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Measurement of anal pressure and motility

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SUMMARY A fine open perfused system and a closed balloon system for the measurement of anal pressure and motility have been compared. Measurements were made in 40 normal subjects and 84 patients with haemorrhoids. The rate of perfusion had a marked effect on the recorded pressure and motility details. The motility pattern was seen most clearly with the balloon probe and the pressure recorded was reproducible and easy to measure, making this a convenient method for recording activity of the internal anal sphincter. Anal motility in normal subjects was characterised by slow pressure waves (10-20/min). The frequency was fastest in the distal anal canal and this frequency gradient may represent a normal mechanism to keep the anal canal empty. Ultra slow pressure waves (0·6-1·9/min) were seen in 42% of patients with haemorrhoids and 5% of normal subjects and arose from a synchronous contraction of the whole internal sphincter.

Many methods have been used to measure anal pressure and motility and conflicting results reported. Differences in methods may account for many of these.

The two main methods available for measurement of anal pressure use fine water-filled polyethylene tubes or small balloons connected to a strain gauge pressure transducer. Fine tubes have the advantage that they cause only slight physical disturbance of the sphincter. It seems essential to perfuse the system to prevent blockage, but it is not clear whether all workers have done this, nor is it known whether the rate of perfusion affects the recording (Hill *et al.*, 1960; Harris and Pope, 1964; Duthie and Watts 1965; Phillips and Edwards, 1965).

Small water-filled balloons incorporated into a probe of uniform diameter are convenient to use because they can be secured easily in position, though they do disturb the resting state of the sphincter to some extent. Fluctuations in pressure are seen more clearly with the balloon system, possibly because they are in contact with a larger area of sphincter. (Lawson and Nixon, 1967; Kerremans, 1969).

Small strain gauges in the anal canal have also been used effectively to study force and motility, but the probes are difficult to construct and prone to mechanical failure (Wankling *et al.*, 1968; Howard and Nixon, 1968; Collins *et al.*, 1969). Whichever method is chosen, the diameter of the probe may be important because higher pressures have been recorded with large probes than with small ones (Hill *et al.*, 1960; Duthie and Watts, 1965; Gutierrez *et al.*, 1975), though if the probe is left in the anal canal for 15 minutes before starting the recording the diameter does not seem so critical (Duthie *et al.*, 1970).

Some workers have attempted to measure the function of the two sphincters separately by recording from two balloons in tandem, a proximal one to record from the internal sphincter, and a distal one from the external sphincter (Gaston, 1948; Schuster *et al.*, 1963; Lawson and Nixon, 1967). This method is valid to some extent if the reflex reactions of the sphincters are studied, but cannot give any estimate of the part each sphincter plays in the production of resting pressure.

The object of this study was to make a direct comparison between an open perfused system and a closed balloon system and to measure pressure and motility in a series of normal subjects and patients with haemorrhoids.

Method

The closed balloon system consisted of a small balloon 1 cm long built into a hollow Perspex rod of 7 mm diameter. The probe was filled with water and the balloon was inflated to produce a slight convexity of its surface. It was then connected via fine polyethylene tubing, internal diameter 1·5 mm and

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1·2 m long, to a Statham type strain gauge pressure transducer (Fig. 1).

The open perfused system consisted of a fine open-ended ureteric catheter of external diameter 1·0 mm and internal diameter 0·5 mm, attached directly to a strain gauge pressure transducer. The system was perfused with water at the rate of 0·2 ml/min from a continuous infusion pump. Both the perfused and the ball balloon probes were marked at centimetre intervals to assist accurate positioning in the anal canal and the tracings of pressure and motility were produced on heat sensitive paper by a Devices multi-channel recording machine.

The recording was taken with the subject on his left side, without bowel preparation and before any digital or proctoscopic examination. The probes were first placed at 1 cm from the anal verge and then moved in succession to 2, 3, and 4 cms from the anal verge. The balloon probe was secured in position by a Perspex crosspiece strapped to the buttocks and with each method the recording lasted at least 16 minutes.

The average anal pressure was estimated at each centimetre position over the four minute recording with reference to a calibration of 100 cm H_2O at the start of the recording. Initially, it was decided to use the mean of the pressures at 1, 2, and 3 cm from the anal verge as the single measurement for each subject, but it became apparent that pressures recorded at the 3 cm position in men were significantly greater than those in women. On the other hand, the maximum pressures measured were similar for the two sexes, so this figure was used for purposes of comparison.

