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ROLE OF THE SIGMOID COLON IN THE DEFECATION MECHANISM WITH EVIDENCE OF SIGMOIDO-ANAL INHIBITORY AND ANO-SIGMOID EXCITATORY REFLEX

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1. ABSTRACT

In spite of voluminous literature that has been written on defecation, the exact mechanism has not yet been fully cleared up. The current study investigated the effect of sigmoid colon (SC) distension on anal motile activity and of anal distension on SC motility. Sixteen healthy volunteers (age 36.2 ± 11.6 SD years, 10 men) were studied. The SC was distended by a balloon in 10 ml increments of CO_2, and the anal, rectal and SC pressure response was recorded before and after their individual anesthetization. The anal, rectal and SC pressure response to anal distension in increments of 2 ml of CO_2 was also registered. SC distension with big volumes (mean 86.2 ± 1.9 ml) effected a SC pressure increase ($p<0.05$) and no rectal pressure response ($p>0.05$); the balloon was expelled to the exterior. Distension of the anesthetized SC caused no SC, rectal or anal pressure response ($p>0.05$, $p>0.05$, $p>0.05$, respectively); the response returned after the anesthetic effect had waned. SC distension while the rectum had been anesthetized, affected a significant SC pressure rise as well as an anal pressure decrease and balloon expulsion to the exterior. Anal balloon distension produced a significant pressure rise of the SC ($p<0.001$) and rectum ($p<0.01$). Distension of the anesthetized rectal neck (anal canal) caused no SC or rectal pressure response ($p>0.05$, $p>0.05$, respectively); response returned after the anesthetic effect had disappeared. SC distension appears to effect anal dilatation while anal distension causes SC contraction. This reciprocal action is suggested to be reflex and mediated through the "sigmoido-anal inhibitory reflex" and the "ano-sigmoid excitatory reflex". These 2 reflexes are believed to keep the SC contracting and the rectal neck dilated until complete SC evacuation occurs. The study seemingly negates the role of rectal distension as a prerequisite for balloon expulsion.

2. INTRODUCTION

Defecation is a complex mechanism which is controlled both reflexly and voluntarily (1-6). Despite numerous contributions in the literature on defecation, the precise mechanism has not been fully defined. We do not know exactly whether the defecation reflex is initiated by distension of the sigmoid colon, rectosigmoid junction or the rectum. Since Gowers, who was followed by other investigators (7-10), rectal distension is considered to initiate the recto-anal inhibitory reflex with a resulting internal anal sphincter relaxation and defecation. Recently, we demonstrated that rectosigmoid junction (RSJ) distension by a balloon effected rectal contraction and internal anal sphincter relaxation, an action which was mediated through the "rectosigmoid-rectal reflex" (11). We suggested that stool accumulation in, and distension of, the rectum is not a prerequisite for rectal contraction (11). It was postulated that the stools passing through the RSJ are transmitted directly to the rectal neck (anal canal) by a wave of "mass squeeze" rectal contraction (11). The rectosigmoid-rectal reflex is proposed to act on an empty rectum while the rectoanal inhibitory reflex seems to be initiated by the distended rectum.

The defecatory urge is claimed to be evoked by passive rectal distension (1,7-10). It is accentuated by rectal contractions which drive the fecal material to the reflexly dilated rectal neck. Recent studies have demonstrated that anal balloon distension causes reflex rectal contraction and evacuation through the anorectal excitatory reflex (12). During passage through the rectal neck the fecal material seems to effect anal distension and stimulate the anal mucosa which is proposed to evoke the anorectal excitatory reflex. Now, the question that needs to be answered is: what could be the effect of sigmoid colon distension on the motile activity of the rectal neck, and of anal distension on the sigmoid colon motility? The current communication investigated these points aiming at shedding more light on the mechanism of defecation.

3. MATERIAL AND METHODS

3.1. Subjects

Sixteen healthy volunteers (mean age 38.2±11.6 SD years, range 28-53, 10 men, 6 women) were enrolled in the study after giving an informed consent. They had no gastrointestinal complaint in the past or at the time of enrolment. Mean stool frequency was 9.8±1.2 SD per week (range 8-11) which agrees with the frequency of normal controls in our laboratory. Physical examination, including neurologic assessment, laboratory work-up, abdominal sonography and colonoscopic studies were normal.

