Electrophysiological Study on the Effect of the Limbic System Stimulation on Intestinal Movement in Rabbits

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Abstract
Irritable bowel syndrome (IBS) is a disease characterized by increased intestinal movement with abdominal pain and changes in bowel habit (either diarrhea or constipation), the clinical expression of which seems to be easily influenced by mental factors such as stress or emotion. To clarify the relationship between intestinal movement and mental activity, we studied the effect of electrical stimulation of subcortical nuclei, especially the limbic system, on intestinal movement. We used the balloon method on the ascending colon of rabbits. Acceleration of intestinal movement was found with 3 Hz stimulation to the corticomedial division of the amygdaloid nucleus (c-AMYG) and cortex pyriformis, and 100 Hz stimulation to the basolateral division of the amygdaloid nucleus (b-AMYG) and caudate nucleus (CAU). The acceleration was found to be due to the tonic effect of parasympathetic nerves. On the other hand, inhibition of intestinal movement was found with 100 Hz stimulation to c-AMYG, 8 Hz stimulation to b-AMYG and 3 Hz stimulation to b-AMYG and CAU. Although the inhibitory impulses were demonstrated to pass through the splanchnic nerve, the existence of some degree of adrenal influence was suggested.

Introduction
Of the various complaints encountered in general practice, both constipation and diarrhea are very common. However, the pathophysiology of these conditions is complicated. Etiologically, organic abnormalities such as tumor or inflammatory constriction are sometimes present, while motor dysfunction of the gastrointestinal tract such as irritable bowel syndrome (IBS), which is being reported increasingly frequently, is found in some cases.

It has been established that gastrointestinal motility is very sensitive to stress stimulation. In 1947 Almy et al. found an attractive report showing that human gastrointestinal motility is influenced by stress loading. They found that in patients whose chief complaints were constipation and abdominal pain, intestinal segmenting movement was increased, while decreased overall intestinal movement was found in patients with diarrhea. Grace et al. found a close relationship between the patient's living environment and mental state on the one hand and the movement of the large intestine and secretory and hemodynamic functions on the other hand, which were said to be enhanced during episodes of anger or anxiety and diminished during episodes of fear, desperation, depression or resignation. A delicate but not objective relationship between the emotional state and gastrointestinal movement was suggested. Also, it was revealed that the emotional state was strongly related with the limbic system.

In the present study using rabbits, we recorded...
the changes in intestinal movement caused by the electrical stimulation of the following subcortical nuclei: amygdaloid nucleus (AMYG), cortex pyriformis (CPY), hippocampus (HPC), septal nucleus (SPM), caudate nucleus (CAU), putamen (PUT), and globus pallidus (GP). The former four nuclei belong to the limbic system, and the latter three to the basal ganglia. AMYG was further divided into two subdivisions: corticomedial division (c—AMYG) and basolateral division (b—AMYG). We also recorded the stimulus-induced changes in the cortical and hippocampal electroencephalogram (EEG) and electromyogram (EMG) of the fore- and hindlimbs. Thus the following experiments were performed to elucidate the relationship between the central nervous system and intestinal movement, especially the relationship between the limbic system and IBS.

Materials and Methods

1) Materials
Rabbits weighting between 1.6 to 2.3 kg each were used. Each rabbit was deprived of food from the day before the experiment. We used 5–9 rabbits for the same experiment as a group.

2) Preparation
After tracheostomy and cannulation, each rabbit was mounted in the prone position on a stereotaxic apparatus (Todai—Noken). The head was securely fixed so that the bregma was located 1.5 mm above the lambda. Both sides of the skull were drilled to make a hole about 10 mm in diameter. According to the brain atlas of Urban et al. depth electrodes were inserted through the hole into certain brain structures such as the limbic system and the basal ganglia. These depth electrodes were Cashewinsu-lated bipolar stainless steel electrodes 250 μ in diameter, which were used for either stimulation or recording.

3) Electrical stimulation of brain structures
Electrical stimulation was applied to several structures in the right side of the brain. Pulses of 1 msec in duration were delivered at a rate of 3, 8 or 100 Hz by an electronic stimulator (Nihon Koden, SEN—3101), and a train of pulses was presented through depth electrodes for 10 sec. The intensity of each stimulation ranged from 0.5 to 6.0 V. The sites of stimulation were verified by preparing tissue specimens after the experiment.

