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Colonic Myoelectrical Activity and Propulsion in the Dog

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Electrical spike activity was recorded on the colon of the dog. The duration of the bursts of the spike was used to divide the spike activity into two different types: long and short spike bursts (LSB and SSB). LSBs lasted from 7 (ascending) to 37 sec (descending) and SSBs lasted about 1 sec, independent of the site. These measurements were applied to colons of colostomized dogs for which the colonic transit time was negatively correlated to the LSBs expressed as percent of the time. The effects of high- and low-residue diets were tested. Intake of large amounts of dry food was associated with an increase of the LSB activity. A meat diet was accompanied with an increase of the SSB activity. These results suggest a propulsive effect for the LSBs stimulated by large amounts of colonic contents while the SSB activity may reflect some degree of emptiness.

Most of electromyographic studies of the colon concerned recording of slow waves and their analysis. These slow waves are labile and occur at a frequency of 5–8 cycles min in the conscious dog (1–3). Modifications of slow-wave frequency in the recto-sigmoid were recently reported in humans suffering from an “irritable bowel syndrome” (4). *In vitro* studies have also provided evidence for disturbances of the slow-wave propagation in the case of idiopathic or laxative-induced diarrhea (5).

But the colonic electromyogram exhibits also spike activity. Two kinds of spike activity, long and short spike bursts, were recorded in humans (6) and others species including the dog (7, 8). Modifications of their patterns were described in some cases of diarrhea and constipation (6).

The large-bowel disturbances were chiefly investigated from manometric records (9) and transit time measurements (10). More precisely, no relationships between the myoelectrical activity and the transit time of digesta have been established for the

large bowel as they were for the small intestine (11, 12).

The following experiments were undertaken, first, to describe the pattern of colonic electrical spike activity in normal and colostomized dogs; second, to correlate the pattern and the colonic transit time in colostomized dogs; and third, to evaluate the modifications of the pattern in modified fecal outputs. The fecal output was, respectively, increased and reduced by giving large amounts of dry food and a low-residue diet (bovine meat).

MATERIALS AND METHODS

Ten female mongrel dogs (14–18 kg), placed in spacious cages and accustomed to receive one daily meal at 1800 hr of 400 g of canned food (Fido, France) were used. In four animals, a colostomy was performed in the low abdominal region, the colon being sectioned at 9–10 cm orad to the rectum; these dogs were fitted with a chronic catheter inserted in the colonic lumen at 2 cm from the ileocolonic junction.

Bipolar intraparietal electrodes made of insulated Ni/Cr wire (13) were positioned in the 10 dogs on the ileum at 10 cm from the ileocolonic junction, on the ascending, descending, and transverse colon at 5, 10, 15, 20, and 25 cm from the ileocolonic junction, respectively. The last electrode site was located at about 5 cm from the stomy in the colostomized dogs.

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Fig 1. Electromyogram of the colon in a 12-hr fasted intact dog for five electrode sites at 5, 10, 15, 20, and 25 cm from the ileocolonic junction. Long spike bursts (LSB) of about 7 sec duration on the ascending colon and more than 30 sec on the descending colon occurred at 15 to 20-min intervals in series lasting from 5 min on the ascending colon to 12 min on the descending colon. Short spike bursts (SSB) of about 1 sec in duration appeared in series localized at one of the electrode sites.

Recordings of colonic electrical activity on an EEG machine (Reega VIII, Alvar, Paris) with a time constant of 0.1 sec, began 10 days after surgery and continued periodically between 800 and 1800 hr for 8–12 weeks. Electromyogram analysis consisted of the determination by visual inspection of the percentage of recording time occupied by long and short spike bursts (LSB and SSB), respectively, in each dog, for three consecutive recording sessions, each lasting 10 hr. According to data collected in humans and pigs (6, 7), bursts of spikes lasting more than 3 sec were classified as LSB and those lasting less than 3 sec as SSB. The recording time occupied by the spike activity was determined using a curvimeter, by summation of the duration of each individual burst for the LSBs and of the duration of periods during which the SSB activity was not disrupted for more than 10 sec. The electrode sites at 5, 10, and 25 cm from the ileocolonic junction were selected as references for the ascending, transverse, and descending colonic activities. A χ^2 Pearson test was performed in each group of dogs (intacts and colostomized) from the total 30 hr of recordings; values are provided as means $\pm$ standard deviation for the two groups of dogs.