3.2. Methods

The subjects were instructed to fast during the night. In the morning the bowel was evacuated by either defecation or enema. If enema evacuation was done, we waited for 1 hour before starting the test so that the functional bowel changes which might have occurred as a result of enema, would have disappeared. A balloon (London Rubber Industries, London) 2 cm in diameter, was applied to the distal end of a Ryle stomach tube (8 French, Pharma Plast Int. AS/DK 3540, Lynge, Denmark) containing multiple lateral apertures. The tube was marked in centimeter intervals to determine the position of the balloon relative to the external anal orifice during tube withdrawal. A metallic clip was applied to the distal end of the tube for fluoroscopic control. A mechanical puller for automatic tube withdrawal was used (9021 H, Disa, Copenhagen). With the subject in the left lateral recumbent position, the lubricated empty balloon was introduced into the anus and fed to the level of the sigmoid colon so that the proximal end of the balloon lay 20 to 25 cm away from the anal orifice. The site of the balloon in the sigmoid colon was under fluoroscopic control when it was found necessary. The tube was connected to a strain gauge pressure transducer (Statham 230 B, Oxnard, CA). Our guide to the sigmoid colon was its location just proximal to the high pressure zone of the rectosigmoid junction.

Simultaneous measurement of the sigmoid colon, rectal and anal pressures was carried out by means of a three-channel microtip catheter (Wiest Urocompact, Los Altos, CA). The latter was introduced per anum so that the distal transducer lay in the SC, the second one in the rectum, 8-10 cm and the third one in the rectal neck, 3-4 cm from the anal orifice. The positioning of the transducers was fluoroscopically controlled.

3.3. Sigmoid colon distension

Carbon dioxide (CO_2) was used to inflate the balloon. The controlled CO_2 source was the Heyer Schulte CO_2 cystometer (Heyer Schulte Corp., Goleta, CA) which has a self-contained CO_2 system with disposable cartridges. The balloon was filled in increments of 10 ml, and the anal, rectal and SC pressures were simultaneously recorded. Throughout the test, the pressure was measured for a period of 15 minutes to establish a steady state; the SC balloon expulsion was also marked.

3.4. Anal distension

We tested the effect of anal distension on the SC and rectal pressures. A 6F balloon-ended catheter was introduced through the anus to lie in the rectal neck 2-3 cm from the anal orifice. The balloon measured 1 cm in diameter. It was inflated with CO_2 in increments of 2 ml, and the SC, rectal and anal pressures were recorded.

3.5. Anesthetization of the sigmoid colon, rectum and rectal neck

We tested the effect of SC distension on the pressure response of the individually anesthetized rectal neck and rectum at 10 minutes after anesthetization and 2 hours later when the anesthetic effect had waned. Also, the effect of anal distension on the SC and rectal pressure response was tested after separate anesthetization of the SC and rectum. The rectal neck was anesthetized with 5 ml of 2% xylocaine (Astra, Södertälje, Sweden) diluted with 5 ml of normal saline, injected in its wall at multiple points. After 2-3 days, the rectum was anesthetized by infusion of 20 ml of 2% xylocaine diluted with 20 ml of saline. Three to four days later, the SC was anesthetized with 20 ml of 2% xylocaine added to 20 ml of saline, which we injected endoscopically at multiple points into the inner circumference of the SC wall. All tests performed with anesthetics were repeated using saline instead of xylocaine.

To define the role of the rectum in balloon expulsion, the rectum was anesthetized and 10 minutes later the SC was balloon-distended in increments of 10 ml and the SC, rectal and anal pressure responses were recorded.

To ensure reproducibility of the results, the aforementioned measurements and recordings were repeated at least twice in the individual subject, and the mean value was calculated. The results were analyzed statistically using the Student's *t* test, and values were given as the mean±standard deviation (SD). Differences assumed significance at $p<0.05$.

