Influence of pudendal block on the function of the anal sphincters

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SUMMARY The function of the anal sphincters has been studied by obtaining continuous recordings of the pressure in the anal canal and the electromyographic activity in the striated sphincter muscles during expansion of the ampulla recti by means of an air balloon. Ten healthy subjects were examined before and after the striated muscles had been entirely paralysed by bilateral pudendal block, making it possible to record the activity from the internal sphincter alone.

The results show that the internal sphincter contributes about 85% of the pressure in the anal canal at rest but only about 40% after a sudden substantial distension of the rectum. During constant substantial rectal distension, the internal sphincter accounts for about 65% of the anal pressure. It is concluded that the internal sphincter in the adult is chiefly responsible for anal continence at rest. In the event of sudden substantial distension of the rectum, continence is maintained by the striated sphincter muscles, whereas both sphincter systems probably have an important function during constant distension of the rectum.

The anal canal is kept closed by a ring of muscle and the pressure in this zone is higher as a rule than in the rectum and the sigmoid colon (Hill, Kelley, Schlegel, and Code, 1960; Duthie and Bennett, 1963). When the rectum is abruptly distended, however, the anal pressure falls because the smooth internal sphincter relaxes (Gowers, 1877; Denny-Brown and Robertson, 1935); this is accompanied by reflex contraction of the striated musculature, namely, the external sphincter and the puborectalis muscle (Gaston, 1948; Goligher and Hughes, 1951), a response that has been termed the 'inflation reflex' (Ihre, 1974). The anal pressure is greatly reduced by division of the internal sphincter (Bennett and Duthie, 1964) and it used to be held that the remaining pressure was maintained by the striated muscles because this displayed continuous tonic activity in awake subjects as well as during sleep (Floyd and Walls, 1953). Further studies with awake and anaesthetized subjects with complete muscular relaxation have shown, however, that the striated muscles contribute to the anal pressure only when a body is present in the anal canal (Duthie and Watts, 1965). Furthermore, as the remaining anal pressure during complete relaxation was the same when the subject was awake as when he was fully relaxed, it was concluded that the reduction of anal pressure upon rectal filling is entirely independent of the striated muscles. This conflicts to some extent with other authors, who report a simultaneous contraction of the striated muscles (inflation reflex).

During a substantial distension of the ampulla recti there is a constant relaxation of the internal sphincter, which precludes a return to the initial anal pressure (Gaston, 1948; Kerremans, 1969; Ihre, 1974). As this relaxation is more pronounced in incontinent than in continent patients with rectal prolapse, it seems that a correct function is of major importance for anal continence (Ihre, 1974). It is still not clear, however, to what extent the internal sphincter normally contributes to the anal pressure during constant substantial distension of the rectum.

The aim of this study has been to map the respective contributions of the smooth internal sphincter and the striated sphincter muscles to anal pressure at rest, after an abrupt distension of the rectum, and during constant distension. For this purpose, selective paralysis of the striated muscles was achieved by means of a pudendal block.
Material and Methods

SUBJECTS

The study was undertaken on 10 adult subjects (three women, seven men) aged 18-50 (mean 26) years. None of them had had anorectal disorders, persistent diarrhoea, or constipation, and none of them had taken medicines regularly. Having been informed in advance about the discomfort and risk of complications, each subject gave his or her personal consent to the study.

PROCEDURE

The examinations were performed in the afternoon, the subject having defaecated normally in the morning. The subject was placed in the left supine position with the hips flexed 90°. The right leg was earthed via a plate electrode attached to the skin. The anus was inspected before introducing the water-filled balloon
to measure the pressure in the anal canal. This instrument (fig 1) consists of a metal cylinder fitted with a latex balloon. It was connected via a pressure transducer (EMT 34, Siemens-Elema) to an amplifier (EMT 31, Siemens-Elema) and an ink-jet recorder (Mingograph 42 B, Elema). The anal pressure was measured at distances of 1, 2, 3, and 4 cm from the anal verge in order to locate the zone of maximal anal pressure. When this had been done, the instrument was withdrawn and a digital examination was undertaken of the ampulla recti and the anal canal. During this examination the subject was asked to squeeze the anal muscles in order to check that this instruction was understood correctly. Having carefully located the puborectalis muscle the investigator used his other hand to insert a concentric needle electrode 45 mm long into this muscle via the skin of the crena ani 1-2 cm dorsal of the anus. Using a proctoscope, a latex balloon was then placed in the ampulla 6-8 cm above the anus. This balloon, which measured about 3 × 1 1/2 cm when empty, was connected to a polyethylene tube about 75 cm long with an internal diameter of 2 mm and an external diameter of 2.2 mm. When the proctoscope had been removed, the balloon was inflated with 50 ml of air, which was immediately evacuated in order to ensure that it lay unfolded. Finally a concentric needle electrode 21 mm long was inserted into the external sphincter via the skin 1/2-1 cm directly to the left of the anus.