On most tracings regular fluctuations in pressure were seen. These had a frequency between 10-20/min, and an amplitude of 5-25 cm H_2O and were referred to as slow waves. An attempt was made to count the frequency of slow waves over a period of two minutes. Other pressure waves which were easily recognisable but less often seen had a frequency of 0·6-1·9/min and an amplitude of up to 100 cm H_2O. These were called ultra slow waves. Sometimes they were sustained in amplitude throughout the recording period, but often they were most prominent at the start and faded away as the recording progressed. To make comparisons between one group of subjects and another the motility pattern at each centimetre position was classified for descriptive purposes into one of three groups (Fig. 2).

1. *Flat tracing* Steady resting anal pressure showing only slow waves. (10-20 per min).
2. *Irregular tracing* Resting pressure unsteady sometimes with marked fluctuations in pressure.
3. *Ultra slow waves* Resting pressure tracing showing regular high amplitude fluctuations in pressure of frequency less than two per minute, with the amplitude of first complete pressure wave greater than 25 cm H_2O. If the amplitude had fallen to less than 25 cm of water at the end of the four minute recording they were called fading ultra slow waves. The amplitude and frequency was estimated from the measurements of the first four complete waves.

Ultra slow waves, if present, were most pronounced at the position of maximum pressure so the motility classification for each subject was taken from the recording at this level.

Fourteen subjects were studied by both methods. Seven were patients with untreated haemorrhoids and seven had been treated. Half were studied with one method first and half by the other, with an interval of five minutes between the recordings. In 10 patients

