Concordance between colonic myoelectrical signals recorded with intramuscular electrodes in the human rectosigmoid in vivo

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Abstract

The myoelectrical activity of the human rectosigmoid colon was studied simultaneously in six subjects at two sites using two pairs of fine wire bipolar electrodes. The electrodes were spaced 2–5 cm apart in the rectosigmoid after insertion into the smooth muscle layers under direct vision at sigmoidoscopy. The electrodes were implanted at positions between 8 and 25 cm from the anal verge in different subjects. The frequency of myoelectrical burst activity together with the burst duration recorded by each electrode pair was examined. The relation of burst frequency and burst duration in the higher and lower placed electrodes was also assessed. In none of the subjects was there evidence of synchrony between the electrode pairs. In addition, there was no relation between the relative position of the electrodes and the intrinsic frequency or duration of myoelectrical bursts. It is concluded that regions of smooth muscle in the unstimulated human colon in vivo act independently and that there is no effective common neuromuscular drive under these conditions.

Understanding of the relation between electrical and motor events in the human colon is still poor.¹² Although much is known about the pattern of innervation of the gut,³ knowledge of the basic mechanisms underlying the origin of the slow wave and its regulation is still lacking.^{4–7} Despite this it seems that variations in slow wave activity set the background membrane potentials upon which spike bursts are superimposed, and if the conditions are favourable a colonic contraction occurs. Colonic contractions, however, may also occur in the absence of spike potentials.^{4,5}

The published reports are divided between results obtained with in vivo and in vitro preparations and there is difficulty in unifying the two sets of data. Further difficulty arises in differentiating what is real and what is artifactual in recording of myoelectrical activity in vivo. From in vivo studies we find variations in slow wave frequencies and in the degree of spike activity in different preparations. This may be accounted for by the differing methods used to study the electrical activities.^{8–10} In vivo studies may be limited by the capacity of the different types of electrode (ring,^{11–13} clip,^{14–17} suction,^{18–19} or abdominal wall electrodes²⁰) to pick up the desired activity. Each electrode type and recording system may pick up different phenomena depending on their physical properties – for example, interelectrode distance, tissue contact,

susceptibility to movement and far field artifact, and effective band pass.

The in vitro work shows clearly patterns of spike activity and slow wave oscillations in electrical activity usually with two dominant rhythms.⁴ Using strips of circular colonic smooth muscle, Chambers *et al*²¹ found only one dominant frequency and they suggested that the seeming occurrence of multiple frequencies may be the result of poorly coupled electrical oscillators.

Understanding of the physiological mechanisms underlying human colonic motility is hampered by the inability to extrapolate findings from animal experiments and the noticeable species differences between experimental animals.⁸ While in vivo human studies are required to assist the understanding of colonic motility, there are methodological problems with these recordings in human subjects, as described above. For example, we have recently shown that in recordings of the human rectosigmoid, skeletal muscle electromyographic activity from the nearby pelvic muscles may also be recorded inadvertently by intracolonic electrodes. Unless precautions are taken, this can contaminate recordings from the rectosigmoid and may make interpretation difficult.²² Furthermore, in much of the previous in vivo work two or three recording electrodes in the rectosigmoid^{14,21–24} were used to gain insight into the underlying motility patterns of normal volunteers or subjects with irritable bowel syndrome. This may be valid provided that these electrodes give results representative of a whole area of the colon. In addition, large electrodes on the mucosal surface may show poorly the underlying colonic smooth muscle activity.⁵

The aim of this study was to use a recording technique that limits the artifactual far field effects from nearby skeletal muscle to look for concordance in electrical activity between two bipolar electrode pairs in the resting rectosigmoid colon. Using electrodes that remain in direct contact with the smooth muscle layers should provide accurate information about focal myoelectrical activity within the rectosigmoid in vivo and show whether a specific rhythm is evident globally within the rectosigmoid. A preliminary account of some findings has been published.²³

Methods

SUBJECTS

Thirteen subjects underwent colonic electromyography using a recently described

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Figure 1: Schematic diagram of electrode assembly showing two pairs of bipolar hook electrodes (E1 and E2). These are inserted under direct vision through a rigid sigmoidoscope. After the electrodes have been inserted, the glass rod and 25 G needle were removed leaving behind the electrode pair hooked into the colonic muscle. There was an adaptation period of 30 minutes before recordings began.

method.^{22,25} The procedure was approved by the local ethics committee and informed written consent was obtained from the subjects. In six subjects prolonged recordings of burst activity were obtained from two intracolonic sites simultaneously. In the other seven subjects recordings with burst activity were obtained only from one of the electrode pairs (see Results). Three of the subjects studied in detail had clinically diagnosed irritable bowel syndrome,²⁶ and patient assessment was further supported by a questionnaire with a high sensitivity for irritable bowel syndrome.²⁷ One subject had a chronic cathartic-induced diarrhoea and the remaining two subjects had no history of gastrointestinal disease. Subjects were fasted overnight and allowed only flat lemonade to drink on the day of the procedure. A Travad enema was used to ensure standard bowel clearance in the rectosigmoid for all subjects. Sigmoidoscopy was carried out with minimal air insufflation. None of the subjects developed any complications from the procedure. None participated in a previous study.²² Except for the patient with cathartic-induced diarrhoea, any medications that could interfere with transit or motility were stopped. The recordings were made in a shielded room with the temperature at 25°C.

