</th>
<th>β</th>
<th>P 1/2, mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.05 (0.81–1.78)</td>
<td>5.85 (3.17–6.53)</td>
<td>9.71 (6.64–12.31)</td>
</tr>
<tr>
<td>CD</td>
<td>0.60 (0.52–1.14)*</td>
<td>1.67 (0.82–2.74)*</td>
<td>4.31 (2.36–5.24)*</td>
</tr>
<tr>
<td>Gua</td>
<td>0.82 (0.57–1.05)</td>
<td>5.87 (4.63–7.06)</td>
<td>5.64 (4.58–6.25)*</td>
</tr>
<tr>
<td>CD+Gua</td>
<td>0.96 (0.67–1.34)</td>
<td>9.84 (8.31–11.05)</td>
<td>8.54 (6.18–9.42)</td>
</tr>
</tbody>
</table>

Values are presented as medians with interquartile range (25–75th percentiles) in parentheses. CD, colon distention. *P < 0.05 vs. baseline.
The mean minimal distention pressure for the anal inhibitory reflex was 26.8 mmHg. The minimal distention pressure required to induce the anal inhibitory reflex (20, and 30 mmHg above the IOP, respectively). The distention pressure was measured by averaging the last 20 s of the distention period. RD was applied by a pressure meter, and the pressure was maintained at 10 mmHg above the rectal individual operating pressure (IOP). Gua (3 mg/kg) was infused intravenously within 5 min. Normally, proximal colon volume was increased with the increasing of distention pressure (see control tracing); RD and/or Gua inhibited this volume increasing (see RD, Gua, and RD+Gua tracings).

levels ($P < 0.01$ vs. rectal distention without guanethidine, ANOVA); the increases became insignificant and were $3.3 \pm 1$, $2.7 \pm 1.2$, and $3.5 \pm 1.7$ ml at distention pressures of 10, 20, and 30 mmHg above the IOP, respectively.

Effects and mechanisms of proximal colon distention on rectal tone. Similarly, isobaric distention of the proximal colon also reduced rectal tone (Fig. 7). The proximal colon distention increased the rectal balloon volume from 110 $\pm 18.5$ ml at baseline to 158 $\pm 12.5$, 130 $\pm 15.1$, and 132 $\pm 10.4$ ml at 10, 20, and 30 mmHg above IOP levels, respectively ($P = 0.02$, 0.04, and 0.04, respectively). No significant differences were noted among three distention levels ($P > 0.05$, ANOVA), suggesting non-pressure-dependent changes of rectal tone in response to proximal colon distention at pressures higher than 10 mmHg above the IOP.

In the presence of guanethidine, the colon distention-induced increase in rectal volume was reduced at all distention levels ($P < 0.01$ vs. rectal distention without guanethidine, ANOVA); the increases became insignificant and were $-5.7 \pm 1.2$, $-3.5 \pm 1$, and $-0.2 \pm 0.3$ ml at distention pressures of 10, 20, and 30 mmHg above the IOP, respectively.

Colonic anal reflex and rectal anal reflex. The minimal distention pressure required to induce the anal inhibitory reflex was higher with the proximal colon than with the rectum. The mean minimal distention pressure for the anal inhibitory reflex was 26.8 $\pm 8.7$ mmHg for proximal colon distention and 12.3 $\pm 3.6$ mmHg for rectal distention ($P = 0.02$, Student’s $t$-test).

Guanethidine blocked the proximal colon anal reflex but had no effects on the rectal anal reflex (Fig. 8, A and B).

The percentage of the anal sphincter relaxation at three lowest effective distention pressures (the mean pressure value was $31.2 \pm 5.7$ mmHg for the colon distention and $14.6 \pm 4.8$ mmHg for rectal distention) was lower with proximal colon distention than that with the rectal distention ($34.3 \pm 6.5\%$ vs. $43.7 \pm 9.8\%$, $P = 0.02$, Student’s $t$-test).

**DISCUSSION**

To the best of our knowledge, this was the first study to comprehensively investigate the long intestinointestinal reflexes from the proximal colon to the rectum and anal sphincter in dogs via the assessment of changes in compliance, tone, and anal sphincter relaxation. The findings demonstrated that rectal distention, and, separately, proximal colonic distention, reduced compliance in the proximal colon and rectum, respectively. Guanethidine attenuated the inhibitory effect of proximal colonic distention on rectal compliance and had mixed effects on the colonic response to rectal distention. Proximal colonic distention required a higher inhibition pressure than rectal distention to induce anal sphincter relaxation.