After amplification (Grass, model P94), the signals from the two EMG electrodes were recorded directly (Mingograph 42 B) and also, in the case of the signal from the external sphincter, after integration (time constant 0.3 sec; Integrator EMT 43 B, Siemens-Elema). The polyethylene tube from the rectal balloon was connected via a three-way valve to a 50-ml glass syringe and an electric pressure transducer (EMT 34), which led in turn after amplification (EMT 31) to the Mingograph recorder.

A brief recording was obtained of the muscle activity at rest; the subject was asked to squeeze maximally and the anal reflex was tested by cautiously drawing the tip of a needle across the perianal skin. These checks ensured, among other things, that the needle electrodes were correctly positioned.

Before the rectal balloon was filled with air, the subject was instructed to tell the investigator as soon as he experienced a slight feeling of filling in the rectum and then, as filling proceeded, when the feeling became so pronounced that he would normally have gone to the lavatory; this will be referred to as a substantial filling of the rectum. After these instructions, the balloon was inflated with air, starting with 20 ml, then 30 ml, and then portions of 50 ml, with an interval of 30 sec between each portion. It took approximately 0.7-0.9 sec to fill each portion. Filling was stopped when the subject was unable to tolerate any further expansion of the rectum (maximal tolerable volume). Some minutes after the rectal balloon had been evacuated, the water-filled anal balloon was reintroduced so that it lay in the zone of maximal anal pressure. As this instrument has a hole down its centre, it could be introduced with the polyethylene tube to the rectal balloon running through it. The integrator was disconnected and the anal balloon was linked up as before to the recorder. A few minutes later, when the anal pressure had stabilized, the subject was asked to squeeze maximally and the pressure rise in the anal canal was registered. The rectum was then filled by stages as above and this was stopped when there was a constant relaxation of the anal pressure, whereupon the rectal balloon was evacuated. Finally a check was made to ensure that the anal balloon had not shifted.

After this investigation, the subject was placed in the lithotomy position, whereupon a bilateral pudendal block was achieved with the perineal technique described by Moore (1965) using mepivacain (either 40 ml 1% or 75 ml 1/2% Carbocain, Bofors, Astra). In two cases the blockade was not effective at the first attempt but proved successful when the procedure was repeated 60 min later. In the other cases the
desired effect materialized after 15 to 30 min, whereupon the subject was returned to the left supine position and the experiments were repeated in exactly the same way as before the blockade. In all cases the two EMG electrodes and the rectal balloon remained in position while the pudendal block was being established.

When all the experiments had been performed, the rectal balloon was re-filled with air in stages (20, 50, 100 ml etc) in the surrounding air in order to measure the pressure which the balloon itself generated at different volumes. These pressures were then subtracted from those measured earlier in the rectum during the first series in order to obtain corrected values for the pressure which the rectum exerted on the balloon (Ihre, 1974). The general procedure resembles that used by Ihre (1974) with a further development of the module for pressure measurements in the anal canal.

Statistics
Standard statistical methods have been employed, using the paired t test where applicable. Data in the text and figures are given a mean ± SE (standard error of the mean).

Results

Effect of Pudendal Block
All subjects reported a loss of sensation in the perianal and genital skin and had difficulty in squeezing the anal musculature voluntarily. The effect was assessed by EMG and by measuring the pressure rise in the anal canal during a maximal voluntary squeeze (fig 2). No EMG activity at all was detected in half of the subjects and only single motor units in the others. The increase in anal pressure during a maximal voluntary squeeze averaged 63 mmHg (range 21-154) before the blockade compared with 4 mmHg (range 0-12) after.

Activity of Striated Muscle Before Pudendal Block
All subjects displayed clear tonic as well as voluntary phasic activity in the puborectalis muscle and the external sphincter (fig 2) and the anal reflex was positive in all cases. In the first filling series an inflation reflex was registered in all cases with 20 ml in the ampulla recti and further reflexes were usually but not always registered as filling proceeded. In two cases the activity in the striated muscle disappeared entirely at a rectal volume of 300 and 350 ml respectively.

Subjective Perceptions and Rectal Pressure
Before the pudendal block, the level of rectal filling at which the subjects reported a slight feeling averaged 35 ml. The feeling became substantial at an average of 155 ml and the maximal tolerable volume averaged 375 ml. The corresponding values after pudendal block were 29 ml, 175 ml, and 325 ml, so that there was no systematic difference. Neither were there any appreciable differences between the rectal pressures at corresponding volumes before and after pudendal block. Slight filling corresponded to a corrected pressure of 10 to 15 mmHg and substantial filling to approximately 20 to 30 mmHg. The rectal balloon never escaped spontaneously from the rectum during filling either before or after pudendal block.

