Rectal reservoir and sensory function studied by graded isobaric distension in normal man

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SUMMARY   The rectal expansion and concomitant sensory function on graded, isobaric, rectal distension within the interval 5–60 cm H_2O was investigated in 36 healthy young volunteers. Anal pressure and electromyography (EMG) from the external anal sphincter were simultaneously recorded. Rectal distension caused an initial rapid expansion followed by transient, often repeated, reflex rectal contractions and a slow gradual increase of rectal volume. The maximal volume displaced by the first reflex rectal contraction was 18 (13) ml, which was less than 10% of the volume at 60 s. The pressure threshold for appreciation of rectal filling was 12 cm H_2O (95% CL 5–15 cm H_2O) and coincided with the threshold for rectoanal inhibition. Urge to defecate was experienced at 28 cm H_2O (15–50 cm H_2O) distension pressure, which was close to the threshold for maximal rectal contraction, also coinciding with the appearance of the external anal sphincter reflex. The interindividual variation of rectal volume on distension with defined pressures varied widely, indicating a considerable variation of rectal compliance in normal man. No correlation was found between rectal volume and sex or anthropometric variables. The relative variations in pressure thresholds for eliciting rectal sensation and rectoanal reflexes were less than the corresponding threshold volumes. It was concluded that the dynamic rectal response to distension reflects a well graded reflex adjustment ideal for a reservoir.

The rectum and anal sphincters constitute a functional unit subserving both defecation and continence. The rectal contribution to faecal continence includes the capacity of the rectum to act as a reservoir. This implies that the rectum, like the gastric fundus and urinary bladder, is likely to contain mechanisms for a receptive relaxation.[1]

Rectal continence also includes a sensory function for rectal loading linked to the central nervous system (CNS). Balloon distension of the rectum may cause a sensation of passing wind or an urge to defecate.[2-4] The location of the sensory nerve endings is controversial, however.[5-8] Information regarding normal rectal reservoir and sensory function in general, and particularly the integrated control of rectoanal and rectorectal reflexes, is sparse because interest has mainly been focused on the anal sphincter function.

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The specific aim of this investigation was to study the dynamic rectal and anal reflex responses to graded isobaric distension and to characterise the concomitant subjective perception of a sudden rectal distension. The applied pressure was varied stepwise from 5 to 60 cm H_2O and was kept constant throughout the distension period by means of a recently described device.[9]

Methods

SUBJECTS
Thirty six subjects, 17 men and 19 women, mean age 31 (5) years (mean (1 SD)), range 23–43 years, were investigated. They were all interrogated as regards bowel habits, abdominal or anorectal conditions and medication and underwent a physical examination. They had no history of laxative use and no symptoms or signs of anorectal disease. Written informed consent to the study was obtained from all subjects. The study protocol was approved by the Ethical Committee of the University of Göteborg.
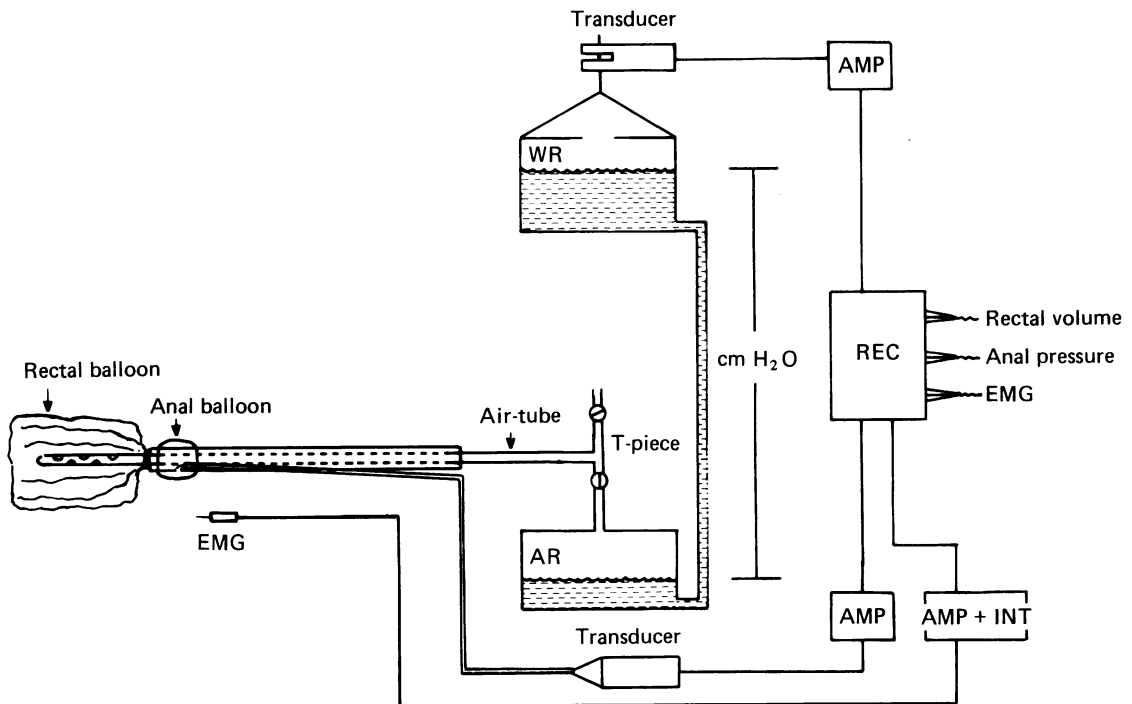
Fig. 1 *Schematic illustration of the experimental setup. For explanation, see text and ref no 9. (By courtesy of* Gut.*)*