The compliance provides an indirect assessment of rectal or colonic wall stiffness (resistance to distention) in terms of the volume increase for a unit pressure rise. It reflects both the capacity and the distensibility (the elastic properties) of the gut wall, which are modified by the muscular activity. This study suggested the existence of a long intestinointestinal inhibitory reflex pathway between the proximal colon and the rectum, and the role of the sympathetic pathway in this reflex. There are several gastrointestinal reflexes, such as, gastrocolonic, gastroileal, small intestine-gastric, rectocolonic, and colocolonic. Usually the activity in one region of the gut has an inhibitory effect on more proximal regions. Previously, cloni-

![Control tracings](http://ajpregu.physiology.org/)

![CD tracings](http://ajpregu.physiology.org/)

![Gua tracings](http://ajpregu.physiology.org/)

![CD+Gua tracings](http://ajpregu.physiology.org/)
The sympathetic supply to the colon was found to have a significant role in the regulation of colonic compliance and rectal tone during mechanical stimulation of the colon (6). Clinically, rectal compliance was found to be decreased in both diarrhea-dominant IBS and constipation-dominant IBS patients (16).

Reflexes within the gut are mediated via extrinsic nerves involved in long and short reflex pathways via the spinal cord and prevertebral ganglia, respectively, and intrinsic nerves playing a role in intestinointestinal inhibitory reflexes. The possible neural pathways involved in this long intestinointestinal or viscerovisceral reflex are extrinsic sympathetic pathways. Two types of reflexes affecting motility are related to sympathetic innervations to the gut: reflexes between gut regions and generalized protective reflexes in response to adverse conditions. Usually, the intervention or function of a distal organ/region regulates motor activities in a more proximal organ/region. The present data showed bidirectional inhibitory effects on compliance of the opposite regions between the proximal colon and the rectum with sympathetic involvement in the rectal response. Further studies are needed to investigate effects of these bidirectional reflexes on gastrointestinal motility.

Data in this study also showed that rectal/proximal colonic distension decreased proximal colonic/rectal tone to a similar degree at three different distention levels of 10 mmHg, 20 mmHg, and 30 mmHg above the IOP and that guanethidine abolished these effects equally at both regions, suggesting the sympathetic mechanism involved in the inhibitory reflexes. Intuitively, one would expect an increase in compliance when an intervention reduces tone. In this study, however, although rectal distention increased the volume of the proximal colon (reduced tone) at the IOP, it actually made the proximal colon less elastic or more rigid at higher distending pressures: only small increases occurred when the distending pressure was increased. This can be appreciated from Figs. 2A and 3: the volume-pressure curve with rectal distention was flat compared with that without rectal distention. Several previous studies have investigated the reflexes between the rectum and descending colon in humans. For rectocolonic reflex, Law et al. (8) reported that rectal distention (8, 16, and 32 mmHg above the operating pressure) decreased descending colon tone, similar to what we found in the proximal colon, indicative of a viscerovisceral inhibitory reflex between the descending or the proximal colon and the rectum. Similarly, Steens et al. (16) found that rectal distension inhibits tonic and phasic motility of the descending colon in healthy controls and IBS patients; and this rectocolonic inhibitory reflex was impaired and attenuated postprandially in IBS patients. However, Ng et al. (13) didn’t find a significant tonic response in the descending colon in response to rectal distension in humans. In regard to the colorectal reflex (rectal response to proximal or descending colon distention), the findings of this study were different from those reported in the studies by Ng et al. and Law et al. in which increased, rather than decreased, rectal tone in response to descending colon distention was noted. The opposite rectal responses might be attributed to the stimulation of different regions (descending colon vs. proximal colon) that may have different dominant reflex pathways (extrinsic or intrinsic). These previous findings and those in the present study seem to suggest that the distention pressure of 8 or 10 mmHg above the IOP is sufficient to induce the rectocolonic reflex or colorectal reflex to the maximal degree.

The rectocolonic inhibitory reflexes serve to delay the delivery of feces when the rectum is filled with stool in a short time, and the colorectal inhibitory reflexes serve to avoid frequent defecation, which may be induced by rectal contractions after each meal. Further studies on both reflexes and their mechanisms may help to explore the exact neural pathways.

