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ELECTRICAL ACTIVITY OF THE LARGE INTESTINE IN NORMAL AND MEGACOLON PIGS

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Résumé

ACTIVITE ELECTRIQUE DU GROS INTESTIN CHEZ LE PORC NORMAL OU ATTEINT DE MEGACOLON. — La motricité du caecum et du côlon a été étudiée par électromyographie durant 6 semaines chez 6 porcs, dont 2 atteints de mégacôlon, alimentés ad libitum ou en un repas unique. Chez les témoins et de 10 à 24 h après un repas quotidien, la motricité du caecum se traduit par l’apparition régulière, 4 à 5 fois par heure, de phases d’activité regroupant, en 4 mn environ, une dizaine de salves de potentiels. L’activité du côlon, étroitement liée à celle du caecum, présente des contractions rapidement propagées de l’iléon à l’ensemble du côlon ainsi que des contractions antipériostaltiques sur la partie proximale du côlon. L’ingestion d’un repas est suivie d’une réponse biphasique : l’une précoce, durant laquelle l’activité caecale est doublée pendant une heure, et l’autre tardive survenant après un délai de 4 à 6 h pendant 6 à 8 heures. Les variations de l’osmolarité et non celles du pH du contenu caecal induisent une hypercinésie permanente du caecum, accompagnée ou non de diarrhée. Le mégacôlon secondaire lié à un rétrécissement congénital de l’anus est caractérisé par un épaississement des couches de fibres musculaires sans réduction du nombre de plexus myentériques ; sur le plan fonctionnel, la motricité caeco-colique est régulière même dans le cas d’un repas quotidien, les réponses postprandiales étant inexistantes.

Introduction

In man and carnivores motility of the colon is characterized by contractile waves unpropagated or propagated over small distances, antiperistaltic contractions on the proximal part and very rare rush movements aborally propagated towards the rectum. Eating increases activity in the colon by way of the gastro-colic reflex (Tansy, Kendall and Murphy, 1972) and caecum filling is directly linked to the passage of ingesta through the terminal ileon which depends upon the amount of food intake and feeding patterns (Ruckebusch et Bueno, 1975). Among other factors which stimulate colonic motility increase in osmotic pressure as well as a decrease in pH may be operative factors of diarrhoea (Fordtran, 1967). Both in man in the case of Hirschsprung’s disease (Ehrenpreis, 1971) and mice (Beilschowsky and Schofield, 1962) megacolon
has been considered as a consequence of motor disturbances subsequent to a low density of myenteric plexuses (Wood, 1973). In the pig, according to Senk (1975), rectal stricture may be at the origin of megacolon in nearly 2% of animals in intensive management.

The aim of the present study is to define the motor patterns of the large intestine in both normal pigs fed ad libitum on a standard diet and in subjects having rectal stricture. Modifications due to feeding and influence of caecal contents (osmolarity and pH) were investigated in the same animals when receiving a daily meal of the same standard diet.

Material and methods

Four Large White pigs, 5 months old and weighing about 50 kg were used as control for 2 pigs of 30 kg at 5 months showing a rectal stricture with subsequent megacolon. The pigs were housed in individual cages and were fed either ad libitum or received a single meal of the same standard diet at 8:30 or 16:00 each day for 2 weeks. The pigs received a diet of (g/kg) barley 700, wheatings 150 and fish meal 150, with tap water ad libitum. The mean intake was 30-40 g of dry matter/kg live weight per day ad libitum and limited to 20 g on daily meal. Pigs presenting a megacolon were capable of ingesting only 30% of this ration.

Motility of the terminal ileum, caecum and colon were studied by electromyography. Under thiopentone anaesthesia, stainless-steel electrodes were fixed in groups of three, 2 mm apart, on the terminal ileum, the caecum, the centripetal and centrifugal turns of ascending colon, transverse colon and descending colon (fig. 1); distances between electrode sites were determined post-mortem. A small catheter (5 mm int. dia.) was fixed on the apex of the caecum thus allowing infusion and/or sampling of caecal contents. A cannula (30 mm int. dia.) was inserted in the descending part of the colon 50 cm oral the rectum and exteriorized on the left side in one of the pigs with megacolon to facilitate the expulsion of digestive contents.