ANORECTAL MANOVOLUMETRY

Anorectal manovolumetry was undertaken using a device recently described and analysed in detail (Fig. 1).[9] Rectal distension and volumetry were done by means of a wide dimensioned water reservoir, suspended on a force displacement transducer (GRASS, FT 10C) and connected to an air reservoir. The air reservoir was connected to a rectal balloon (a high compliance polyethylene bag) by means of an air tube from the air reservoir. The length of the rectal balloon was 120 mm (maximal volume 500 ml). By adjusting the height of the water reservoir above the air reservoir, the pressure in the air reservoir could be predetermined and, because of the wide dimensions of the reservoirs, the pressure remained almost constant despite shifts of fluid between the reservoirs. The volume change of the rectal balloon – that is, rectal volume, was monitored as weight change of the water reservoir (1 g=1 ml) and recorded on a Polygraph (GRASS, model 7D).

Anal pressure was simultaneously recorded by means of a disposable endotracheal tube (Malinckrodt, no 7, od 10 mm) with the cuff serving as an anal probe. The cuff and its tubing were filled with water and connected to a Statham pressure transducer (P 23 Db). Anal pressure was con-

tinuously recorded on the Polygraph. Electromyographic recording from the external anal sphincter was obtained with a concentric needle electrode (DISA no 13, L50, od 0·45 mm). The signal was passed through a preamplifier and integrator (GRASS, model 7 P3B). After integration (time constant 0·5 s), the signal was recorded as a semi-quantitative plot of striated muscle activity. Electromyography in conjunction with anal pressure was used for the qualitative separation of internal and external sphincter activity.

INVESTIGATIONAL PROCEDURE

The subjects were asked to empty the rectum and bladder before the investigation. No bowel preparation was used. The investigation was conducted with the subjects in the left lateral position with their hips and knees flexed to 90°. The rectal balloon was placed in the rectal ampulla above the anorectal ring by means of a sigmoidoscope. The anal probe, thread on the air tube, was then positioned in the anal canal so that the subcutaneous portion of the external sphincter just closed over the lower end of the cuff. The needle electrode was inserted in the subcutaneous portion of the external anal sphincter 10–15 mm postero-lateral to the anal verge after skin preparation with chlorhexidine (0·5%) in alcohol.

The investigation was done as a series of balloon distensions with 5 cm H_2O increments. Each distension lasted 60 s, and the rectal volume changes were continuously recorded. Each distension was followed by complete deflation of the rectal balloon for about one minute. The subjects were told to report when the distension caused a sensation of rectal filling or when an urge to defecate was experienced.