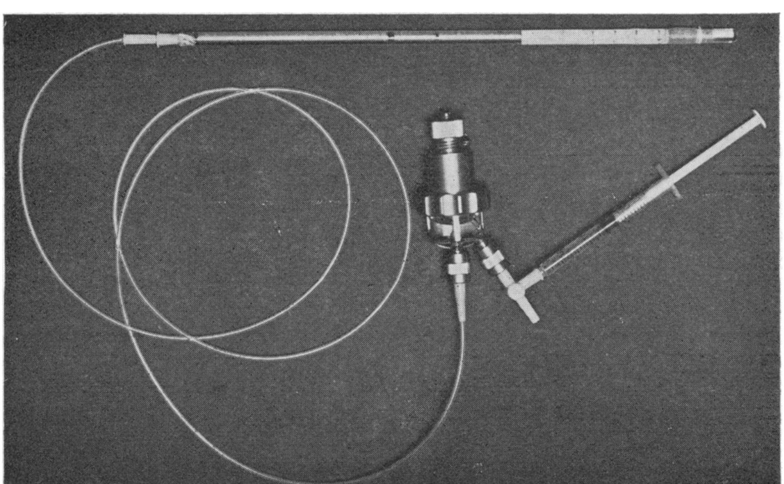

Fig. 1 *The balloon probe and the strain gauge pressure transducer.*

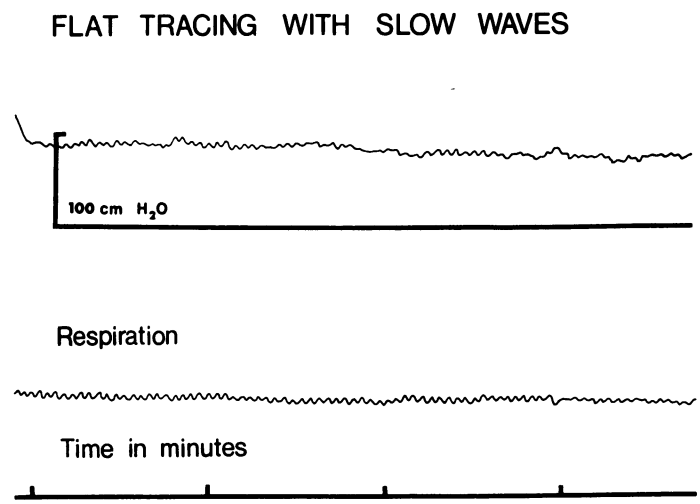

Fig 2a

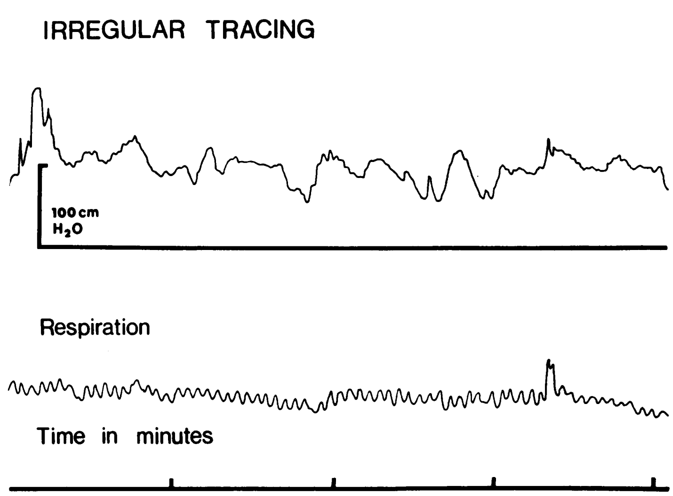

Fig 2b

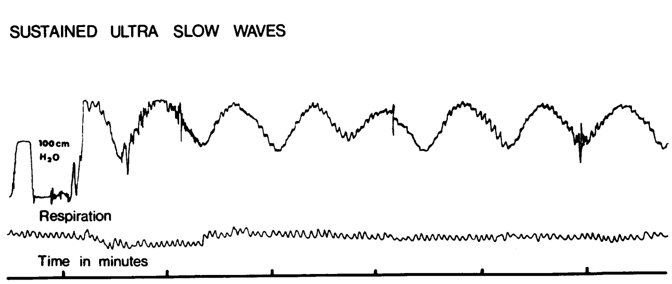

Fig 2c

Fig. 2 (a) *Flat tracing from a normal subject.* (b) *Irregular tracing from a patient with haemorrhoids.* (c) *Sustained ultra slow waves from a patient with haemorrhoids.*

the balloon tracing was repeated after an interval of a few minutes to examine the reproducibility of the method.

The effect of different perfusion rates down the fine tube were studied in five subjects.

Forty asymptomatic subjects and 84 patients with haemorrhoids then had a detailed anal pressure recording with the balloon system. The mean age of the controls was 47·9 ± 15·2 SD years and of the patients with haemorrhoids 47·4 ± 31·1 SD years. Seventy-five per cent in each group were men.

Results

COMPARISON OF TWO METHODS

The mean maximum anal pressure recorded with the balloon probe (83·3 ± 28·2 SD cm H_2O n = 14) was significantly higher than that estimated with the perfused system (73·3 ± 29·8 SD cm H_2O n = 14 $P < 0.01$). There was an excellent and highly significant correlation between the results of the two methods ($r = 0.90$ $P < 0.0001$).

The pattern of motility recorded by the two methods was often similar but slow waves were usually seen more clearly and the resting pressure was often less irregular with the balloon probe. The amplitude of ultra slow waves was higher when recorded with the balloon probe than with the perfused probe (Fig. 3).

REPRODUCABILITY OF TRACING WITH BALLOON SYSTEM

The mean maximum anal pressure of the first recording (89·4 ± 27·7 SD cm H_2O n = 10) was almost identical with that of the second recording (89·8 ± 20·3 SD cm H_2O). The correlation coefficient was highly significant ($r = 0.94$).

ACCURACY OF PRESSURE ESTIMATION FROM TRACING

The maximum anal pressure in each of the 20 random tracings was estimated independently by two observers. Ten of the tracings were from normal subjects and 10 were from patients with haemorrhoids. One observer did not know the diagnosis. The mean maximum pressure recorded from the 10 normal subjects was identical for the two observers (80·2 ± 23·0 SD cm H_2O and 80·1 ± 21·4 SD cm H_2O). The results were similar in the 10 patients with haemorrhoids (119·2 ± 17·3 SD cm H_2O and 119·8 ± 15·2 SD cm H_2O). The correlation coefficient for the two sets of measurements from normal subjects was $r = 0.98$ and from patients with haemorrhoids $r = 0.90$.

EFFECT OF VARYING PERFUSION RATES

The pressure obtained when the rate of perfusion was 0·2 ml/min was much higher than with the rate of 0·2 ml/hour. Details of motility were present with the fast rate, but absent with the very slow rate.