4. RESULTS AND DISCUSSION

The tests were completed and evaluated in all the subjects with no adverse side effects during or after the procedure. The mean resting pressure in the SC was 9.8±1.8 cm H_2O (range 8-12), in the rectum 8.6±1.2 cm H_2O (range 6-10) and in the rectal neck 73.2 ± 9.2 cm H_2O (range 60-80).

4.1. Response of the rectum and rectal neck to SC distension

When the SC was distended in increments of 10 ml up to 70-80 ml of CO_2 (mean 76.6±2.2) we did not obtain significant SC, rectal or anal pressure responses ($p>0.05$, $p>0.05$, $p>0.05$, respectively; Figure 1). Sigmoid distension with 80-90 ml of CO_2 (mean 86.2±1.9) effected a significant increase of SC pressure to a mean of 43.6±6.2

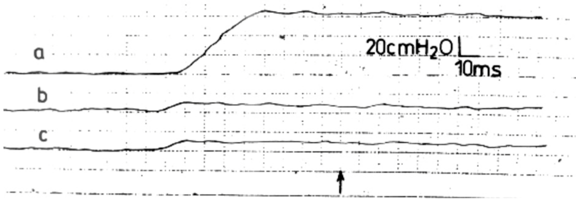

Figure 1. Pressure tracing showing no anal (a), rectal (b) or sigmoid colon (c) pressure response to sigmoid colon distension with 70 ml of CO_2, ↑ = distension

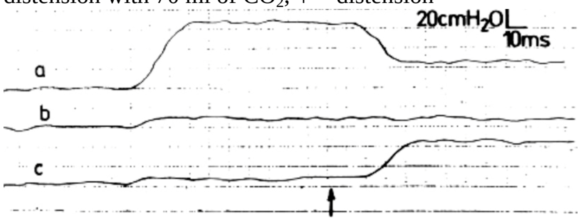

Figure 2. Pressure tracing showing decrease of anal pressure (a), no rectal pressure response (b) and increase of sigmoid colon pressure (c) upon sigmoid colon distension with 90 ml of CO_2, ↑ = distension

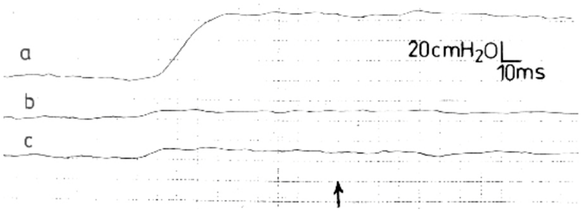

Figure 3. Pressure tracing 10 minutes after sigmoid colon anesthetization. No anal (a), rectal (b) or sigmoid colon (c) pressure response to sigmoid colon distension with 90 ml of CO_2, ↑ = distension

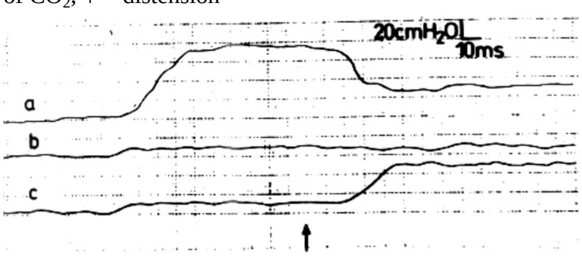

Figure 4. Pressure tracing 10 minutes after rectal anesthetization. Sigmoid colon distension with 90 ml of CO_2 effected anal pressure decline (a), no rectal pressure response (b) and sigmoid colon pressure rise (c) , ↑ = distension

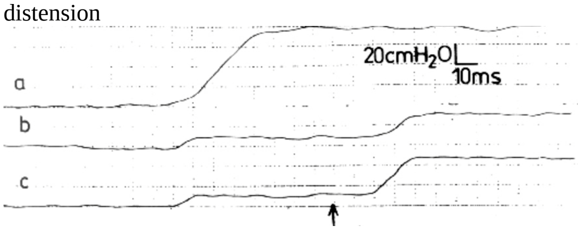

Figure 5. Pressure tracing showing increase of sigmoid colon (c) and rectal (b) but no anal (a) pressure response upon anal balloon distension with 2 ml of CO_2, ↑ = distension

cm H_2O (range 35-55; $p<0.001$), a decrease of anal pressure to a mean of 24.3±2.6 cm H_2O (range 20-32, $p<0.05$; Figure 2) and the balloon was expelled to the exterior. No significant change ($p>0.05$) in the rectal pressure occurred (Figure 2).