PRESENTATION OF RESULTS
Results are presented as mean (1 SD), with 95% confidence limits of the observations within parenthesis. Note that the confidence limits of distension pressure are given as the factual pressure levels used that included at least 95% of the observations. Log-transformation of data was used when positively skewed distribution of the dependent variable was observed.

Results

DYNAMIC VOLUME CHANGE
Representative recordings of the dynamic rectal volume change are shown in Figure 2, showing the main characteristics of the motility pattern observed at different distension pressure levels. Immediately after commencement of the isobaric rectal distension, there was a rapid volume increase at all pressures, reaching a peak within a few seconds. The initial rapid volume expansion was followed by a period with a retarded inflow (on 50 cm H_2O) or even a short lasting outflow (at 20 and 30 cm H_2O) from the rectal balloon, having a wave form character. This reflex rectal contraction (see below) could not be observed at 10 cm H_2O. This phase was in turn followed by a gradual volume increase until cessation of distension at 60 s. On distension with 20 cm H_2O, repetitive contractions were seen during the latter phase of distension. The volume curve at 50 cm H_2O approaches a square wave response.

For practical purposes, the volume changes could be arbitrarily divided into three phases. Phase A commenced at 0 and ended at four seconds, which represents the time for the first accurate volume recording.[9] Phase B (from four to 18 seconds after commencement of the distension) included the volume fluctuation caused by the first rectal contraction. The slow gradual volume increase from 18 to 60 s represents phase C (Fig. 2).

The mean rectal volume at the end of phase A (=initial volume), phase B and phase C (=end volume) as a function of the applied distension pressure is presented in Figure 3. The increase of rectal volume was close to linear in the pressure interval 15 to 40 cm H_2O. Rectal volumes at the end of phase A, B, and C at 10 to 50 cm H_2O are
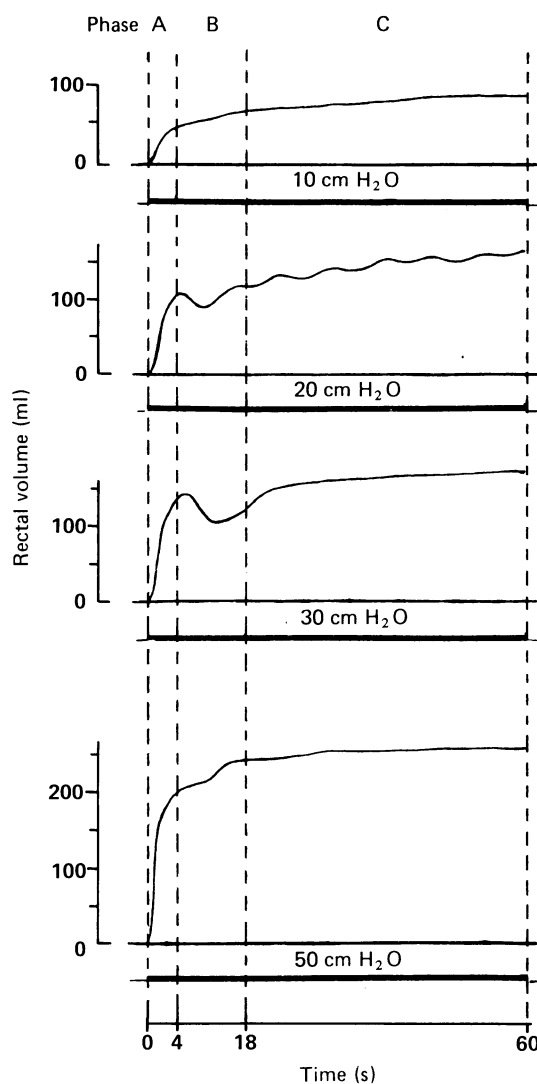

