Electromyography of the Internal Anal Sphincter Performed Under Endosonographic Guidance

Description of a New Method

Michael Sørensen, M.D.,* Michael Bachmann Nielsen, M.D.,*
Jan Fog Pedersen, M.D., Ph.D., John Christiansen, M.D., Ph.D.

*From the Department of Surgery D and * Ultrasonic Laboratory, Glostrup Hospital, University of Copenhagen, Glostrup, Denmark*

PURPOSE: The aim of our study was to investigate internal anal sphincter electromyographic signals. METHODS: Electromyography of the internal anal sphincter was performed with platinum wire electrodes in six healthy volunteers (three males and three females), inserted under endosonographic guidance. Platinum wire electrodes were also inserted into the external anal sphincter. Activity of both the internal and external anal sphincter in a 40-second period was measured. RESULTS: Internal anal sphincter median activity was 22.1 (range, 5.5–67.6) μV. Slow-wave activity was 47 cycles/minute (range, 34–55 cycles/minute). After inflation of a rectal balloon with air until a constant relaxation of the anal canal was obtained, a decrease in internal anal sphincter activity to 15.9 (1.2–31.3) μV as well as a decrease in slow-wave activity to 34 cycles/minute (range, 27–40 cycles/minute) was found. The original internal anal sphincter EMG was resumed after deflation of the rectal balloon. External anal sphincter median activity was 3.1 (range, 0.77–18.6) μV. During inflation of the rectal balloon, a reflex increase in external sphincter EMG activity was found. With the rectal balloon fully inflated a part of this increase was still present, 11.0 (1.9–24.6) μV. In some of the subjects, this increased activity was superimposed on the internal anal sphincter recordings as well. During a voluntary squeeze it was not possible to identify internal anal sphincter activity due to activity of the external anal sphincter totally overriding the internal anal sphincter signal. CONCLUSION: Precise EMG recordings from the internal anal sphincter is possible with endosonographic guidance of the electrodes, except during voluntary squeezing of the external anal sphincter. [Key words: Electromyography; Endosonography; Internal anal sphincter]

Sørensen M, Nielsen MB, Pedersen JF, Christiansen J. Electromyography of the internal anal sphincter performed under endosonographic guidance: description of a new method. Dis Colon Rectum 1994;37:138–143.

Most studies on internal anal sphincter function are based on recording of anal canal resting pressure.[1] Although electromyographic studies of the puborectalis muscle[2] and the external anal sphincter are widely used,[3,4] the electromyographic study of the internal anal sphincter has received less attention. Surface electrodes placed in the anal canal[5] or wire electrodes[6,7] placed blindly into the internal anal sphincter have been used. Since anal endosonography visualizes both the external and the internal anal sphincter,[8,9] it should be possible to obtain electromyographic recordings from the internal anal sphincter by placing platinum wire electrodes under guidance of endosonography.

MATERIALS AND METHODS

Six healthy volunteers (3 males and 3 females), median age 38 (range, 28–53) years with no history of anorectal dysfunction participated in the study.

Electromyography

Before anal endosonography was performed, a wire hook electrode was prepared as described by Basmajian and Stecko.[10] Two platinum wire electrodes with a diameter of 0.07 mm were threaded through a 120-mm 26-gauge needle (Spinocan®; B. Braum Melsungen AG). *To increase selectivity and reduce noise from adjacent structures, bipolar electrodes were used.*[11] Anal endosonography was performed by the same investigator with the subjects in the left lateral position. A Brüel & Kjær (Nærum, Denmark) ultrasound scanner-type 1846 with a 7-MHz endoprobe, type 8551 (focus 1–6 cm, Sector 112°) was used. This probe enables multiplanar imaging and has a built-in needle guide for transrectal/transanal biopsy. The internal sphincter

No reprints are available.

was located in longitudinal images and the EMG needle placed transanally in the internal sphincter under ultrasonographic guidance through the built-in needle (Fig. 1). The thickness of the internal sphincter was measured in transverse image before inserting the needle. The needle was immediately removed, leaving the platinum wires in the internal anal sphincter.

