New method of measuring forces in the anal canal

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The function of the anal sphincters has been measured using many different techniques, from large balloons (Denny-Brown and Robertson, 1935; Schuster, Hendrix, and Mendeloff, 1963) to small balloons or open-ended tubes (Duthie and Watts, 1965; Harris and Pope, 1965; Phillips and Edwards, 1965), and more recently a small force gauge (Collins, Duthie, Shelley, and Whittaker, 1967). Each unit records the effect of sphincter function at a single position in the anal canal and each must be moved up and down the anal canal in order to obtain a picture of the function of the whole length of the sphincter. A new technique has been developed from which simultaneous measurements of sphincteric squeeze can be recorded from 16 different sites in the anal canal without moving the gauge.

The multiple force gauge has been used in an attempt to establish the importance of the different components of the voluntary muscle in the anal sphincter.

THE MULTIPLE FORCE GAUGE

The multiple force gauge (Fig. 1) consists of a brass core 1 mm diameter on which were mounted four metal discs of 5 mm diameter from which 16 stainless steel cantilevers projected. To each cantilever was bonded a semiconductor strain gauge (gauges type 1A-1A-350P, Ether Ltd). The cantilevers were anchored at 90° intervals in the metal discs, which were 1 cm apart. Each strain gauge was placed in a circuit as one arm of a resistance

bridge, the output of which was amplified and displayed on an ultraviolet light recorder at a sensitivity corresponding to 1.5 g weight per 1 cm. Each force gauge was calibrated by applying a force of 6 g weight to the midpoint of each platform and adjusting the amplification so that the recorded trace moved 4 cm. Like previous force gauges used (Collins *et al*, 1967; Wankling *et al*, 1968) each cantilever responded only to radial force, so radial force acting at 16 separate sites in the anal canal could be measured. A 12-channel ultraviolet light recorder was used so the output from a maximum of 12 strain gauges could be recorded at any one time.

METHOD

Twenty-six men, aged 21 to 66 years, without any anorectal abnormality, have been studied with the multiple force gauge. The gauge proved to be fragile and towards the end of the series a number of gauges ceased to function. The study was terminated when only five remained working. In the latter stages of the study it was necessary to insert the force gauge at a different axial rotation in consecutive patients in order to obtain force readings from each of the 16 positions.

Each subject lay on his left side and the multiple force gauge was placed through a proctoscope in the anal canal so that the proximal ring of force gauges was at 1 cm from the anal verge (Fig. 2). The proctoscope was then removed, the axial position of the force gauge was checked, and measurements were made with the subject at rest and before, during, and after the following manoeuvres.

VOLUNTARY SQUEEZE The patient was asked to contract the muscles in the anal region. That the patient knew exactly what to do was checked beforehand by asking him to squeeze onto a finger inserted into the rectum. A generalized contraction of the abdominal and gluteal muscles was discouraged.

VALSALVA MANOEUVRE The subject was instructed to blow into a mouthpiece to maintain manometric pressure of 50 mm Hg for 10 to 20 seconds.

INTERPRETATION OF RECORDS In many of the records there were spontaneous fluctuations in the radial forces; these were sometimes in rhythm with the pulse, sometimes with respiration, but often unassociated with either. When of slow, regular rhythm they were thought to represent the smooth muscle activity of the internal

FIG. 1. Multiple force gauge showing eight of the 16 cantilevers which are set at 90° to each other in four rings 1 cm apart.

FIG. 2. Diagram of the multiple-force gauge in position in the anal canal.

sphincter (Wankling, Brown, Collins, and Duthie, 1968). When fluctuations were evident the reading was taken as the average value about which the fluctuations occurred. During voluntary squeeze or the Valsalva manoeuvre this reading was taken for the five-second period after the initial response. For each patient the mean of three such readings was taken for analysis.

RESULTS

VOLUNTARY SQUEEZE Voluntary contraction of the anal musculature was accompanied by a significant increase in the radial force recorded from all of the 16 sites in the anal canal except the anterior points at 2 and 3 cm from the anal verge (Table I). At these two levels there was a considerable increase in the force posteriorly without a corresponding change in that recorded from the anterior wall of the anal canal. This was probably caused by the forward

pulling effect of the pubo-rectalis sling (Fig. 3). At the lower end of the anal canal (1 cm from the anal verge) there was a marked increase in force from all quadrants. This probably represents the true sphincteric squeeze of the circularly arranged external sphincter muscle.

FIG. 3. Diagram of the forward pulling effect of the pubo-rectalis component of the levator ani.