Fig. 2 *Representative recordings of the dynamic rectal volume expansion on distension with different pressures selected to show typical features of rectal motility. Note the rectal contractions (at 20, 30, and 50 cm H_2O) which cannot be distinguished on distension with 10 cm H_2O.*

presented in Table 1. No difference of rectal volume (calculated for end volume at 10 to 50 cm H_2O rectal distension) was found between men and women. Neither was there any significant correlation between end volume and body weight, height or body surface area. The rectal volume recorded 4 s after commencement of the distension was 55%, 61%, 71%, 77%, and 81% of the end volume at a distension pressure of 10, 20, 30, 40, and 50 cm H_2O, respectively.
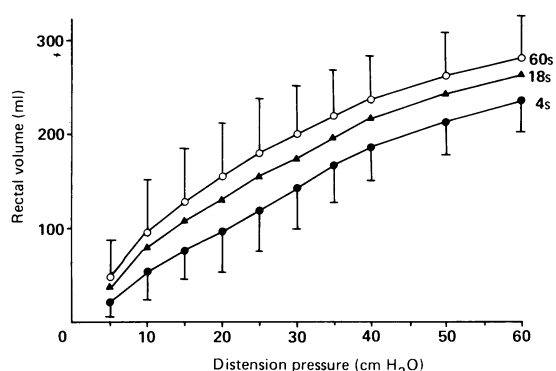
Fig. 3 *Rectal volumes at 4, 18 and 60 s after onset of rectal distension as functions of applied pressure (compliance). Vertical bars on upper (60 s) and lower (4 s) curves denote 1 SD.*
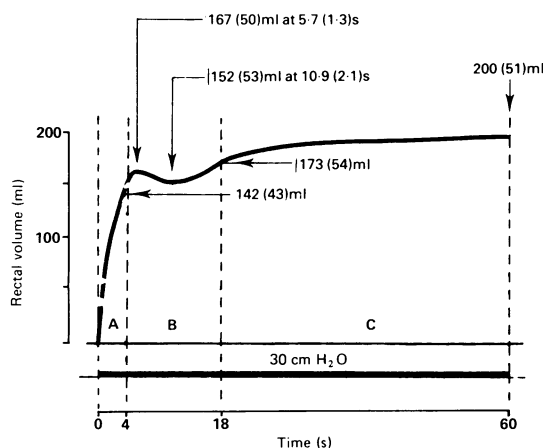

Fig. 4 *Mean rectal volume curve on distension with 30 cm H_2O for 60 s. Note the rapid volume increase during phase A, the rectal contraction during phase B and the slow inflow during phase C. Peak and minimal volume registration for the first rectal contraction are also shown. Figures denote mean (SD).*

RECTAL CONTRACTION

A reflex rectal contraction could be identified from the volume recording in 32 of 36 subjects. In these 32 subjects, the pressure threshold to elicit the rectal reflex contraction was 17 (5) cm H_2O (10–25 cm H_2O). The maximal volume reduction was 18 (13) ml) (<60 ml) and appeared at a distension pressure of 27 (8) cm H_2O (15–40 cm H_2O). No volume reduction was observed at a distension pressure in excess of 49 (11) cm H_2O (25–60 cm H_2O).

Figure 4 is a schematic representation of the mean volume change at 30 cm H_2O rectal distension. The reduction of rectal volume was 15 (13) ml (<60 ml). The calculated frequency of the volume change was 0·11 (0·04) Hz (0·22–0·05 Hz).

The initial volume reduction was followed by repetitive rectal contractions in 23 subjects. These appeared as damped sinusoidal waves in 15 subjects and waves of unchanged amplitude in eight subjects (Table 2). The frequency of the repetitive rectal contractions was characteristic for each individual and was identical with the first contraction. The frequency in each individual did not change with the distension pressure.

PERCEPTION OF RECTAL SENSATION

A sensation of rectal filling and an urge to defecate was reported and readily separated by all subjects. The pressure and volume characteristics of the sensory function are presented in Table 3, i and ii. The pressure difference in the thresholds for evoking

Table 2 *Pressure and volume characteristics for evoking rectal contraction*

	Rectal distension pressure, cm H_2O	
	Mean (1 SD)	95% conf limits
i First rectal contraction		
Threshold	17 (5)	10–25
Maximal	27 (8)	15–40
Vanished	49 (11)	25–60
ii Repetitive Contractions		
Threshold	19 (7)	10–35
Maximal	24 (8)	10–35
Vanished	31 (8)	15–40