OTHER PATTERNS OF ANAL MOTILITY

In addition to the three main patterns of motility described previously, other details were sometimes observed:

1. Spasmodic contraction of the external sphincter

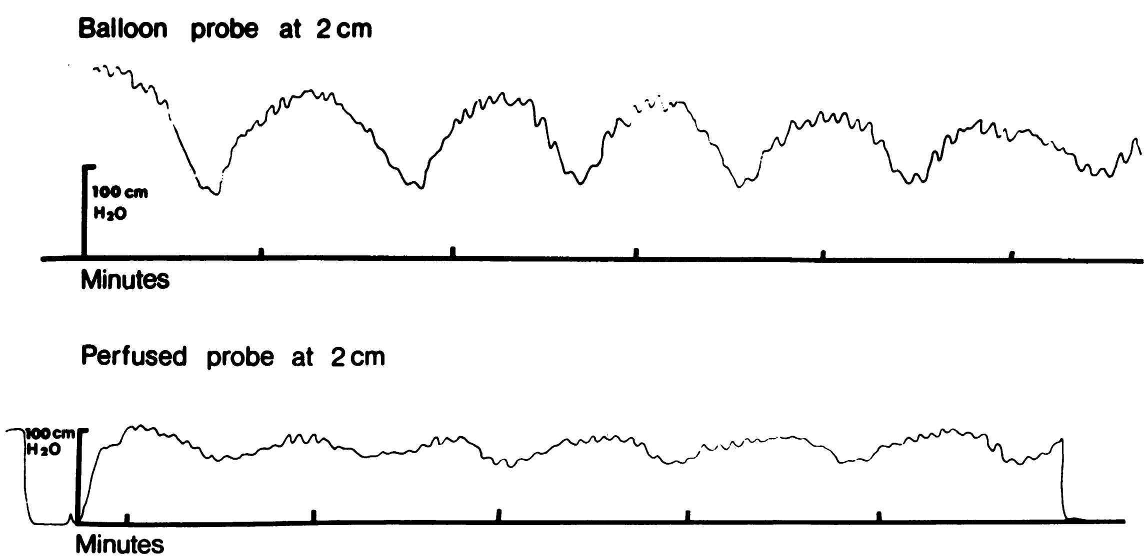

Fig. 3 *In the same patient ultra slow waves have a higher amplitude when recorded with the balloon probe.*

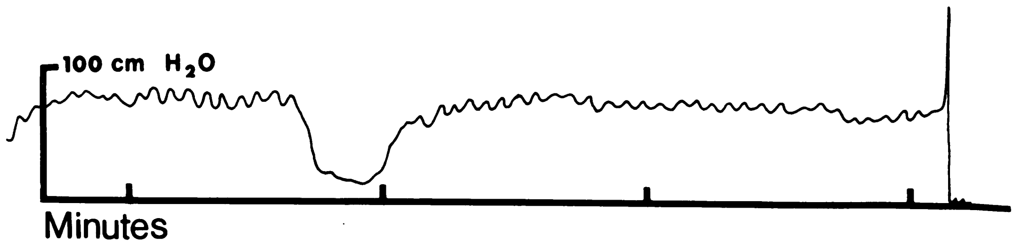

Fig. 4 *Spontaneous relaxation of the internal sphincter.*

which produced sharp peaks in pressure superimposed on the basic motility pattern.

2. A sudden drop in pressure followed by a slow return to normal (Fig. 4). This was usually associated with a feeling of flatus in the rectum. The drop in pressure corresponded with the most acute sensation and the rise in pressure coincided with disappearance of the sensation. The pattern of pressure drop is similar to the reflex relaxation of the internal sphincter induced by rectal distension with a balloon.

3. Superimposition of the arterial pulse was sometimes very obvious and was confirmed by counting pulse rate.

MEASUREMENT IN PATIENTS

Maximum anal pressure

The mean maximum anal pressure of the 84 patients with haemorrhoids (107·8 ± 23·0 SD cm H_2O) was much greater than that of the 40 controls (85·0 ± 20·5 SD cm H_2O). This difference was highly significant (z = 5·42, P < 0·001). The mean resting pressure was significantly higher in patients with haemorrhoids than in control subjects at all levels in the anal canal (Table 1). In patients with haemorrhoids the highest pressure was at 2 cm from the anal verge, but in controls it was equally high at 1 and 2 cm.

