The effect of stimulation on the myoelectrical activity of the rectosigmoid in man

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SUMMARY  The myoelectrical activity of the rectosigmoid has been studied in 66 subjects at rest and after stimulation with either pentagastrin 6·0 μg/kg/hr intravenously in 21 cases, neostigmine 0·5 mg intramuscularly in 20 cases, or two bisacodyl suppositories in 19 cases.

Two electrical rhythms were present at rest. A faster rhythm (frequency 6-9 cycles/min) predominated and its incidence was significantly increased by neostigmine at all levels in the rectosigmoid and by bisacodyl in the rectum only. The incidence of the slower rhythm (frequency 2-5-4-0 cycles/min) was significantly increased by pentagastrin which had no effect on the faster rhythm. The amplitude of each basic electrical rhythm rose when its incidence was increased. Motor waves were augmented corresponding to which of the two electrical rhythms was increased after stimulation.

Although much of the basic knowledge of gastrointestinal smooth muscle electrical activity has been obtained from preparations in vitro of colonic smooth muscle, eg, taenia coli of guinea pig, very little information is available on the myoelectrical rhythm of the large bowel in vivo. Results suggest that both in animals (Wienbeck, Christensen, and Weisbrodt, 1972) and in man (Couturier, Roze, Couturier-Turpin, and Debray, 1969) the main electrical waveform, variously known as basic electrical rhythm, pacemaker potential, or slow wave, is not present all the time but appears in sequences. We have extended these studies in the rectosigmoid in normal subjects both at rest and following various forms of large bowel stimulation.

Methods

Sixty-six subjects with no known colonic or anorectal disease have been studied using mucosal suction electrodes mounted on a tube and introduced 5 to 30 cm from the anus through a sigmoidoscope with the subject laying on the left hand side. Thirty minutes were allowed for the subject to settle before recordings were commenced. Records were made for at least 60 minutes at rest and then for a further hour following stimulation in 60 of the subjects. (The nature and extent of the investigations were explained to the subjects who gave informed consent). Stimulation was by means of pentagastrin 0·6 μg/kg/hr intravenously (21 subjects), 0·5 mg neostigmine intramuscularly (20 subjects), or the use of two bisacodyl suppositories (19 subjects).

The electrical activity of the colorectal smooth muscle was recorded by means of stainless steel electrodes 0·25 mm in diameter mounted in a rubber cup attached to a polythene tube 5 mm in diameter. The electrode was sucked onto the bowel wall to a negative pressure of 20 cm Hg so that the electrode penetrated the bowel to a depth of approximately 2 mm (fig 1). Previous workers (Monges and Salducci, 1970) have shown that a rubber cup not only enhances adherence of the electrode to the bowel mucosa but also diminishes movement artefact when the bowel contracts vigorously. Tubes with one to three electrodes were used in each study. Monopolar records were made with the indifferent electrode placed on the scarified skin over the right iliac fossa. The signals from the electrodes were fed into an amplifier (frequency response 0-02 Hz to 1 KHz) and then to a UV recorder. A parallel output was recorded on magnetic tape for computer analysis. Filters with a frequency range between 3 and 5 cycles/minute, 6 and 9 cycles/minute, and 9 and 14 cycles/minute were occasionally used.

A pneumograph was used to distinguish respiratory artefacts from true wave activity. Motility was
simultaneously recorded by means of fine open-tipped polythene catheters 1 mm internal diameter passed along the large tube and brought out opposite each electrode. The catheters were perfused with 0.15 molar saline at a rate of 10 ml/hour by a Palmer constant infusion pump. The proximal end of each catheter was connected to a strain gauge pressure transducer (SE 76/8) whose output suitably amplified, was also recorded on UV paper.

The UV paper records were analysed visually and a note was made of the percentage of recording time during which regular electrical waves were present (percentage electrical activity), the frequency of the basic electrical rhythm, and the amplitude of the waves.

The data on magnetic tape were digitized and fed into a Conpac computer with a conversational/display system (Linkens and Cannell, 1973) on which cross-correlation functions and fast Fourier transformations were performed. Auto- and cross-correlation functions were also calculated using a Biomac 1010 correlator. Visual and computer analyses of slow wave frequencies agreed closely.

In the analysis of the motor activity the duration and amplitude of each pressure wave were measured. For each recording the percentage motor activity was calculated by adding together the duration of all waves and expressing the sum as a percentage of the recorded time.