Figure 2: Data from two separate time periods in one subject. Data were obtained with two electrode pairs separated by less than 5 cm in the proximo-distal direction (CEM 1, CEM 2). They show typical burst activity with no correlation between burst frequency or burst duration between the two electrodes. (Vertical calibration: 200 μ V.)

ELECTRODE INSERTION TECHNIQUE

In all subjects, two pairs of teflon coated, stainless steel, fine wire electrodes (50 μ m diameter) were implanted under direct vision 2–5 cm apart in the longitudinal direction at a distance of 8–25 cm from the anal verge into the smooth muscle of the rectosigmoid by sigmoidoscopy (Fig 1). Specific details of the method have been published previously.^{22,23} In each electrode pair, both distal ends were bared of insulation for 2 mm. The interelectrode distance within the pair is relatively small (0.5–2 mm). A similar method of insertion of each electrode pair was used in all subjects. Electrodes were inserted in the same apparent aboral line in the posterior aspect of the bowel wall. The needle holder was passed through the sigmoidoscope until the needle tip was just indenting the mucosal surface. The needle holder was then advanced until tissue resistance declined suddenly. Based on studies performed intraoperatively (abdomino-perineal resections) this decline in tissue tension was associated with the emergence of the needle tip on the serosal surface of the sigmoid colon. After this point the needle and needle holder were withdrawn. This left the electrode pair within the bowel wall, presumably in contact with the smooth muscle layers. The tips of the recording wires could not be seen through the sigmoidoscope. Once the electrodes were implanted the sigmoidoscope was withdrawn.

In addition to the electromyographic signals, the pressure near the electrodes was measured with a fluid perfused catheter. This was done to correlate any sudden changes in pressure with electrical activity recorded nearby. Unfortunately, intraluminal pressure reflects the average pressure over a relatively long segment of colon and is unlikely to reflect activity of a small area of bowel. The electrocardiogram was also recorded with leg and arm leads. Similar electrical recordings have been obtained when the perfusion was stopped or in other studies in which no catheter was introduced into the colon.

RECORDING AND ANALYSIS TECHNIQUES

Recording of activity began after a 30 minute adaptation period following removal of the sigmoidoscope. Data were recorded for up to three hours. The presence of far field artifactual contamination of recordings by nearby skeletal muscle electromyographic activity from the pelvic floor was assessed every 5–10 minutes. The subjects were required to perform a series of manoeuvres including coughing, deep breathing, bearing down, hip flexion, and tightening of the anal sphincter. Only recordings produced by the manoeuvres that were free of far field activity were studied in detail. All signals were recorded on VHS tape using a TEAC XR-310 high frequency data cassette recorder (DC–1.25 kHz) and analysed off line. Signals were amplified ($\times 50$ –200 000), band pass filtered at 1.6 Hz–3.2 kHz, notch filtered (50 Hz), and subsequently full wave rectified and integrated with a time constant of 100 milliseconds. Recorded data were then played out on paper using a Siemens-Elema Mingograph (flat frequency response to 1 kHz).

Figure 3: Five repetitive sweeps of a unitary burst of colonic myoelectrical activity shown superimposed (A) and as a raster (B). Recording made 10 cm from the anal verge in a normal subject. (Vertical calibration: 250 μ V.)

The burst frequency together with the burst duration were quantitated manually for all recordings. The data from two sites within the colon were then compared statistically. No measurement of burst duration was made for one electrode site in which bursts of very brief duration only occurred (<50 ms, see Fig 3). Given the variation in myoelectrical activity between electrode pairs and the variation between subjects (see Results), a non-parametric measure of correlation was used (Spearman rank correlation). Statistical significance was set at the 5% level.

Results

Myoelectrical burst activity was recorded in all subjects. In six of 13 subjects, bursts of colonic myoelectrical activity occurred at both recording electrodes. For seven subjects, activity was recorded at one site only while the other side seemed quiescent. An example of activity recorded simultaneously at two different active sites is given in Figure 2. The intramuscular recording typically shows 'multi-unit' activity with individual bursts showing variable amplitude and morphology. Two or three different sources of focal activity could often be detected. On rare occasions an isolated potential of constant shape was recorded repetitively. An example is shown in Figure 3. This unit had a mean (SEM) background frequency of 21.7 (1.8) bursts per minute.

