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INTESTINAL MOTOR AND TRANSIT DISTURBANCES ASSOCIATED WITH EXPERIMENTAL COCCIDIOSIS (EIMERIA MAGNA) IN THE RABBIT

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PERTURBATIONS DE LA MOTRICITÉ INTESTINALE, DU DÉBIT ET DU TRANSIT DES DIGESTA CHEZ LE LAPIN INFESTÉ PAR EIMERIA MAGNA. — La motricité digestive, a été analysée pendant six jours précédant et 18 jours suivant une infestation par 100 000 oocystes d’E. magna chez trois lapins munis d’électrodes intrapariétales chroniques. Le débit et le transit des digesta ont été déterminés au niveau de l’intestin grêle distal pendant la même période à l’aide de techniques de dilution de traceur chez trois autres sujets munis d’un cathéter intraluminal et d’une canule respectivement à 1,2 et 0,4 m en amont de la valvule iléo-caecale. Les principales perturbations de la motricité de l’intestin grêle se traduisent par une désorganisation du profil moteur à partir du 4e-5e jour suivant l’infestation et une profonde inhibition les 8e-9e jours. La motricité gastrique est inhibée du 4e au 8e jour alors que la fréquence des contractions caecales est accrue les 8e-9e jours. Une augmentation du débit des digesta apparaît les 8e et 9e jours avec chez deux sujets un ralentissement concomitant du transit et chez un sujet une accélération. Hypomotricité intestinale et augmentation du débit des digesta semblent constituer les deux perturbations primaires dont les conséquences se traduisent au niveau de la motricité gastrique et caecale ainsi qu’au niveau du transit des digesta.

Diarrhoea is the most common symptom of coccidiosis in various mammals but its extent is very variable, and mainly depends upon the coccidia species (Davis et al., 1963). In the young rabbit this pathological state is accompanied by a reduced rate of weight gain and a decrease in food intake (Weisbroth et al., 1974; Coudert et al.; 1976, Licois et al., 1978a).

Recently, it has been shown that in experimental coccidiosis in the rabbit digestive disturbances consisted of an increase in the amount of water in digestive contents and changes in the rates of absorption of sodium and potassium at the site of coccidia implantation (Licois and Mongin, 1980). Yet, as far as we know, no information is available about the modifications of the digestive motility and the subsequent changes in the flow and transit of digesta in cases of diarrhoea associated with coccidiosis. Such modifications have already been described in various cases of diarrhoea in ruminants (Bueno et al., 1980) as well as in some cases digestive parasitism without faecal output disturbances (Bueno et al., 1981).
This work was undertaken to establish the modifications of the intestinal motility and of the transit of digesta after experimental infection with *Eimeria magna* in the young parasite-free rabbit.

This species of coccidia does not induce true diarrhoea in that there is no increased output of watery faeces; faecal output decreases as does faecal dry matter content (Licois and Coudert, 1976). Nevertheless, this coccidia, found only in the distal small intestine, was chosen for its short duration of clinical symptoms (seven days) and for the lack of mortality consistent with a chronic experiment.

The motor disturbances were investigated by electromyography for all the parts of the digestive tract whereas measurements of both flow and transit time were performed in the distal small intestine using marker dilution techniques.

**Materials and Methods**

**Animal preparation**

Six Fauve de Bourgogne rabbits seven weeks old at the beginning of the experiments were used. They came from a protected breeding station and were free from intestinal parasites. They received ad libitum concentrates free from anticoccidian agents (UAR 112) and the daily food intake and weight of animals were measured each morning.

In three animals, under halothane anaesthesia (Fluothane ND), ten groups of three insulated Ni/Cr electrodes (0.08 mm in diameter) were implanted in the wall of digestive tract according to Ruckebusch (1973). The electrodes were positioned on the stomach at 2 cm from the pylorus, on the small intestine at 0.1 m from the pylorus and at 0.4, 0.8 and 1.2 m from Treitz’s ligament. The last five groups of electrodes were placed at 0.2 and 0.5 m from the ileo-caecal valve, on the 10th coil of the caecum, on the proximal and distal colon at 0.2 m both sides of the fusus coli. The free ends of the electrodes were exteriorized at the back of the neck.