Balloon distension of the SC 10 minutes after SC anesthetization effected no significant anal or rectal pressure changes ($p>0.05$, $p>0.05$, respectively, Figure 3). Three hours later, when the anesthetic effect had worn off, SC distension produced anal and rectal pressure responses similar to those prior to anesthetization ($p>0.05$).

When we tested the role of the rectum in balloon expulsion, SC distension 10 minutes after rectal anesthetization caused SC pressure rise, anal pressure decline and balloon expulsion to the exterior; we got no rectal pressure response (Figure 4). The pressure values upon SC distension were similar to those prior to anesthetization with no significant difference. When the aforementioned tests were repeated using saline instead of xylocaine, we obtained results similar to those without saline injection with no significant difference.

4.2. SC and rectal pressure response to anal distension

When we distended the rectal neck with 2 ml of CO_2 we got a significant SC and rectal pressure increase to a mean of 39.2±5.5 cm H_2O ($p<0.001$) and 28.2±4.9 cm H_2O ($p<0.01$; table 1; Figure 5), respectively. There was no anal pressure response. The SC and rectal pressure exhibited a progressive significant increase with the 4-and 6-ml anal balloon inflation ($p<0.001$, $p<0.001$; table 1; Figure 6). When we increased the balloon distension to 8 and 10 ml, the SC and rectal pressure response was similar to the 6-ml distension with no significant difference ($p>0.05$; table 1). The anal pressure did not show a significant change with any of the distending volumes. We did not inflate the balloon beyond 10 ml in order to avoid a possible injury of anal sphincters or musosa.

Anal balloon distension 10 minutes after anal anesthetization effected no significant SC or rectal pressure changes ($p>0.05$) while 3 hours later the SC and rectal pressure responses to anal distension were similar to those prior to anesthetization ($p>0.05$).

The aforementioned results were reproducible with no significant difference when the test was repeated in the individual subject.

The findings in the current study may shed some light on the defecation mechanism. The distended balloon simulates the fecal bolus (13). The increased pressure of the SC upon balloon distension presumably indicates SC contraction (14). It occurred only with large volume balloon distension. This resulted in decrease of the anal pressure and denotes anal dilatation. Although the rectum showed no pressure response to SC distension, the SC balloon was expelled to the exterior. The distended SC balloon was also expelled from the SC to the exterior while the rectum was anesthetized. These findings suggest that

Table 1. Anal, rectal and sigmoid colon pressures upon anal distension with CO_2⁺.

	Pressure (cm H_2O)					
Anal distending volume	*Anal*		*Rectal*		*Sigmoid colon*	
	Mean	Range	Mean	Range	Mean	Range
0 (basal)	73.2 ± 9.2	60 – 80	8.6 ± 1.2	6 – 10	9.8 ± 1.8	8 – 12
2	72.1 ± 8.9º	60 – 80	28.2 ± 4.9*	20 – 32	39.2 ± 5.5**	33– 50
4	73.5 ± 9.3º	62 – 78	36.5 ± 6.2**	29 – 46	48.6 ± 8.2**	39 – 58
6	73.2 ± 9.2º	60 – 78	47.3 ± 7.9**	40 – 58	57.2 ± 7.9**	48 – 70
8	72.6 ± 9.1º	58 – 80	46.2 ± 8.1**	38 – 55	59.4 ± 8.3**	47 – 72
10	73.2 ± 9.3º	60 – 82	47.6 ± 8.2**	38 – 57	57.6 ± 8.1**	50 – 70

+ Values were given as the mean ± standard deviation (SD), º $p>0.05$, * $p<0.01$, ** $p<0.001$, P values were compared to the basal volume