The results of electrical and motor activity were expressed as resting and stimulated for 60 minutes. In addition, a peak activity was calculated after stimulation in which the mean of the two consecutive 10-minute periods showing most change was multiplied by 6 for comparison with the resting values.

Results of Resting Studies

Slow Wave Activity
Two distinct rhythms were recognized.

6-9 Cycles/minute
Throughout the rectum and lower sigmoid the predominant slow wave frequency was in the range

![Fig 1](Image)

Fig 1 Mucosal suction tube used to record electrical and pressure waves. The rubber cup is sucked on to the bowel wall and the needle electrode pierces the mucosa. The open-ended tube records pressure changes at the corresponding level.

![Fig 2](Image)

Fig 2 Recording at 8 cm from anal verge to show the faster basic electrical activity (BER) with a frequency of 6.5 cycles/minute.
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Fig 3 The mean frequency of BER recorded at each site in the rectosigmoid. Note the two separate frequency populations. The faster frequency tends to decrease nearer the anus.

6-9 cycles/minute (fig 2). This rhythm occurred alone or combined with the slower rhythm (see below) and was present for some proportion of the time in each subject. The frequency was stable during its appearance in the one individual, varying less than 1 cycle/minute during the recording period of 60 minutes. There was a tendency for the frequency to diminish near the anus (fig 3). The amplitude of these slow waves did not change significantly at any level in the rectosigmoid (see table).

2.5-4 Cycles/minute
A slower frequency of slow waves at approximately 3 cycles/minute was observed (fig 4). This rhythm occurred less frequently but was also stable within 1 cycle/minute during the study at one site and had a larger amplitude than the predominant rhythm (see table). While two frequencies were usually separate they could be superimposed at the one electrode and in this instance fast Fourier transforms of the data were most useful in distinguishing them. When both rhythms were present in the same recording no fixed relationship between them was discernible.

This slower rhythm displays properties similar to that obtained from gastric recordings (Kwong, Brown, Whittaker, and Duthie, 1970). The frequency and amplitude are comparable. Similarly, it often appears to consist of an initial fast component lasting two to four seconds and a slower component of 13 to 17 seconds. Two studies were performed to establish whether this rhythm was indeed intrinsic to the large bowel or whether it was picked up from the stomach.

1 Two patients were studied after total gastrectomy. In patient A recordings were obtained at levels 18 and 12 cm from the anal verge and in patient B (fig 5) at 9 cm from the anal verge. In each patient a slower rhythm was present for a proportion of recording time (patient A, 7-5 and 21-2%; patient B, 20%).

2 Gastric recordings were obtained by means of cutaneous electrodes over the stomach in three subjects whilst simultaneously recording from the rectosigmoid. From each site a basic electrical rhythm about 3 cycles/minute was observed but the frequencies were not identical nor did the two signals display a close cross-correlation on the Biomac correlator.

Percentage electrical activity
The slow wave activity was not present all the time. The proportion of time that regular BER was present is expressed as a percentage of the total recording time and is reported as the percentage electrical activity. In the rectosigmoid, 15-25 cm from the anus, the percentage electrical activity was lower at 25% than in the lower rectum 5-10 cm from the anus, where it was present for an average of 67% of recording time (fig 6). The percentage activity

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<table>
<thead>
<tr>
<th>Distance from Anus (cm)</th>
<th>Resting</th>
<th>Pentagastrin (21 Subjects)</th>
<th>Neostigmine (20 Subjects)</th>
<th>Bisacodyl (19 Subjects)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fast</td>
<td>Slow</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>5-9</td>
<td>0.54 ± 0.01</td>
<td>0.99 ± 0.01</td>
<td>1.25 ± 0.14</td>
<td>0.69 ± 0.14</td>
</tr>
<tr>
<td>10-14</td>
<td>0.5 ± 0.03</td>
<td>0.65 ± 0.09</td>
<td>1.05 ± 0.12</td>
<td>0.65 ± 0.07</td>
</tr>
<tr>
<td>15-19</td>
<td>0.49 ± 0.03</td>
<td>0.96 ± 0.31</td>
<td>1.03 ± 0.12</td>
<td>0.69 ± 0.05</td>
</tr>
<tr>
<td>20-24</td>
<td>0.44 ± 0.03</td>
<td>0.65 ± 0.06</td>
<td>1.23 ± 0.29</td>
<td>0.63 ± 0.04</td>
</tr>
<tr>
<td>&gt;25</td>
<td>0.43 ± 0.04</td>
<td>0.85 ± 0.05</td>
<td>1.03 ± 0.11</td>
<td>0.61 ± 0.02</td>
</tr>
</tbody>
</table>