In three other rabbits the tip of an open catheter (external diameter : 2mm) was inserted in the lumen of the small intestine at 1.20 m from the ileo-caecal valve and exteriorized on the back of the neck. A silastic T-shaped cannula (external diameter : 8 mm) was placed 0.8 m aborally to the catheter and exteriorized in ventro-lateral position.

**Electromyographic records**

Recordings of the electrical activity on an eeg machine (Reega XII, Alvar, Paris) with a time constant of 0.1 sec began one week after surgery. In addition, the electrical activity of the duodenum, of the jejunum at 1.5 m from Treitz’s ligament, of the ileum at 0.5 m from the ileo-caecal valve and of the proximal colon was automatically plotted each 20 sec by means of a four-channel integrator on a potentiometric recorder (Latour, 1973).

**Measurement of flow of digesta and transit time**

Measurements of flow rate and transit time of digestive contents were performed in the three rabbits fitted with intestinal catheter and cannula using a marker dilution technique previously described (Bueno et al., 1975b). A test solution containing NaCl 140 mM, D-Mannitol 16.7 mM and 0.4 % w/v solution of polyethylene glycol (PEG, mol. wt. 4000) was infused through the catheter at a rate of 1 ml.min⁻¹. One hour after the beginning of infusion, samples of digestive contents were obtained from the cannula at 15 min intervals for 2 hours. After this, the infusion was continued and a bolus of phenolsulfonaphtaleine (PSP, 1 ml, 20 mg) was rapidly injected through the catheter and samples were taken at the cannula every 2 min for 1 h. The PEG concentration was determined by the method of Hyden (1955) and the flow rate of digesta (F) was calculated from the concentration of PEG in the test solution (C) and in the samples (c) and the rate of infusion (f) according to the following relationship : \[ F = f(C - c)/c. \] The PSP concentration was determined according to Smith (1964) and the transit time was calculated from the time at which the peak of PSP concentration was recorded (Barreiro et al., 1968).

**Experimental design**

After a 6 day control period all the rabbits were infected with 100 000 *Eimeria magna* oocysts by the oesophageal route. Intestinal motility flow of digesta and transit time were analysed during 18 days after infection.

Recordings of electrical activity were obtained each day between 8:00 and 18:00 h for the 24 days of the experiment. Integrated records
were performed 24 h per day throughout the whole experiment.

The flow of digesta and the transit time were determined every 2 days during the control period and for days 1-6 and 12-18 after infection. Flow and transit time were determined each day from the 6th to the 12th day after infection.

Results

Food intake, weight gain, faecal output

Disturbances of food intake, weight gain and faecal output appeared from the 4th to the 8th day after infection. The food intake decreased by about 50 % and the daily weight gain — 30 g/day during the control period — was reduced near zero and on the 5-6th day a weightloss of 10-20 g/day was observed. The faecal output was reduced from 90.4 ± 4.05 to 44.7 ± 3.5 g/day and the faecal dry matter from 50.7 ± 1.05 % to 39.3 ± 9.42 % (v/w).

Motor disturbances

Small intestine: in the rabbit fed ad libitum, electromyograms of the small intestine exhibited both slow-waves and bursts of spikes. On the duodenum, groups of 2-4 spike bursts appeared at a rate of 3.2 ± 0.4/min. Below Treitz's ligament, spike bursts were organized in migrating myoelectric complexes (MMC) which consisted of two phases: one of irregular spiking activity (ISA), very variable in duration (range 50-300 min), followed by a phase of regular spiking activity (RSA).

![Digestive electromyograms after infection by 10⁵ oocysts of E. magna in one rabbit. During the control period migrating myoelectrical complexes including a phase of regular spiking activity (R.S.A.) and a phase of irregular spiking activity (I.S.A.) are present on the small intestine. Five days after infection the frequency of gastric contractions was reduced and the activity of the jejuno-ileum was grouped in series of spike bursts. On the 9th day after infection motility of the small intestine was strongly inhibited and the frequency of caecal contractions had increased.](image-url)
The phases of RSA were propagated over the small intestine from near Treitz's ligament to the ileo-caecal valve. They lasted 4.8 ± 0.9 min and were propagated at a mean velocity of 12.0 ± 3.4 cm/min on the proximal jejunum; their duration increased progressively with the distance from the pylorus, reaching 10.3 ± 1.8 min in the ileum, while their velocity decreased (4.1 ± 1.7 cm/min). These MMC occurred at a mean rate of 5.7 ± 0.6/24 h and were separated by a period of quiescence lasting 9.6 ± 3.5 min.