Anal Pressure
When the anal balloon was re-introduced for the second filling series before pudendal block, an anal reflex was elicited as indicated by a fairly high initial anal pressure and greatly increased EMG activity in the striated muscles. The pressure fell back fairly soon to a stable level (maximal anal pressure). When the same procedure was repeated after pudendal block, there was no anal reflex and the pressure was stable from the start. The mean maximal anal pressure before the block was 64 ± 3.5
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**Fig 3** Electromyographic recordings and anal pressure before pudendal block during stepwise filling of the rectum. At a volume of 20 ml there is a clear inflation reflex and the anal pressure rises briefly before relaxing. The lower curve shows a diagrammatic representation of relaxation and constant relaxation: a = remaining pressure during relaxation, b = relaxation, c = remaining pressure during constant relaxation, and d = constant relaxation.

**Fig 4** Electromyographic recordings and anal pressure during stepwise filling of the rectum after pudendal block in the same subject as in figure 3.
mmHg (range 44-80) compared with 54 ± 4.4 mmHg (range 38-80) after the block. The difference is significant (p < 0.05). The zone of maximal anal pressure lay at a mean of 1.4 cm from the anus before the block and 1.1 cm after the block, a difference that is not statistically significant.

The anal pressure displayed a clear cyclical activity in nine of the 10 subjects before as well as after the block, with a rate of 70 c/min (figs 3 and 4). The amplification was too low to permit measurements of the amplitude but this appeared to be substantially the same before and after the block in every case. Electrocardiographic recordings were obtained simultaneously with the anal pressure in four subjects and it was found that the anal pressure waves were completely synchronous with cardiac activity, indicating that they were generated entirely by circulatory factors.

When the ampulla recti was filled with the first 20 ml of air, a definite relaxation of the anal pressure was registered in nine subjects before the block and in all 10 after the block. Clear relaxations were registered at all subsequent stages of filling and these were accompanied by a reduction or cessation of the cyclical activity mentioned above. With no pudendal block, this relaxation was immediately preceded in some cases by a brief increase in anal pressure, always together with an inflation reflex on the EMG from the striated muscles. These brief pressure increases never occurred after pudendal block.

The relaxations became deeper and lasted longer as filling of the ampulla recti proceeded. After a relaxation the anal pressure returned to a stable level and the cyclical activity reappeared. In the early stages of filling this stable level was the same as the initial anal pressure. When the rectal volume had become larger, however, the level fell, a phenomenon referred to elsewhere as constant relaxation.

**RELAXATION**

The manner in which the relaxations have been measured is indicated in figure 3. At each rectal volume the relaxation was greater after the pudendal block than before, the differences being significant (p < 0.05) with 100, 150, and 200 ml in the ampulla recti.

As a result, the remaining anal pressure at maximal relaxation (indicated by a in fig 3) was lower after the block, as shown in fig 5; the differences, which increased with the volume in the rectum, are significant (p < 0.05 for rectal volumes 0-20 ml and p < 0.01 for larger volumes). At rectal volumes of 100 ml or more, ie, when the subject started to experience a definite need to defaecate, the curves flattened out and presented a stable level of about 35 mmHg before and about 12 mmHg after the block. These levels may be compared with a rectal pressure of 20 to 30 mmHg for volumes between 100 and 200 ml. The percentage contribution of the internal sphincter has been estimated by dividing the anal pressure after pudendal block by the corres-

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**Fig 5** The remaining anal pressure (a in fig 3) at maximal relaxation. When the rectum is substantially filled, the level stabilizes at an average of 35 mmHg before pudendal block (●) compared with 12 mmHg after block (○).

**Fig 6** Remaining anal pressure when this has stabilized after a relaxation (c in fig 3). The level falls more rapidly after pudendal block (○) than before (●), indicating that the striated muscles offset the constant relaxation of the internal sphincter.
The pressure, Discussion about 65% (fig 8). Rectum's internal pressure before the block in each subject.

**CONSTANT RELAXATION**

As already indicated, the anal pressure returned to a stable level 20 to 30 sec after the rectum had been inflated with a portion of air, and when the rectal volume was more than 100 ml this level was lower on average than the initial anal pressure. At rectal volumes of 150, 200, and 250 ml this decrease in the level of anal pressure (indicated by d in fig 3) was significantly greater (p < 0.05) after the pudendal block than before. This is shown in fig 6, where it will be seen that the remaining anal pressure became lower as the rectal volume increased above 100 ml. After pudendal block this pressure was consistently lower and fell more rapidly as the rectal volume increased, in keeping with the more marked constant relaxation under these conditions. For rectal volumes up to 200 ml, however, the anal pressure was always higher than the corresponding rectal pressure before as well as after pudendal block. The internal sphincter's percentage contribution to the anal pressure, estimated as above, amounted to about 65% at constant substantial distension of the rectum (fig 8).