The external anal sphincter electrode was prepared by threading two platinum wires of the same dimensions as described above through a standard needle for subcutaneous injections (23 gauge). This electrode was inserted blindly into the superficial part of the external anal sphincter. The needle was immediately removed, leaving the platinum wires in the external anal sphincter. The wire electrodes were well tolerated by all of the subjects. Finally, a ground electrode was placed on the lateral part of the right thigh.

The platinum wires from both sphincters and the ground electrode were connected to an EMG apparatus (Counterpoint, Dantec, Denmark). A rectified EMG signal with a time constant of 0 milliseconds was studied for both EMG signals. Filter settings for the external anal sphincter EMG were 0.5 kHz (lower limit) and 10 kHz (upper limit) while filter settings for the internal anal sphincter EMG were 0.2 Hz (lower limit) and 500 Hz (upper limit). Amplification was 10,000 to 500,000 times for the external anal sphincter signal and 10,000 to 50,000 times for the internal anal sphincter signals.

The EMG apparatus allows a direct measurement of the area under the curve, enabling a calculation of mean activity. Rectified signals were used because the apparatus then allowed up to 20-second periods to be measured at the time, whereas using the raw signals would only allow 2-second periods. Two 20-second periods without artifacts were used for the analysis. The subjects were kept at rest at least 10 minutes before any recordings were made. *No local anesthesia was used.*

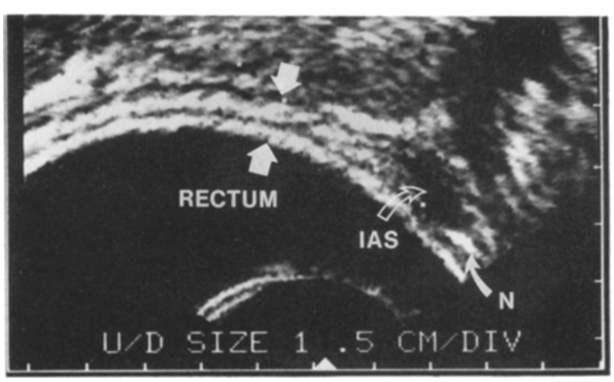

Figure 1. Endoluminal anal sonogram. Longitudinal image showing hypoechoic (dark) internal anal sphincter (IAS) in continuity with the rectal wall (arrows). The EMG needle (N) has been placed in the middle of the internal sphincter under sonographic guidance.

Rectoanal Inhibitory Reflex and Anal Manometry

A perfused, low-compliance open-ended polyvinyl pressure catheter was placed in the anal canal, situated at the point of maximum resting pressure, and a latex balloon was placed in the rectum 10 cm from the anal verge. A pressure catheter as described above was placed between the balloon and the rectal wall. Both pressure catheters were connected to Statham transducers connected to manometers. Analog signals from both manometers were connected to the EMG apparatus, and the signals were digitalized and displayed on the monitor synchronously with the EMG recordings. Mean pressure in the anal canal was measured for the same 40-second periods used for measuring EMG activity. Rectoanal reflex was elicited by inflating the rectal balloon in increments of 50 ml until a constant relaxation of the internal anal sphincter was obtained. No bowel preparation was used in any of the subjects.

The experimental setup is demonstrated in Figure 2.

Statistical Analysis

Wilcoxon's rank sum test for paired data was used for comparing internal anal sphincter EMG and slow-wave activity as well as external anal

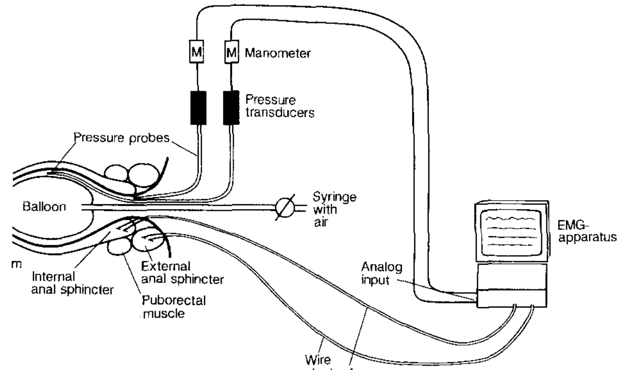

Figure 2. Experimental setup (for details see text).