Sometimes the motor profile was characterized by peristaltic bursts of spikes quickly propagated (10 cm/sec) over distances varying from 0.5 m to the total length of the small intestine.

Significant changes in the pattern of jejuno-ileal motility began on the 4-5th day after infection. The motor profile observed on the 5th day mainly consisted in a disruption of the MMC. Spiking activity only consisted of groups of 2-4 bursts of spikes appearing at 0.5-2 min intervals (fig. 1). This profile persisted without nycthemeral variations until the 8-9th day after infection.

From the 8-9th day to the 11-12th day after infection the spiking activity was strongly inhibited and only occasional bursts of spikes of low amplitude occurred irregularly (fig. 1). This inhibition was seen clearly on the integrated records (fig. 2) and lasted 3-4 days. Recovery of the normal pattern was rapid and, in the three rabbits, a pattern of intestinal motility identical to that observed in the control period was present by the 14th day after infection.

![Fig. 2. — Integrated electromyogram of the ileum. In the same rabbit the upper pannel shows a typical motor profile with a phase of regular spiking activity (R.S.A.). This profile is disorganized on the 5th day after infection and the intestinal motility is strongly inhibited on the 9th day.](image-url)
The duodenal motility was only slightly inhibited from the 4 to 6th day after infection, the frequency of the groups of spike bursts being reduced from 3.2 ± 0.4/min to 2.1 ± 0.4/min.

**Stomach and large bowel**: No slow-waves were detected in the antrum and the electromyogram consisted of bursts of spikes lasting about 3-5 sec occurring at a mean frequency of 3.5 ± 0.6/min, but this frequency varied from 0.5/min between the meals and 5/min during the meals. From the 4th to the 8th day after infection, i.e. during the period of decreased food intake, the mean frequency of antral contractions decreased from 3.5 ± 0.6/min to 2.6 ± 0.3/min with a minimum of 1.8 ± 0.1/min on the 5th day.

The electromyogram of the caecum consisted of spike bursts lasting about 3 sec occurring at mean frequency of 2.3 ± 0.3/min. Strong disturbances of the caecal motility appeared only on the 8th and 9th days after infection. The mean frequency of the contractions increased to 4.6 ± 1.25/min. Moreover the duration of spike bursts was nearly halved, the regular pattern of contractions was abolished and the spike bursts occurred in groups of 3 or 4 (fig. 1).

The electrical activity of the proximal colon was characterized by short spike bursts for 70 % of the time during hard faeces production; in the distal colon electrical activity consisted mainly of long spike bursts for 25 % of the time both in the control period and in the period of infection. The duration and the timing of the cyclic periods of inhibition of the proximal colon and of increased activity of the distal colon, which occur during production of soft faeces, remained unchanged after coccidia infection.

**Jejuno-ileal rate of flow and transit time of digesta**

During the control period the rate of flow of digesta in the intestinal segment 1.2-0.4 m from the ileo-caecal valve ranged between 0.2 and 0.4 ml/min. Until the 8th day after infection no modification of the flow of the digesta was observed. An increase of the flow appeared during the 8th and 9th day after infection; the flow reached about 2 ml/min in two rabbits and 5 ml/min in the third rabbit (fig. 3). After the 10th-12th day the rate of flow returned to the control values. Concomitantly, the transit time of marker through the 0.8 m jejuno-ileal segment changed. During the con-

![Fig. 3. — Rate of flow and transit time of digesta in a 0.8 m segment of distal small bowel. In three rabbits, the rate of flow is increased on the 8-9th days after infection. In rabbits 4 and 5 transit time is lengthened while it is shortened in rabbit 6 for which increase in rate of flow is higher.](image)
trol period and the first six days after infection, the mean transit time varied between 20 and 30 min. On the 8-9th days after infection, the transit time increased to 40-50 min in the two rabbits showing a moderate increase of the rate of flow of digesta, but decreased to less than 10 min in the rabbit showing the largest increase in rate of flow.

Discussion

The present study demonstrates that an experimental infection by *E. magna* in rabbit mainly induced an intestinal hypomotility with a disorganisation of the motor profile and an increase of the rate of flow through the small intestine.