VALSALVA MANOEUVRE There was relatively little increase in force at any of the 16 positions. Such increases as did occur were distributed in much the same way as those resulting from voluntary squeeze.

DISCUSSION

The multiple force gauge was developed in order that simultaneous recordings could be made of the forces acting at a number of sites inside the length of

TABLE I

MEASUREMENTS OF RADIAL FORCE IN THE ANAL CANAL, SHOWING CHANGES FROM RESTING VALUES

Distance from Anal Margin (cm)	Voluntary Squeeze				Valsalva Manoeuvre			
	Posterior	Anterior	R. Lateral	L. Lateral	Posterior	Anterior	R. Lateral	L. Lateral
4	0.56 ± 0.16 (20)	0.93 ± 0.19 (23)	1.1 ± 0.30 (20)	1.3 ± 0.29 (16)	0.27 ± 0.18 (12)	0.36 ± 0.09 (15)	0.57 ± 0.22 (14)	0.41 ± 0.20 (9)
3	1.8 ± 0.18 (21)	-0.07 ± 0.16 (15)	1.2 ± 0.36 (15)	1.4 ± 0.19 (15)	0.37 ± 0.15 (13)	-0.03 ± 0.07 (9)	0.11 ± 0.09 (9)	0.21 ± 0.09 (8)
2	2.3 ± 0.21 (26)	0.09 ± 0.15 (22)	1.4 ± 0.22 (18)	1.5 ± 1.7 (26)	0.74 ± 0.16 (14)	0.01 ± 0.09 (13)	0.21 ± 0.09 (15)	0.39 ± 0.15 (18)
1	2.9 ± 0.34 (16)	2.2 ± 0.34 (14)	1.9 ± 0.24 (15)	2.5 ± 0.42 (15)	0.87 ± 0.34 (8)	0.71 ± 0.25 (8)	0.81 ± 0.24 (9)	0.71 ± 0.24 (8)

Mean values ± SEM in g weight.
Number of subjects in brackets.

FIG. 4. A record of the effect of voluntary squeeze and a Valsalva manoeuvre on the radial forces at 11 sites in the lumen of the anal canal.

the anal canal without having to move the gauge. The force measured was a qualitative change from resting level rather than the absolute force acting on the strain gauge because provision was not made in this model for compensation for temperature, and baseline force readings were so variable from gauge to gauge that no meaningful interpretation could be made. However, the gauge responded equally to applied force once in the constant temperature surroundings of the anal canal. Steps are being taken to remedy this defect and to render the cantilevers more robust. The gauge is useful because it shows simultaneous differences in the force responses at different positions in the anal canal. These differences cannot be measured by pressure measurements or the earlier zeppelin-shaped force gauge. Measurements taken during a voluntary squeeze suggest that, in normal subjects, there is no radial force from the sphincter muscle anteriorly at the level where the pubo-rectalis component of the levator ani pulls the anal canal forward. At the lower end of the canal the sphincter muscle squeezes radially from all round the anal canal. The effect of

the pubo-rectalis sling has been demonstrated radiographically (Phillips and Edwards, 1965) and the contraction of the lower part of the external sphincter has frequently been shown electromyographically (Taverner and Smiddy, 1959; Porter, 1962; Duthie and Watts, 1965). The anal canal is thought to change its configuration by a forward movement of the upper end during a voluntary squeeze and it might be expected that the resulting alteration in the angle between rectum and anal canal provides an important contribution to voluntary anal continence as well as the more obvious squeeze effect at the lower end of the canal.

A Valsalva manoeuvre was used as an effective and reasonably controlled method of producing an increase in intraabdominal pressure. It has been shown that there is an accurate correlation between expiratory pressure and intrarectal pressure during a Valsalva manoeuvre (Collins *et al*, 1967). As with the zeppelin-shaped force gauge used previously there is relatively little increase in force measured at any of the points in the anal canal during the Valsalva manoeuvre. There is no evidence to suggest that the lateral walls of the anal canal are pushed together when intraabdominal pressure is raised. Under normal circumstances the anal sphincter appears to remain competent without any further squeeze being required, as was suggested by Harris and Pope (1964), but a voluntary squeeze acts as an emergency method of maintaining continence when required.

SUMMARY

A new recording device has been developed to measure forces acting simultaneously at 16 different points in the anal canal. Using this gauge, the sling effect of the pubo-rectalis muscle and the sphincter effect of the lower fibre of the external anal sphincter appear to be most active during a voluntary squeeze whereas during the Valsalva manoeuvre radial force is increased relatively little at any point in the anal canal.

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