Data for the six subjects in whom activity was recorded at both sites are given below. Burst activity from the electrode pairs in all subjects

ranged from 0 to 49 bursts per minute with a 50 millisecond to 8 second range for duration of the bursts (Fig 4). The mean (SEM) burst frequency for all the electrodes in the subjects was 10.9 (3.6) bursts per minute. The mean (SEM) duration of burst activity for the electrodes in the subjects was 3 (0.47) seconds. In this limited group there was no difference in either the duration or frequency of burst activity between the two normal subjects and three patients with irritable bowel syndrome.

There was no detectable tendency for bursts of colonic myoelectrical activity to occur in both electrodes at the same time, or for the duration of the bursts to change over time in both electrodes in a predictable or periodic way (Fig 2). This was examined by measurements of the correlation between burst frequency (and burst duration) for the two simultaneous recordings. Measurements were made of burst frequency (and mean duration) for each minute of the recording sequence. In no subject was there a statistically significant correlation between burst frequency (Fig 4) or burst duration (Fig 5) at the two recording sites. Measurements were made of burst frequency (and duration) for each minute of the recording sequence. The Spearman rank correlations ranged from -0.396 to 0.409 for burst frequency, and -0.156 to 0.237 for burst duration and none was statistically significant at the 5% level. Individual burst frequency and burst duration were assessed specifically for the higher and the lower electrode pair. The electrode with the higher intrinsic frequency of activity or duration of activity was not related to its position in the colon. No overt correlation

Figure 4: Data from four subjects showing relation between lower and upper electrode pairs for burst frequency (bursts/min). The burst frequency was measured for each minute of the recording sequence for both electrode pairs. There was no significant correlation between the burst frequencies recorded at the two sites.

Figure 5: Data from same four subjects as in Figure 4 showing relation between lower and upper electrode pairs for mean burst duration (in seconds). The burst duration was measured for each minute of the recording sequence for both electrode pairs. There was no significant correlation between the burst duration at the two sites.

existed between myoelectric activity and local intracolonic pressure changes as previously reported with this technique.^{22 25}

Discussion

We have shown that when the rectosigmoid is empty there is no obvious concordance between individual activity picked up by closely spaced electrode pairs (2–5 cm apart). That is, when burst activity occurs in one electrode pair, there is no corresponding activity in the other electrode pair. This observed difference in activity is unlikely to be accounted for by delayed conduction or propagation within the colon as the intrinsic burst frequency (and duration) for the two electrode pairs was usually different. This non-concordance between the electrode pairs was noted despite the occasional tendency for far field activity from smooth muscle foci between the electrode pairs to be detected. Any far field effects from whatever source (even pelvic skeletal muscles²² would create a tendency for concordance. This was not what we observed. The findings suggest that spike burst activity in the absence of any stimulation propagates poorly, and that each focal area of smooth muscle within the human rectosigmoid 'seen' by the electrodes seems to behave independently under these conditions.

It is necessary to consider the possibility that these recordings reflected some local movement artefact. We think this unlikely, however, for the following reasons. Firstly, the recordings showed no evidence of propagation, which should have occurred if there were substantial colonic contraction. Secondly, the lack of concordance between sites was often eliminated if a

balloon was inflated proximal to the recording electrode.²³ Thirdly, the recorded potentials sometimes showed a remarkable similarity over time (Fig 3), suggesting that a local unitary event was being recorded. While it is not possible to be certain from which muscle layers the recordings originate, it is likely that activity in the bulkier circular muscle dominates.

In recordings of colonic pressure at sites a few centimetres apart in normal subjects and patients with diverticular disease, Painter and Truelove²⁸ found that colonic pressure often increased at one site but not at adjacent sites. Assuming that these pressure increases derived from focal myoelectrical activity, their finding is consistent with our observations. In addition, Huizinga *et al*²⁹ have shown that appreciably different activity can occur at separate sites along strips of human colon studied in vitro. Studies of electrotonic spread in the human and dog colon in vitro³⁰ have shown low coupling in the short axis of the smooth muscle cells in the circular muscle layer. These electrophysiological studies are consistent with our findings. Because electrode pairs were inserted in precisely the same way in each experiment, and because of the relatively large volume of circular muscle, the poor concordance between the closely spaced electrode pairs is unlikely to have been due to domination of the recordings by activity in the longitudinal layer. This finding of different relative burst activities in nearby electrodes in vivo indicates that there is a lack of effective common neurohumoral drive to the resting colon and that each smooth muscle syncytium may function at its own basal rate.

An implication of this concept is that in recording from the rectosigmoid, many electrode pairs over a large distance may be required

to gain an accurate assessment of the overall activity of the colon. Inconsistencies in the results from irritable bowel patients and normal subjects¹⁴ or patients with irritable bowel and psychoneurotic patients¹⁷ may be partly attributed to the failure of the electrodes used to obtain adequately representative motility assessments of the area of the colon. If a limited number of electrodes are available, then the response of the colon to dynamic stimulation may be helpful in recognising subgroups of functional bowel disorder with an abnormal physiology.

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