The sympathetic supply to the colon was found to have purely inhibitory effects on both muscular coats of the bowel (7, 8). In vivo studies of the colonocolonic inhibitory reflex also showed that the colonocolonic inhibitory reflex is mediated via the extrinsic nerves to the colon with the involvement of α2-adrenoceptors (6). One of our studies (4) showed that rectal distention inhibited postprandial antral motility and impaired gastric slow wave in dogs, and the inhibitory effects were mediated via the adrenergic pathways. Tonic reflexes in the colon and rectum are believed to play an important role in health and in functional bowel disorders. Nutrient ingestion

Fig. 8. Colonic anal reflex and rectal anal reflex. A: typical tracing (60 s) of proximal colon distention-induced anal sphincter relaxation at different distention levels with or without Gua, CD1 = 25 mmHg, CD2 = 30 mmHg. Gua blocked the distention-induced reflex, suggesting the involvement of the sympathetic pathway. B: typical tracing (60 s) of RD-induced anal sphincter relaxation at different distention levels with or without Gua (RD1 = 12 mmHg, RD2 = 15 mmHg, and RD3 = 18 mmHg). Gua did not block the rectal anal reflex. Arrows indicate the onset of distention.
significantly increased cecal tone, and rectal distention abolished this effect (11). IBS patients demonstrated altered autonomic responses to feeding and colonic distension (14). Normalization of rectal evacuation and postprandial sigmoid tone in patients with evacuation disorders by biofeedback training also support the presence of a rectocolonic inhibitory reflex (10). It was stated that not only pelvic nerve-related mucosal intrinsic reflex and sacral excitatory reflex, but also colonic nerve-related lumbar inhibitory reflex was involved in the defecation reflex (rectoanal reflex), suggesting the control of defecation reflex by sympathetic nerves (17). A previous study reported that the rectum received a dense afferent innervation by a distinct population of low threshold, slowly adapting mechanoreceptors with specialized intraganglionic laminar endings, which was not found more proximally in the colon (9). It is reasonable that guanethidine presented different effects on the proximal colon and rectum during distention of the opposite regions in this study.

Comparison of the effects of proximal colonic distention and rectal distention on anal sphincter relaxation indicated that proximal colonic distention could also induce anal sphincter relaxation, but required a higher distention pressure than the rectum. It was interesting to note that guanethidine only blocked the inhibitory anal reflex induced by proximal colonic distention, but not rectal distention. This may suggest the predominant control of the sympathetic pathway on the long reflex pathway in the proximal colon, whereas a partial or minimal role on the short reflex pathway in the rectum. The extrinsic lumbar inhibitory outflow was reported to cause marked inhibition of the rectoanal reflex via the lumbar colonic nerves (18). The colonocolonic inhibitory reflex was found to be mediated via the extrinsic nerves (6). It should be noted that guanethidine blocks the release of noradrenaline via the inhibition of the Mg$^{2+}$ ATPase-dependent pumps at the presynaptic terminal, but has no effect on its spontaneous release. Therefore, the administration of guanethidine in this study might not completely block the sympathetic pathway.

**Perspectives and Significance**

The rectum and the colon serve as reservoirs for gut luminal contents. Our results suggest that retention of the contents (presented as distention in the study) at any region of the colorectum may result in dysfunctions of other regions through the long intestinointestinal tonic reflexes with possible involvement of the sympathetic pathway. The existence of inhibitory reflexes between the proximal colon and the rectum may also help explain why patients with pelvic floor dysfunction and constipation often have slow colon transit, and why constipation-dominant IBS patients often have reduced rectal compliance. Rectal anal inhibitory reflex is an important physiological reflex that facilitates defecation. However, it is unclear whether this inhibitory reflex is only limited to the rectum. In this study, we have found that a similar inhibitory reflex can also be solicited by proximal colon distention; however, a higher distention pressure is required. These findings suggest that retention of feces in the colon may also facilitate defecation, although to a degree less than rectal retention of feces.

In summary, distention-related changes of tone and compliance suggest the long inhibitory reflexes between the proximal colon and the rectum with the involvement of the sympathetic pathway. The anal sphincter is less sensitive to the distention of the proximal colon than the distention of the rectum.

**GRANTS**

This work is partially supported by National Institute of Diabetes and Digestive and Kidney Diseases research grant DK-075155.

**DISCLOSURES**

No conflicts of interest, financial or otherwise, are declared by the author(s).

**REFERENCES**