Table Amplitude of colorectal basal electrical rhythm (mV)¹

¹Figures are mean ± standard error of the mean

*Significant difference
Fig 4  Recording at 8 cm from the anus before and after infusion of pentagastrin 6·0 µg/kg hr. The control electrical BER at 2·7 cycles/minute is emphasized on the trace marked filter and no motor activity is seen on the pressure trace. After pentagastrin the amplitude of the BER is increased and motor waves are present with each electrical wave.

Fig 5  Recording at 15 cm from the anus in a patient following total gastrectomy showing an electrical trace with a BER of 3 cycles/minute also present on the filter.
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Results after Stimulation

PENTAGASTRIN

Electrical activity
Fourteen of the 21 subjects showed 3 cycles/minute slow wave frequency and pentagastrin significantly increased its incidence. There was no alteration in the percentage incidence of the faster rhythm in any subject (fig 8). The frequency of both slow and fast rhythms was not altered but the amplitude of the slower rhythm was statistically significantly elevated (see table).

Motor activity
In the 14 subjects who had an increase in electrical activity at 3 cycles/minute, motor stimulation also occurred. The increase in motility was due to the appearance of regular pressure waves coupled with the slower electrical rhythm (fig 4). These waves had a duration of 10 to 20 seconds, were biphasic in appearance, and resembled type II waves.

NEOSTIGMINE

Electrical activity
The percentage incidence of total recording time that the faster activity was present increased significantly at all levels except in the lower rectum (fig 9). No change was noted in the frequency of either the faster or slower rhythm. The amplitude of the faster rhythm was statistically significantly elevated after neostigmine but there was no change in the slower wave amplitude see (table). Action potentials were frequently observed.

Motor activity
In each subject the percentage motility increased at all levels in the rectosigmoid beginning 12-18 minutes after stimulation with neostigmine and remained elevated for at least 4 hours.

Fig 6 The total percentage electrical activity recorded at each site in the rectosigmoid which is greater in the lower rectum than in more proximal sites in the rectosigmoid.

Fig 7 Recording at 6 cm from the anus. Top trace—filter set at 6-9 cycles/minute, showing the waxing and waning of the electrical record seen in the unfiltered form on the lowest trace. The central filter channel was set at 2-5 cycles/minute and shows no regular activity.
after an injection of neostigmine and lasting 20-30 minutes. The pressure waves appeared to correspond with the faster electrical rhythm (fig 9). Occasionally there was an elevation of the base line suggesting a general increase in tonus with type I waves superimposed—type III waves (Chaudhary and Truelove, 1961).

**BISACODYL**

**Electrical activity**

The percentage incidence of the faster electrical rhythm was increased in the lower rectum after the introduction of the suppositories (fig 10). Neither the frequency nor the amplitude of either rhythm was significantly altered following bisacodyl.

**Motor activity**

Increases in motility after the introduction of bisacodyl suppositories usually occurred after five to seven minutes and the response lasted 25 to 30 minutes.

The chief effect was to cause a marked increase in low pressure (5-10 cm) type I motor waves at levels up to 15 cm from the anus (fig 11). These waves were frequently associated with the urge to defaecate.

**Discussion**

We have shown three distinct myoelectrical states within the rectosigmoid. (1) A faster electrical rhythm (frequency 6-9 cycles/minute) which is the predominant basic electrical activity but its amplitude is lower than the slower rhythm (see table). (2) A slower electrical rhythm (frequency 2-5-4 cycles/minute). (3) Stretches of electrical silence in which no obvious slow wave activity is seen. Above the lower rectum this state of inactivity predominates (fig 6). Other authors have also commented on the irregular nature of the basic electrical activity in this area (Provenzale and Pisano, 1971).

Is there an adequate physical explanation for this fluctuating pattern of electrical activity? It is unlikely that the periods of inactivity are the results of technical artefact since between the silent periods quite regular slow wave activity occurs in sequences with waxing and waning of amplitude. Also we have
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Fig 10 The peak percentage incidence of each rhythm before and after stimulation with bisacodyl and the corresponding changes in percentage motility. There is an increased incidence of the faster BER corresponding with a rise in percentage motility in the more distal area of the rectosigmoid only.