From 10 days after surgery, electrical activity was recorded for a period of 6 weeks, using a twelve-channel, «direct writing» polygraph (Reega XII, Alvar electronic, 93 - Montreuil) at a recording speed of 2.5 mm/sec and 4.5 cm/min. Concurrent summation of the electrical activity from two electrode sites at 20-sec intervals was obtained by a double linear integrator circuit (Latour, 1973) connected to a potentiometric recorder.

Osmolarity of caecal contents was measured by cryoscopy (Advanced Instruments Osmometer) before and during an infusion into the caecum of D-mannitol (100, 200, 300, ... 800 mOsm/l), NaCl (800 mOsm/l) and NaCl + Mannitol (800 mOsm/l) at a rate of 8 ml/min during 2 hours. Changes in caecal pH were similarly induced using an hydrochloric acid of buffered citrate solution (pH 2 or 4) adjusted at 300 mOsm/l by D-mannitol.

Histological examinations of the colonic wall were carried out at the end of the experiment by examination of the thickness of the muscular layers and mucosae on fixed sections. Auerbach plexuses were identified and numbered by their level of cholinesterasic activity using the Koelle and Friedenwald method (1949).
Results

1. — Basic motility patterns

From 10 to 24 h after a daily meal, the electrical activity recorded from different sites of the caeco-colic segments was limited to rapid potential changes occurring as bursts of spikes either isolated or in series. In the entire caecum, bursts of spikes of about 7 sec in duration were recorded at a rate of 2.9 per min in phases lasting 4 min and occurring at a mean frequency of 4 per hour (table 1). In fact, caecal activity was linked to the activity of the terminal ileum: the number of activity phases was increased by 30 % every 70-90 min when a myoelectric complex migrates towards the ileo-caecal junction and decreased when the ileum is quiescent.

In the ascending colon, phases of activity were associated with those of the caecum but lasted from 6 to 9 min. Their intervals were interspersed with short bursts of spiking activity so that the total spiking activity reached 40 % of the recording time. Whatever the site on the ascending colon, numerous spike bursts of a phase of activity seemed unpropagated between consecutive turns. However propagated activity at a speed of 5 to 10 cm/sec might be distinguished, more often in an oral-aboral direction on the centripetal turns and in aboral-oral direction on the centrifugal turns of the colon. Antiperistaltic activity also occurred without any particular hour-to-hour variations (fig. 2).

The activity of the descending colon resembled that of the proximal colon except that the spike bursts might last from 5 to 30 sec and that the percentage of total recording time was slightly higher. Summation of spiking activity at 20-sec intervals showed a clear cyclic distribution of the phases of motility for the caecum and disappearance of the phases of quiescence on the colon, especially its distal part (fig. 2).

In addition to this motor profile, a few fused bursts of spike potentials of high amplitude (250 to 300 μV) were seen propagated along the entire caeco-colonic segment in less than one minute every 30 to 45 minutes. This activity which resembles the propulsive or mass movements already described in man started on the terminal ileum at the occurrence of the phase of irregular activity of a myoelectric complex at this level.

2. — Postprandial patterns

When receiving one daily meal caecal activity was nearly doubled at the time of eating (6.8 versus 4.1/h) during 1 hour and increased 5 to 6 h after feeding for about 6 hours. A similar response was observed if the meal was given at 8:30 instead of 16:00 (fig. 3). In some instances the early and late responses to feeding were not separated by a phase of lower activity so that a postprandial increased activity was recorded continuously during nearly 10 hours. Propagated spike bursts were increased by 30 and 80 % during respectively the early and late responses to feeding.

When fed ad libitum, the daily amount of food intake was divided into 12.4 ± 2.6 meals. Caecal spiking activity was continuously higher than when receiving only one daily meal. The high level of spiking activity was obtained by a strong increase in the number of their phases from 4 to 10-11/h and despite their decrease in duration from 4 to 2 or 3 min.
Fig. 2. — Cæco-colonic motility. The direct record shows a series of spike bursts of the cæcum and an antiperistaltic sequence (\(\swarrow\)) in the proximal colon. Summing the potentials (integrated record) shows that the phases of spiking activity are more individualized for the cæcum than for the distal colon.
Similar relationships were recorded on different parts of the colon, especially the distal colon for which the percentage of spiking activity was nearly 60% of the recording time when fed ad libitum instead of 40% for a daily meal.