Table 1 *Rectal volume at 4, 18 and 60 s on various distension pressures*

Rectal distension pressure, cm H_2O	Rectal volume, ml (mean (1 SD)) at		
	4 s	18 s	60 s
10	53 (31)	80 (52)	96 (56)
20	96 (44)	130 (56)	155 (56)
30	141 (43)	173 (54)	200 (51)
40	184 (34)	217 (44)	238 (45)
50	212 (35)	243 (45)	261 (46)

Table 3 *Pressure and volume characteristics for rectal sensory function*

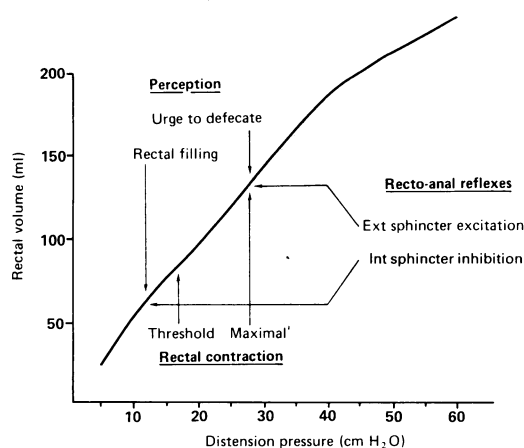| Threshold for evoking	Distension pressure, cm H_2O		Rectal volume (ml at 4 s)	
	Mean (1 SD)	95% conf limits	Mean (1 SD)	95% conf limits
i Perception of filling	12 (4)	5–15	68 (57)	11–238
ii Perception of urge	28 (11)	15–50	138 (69)	26–285
iii Recto-anal inhibition	12 (3)	10–15	68 (33)	13–133
iv Ext sphincter excitation	28 (7)	15–40	133 (55)	24–241

Fig. 5 *Rectal sensory function and thresholds for reflexes as projected on the compliance curve at 4 s. Note tendency to grouping of the mean pressure values at 12 cm H_2O and 28 cm H_2O.*

a feeling of rectal filling and for producing an urge to defecate was 17 (9) (10–30) cm H_2O. Any sensation reported during phase A was in most subjects maintained during phase B but disappeared or was significantly reduced during phase C. However, in some subjects the initial feeling of rectal filling was transformed into an urge to defecate during phase C.

RECTOANAL AND RECTORECTAL REFLEXES

The threshold pressure for eliciting a rectoanal inhibition was 12 (3) (10–15) cm H_2O, with a corresponding initial volume of 68 (33) (13–133) ml. The 95% confidence limits for the difference between the threshold for perception of rectal filling and rectoanal inhibition (Table 3, i and iii) in the individual subject was 9·1 cm H_2O. A clear cut increase of external sphincter activity, verified by the EMG record, was noted at the same distension pressure as that evoking an urge to defecate (Table 3, ii and iv). There was no difference in threshold between men and women in any of the above tested reflexes. (Fig. 5).

Discussion

In this study, the dynamic rectal volume change was recorded on rapid distension with a constant and predetermined pressure – that is, isobaric volume changes. This method differs from the standard manometric situation, in which rectal pressure is measured for given volumes, but has been used in the investigation of other reservoir organs such as the urinary bladder[10] and the stomach.[11] It was originally designed for the recording of large volume changes

occurring during constant intraluminal pressure in hollow organs and was therefore considered suitable for the rectum.

RECTAL RESERVOIR

The dynamic volume change on distension of the rectum showed some constant features: the initial expansion on distension was rapid and a major fraction of the end volume was reached within a few seconds. After the initial rapid expansion, rectal reflex contraction caused a temporarily reversed or retarded inflow. Despite continued distension during phase C, virtually no motility was recorded in most subjects. This type of performance can be considered suitable for a reservoir organ. Previous studies on rectal volume capacity have shown only a marginal pressure increase on slow filling before the maximal tolerable volume is reached[12] and these data are in concert with the present findings showing that even on rapid distension rectal motility displaced only a minor fraction of the rectal volume (see below). In fact, the rectal volume expansion differed but little from the hypothetical inflow into a viscoelastic bag. More than two-thirds of the end volume was reached 4 s after the onset of rectal distension (>25 cm H_2O).