Fig 11 Recording at 6 cm in the rectum three minutes after giving two bisacodyl suppositories showing pressure waves synchronous with each cycle of the faster basal electrical rhythm.

now observed this phenomenon in 136 recording sites in 66 subjects. Thus it does appear to be a true physiological property of colorectal smooth muscle. It is possible to explain these various patterns on the basis of the relaxation oscillator theory. Intestinal smooth muscle may be regarded electrically as a series of loosely coupled slow wave oscillators (Nelsen and Becker, 1968; Diamant and Bortoff, 1969; Diamant, Rose, and Davison, 1970). If one assumes that the output of adjacent oscillators in the
rectosigmoid is relatively unstable a situation may arise in which there is mutual interference between two or more oscillators. Recent studies on simulation by means of electronic modelling have demonstrated that summing the output of four relaxation oscillators with the same frequency can produce two separate rhythms with periods of inhibition. Since one can show waxing and waning of the amplitude of the basic electrical activity (fig 7) one can reasonably assume to be recording from more than one relaxation oscillator. In contrast, intracellular recordings show little fluctuation in amplitude and probably indicate the output of one relaxation oscillator.

Another possible explanation is that the faster rhythm is the intrinsic one whereas the slower rhythm is conducted from more proximal areas of the large bowel. An analogous situation has been found in the proximal duodenum (Duthie, Brown, Robertson-Dunn, Kwong, Whittaker, and Waterfall, 1972) where the intrinsic 12 cycles/minute rhythm has been demonstrated, superimposed on the 3 cycles/minute rhythm conducted from the antrum. In support of this we have found that there is a strong cross correlation between the slower rhythm detected at two sites in the rectosigmoid.

Separate studies on patients with total gastrectomies and comparison with recordings from cutaneous electrodes over the gastric area have confirmed the slower rhythm to be intrinsic to the large bowel and not transmitted from the stomach. In addition, the slower frequency is not exactly half the faster, consequently harmonics alone could not be the explanation.

The origin of the slow wave activity in the colon is at present not absolutely clear. Studies in vitro, mainly on the cat colon, have suggested an origin in the circular layer with spread both circumferentially and in the long axis (Christensen and Hauser, 1971; Caprilli and Onori, 1972; Christensen and Rasmus, 1972). On this basis the higher percentage electrical activity observed in the lower rectum may be related to the greater bulk of circular muscle present at this level. Studies in vitro in human colon (Vasanis, Ustach, and Schuster, 1971) localize the origin in the taenia coli with spread to intervening longitudinal and to circular muscle. The two intrinsic rhythms might originate from and spread to different layers of colonic smooth muscle.

The results of stimulation studies also tend to corroborate the presence of two separate myogenic rhythms. The controversy over the role of pentagastrin and gastrin in controlling colonic motility has waged for some time. Waller and Misiewicz (1970) concluded that they do not have a direct role in the colonic response to meals, whereas Logan and Connell (1966) noted some increase in motility with pentagastrin. Our results have indicated a direct 1:1 coupling of motor waves with the slower basic electrical activity only. Those recording with pure 6-9 cycles/minute activity showed no increase in percentage motor activity in response to pentagastrin. We suggest that pentagastrin selectively stimulates oscillators with a frequency of 3 cycles/minute. In subjects not showing the slower basic electrical activity at the time of recording at that particular site there was no motor response to pentagastrin. This could explain the different opinions expressed on the effect of gastrin on colonic motility.

Conversely, both neostigmine (at all levels tested) and bisacodyl suppositories (local effect only) selectively stimulate the faster basic electrical activity but do not have any effect on the slower basic electrical activity. A uniform motor response was obtained by these substances because the faster basic electrical activity was present in each subject.

The three stimuli were chosen to give a hormonal, a neurohumoral, and a local effect. In these preliminary studies their relative importance has not been studied nor their interrelation with other substances having effects on the colon, eg, cholecystokinin (Harvey and Read, 1973), 5-hydroxytryptamine (Misiewicz, Waller, and Eisner, 1966), Bradykinin (Murrell and Deller, 1967), and prostaglandins (Misiewicz, Waller, Kiley, and Horton, 1969). The possible significance of the differential stimulation of the two basic electrical rhythms has not been explained. The fundamental functions of transport and expulsion of colonic content must also be correlated with myoelectrical findings.

References


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