3. **Influence of osmotic pressure and pH**

The osmolarity and the pH of the caecal contents were respectively 321 ± 12 mOsm/l and 6.81 ± 0.41 (n = 90) for 16 h after a meal. Increased osmolarity by infusion at a rate of 8 ml/min of D-mannitol (600 mOsm/l) measurements performed in 4 normal subjects was accompanied by complete disorganization of the motor profile when the caecal osmolarity reached 470 mOsm/l. A similar effect was obtained by reduction of the caecal osmolarity to 170 mOsm/l using infusion of D-mannitol at 100 mOsm/l. In both cases, bursts of spike potentials occurred randomly thus obliterating phases of quiescence (fig. 4).

No relationships were found between the duration of disorganization and osmotic pressures of the infused solutions or caecal contents. The effect was maximal for an osmolarity of the caecal contents above 500 mOsm/l and, for the same osmolarity, reduced when D-mannitol was entirely or partially replaced by NaCl (table 2). The continuous spiking activity induced by the infusion of hypertonic D-mannitol or NaCl (700 and 800 mOsm/l) was accompanied by a diarrhoea occurring in 90 min and persisting during 2 to 4 hours.

No changes in the motility were observed after infusion of buffered citrate of D-mannitol at pH 4 despite in some instances emission of liquid faeces. Infusion of D-mannitol at 300 mOsm/l in the same conditions induced neither disorganization nor diarrhoea.

4. **Disturbances linked to the presence of rectal stricture**

In the two pigs, extreme narrowing of the rectum and abdominal distension were characteristics. At opening the abdomen for

![Fig. 3. — Influence of feeding pattern on spiking activity of the caecum. Phases of activity are given for 3 consecutive days in four pigs fed ad libitum (C) or receiving a daily meal at 16:00 (G). The mean values are indicated in brackets.](image)

![Fig. 4. — Effect of an increased osmolarity of the caecal contents on motility. Continuous spiking activity was induced by an infusion of 1 l of D-mannitol at 800 mOsm/l in 120 min which increased the osmolarity of the contents from 325 to 510 mOsm.](image)
Fig. 6. — Caeco-colonic motility in a pig with megacolon. (Electrode sites as in fig. 2.) Regular phases of activity lasting 2-3 min were recorded in the musculature of descending colon (direct record). Subsequently integrated record on the colonic spiking activity resembled that of the caecum.
electrodes implantation, the large intestine was dilated by gas except the distal colon where the wall was thickened and the lumen narrowed.

Histological examination confirmed the increased thickness of the different muscle layers of the middle and distal parts of the colon, especially for the circular muscular layers beyond the 5th centripetal turn of the colon (fig. 5). However the number of Auerbach’s myenteric plexuses remained the same as in controls (56 ± 7 per cm²).

Three major differences were observed in the pigs with a megacolon:

(i) the daily food intake ad libitum was reduced by 30 % when compared to normal pigs and faeces were liquid (5 % dry matter);

(ii) the phases of caecal spiking activity were both shortened and increased in frequency but duration and frequency of spike bursts were unchanged (table 1). Spike bursts occurred in phases on the colon as on the caecum so that the integrated record of a megacolon resembled that of the caecum (fig. 6). Activity of the whole colon was increased and the phenomenon was emphasized for the distal colon which exhibited cyclically periods of continuous activity lasting 2-4 minutes.

(iii) by contrast, with control pigs, the act of feeding was not followed by either an early or late response of the colon. Opening the cannula on the distal colon during 24 or 48 h allowing a continuous outflow of digestive contents only induced changes of the motor profile which consisted of a decreased frequency by 20 % of the phases of activity of the caecum and colon accompanied by a 85 % increase of the daily food intake.

**Discussion**

The large intestine is primarily a collection point for the intestinal stream which periodically transports the contents from the proximal (ascending) to the distal (descending colon). Its normal motor pattern is characterized in pigs by periods of activity and inactivity well individualized namely on its proximal part, i.e. the caecum and ascending colon. The essential role of this activity

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**TABLE 2**: Influence of osmotic pressure of the caecal contents on caecal motility. Mean ± SD values for 2 perfusions in 4 pigs.