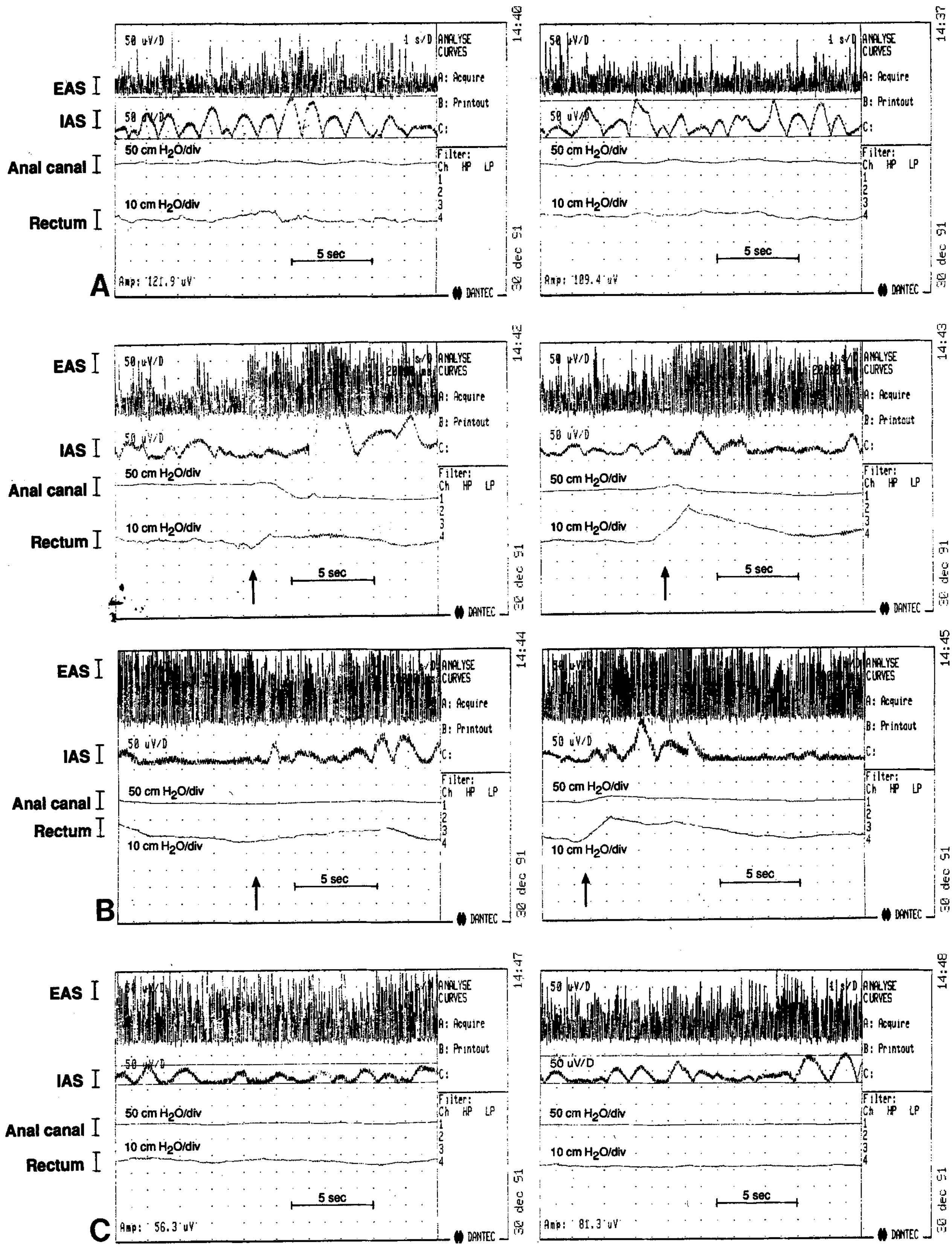

Figure 3. A. Simultaneous recording of external anal sphincter activity (EAS), internal anal sphincter activity (IAS), anal canal pressure and rectal pressure before inflation of the rectal balloon. Bars on the left of the panels indicate 1 div. B. Simultaneous recording of external anal sphincter activity (EAS), internal anal sphincter activity (IAS), anal canal pressure and rectal pressure during inflation of the rectal balloon. Arrows indicate inflation of 50 ml of air to the balloon. Note

increase in external anal sphincter activity while internal anal activity decreases after a brief increase in activity (upper and lower right panels). Bars on the left of the panels indicate 1 div. C. Simultaneous recording of external anal sphincter activity (EAS), internal anal sphincter activity (IAS), anal canal pressure and rectal pressure two minutes after inflation of the rectal balloon. Note increase in external anal sphincter activity as well as decrease in internal anal sphincter frequency and amplitude compared with A. Bars on the left of the panels indicate 1 div.

sphincter activity. Friedman's test was used for comparing sex differences in internal anal sphincter slow-wave activity.

RESULTS

During inflation of the balloon a transient increase in anal canal pressure occurred (2–3 seconds) followed by a rapid decrease. All subjects demonstrated a clear rectoanal inhibitory reflex. Pressure decrease in the anal canal was in the range of 3 to 47 cm of H_2O (Table 1).

A full examination of one subject is shown in Figure 3. Figure 4 shows measurement of the area under curve. In five of six subjects, an increase in both internal and external EMG recordings were seen on inflation of the rectal balloon, but after a few seconds a decrease occurred in internal anal sphincter activity and in the amplitude of the slow waves as well as in slow-wave frequency (cycles/minute), while external anal sphincter activity was still increased (Table 1).

One subject had a slight increase in internal anal sphincter frequency (39 cycles/minute to 40.5 cycles/minute); however a decrease in internal anal sphincter activity was still found (32.8 to 31.3 μV). This subject had a decrease in anal canal pressure of only 3 cm of H_2O with a constant relaxation of the anal canal (from 13.4 cm of H_2O to 10.3 cm of H_2O).