**Discussion**

The method adopted in this study is a two-stage procedure. During the first expansion of the ampulla recti, when EMG recordings are obtained from the striated muscles, there is only a thin polyethylene tube in the anal canal; continuous pressure recordings are then obtained from the anal canal when the rectum is dilated a second time. This means that the conditions under which the anal pressure is recorded during rectal filling are the same before and after pudendal block in that in both cases the rectum has been expanded maximally 5-10 min earlier. Furthermore, as a body in the anal canal may stimulate the striated muscles (Duthie and Watts, 1965), the activity in this muscle can be assessed more reliably when the device for measuring anal pressure is not in situ.

The external sphincter and the puborectalis muscle are innervated from the second to fourth sacral roots via the pudendal nerve, whereas the internal sphincter receives fibres from intramural plexuses as well as from autonomic nerves in the lesser pelvis. A pudendal block should therefore paralyse the striated sphincter muscles without affecting the smooth internal sphincter. As the block appeared to be successful in the present experiments, the anal pressure after the block can be attributed to the smooth internal sphincter alone, while the pressure before the block represents the combined effect of this and the striated sphincter muscles.

Maximal anal pressure was significantly reduced after pudendal block from a mean of 64 mmHg to 54 mmHg, indicating that the internal sphincter contributes approximately 85% of the anal pressure.
at rest. This agrees with earlier studies (Duthie and Watts, 1965) and is strong evidence of the important part played by the internal sphincter in maintaining continence at rest.

During rectal filling the well documented relaxation of the internal sphincter was observed at the same rectal volumes as reported earlier (Schuster, Hookman, Hendrix, and Mendeloff, 1965; Kerremans, 1969; Ihre, 1974). This relaxation was preceded in certain cases by a brief increase in the anal pressure and this was always accompanied by a burst of EMG activity from the striated muscles. This brief increase in pressure never occurred after the external sphincter and the puborectalis muscle had been paralysed by the pudendal block. These findings strongly support the earlier suggestion (Kerremans, 1969; Varma and Stephens, 1972; Ihre, 1974) that the brief pressure increases are due to an inflation reflex from the striated muscles.

As the relaxation of anal pressure during rectal filling was greater after than before pudendal block, it seems that the inflation reflex in the striated muscle counteracts this relaxation and helps to increase the pressure in the anal canal. The anal pressure at maximal relaxation after pudendal block stabilized around 12 mmHg when the rectum was substantially distended. This pressure came entirely from the internal sphincter plus any effect of purely mechanical factors in the anal canal. The activity of striated muscle can therefore be said to have accounted for the loss of pressure compared with the level of 35 mmHg before the block. The difference is strong evidence of the striated sphincter muscles’ function in maintaining continence during sudden, substantial distension of the rectum. These results do not entirely agree with the finding of Duthie and Watts (1965) that when the rectum was distended with 100 ml of air the anal pressure was much the same in awake patients and in those who had been anaesthetized with complete muscular relaxation. The internal sphincter’s percentage contribution to the anal pressure during maximal relaxation with different rectal volumes is shown in figure 7.

The present study confirms earlier reports that the anal pressure does not return to the initial level when the rectum is distended still further (Gaston, 1948; Kerremans, 1969; Ihre, 1974). The significantly greater fall of pressure after pudendal block suggests, however, that the constant relaxation of the internal sphincter is normally counteracted to some extent by the striated muscles. During constant substantial distension of the rectum it is probable that the smooth internal sphincter and the striated muscles both play a major part in maintaining continence. The internal sphincter’s percentage contribution to the anal pressure when this has stabilized after a distension of the rectum is shown for different rectal volumes in figure 8.

The pudendal block had no effect on rectal sensitivity, in keeping with earlier studies (Goligher and Hughes, 1951).

The present study accordingly shows that the resting pressure in the anal canal is very largely conditioned by the internal sphincter, thereby confirming its major importance for continence at rest. The importance of the striated muscles for continence becomes decisive in turn—contributing the greater part of the anal pressure—when the rectum is suddenly distended. When the situation then stabilizes, ie, 20-30 sec after a sudden substantial distension, and the subject experiences a definite need to defaecate, the internal sphincter accounts for just over half the anal pressure and both sphincter systems probably have an important function at this stage.

These findings agree with certain clinical observations. The activity in the striated muscles is extinguished during urination (Porter, 1962) and the anal canal is continent in most individuals if they have no definite urge to defaecate. Continence is apparently maintained under these circumstances solely by the smooth internal sphincter. When there is a constant, very strong urge to defaecate, on the other hand, most individuals find it quite impossible to urinate without defaecating at the same time. That is to say, in this situation, which probably involves some constant relaxation of the internal sphincter, anal continence cannot be maintained without activity from the striated muscles.

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