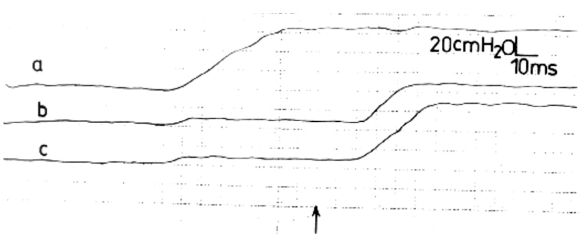

Figure 6. Pressure tracing showing increase of sigmoid colon (c) and rectal (b) but no anal (a) pressure response upon anal balloon distension with 6 ml of CO_2, ↑ = distension

the rectum did not share in balloon expulsion. In the meantime, the increased SC pressure upon anal balloon distension supposedly indicates enhancement in the SC motile activity which increased upon rise in the anal distending volume.

We postulate that as soon as the SC distension with stools reaches a certain volume, the mechanoreceptors in the SC wall are stimulated and initiate SC contraction. It seems that SC contraction evokes reflex relaxation not only of the RSJ as previously demonstrated (15) but also of the rectal neck, thus allowing the stools to pass to the exterior without rectal contraction. In the meantime we hypothesize that the stools during their passage through the dilated rectal neck lead to anal mucosal stimulation which appears to effect SC contraction. This is suggested to keep the SC feeding the rectal neck with stools until the SC has been evacuated. It appears that there is a reciprocal reflex action between the SC and the rectal neck that seems to keep the stools passing from the SC to the rectal neck until the former becomes empty. Thus, the contracting SC opens the rectal neck, and the stool column maintains anal dilatation which in turn keeps the SC contracting until it completely evacuates its stool content and relaxes with subsequent closure of the rectal neck.

4.3. The sigmoido-anal inhibitory reflex and ano-sigmoid excitatory reflex

The anal dilatation occurring upon SC contraction postulates a reflex relationship between the 2 actions. This relationship could be elicited and was reproducible in all the examined subjects. The reproducibility and disappearance of the reflex action when we anesthetized the SC or the rectal neck, the assumed two arms of the reflex arc, point to the constancy of the reflex relationship and represent a plausible hypothesis for the possible involvement of an unrecognized reflex which we term "sigmoido-anal inhibitory reflex". It is suggested that this reflex is evoked when the SC becomes fully distended and contracts, leading to reflex rectal neck opening.

It may be argued that the anal dilatation is due to rectal distension and is mediated through the recto-anal inhibitory reflex (7-10). Considering, however, the absence of rectal pressure response to SC distension as well as the expulsion of the SC balloon while the rectum was being anesthetized would negate such argument and the role of the rectum in balloon expulsion. We postulate that rectal ampulla distension acquires importance if the urge to defecate is suppressed and the stools accumulate in the ampulla, or if the sigmoido-anal inhibitory reflex is not evoked due to the presence of SC or anal pathology. Further evidence that rectal distension is not essential to initiate anal dilatation is the tendency of the recto-anal inhibitory reflex to recover late after low anterior rectal resection (16-20).

The current study also demonstrated that the SC contracts on anal distension; a reflex mechanism is suggested to exist between the 2 arms. The reproducibility of this reflex action as well as its absence on anesthetization of the SC or rectal neck, the assumed 2 arms of the reflex arc, are an indication of the constancy of this relationship, which we term the "ano-sigmoid excitatory reflex". The receptors of the afferent sensory limb appear to exist in the anal mucosa. It is believed that the passage of fecal material through the rectal neck stimulates the anal mucosa receptors leading to SC contraction. Therefore, as long as the feces are passing through the rectal neck, the SC maintains contraction until complete SC evacuation is achieved.

In conclusion, it appears that SC distension effects anal dilatation while anal distension leads to SC contraction. This reciprocal action is suggested to be reflex and is mediated through the sigmoido-anal inhibitory reflex" and "ano-sigmoid excitatory reflex". These 2 reflexes are believed to keep the rectal neck dilated and the SC contracting until complete SC evacuation has occurred. The study presumably negates the role of rectal distension as a prerequisite for balloon expulsion except under certain circumstances such as defecatory urge suppression or in case of SC or anal pathologies.

5. ACKNOWLEDGMENT

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