In some of the subjects an immediate measurement of internal anal sphincter activity could not be performed, on inflation of the rectal balloon, due to external anal sphincter activity overriding the internal anal sphincter recordings. However, within 30 seconds internal anal sphincter activity could be identified in these subjects.

Men had higher internal anal sphincter activity than women due to higher amplitudes of the slow waves. Both slow-wave activity and the internal anal sphincter thickness was the same in both sexes (Table 2).

DISCUSSION

This study demonstrates that good quality EMG recordings of the internal anal sphincter with platinum wire electrodes is possible. A simultaneous decrease in both internal anal sphincter activity and anal canal resting pressure was found. By using a rectified EMG signal a calculation of a mean EMG activity parallel to calculation of a motility index in the gastrointestinal canal is possible.[12] In fact our calculation of anal canal pressure is actually a motility index for a 40-second period.

In the resting state, we found internal anal sphincter slow-wave activity of approximately 47 cycles/minute (34–55 cycles/minute) which is in contrast to previous studies on internal anal sphincter EMG, where slow-wave activity was found to be 18 to 30 cycles/minute.[5, 6, 11] With the rectal balloon inflated, the internal anal sphincter activity was higher than 28 cycles/minute. This difference in frequency compared with other studies is probably attributable to the fact that using a rectified EMG signal means that any negative slow-wave component will be registered above the baseline and thus be measured as a new slow wave. The true frequency will, therefore, be approximately half of the frequency recorded. Therefore, if a measure-

Table 1.
Results of Anal Manometry and EMG Recordings in the Internal and External Anal Sphincters

	Before Inflation Median (range)	After Inflation Median (range)
Anal canal (mean pressure, cm H_2O)	39.5 (13.4–64.5)	10.1 (6.9–21.3)
Internal anal sphincter (mean activity, μV)	22.1 (5.5–67.5)	15.9 (1.2–31.3)*
Internal anal sphincter (median amplitude, μV)	39 (18–95)	23 (11–43)*
Internal anal sphincter (frequency, cycles/min)	47 (34–55)	34 (27–40)
External anal sphincter (mean activity, μV)	3.1 (0.77–18.6)	11.0 (1.9–24.6)*

* $P < 0.05$ (Wilcoxon's rank sum test for paired data).