<table>
<thead>
<tr>
<th>Infusion</th>
<th>Osmolarity (mOsm/l)</th>
<th>Final osmolarity (mOsm/l) or pH</th>
<th>Duration of increased motility (min)</th>
<th>Diarrhoea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demineralized water</td>
<td>0</td>
<td>78.00 ± 4.0</td>
<td>82 ± 11</td>
<td>0</td>
</tr>
<tr>
<td>D-mannitol</td>
<td>300</td>
<td>320.00 ± 12.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>471.00 ± 19.0</td>
<td>95 ± 9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>510.00 ± 20.0</td>
<td>173 ± 23</td>
<td>+</td>
</tr>
<tr>
<td>NaCl</td>
<td>800</td>
<td>508.00 ± 31.0</td>
<td>103 ± 13</td>
<td>+</td>
</tr>
<tr>
<td>Citrate buffer (pH 4)</td>
<td>300</td>
<td>5.04 ± 0.2</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Mannitol + HCl (pH 4)</td>
<td>300</td>
<td>6.87 ± 0.4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Fig. 5. — Wall thickness of the large intestine.** The wall of the entire colon is thickened four fold beyond the 5th centrifugal turn of its proximal part.
seemed to assure mixing and low aboral progression of the contents, since the colonic transit time averages about 35 hours according to Ishikawa and Sugimura (1972) and Keys and De Barthe (1974).

Propagation of both peristaltic and antiperistaltic contractions are always limited to a short distance not exceeding 2 or 3 turns of colon and may thus be considered as only propelling slightly the contents. By contrast, the propagation of fused spike bursts from the terminal ileum along the colon is comparable to those already observed in the rabbit by Fioramonti and Ruckebusch (1974) or the gross movements which are induced by eating in man (Holdstock et al., 1970).

A striking feature indicated by the recordings is the biphasic response of the large intestine to feeding. The early phase corresponds to the gastrocolic reflex described in dog as under a neural control mechanism by Tansy, Kendall and Murphy (1972). By contrast, the late response occurred when the digestive contents are propelled through the ileo-caecal junction, i.e. about 6 hours after the meal. This is in accordance with the fact that ileal quiescence which corresponds to a lack of transit (Bueno, Fioramonti and Ruckebusch, 1975) is followed by increased inactivity of the colon. However, it is noticeable that the caecum acts as a reservoir thus dampening any variation in the ileal contents. For example, when fed *ad libitum*, 80% of the amount of food is taken between 8:00 and 12:00 (Ruckebusch and Bueno, 1976) but such circadian variations are not reflected at the colonic level. Possibly for the same reason, only acute changes in osmotic pressure or acidity were capable of inducing variations in motility.

The clinical signs of two pigs with megacolon were similar to those described in rectal stricture by Lillie, Olander and Gallina (1973). The subsequent morphological changes in wall thickness seemed to be of mechanical origin resembling that observed after chronic occlusion. The major consequence of such a situation is an increased activity of the whole colon and the lack of response to feeding (gastro-colic reflex) might be obliterated by such a permanent hyperactivity. Finally, the influence on the motility of distension by contents is well demonstrated by the decreased caecal activity following the expulsion of contents through the open colonic cannula.

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**Summary**

Motility of the large intestine was investigated electromyographically in 6 pigs, 4 were normal and 2 presented a megacolon. The pigs were fed once daily or *ad libitum* a standard diet. Electrodes were fixed at different sites of the caecum and the ascending, transverse and descending colon and the electrical activity was continuously recorded during 4 to 6 weeks.

In pigs from 10 to 24 h after a daily meal, activity of the caecum was observed as bursts of spike potentials lasting 5-7 sec in phases of 4 min in duration. The mean frequency of these phases was 4 per hour. The colonic activity also showed series of bursts but some originating from the terminal ileum were propagated through the whole colon; in addition, antiperistaltic contractions were recorded on the proximal part of the colon. Feeding was followed by an early response lasting about one hour during which spiking activity was doubled. A late response of 6 to 8 hr in duration was present beginning 4 to 6 hr after the meal was started. Changes of the osmolarity of caecal contents but not of pH were able to produce hypermotility with diarrhoea.

Megacolon subsequent to a hereditary anal stricture was accompanied by thicker muscular layers of descending colon without changes in the density of the myenteric plexuses. Spiking activity of distal colon was continuous during periods lasting 2-4 min. Responses of the whole colon to feeding were damped.
References