Sex and anal pressure

In male subjects the pressures throughout the anal canal were higher than in females whether they had haemorrhoids or not. In the control subjects the difference was significant at 2, 3, and 4 cm from the anal verge, but not at the 1 cm position. In the patients with haemorrhoids, the difference was significant at 3 and 4 cm but not at 1 and 2 cm (Table 2).

Anal motility

Slow waves, though usually visible were difficult to count. A reasonably accurate count over at least two minutes could be made at 1, 2, and 3 cm in the anal canal in only two of 40 controls and four of 56 patients with haemorrhoids. Counts at one or two positions in the anal canal were possible in an additional 11 controls and another 22 patients with haemorrhoids. Countable slow waves were thus present at at least one position in 32·5% of the controls and 46% of the patients with haemorrhoids.

Table 1 *Resting and pressure*

	Resting anal pressure (cm H_2O)			
	1 cm	*2 cm*	*3 cm*	*4 cm*
Controls				
Mean	74·7	74·6	52·4	25·6
SD	23·7	23·0	25·4	17·9
n	40	40	40	33
Haemorrhoids				
Mean	94·3	97·5	74·5	45·5
SD	24·6	26·0	31·3	27·8
n	84	84	84	57
z	4·25	4·95	4·19	4·13
P	0·001	0·001	0·001	0·001

Table 2 *Sex and anal pressure*

	Resting anal pressure (cm H_2O)			
	1 cm	*2 cm*	*3 cm*	*4 cm*
Controls				
Male				
Mean	73·1	79·2	57·6	30·1
SD	26·2	20·6	24·4	18·7
n	30	30	30	23
Female				
Mean	79·6	60·9	36·8	15·2
SD	13·9	25·5	22·9	10·4
n	10	10	10	10
t	1·0	2·3	2·4	2·9
P	NS	0·05	0·025	0·01
Haemorrhoids				
Male				
Mean	92·8	100·0	81·5	52·1
SD	24·2	24·8	29·4	27·7
n	62	62	62	42
Female				
Mean	98·4	90·7	54·8	27·1
SD	25·9	28·8	28·6	18·9
n	22	22	22	15
t	0·92	1·45	3·7	3·2
P	NS	NS	0·001	0·005

Table 3 *Anal motility*

	Slow wave frequency		
	Distance from anal verge		
	1 cm	*2 cm*	*3 cm*
Controls (40)			
Mean (/ min)	17·5	16·5	13·5
SD	2·4	2·0	1·9
n	6	10	10
Haemorrhoids (56)			
Mean (/ min)	19·2	15·7	13·7
SD	4·2	2·8	1·5
n	9	17	15

Table 4 *Classification of anal motility*

	Anal motility at maximum anal pressure			
	Haemorrhoids		*Controls*	
	(no.)	(%)	*(no.)*	(%)
Flat	42	50·0	28	70·0
Irregular	7	8·3	10	25·0
Fading ultra slow waves	9	10·7	2	5·0
Sustained ultra slow waves	26	31·0	0	0
	84	100	40	100

There was a trend to a slower frequency of slow waves as the probe was advanced further into the anal canal in both the control subjects and the patients with haemorrhoids (Table 3). This frequency gradient was often obvious on several other recordings even though it was impossible to make an accurate count (Fig. 5). It was impossible to measure the amplitude of slow pressure waves because they varied from one minute to the next in some tracings, and sometimes regular waxing and waining occurred.

Ultra slow waves, either sustained or fading, were present in two of the 40 controls (5%) and in 35 of the 84 patients with haemorrhoids (42%). This difference was highly significant ($x = 20·7$, $P < 0·0005$; Table 4). In the patients with haemorrhoids