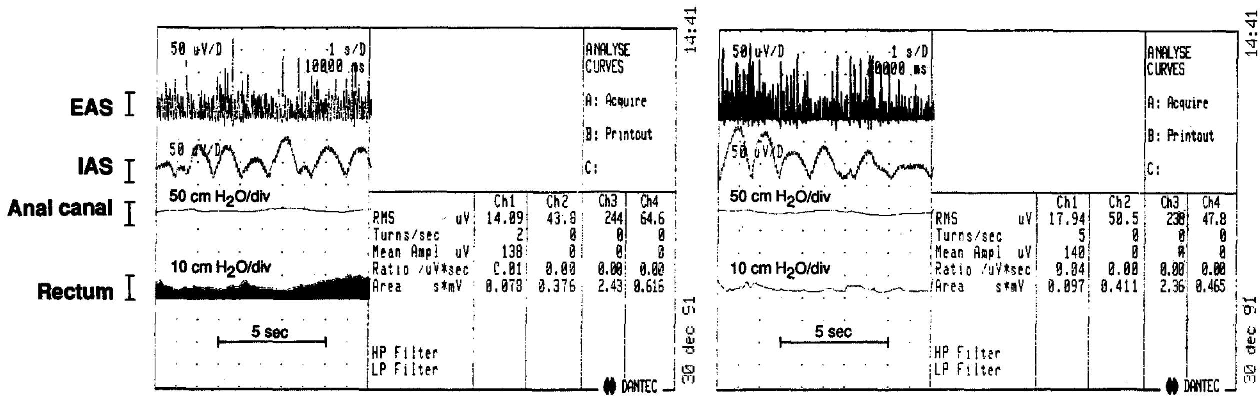

Figure 4. Measurement of area under the curve. The left panel of Figure 3A is used to show measurement of the area under the curve. The panel is divided into two 10-second periods that are measured separately. In the left panel, the area has been measured for the top three tracings while the area for the rectal pressure recording is displayed. The area for each tracing is shown in the text on the right of each panel. In the right panel, the area under the curve for the top tracing is displayed, while the areas of the other tracings have already been measured. External anal sphincter activity in 10 seconds was 0.079 mV*S and 0.097 mV*S, respectively. Mean external anal sphincter activity was thus 7.9 μV and 9.7 μV, respectively. Mean activity of the internal anal sphincter was 37.6 μV and 41.1 μV. The pressure recordings are also displayed in mV in the text of the panel and need transformation to cm H_2O. Bars on the left of the panels indicate 1 div.

Table 2.
Sex Differences in Internal Anal Sphincter EMG Recordings and Internal Anal Sphincter Thickness

	Female Median (range)	Male Median (range)
Mean slow wave activity (cycles/min)		
Before inflation	49.5 (34.5–51.0)	45 (39.0–55.5)
After inflation	28.5 (27.0–36.0)	40.5 (33–48)
Amplitude (slow waves) (μV)		
Before inflation	18 (18–23)	65 (55–95)*
After inflation	13 (11–18)	43 (28–85)*
Thickness of internal anal sphincter (mm)	2.0 (1.25–2.0)	1.5 (1.25–1.75)

* $P < 0.05$ (women compared with men, Friedmann's test).

ment of frequency is wanted, a different setup should be used. The external anal sphincter is anatomically close to the internal sphincter and has a tone at rest in contrast to other striated muscles.[13] Not surprisingly, external anal sphincter activity was superimposed on some of the internal anal sphincter recordings, since the filter settings we used (0.2–500 Hz) would allow some external anal sphincter activity to be measured in the internal anal sphincter recordings. With a filter setting in the range of 0 to 10 Hz, which has been used for measuring colonic myoelectric complexes,[14] probably no external anal sphincter activity would be found in the internal anal sphincter recordings.