Intestinal motor disturbances have already been supposed with the identification of ileal intussusception in rabbits extensively parasitized by *E. perforans* (Weisbroth and Scher, 1975; Ogunbiyi and Uche, 1981). Disorganisation of the MMC and hypomotility seems to be a common phenomenon in some digestive diseases. For example, a disorganisation was noticed after infection by *Trichostrongylus axei* in sheep (Bueno et al., 1975a) or in cases of bacterial overgrowth of the small intestine in humans (Vantrappen et al., 1977); hypomotility of the small intestine was observed in diarrhoeic calves (Bueno et al., 1980) or in cases of gastric ulcers in rats and dogs (Fioramonti and Bueno, 1980). Thus the motor disturbances observed are not specific to the rabbit coccidiosis. Moreover, the peculiar pattern of repetitive bursts of action potentials observed in anaesthetized rabbits infected by invasive strains of *Escherichia coli* (Burns et al., 1980) was not found in disturbances associated to *E. magna*.

In these experiments, coccidiosis induced a decrease in motility only at the site of coccidia development in the distal small intestine. In most other cases, diarrhoea decreases the motility of the entire small intestine (Bueno et al., 1980). Our observations do not support the hypothesis that hypomotility of the whole digestive tract is associated with diarrhoea in the rabbit, whatever the aetiology of the diarrhoea (Laplace, 1978).

The beginning of the observed disturbances (4-5th day after infection) corresponds to the beginning of symptoms (anorexia, decrease in weight gain) already described by Coudert et al. (1976) and to the schizogony of coccidia. The increase of the flow of digesta was observed later (8-9th day after infection) and corresponds to the changes in mineral metabolism described on the 8th day by Licois et al. (1978a, b). The large increase in the flow of digesta indicates that this period is characterized by a decrease in intestinal absorption and/or an increase in secretion. The variations in transit time may be explained by differences in the compliance of the intestine when submitted to an increase in flow associated with hypomotility: the reduction of the motility allowed the intestine to distend and slowed the transit while flow increased, presumably because of the greater volume of secretion and/or reduced absorption; if the intestinal wall is unable to distend any more, the increase in flow must be accompanied by a shortening of transit time, such as occurred in the third rabbit.

The hypermotility of the caecum may be a consequence of an increase in the volume of its contents; caecal hyperactivity, with the same pattern of contractions as in the infected rabbits, has been observed in sheep when the ileal flow is increased (Fioramonti and Ruckebusch, 1978). A striking feature in the rabbit is that the changes in ileal flow appeared after the disturbances of the faecal output, showing the capacity of the large bowel to absorb large amounts of fluid. Such a colonic reabsorption has already been observed in rabbits infected by *E. intestinalis* or *E. flavescens*. (Licois and Mongin, 1980).

Gastric hypomotility can be a consequence of small intestine disturbances. It has been demonstrated in the rat that injuries to the small intestine mucosa induce an inhibition of gastric emptying which is probably nerve-mediated (Kent et al., 1975). However, why the small intestine disturbances were prolonged compared to those of the stomach remains unclear. Gastric hypomotility and anorexia occurred simultaneously and this fact suggests that the cause of the decrease in food intake was the gastric stasis.

Finally, it can be concluded that *E. magna*, a coccidia localised to the distal small intestine, induced primary disturbances of small intestine motility and flow of digesta. Disturbances of gastric and caecal motility and of the intestinal transit time can be considered as a consequence of the primary dysfunction of the small intestine.

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Summary

Digestive motility has been analyzed in three rabbits chronically fitted with intraparietal electrodes, during 6 days before and 18 days after infection with 100,000 oocysts of *E. magna*. The rate of flow and the transit time of digesta in the small intestine were determined during the same period by marker dilution techniques in three other rabbits fitted with an intraluminal catheter and a cannula at respectively 1.2 and 0.4 m from the ileo-caecal valve. The main disturbances of small intestine motility consisted in a disorganization of the motor profile from the 4-5th day after infection and in a strong inhibition on the 8-9th days. Gastric motility was inhibited from the 4th to the 8th day while the frequency of caecal contractions increased on the 8-9th days. An increase of the rate of flow of digesta appeared on the 8-9th days with a concomitant increase of the transit time in two rabbits and a decrease of transit time in the third rabbit. Intestinal hypomotility and the increase of digesta flow seemed to be the two primary disturbances, the consequences of which were the changes in the gastric and caecal motility and in the transit time of digesta.

References