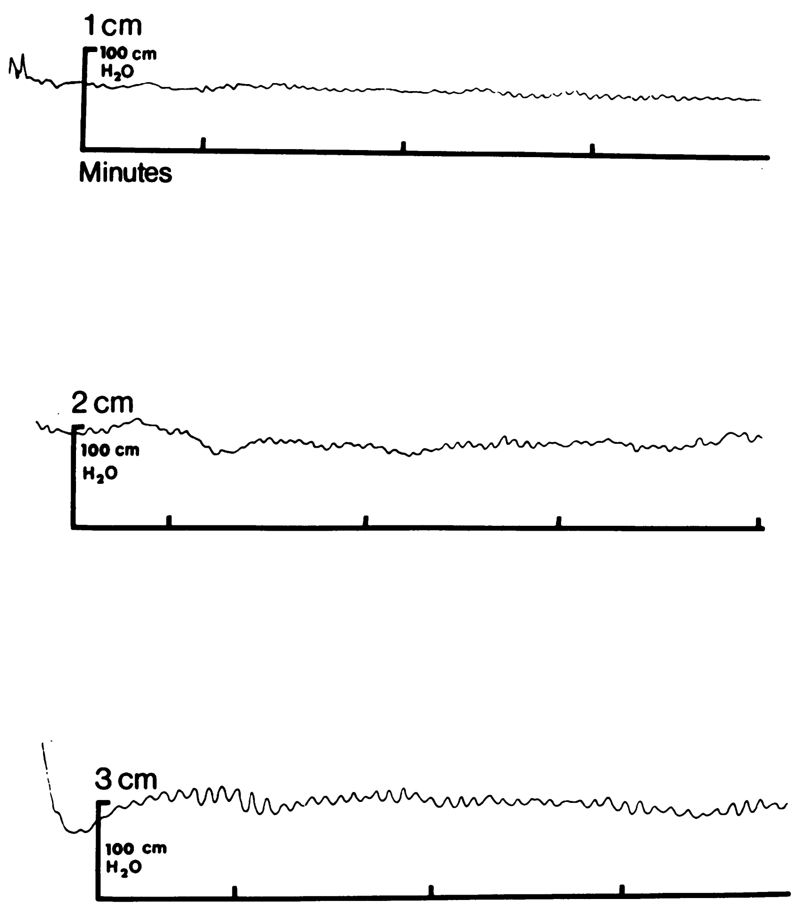

Fig. 5 *Typical motility at centimetre steps from the anal verge. Slow waves appear slower and higher in the proximal anal canal.*

Table 5 *Ultra slow wave frequency and amplitude*

	Distance from anal verge		
	1 cm	*2 cm*	*3 cm*
Mean frequency (/ min)	1·18	1·14	1·14
SD	0·23	0·20	0·25
n	21	29	17
Mean amplitude (cm H_2O)	49·5	54·9	38·2
SD	21·5	24·0	19·9
	21	29	17

there was no difference between frequency of ultra slow waves at different levels in the anal canal. Maximum amplitude occurred at the position of maximum anal pressure (Table 5).

Discussion

The balloon system was a convenient method to use. Anal pressure was reproducible and easy to estimate and motility details were well shown.

The rate of perfusion had a marked effect on recorded pressure and motility in the perfused system. Details of motility were seen only with a relatively fast rate of perfusion and the pressure recorded was also higher. This had not been reported previously in relation to anal pressure measurements and may explain some of the conflicting results of various workers.

Slow waves represent basal activity of the internal sphincter. They are not related to respiration or the electromyographic activity of the external sphincter (Kerremans, 1969) and they are present under anaesthesia with the external sphincter paralysed (Hancock, 1976). The results of this study demonstrated a gradient of slow wave frequency with the fastest waves in the distal anal canal. Kerremans (1969) suggested that this would produce an inward movement of anal contents, and may be a normal mechanism to keep the anal canal empty. In contrast with this study, he did not observe the motility gradient in patients with haemorrhoids.

Ultra slow pressure waves also represent activity of the internal sphincter. In this study they were seen in only 5% of normal subjects, but others have recorded these pressure waves more often (Kerremans, 1969; Gutierrez *et al.*, 1975). They may, therefore, be a normal feature but their appearance depends on the recording method and the definition of their presence. Ultra slow waves were seen significantly more frequently in patients with haemorrhoids, but it was not clear if this presumed overactivity of the internal sphincter was primary or secondary. They are present when the external sphincter is paralysed and are associated with the highest anal pressure. They disappear after anal dilatation for haemorrhoids (Hancock and Smith, 1975). When present they had the same frequency at all levels in the anal canal, so presumably represented a synchronous contraction of the whole internal sphincter. Their presence may have some relation to stimulation of the sphincter by the probe because they sometimes showed signs of fading in amplitude. However, they were also seen with a fine perfused probe provided the rate of perfusion was fairly fast (0·2 ml/min) and this caused negligible stimulation.

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