With anal endosonography the anal sphincters can be visualized in both transverse and longitudinal images.[9] The internal anal sphincter is only a few millimeters in thickness. Thus, even a slight deviation of the needle from the puncture line will result in the needle being misplaced. In two of the subjects, two needle insertions were needed before the needle was located in the center of the internal anal sphincter. However, since the needle can be fully visualized, the procedure is easy to perform.

The large variability in the EMG recordings is possibly, in part, attributable to variations in the distance between the wires of the bipolar electrode. If this distance is too long, interference from the surrounding striated muscles may distort the recording.[15] Like in other studies we had no precise knowledge of the distance between the two platinum wires which may explain the rather large variability found in both internal and external anal sphincter activity. Another reason may be that the size of the recording surfaces was not exactly the same. A few millimeters of the insulation at the tips of the wires were burned off, but probably not to exactly the same extent in all of the electrodes.

The observed sex difference in internal anal sphincter activity, may, in part, be attributable to differences in electrode placement. Reproducibility studies as well as studies of a larger number of subjects is needed before any valid conclusions can be drawn.

CONCLUSION

EMG recordings from the internal anal sphincter is possible with endosonographic guidance of the electrode. However, a more uniform design of the electrode is needed if a more precise quantification is wanted.

REFERENCES

1. Felt-Bersma RJ, Meuwissen SG. Anal manometry. Int J Colorectal Dis 1990;5:170–3.
2. Bartolo DC, Jarrett JA, Read MG, Donnely TC, Read NG. The role of partial denervation of the puborectalis in idiopathic fecal incontinence. Br J Surg 1983;70:664–7.
3. Neill ME, Swash M. Increased motor unit fibre density in external anal sphincter muscle in ano-rectal incontinence: a single fibre EMG study. J Neurol Neurosurg Pshchiatry 1980;43:343–7.
4. Swash M. Anorectal incontinence: electrophysiological tests. Br J Surg 1985;72(Suppl):S14–5.
5. Luborski DZ, Nicholls RJ, Burleigh DE, Swash M. Internal anal sphincter in neurogenic fecal incontinence. Gastroenterology 1988;95:997–1002.
6. Braun J, Raguse T. Pathophysiological role of the internal anal sphincter in chronic anal fissure. A Gastroenterol 1985;23:565–72.
7. Sun WM, Read NW. Anorectal function in normal human subjects: effects of gender. Int J Colorectal Dis 1989;4:188–96.
8. Law PJ, Bartram CI. Anal endosonography: technique and normal anatomy. Gastrointest Radiol 1989;14: 349–53.
9. Nielsen MB, Pedersen JF, Hauge C, Rasmussen Ø, Christiansen J. Endosonography of the anal sphincter: findings in normal volunteers. AJR 1991;157: 1199–1202.
10. Basmajian JV, Stecko G. New bipolar electrode for electromyography. J Appl Physiol 1963;17:849.
11. Staalberg E. Trontelj JV. Single fbre electromyography. Surrey: Mirvalle Press, 1979.
12. Kellow JE, Gill RC, Wingate DL. Modulation of human upper gastrointestinal motility by rectal distension. Gut 1987;28:864–8.
13. Swash M, Snooks SJ. Electromyography in pelvic floor disorders. In: Henry MM, Swash M, eds. Coloproctology and the pelvic floor. London: Butterworth, 1985.
14. Sarna SK. Myoelectric correlates of colonic motor complexes and contractile activity. Am J Physiol 1986;250:G213–20.
15. Wegman EA, Aniss AM, Bolin TD, Davis AE, Gandevia SC. Human rectosigmoid electromyography: a new approach and some pitfalls. J R. Soc Med 1989;82:88–90.