Diet. For two weeks, the 6 intact dogs received a standard regimen of 400 g/day of canned food (Fido: dry matter 21.7%, protein 7.7%, fat 4.5%, carbohydrates 6.8%, minerals 2.6%). Then, during a period of two weeks, the diet consisted of a large amount (500 g/day) of dry dog food (Royal Canin: dry matter 88%, protein 20%, fat 6%, carbohydrates 55.5%, minerals 6.5%); four of the dogs accepted the full ration offered and produced for periods of 2–4 days abundant and soft feces. During a third period of two weeks, only bovine meat (300 g/day) was offered; three of the dogs produced scarce and hard stools during periods of 3–6 days. In all dogs, the daily fecal output and the stool dry matter were measured. However, only the results of dogs presenting a difference in the daily weight

of stools of at least 30% from that observed with the standard diet during 3 successive days were taken into account.

Transit Time. In the 4 colostomized dogs receiving the standard diet, the transit time was measured at intervals of 3 days during EMG recording sessions using phenol red as inert marker. A single bolus (1 ml containing 10 mg phenol red) was rapidly injected through the catheter 10 min after the occurrence of a phase of regular spiking activity on the ileal electrode site, that is, in the absence of any major change of the ileal flow of digesta (11). Feces flowing through the colostomy were continuously collected, and their time of appearance after the bolus injection was noted. The concentration of phenol red was determined by a colorimetric method in each sample of feces eliminated at the fistula. The transit time of the bolus was calculated from the time at which feces containing the maximal concentration of phenol red had been collected, as previously described for the small intestine (11). The results were plotted as a percentage of LSB and SSB, and the electrical activity was recorded during each of the 38 measurements of transit time.

Results

Patterns of Myoelectrical Activity of Canine Colon.

In the intact dog fasted for 14 hr, long and short spike bursts were recorded in all parts of the colon (Figure 1). Long spike bursts had a mean duration of 6.9 ± 3.1 sec on the ascending colon at 2 and 5 cm from the ileocolonic junction, where they appeared at a frequency similar to that of the slow waves but without evident temporal relationships. The duration of LSB was longer on the transverse colon (14.3 ± 3.7 sec) and lasted 37 ± 9 sec on the

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TABLE 1. CHARACTERISTICS OF ELECTRICAL SPIKING ACTIVITY OF ASCENDING (ASC), TRANSVERSE (TRANS), AND DESCENDING (DESC) COLON IN INTACT AND COLOSTOMIZED DOGS*

	Intact Dogs (N = 6)			Colostomized dogs (N = 4)		
	Asc.	Trans.	Desc.	Asc.	Trans.	Desc.
Total spiking activity†	18.3 ± 5.4	41.5† ± 8.6	47.6‡ ± 11.9	18.7 ± 4.9	39.0 ± 7.1	40.1 ± 6.0
Long spike bursts†	12.5 ± 7.8	20.5 ± 7.7	22.9‡ ± 5.5	15.4 ± 4.2	28.3 ± 7.0	31.7§ ± 6.6
Mean duration of periods (min)	4.9 ± 2.0	7.4 ± 3.8	12.7‡ ± 5.0	4.3 ± 3.1	6.9 ± 2.4	8.9 ± 5.2
Recurring intervals (min)		28.4 ± 9.0			26.5 ± 5.2	
Short spike bursts†	5.8 ± 2.1	11.0 ± 4.4	24.7‡ ± 6.9	3.3 ± 1.4	10.7 ± 5.1	8.4§ ± 3.4

*Mean values ± SD for three recording sessions of 10 hr in each dog starting 14 hr after receiving canned food.