RECTAL CONTRACTIONS

Phase B was characterised by a rectal contraction which either retarded the inflow (five of 36 subjects) or reversed the inflow to a temporary outflow from the rectal balloon (27 of 36 subjects). Single pressure peaks on rapid rectal distension, representing a rectal contraction, have been demonstrated by several previous investigators.[6 13–17] The reflex contraction was abolished by spinal anaesthesia[14] and it was concluded that the contraction represented a spinal reflex. Read *et al*[17] reported repeated contractions with a frequency of 6–10 cycles/min in 71% of their normal controls, which is in accordance with our findings of three to 13 cycles/min in two-thirds of the subjects. It should be noted in this context that balloon distension of the sigmoid colon using the present technique causes regular and perpetual contractions of significant magnitude.[18]

In this study, it was found that the rectal reflex response to rapid distension was of limited magnitude and duration. In fact, no rectal contraction could be identified in four of 36 normal subjects and distension with a pressure exceeding 50 cm H_2O abolished the contraction. If balloon distension is an appropriate and sufficient stimulus to activate the mechanisms which operate during defecation, the present results indicate that the contribution of rectal contractions to the expulsion of faeces during defecation is of less importance compared with, for instance, raised intra-abdominal pressure.[19] If

balloon distension is not a sufficient stimulus to trigger the 'defecation reflex', the limited response observed in this study may represent an inhibition from spinal and/or supraspinal centres – that is, continence function. Such an inhibition might reflect social behaviour training (toilet training) or a true subconscious reflex. The latter concept is supported by observations in patients with high spinal cord lesions, who consistently show rectal contractions that completely empty the rectal balloon during phase B (own unpublished observations), consistent with the findings of Denny-Brown and Greame-Robertson.[13] Further studies are needed to establish the integrated control of this reflex. We conclude that the normal rectal excitatory response to sudden isobaric distension displaces only a minor volume and that a rectal contraction that displaces more than 60 ml under the present conditions is less likely (2·5%) to be normal.

RECTAL SENSORY FUNCTION

Subjective perception of rectal distension has been investigated by several authors. The techniques used have varied but most authors use volume as the independent variable, in contrast to the present investigation, in which pressure is the independent variable. For meaningful comparison of observations on rectal sensory function, the length and anatomical position of the distending balloon must be clearly defined, as must the quality of the sensation. The qualities of rectal sensation under study have varied from initial transient sensation[17 20-28] to constant feeling of distension,[20 28-30] initial feeling of urge to defecate,[17 20 31] constant feeling of urge to defecate,[17 27 31] maximal tolerable volume,[17 20 22 24-26] and pain.[17] We have preferred to focus on the initially evoked sensation as it has been demonstrated that the quality and the intensity of the experienced sensation varies with time.[4] This is in concert with the present results, which showed that the sensation reported by the subjects during phase A sometimes disappeared or changed in intensity or character during phase C, despite constant distension pressure.

A close association was found between the pressure thresholds to evoke a feeling of rectal filling and to elicit the rectoanal inhibitory reflex. This supports the hypothesis that the subjective perception of rectal filling and the autonomous inhibitory reflex may be functionally closely linked – that is, sampling reflex. Moreover, a separation of the thresholds for the two functions may indicate an abnormality in either. Demonstration of a rectoanal inhibitory reflex when subjective perception is not at hand is considered to be pathological and used in the definition of dyschezia,[29] a condition resulting in a profound disturbance of defecation.

PRESSURE V VOLUME

The study shows a considerable variation of rectal volume in response to distension with a constant, preset pressure. The variation was coupled neither to sex nor to anthropometric data and probably reflects a physiological variation of rectal compliance. This normal and wide variation of rectal compliance is of significance when rectoanal functions are related to distension with defined volumes, and makes it difficult to separate normal from abnormal responses. This may also be an important explanation why conventional rectoanal manometry has not fulfilled the original expectations of the method as a diagnostic tool. Our preliminary data suggest that investigation of various modalities of rectoanal function in relation to applied rectal pressure instead of volume may increase the diagnostic sensitivity and support therapeutic decisions.[32]

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