†As a percentage of the recording time.

‡Significantly different from ascending colon, $P < 0.01$.

§Significantly different from intact dogs, $P < 0.01$.

descending colon at 25 cm from the ileocolonic junction. The propagation of 20–40% of the LSBs in aboral direction at a speed of 2.4 ± 0.5 mm/sec was clearly observed between two electrode sites at less than 5-cm intervals. The LSBs were grouped in periods lasting 4.9 ± 2.0 min on the ascending colon at 2 cm from the junction; the duration of these periods increased progressively along the colon and reached 12.7 ± 5.0 min on the descending colon at 25 cm from the junction. These periods of LSB activity recur cyclically at intervals of 28.4 ± 9.0 min

on all parts of the colon and occupied, respectively, 12.5, 20.5, and 22.9% of the recording time on the ascending, transverse, and descending colon (Table 1).

Short spike bursts lasted 1.0 ± 0.3 sec and also occurred in more or less regular series for periods of 10–25 min without cyclic organization. These periods occurred independently from the LSB phases, and no evident propagation of an SSB between two electrode sites 5 cm apart was observed. Of all the spike activities in the distal parts of the colon, SSB

Fig 2. Relationships between the colonic transit time determined by PSP elimination curves and the percentage of the recording time of long spike bursts (LSB) in 4 colostomized dogs. Each value corresponded to a single experiment performed in one of the dogs designated by individual symbols.

TABLE 2. RELATIONSHIPS BETWEEN ELECTRICAL SPIKING ACTIVITY OF TRANSVERSE COLON AND FECAL OUTPUT IN INTACT DOGS*

	Canned food (N = 6)	Dry dog food (N = 4)	Meat (N = 3)
Myoelectrical activity (% of recording time)			
Total spiking activity	39.0 ± 7.1	51.7 ± 8.2†	51.1 ± 3.9†
Long spike bursts	28.3 ± 7.0	47.6 ± 11.0†	9.5 ± 6.2†
Short spike bursts	10.7 ± 5.1	4.1 ± 0.9†	41.6 ± 9.0†
LSB/SSB ratio	2.6	11.6	0.2
Fecal output during recording periods			
Stool consistency	Solid	Soft	Hard
Weight of stools			
daily amount (g)	92.6 ± 26.1	183.4 ± 42.2†	30.3 ± 9.2†
Dry matter	21.0 ± 2.4	11.4 ± 1.6†	32.6 ± 4.4†

*Mean values ± SD for 3 recording sessions of 10 hr in each dog, starting 14 hr after receiving canned food, dry dog food, or meat.

†Significantly different from canned food, $P < 0.01$.

activity was the predominant kind occupying $24.7 \pm 6.9\%$ of the recording time vs 5.8 ± 2.1 and $11.0 \pm 4.4\%$ on the ascending and transverse colon, respectively.

Effects of Colostomy. The myoelectrical activity of the colostomized dog differed only on two points from that observed in the intact dog. First, the LSB activity was greater on the distal part of the colon and the periods of LSB recurred more regularly on the descending colon as indicated by the low standard deviation shown in Table 1. Second, the descending colons of colostomized dogs had 65% less SSB activity (Table 1).

Patterns of Myoelectrical Activity Associated with Colonic Propulsion. Direct observation showed that the flow of colonic contents through the colostomy was intermittent, as small gushes of 5–17 g followed the development on the whole colon of a period of LSB activity. When a bolus of phenol red was injected into the proximal colon, the first colored feces appeared through the colostomy after about 60 min, ie, after the development of 2–3 periods of LSB activity. Peaks of maximal concentration of the marker were recorded between 60 and 300 min after its injection, corresponding to 2–14 periods of LSB activity. These fluctuations of the transit time in colostomized dog were significantly correlated to variations in the occurrence of LSB activity expressed as a percentage of the recording time (Figure 2). By contrast, the changes in the presence of SSB activity were not significantly related to the different variations of the transit time.

Effects of Diet. The onset of abundant and watery stools (11% dry matter vs 21%) occurred within 48 hr in the 4 dogs which ingested all the dry food offered (440 g dry matter). The daily amount of stools,

which was nearly doubled, averaged 183 ± 42 vs 92.0 ± 26.1 g for canned food (87 g dry matter). This phenomenon was accompanied by a 23% increase of the total electrical spiking activity (Table 2). The LSB activity represented about 90% of this activity (Figure 3) at the expense of the SSB activity, so that the LSB/SSB ratio reached 11.6 vs 2.6 for canned food.

A reduced daily fecal output and hard feces (30.3 ± 9.2 g) appeared after 2–4 days and during 10–12 days in 3 of the 6 dogs offered 300 g of meat once a day. During this period, the total electrical spiking activity was increased by 23%. The SSB activity represented 82% of this activity at the expense of LSB activity. This pattern occupied less than 10% of the recording time so that the LSB/SSB ratio diminished to 0.2 vs 2.6 for canned food. The last panel in Figure 3 shows the continuous uniform pattern in SSB activity. There was no apparent tendency of propagation from one electrode site to another.

DISCUSSION

The present study demonstrates the existence in dogs, as in humans (6) and pigs (7), of two major patterns of colonic spike bursts: LSB and SSB, and the relationships between LSB activity and propulsion of the large-bowel contents. In dogs, the LSBs are grouped in series recurring cyclically at 30-min intervals and seemed propagated down along the colon as the “migrating spike bursts” in the cat (14). Like the migrating spike bursts of the cat colon *in vitro* (14), the LSBs observed *in vivo* in the dog are unrelated to the slow waves, despite their similar rate on the proximal colon only. The periods of LSB activity were similar in frequency and duration

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Fig 3. Patterns of colonic myoelectrical activity recorded from three electrode sites on the ascending, descending and transverse colon at, respectively 5, 25, and 15 cm from the ileocolonic junction, in a dog receiving canned food (400 g), a large amount (500 g) of dry cereal-rich food, or only meat (300 g). The values in parentheses indicate the fecal output and the dry matter (DM) of the feces measured on the day of the record presented.

to the phases of high colonic pressure recorded in both proximal and distal canine colon by Adler and Templeton 40 years ago and associated with propulsion of the large-bowel contents (15). Their presumed electrical equivalent (the periods of LSB activity) were found here to be negatively correlated with transit time. These results are in agreement with those obtained in pigs for which a decrease of the dietary fiber was associated with a lengthened transit time and a reduced number of LSBs (7).

Another point to be mentioned is that the total electrical spiking activity was increased in both low and high fecal output induced by dietary changes. Watery stools were obtained in dogs which ingested large amounts of dry dog food. The increase in colonic electrical spiking activity is mainly that of LSB activity involved in the propulsion of a large amount of stools. However, such effects are not in accordance with the low-amplitude pressure waves

(9) and the reduced spiking activity of the distal colon (6) observed in chronic diarrhea in man. They must therefore be considered in carnivores like dogs as the result of unusual feeding habits.

By contrast, the increase in SSB activity associated with the reduction of the fecal output and the production of hard feces induced by meat is similar to that observed in the human spastic colon which is associated with localized high pressures (9). This similarity suggests that the pathological records obtained in constipated patients may be only a consequence of the abnormal fecal output or colonic propulsion. Accordingly, the SSB activity may be associated with the production of hard feces as well as the consequence of colonic vacuity linked to a low-residue diet.

Finally, the total electrical activity of the colon was not an index of the colonic motor changes since it was greater with both low and high fecal output.

By contrast, the LSB/SSB ratio reflects the volume of fecal output, the presence of LSBs being enhanced for an increased amount of soft feces whereas SSB activity predominates in the case of scarce and hard feces.

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