4) EEG and EMG recordings
The hippocampal EEG was recorded with bipolar depth electrodes from the contralateral side of the stimulation. For cortical EEG, two disk electrodes, each 10 mm in diameter, were secured symmetrically on both sides of the skull at the site rostral to the coronal suture. A circular disk electrode on an earlobe served as a ground.

The evoked muscular discharge was derived from both the forelimb flexor and hindlimb extensor muscles. Two disk electrodes of the same shape as the cortical electrodes were attached for bipolar derivation at a distance of about 1 cm. Both EEG and EMG were amplified by an electroencephalograph (Nihon Koden, ME—95D). The time constants for EEG and EMG were 0.3 sec and 0.05 sec respectively, and the high cut filter was 60 Hz and OFF, respectively.

5) Recording of intestinal movement
For the recording of intestinal movement, the balloon method was employed. First, the right abdominal area was extensively shaved and a longitudinal incision of about 4～5 cm was made. The ascending colon was exposed out of the incision and ligated at a position about 20 cm anal to the cecum. Then a small incision was made in the ascending colon about 3 cm caudal to the ligation and the intestinal contents in the region between the sites of ligation and incision were thoroughly removed.

A balloon was inserted from the incision down to the site of ligation, and the rubber tube connected to the balloon was ligated together with the caudal part of the ascending colon. The distance between the two ligated sites was kept at about 1.5 cm. The balloon, made of thin rubber film, was inflated by supplying a certain quantity of air from the rubber tube connected to the balloon so as to obtain an internal pressure of 20～30 mmHg, with the internal pressure of the balloon changing in response to the movement of this segment of the
intestine. Changes in pressure were converted to electrical signals with a transducer (Gould HB, P−50). Potentials were led to both a strain amplifier (Nihon Koden, RP−5) and an integrator (Nihon Koden, RFJ−5) and recorded with Medicalcorder (Nihon Koden, PMP−3004).

6) Vagotomy
For rabbits in the vagotomy group, the bilateral vagus nerves were cut right after the insertion of the tracheal cannula. The level of section was identical to the tracheal incision.

7) Splanchnicotomy and adrenalectomy
For rabbits in both the splanchnicotomy and adrenalectomy group, excision was performed before operating the balloon method. We employed Fukuhara's extraperitoneal exposure method.

8) Pharmacological study
Propranolol, a common β−blocker, was administered to a group of rabbits. A dosage of 0.3 mg/kg each was administered from an auricular vein three minutes before recording.

9) Evaluation of results
Both the EEG and EMG were evaluated by visual inspection. For quantitative analysis of intestinal movement, the number of peaks of the integrated wave in the pre− and post−stimulative 30 second periods were compared. Statistical analysis of the results was performed using one−way analysis of variance followed by Student's t−test. Values were expressed as means ± SD and the level of significance was defined as p<0.05.

Results
1. Effect of 3 Hz stimulation on the limbic system and basal ganglia. While a 3 Hz stimulation was applied to c−AMYG, spike and wave complex−like waves appeared in both the cortical and hippocampal EEG. Fig. 1−a shows a representative example. From the upper row, FC shows EEG derived from the frontal cortex, HPC shows EEG derived from the hippocampus, FEMG and HEMG show the EMG derived from the forelimb flexors and hindlimb extensors. INTEST MOV shows the changes in internal pressure of the balloon and INTEG shows the integrated wave of INTEST MOV. The underline shows the period of electrical stimulation. In this case, the amplitude of INTEST MOV increased soon after the stimulation, continuing for about 90 seconds. The number of peaks in the integrated wave also increased from 8.3 to 10.4 per 30 seconds. The same experiment was performed in 9 rabbits. Acceleration of intestinal movement was noted in all cases, with its duration ranging from 40 ~ 150 seconds. When a 3Hz stimulation was applied to other nuclei (b−AMYG, CPY, HPC, SPM, CAU, GP, PUT), spike and wave complex−like waves appeared in the EEG in the same manner as in c−AMYG. Fig. 2 shows the changes of intestinal movement induced by 3Hz stimulation to these nuclei. Five to nine rabbits were used in each group. A significant acceleration of intestinal movement was noted with stimulation to c−AMYG (24.6 ± 13.8%, p < 0.01), CPY (45.8 ± 8.0%, p < 0.01), while inhibition was seen with stimulation to b−AMYG (−13.6 ± 5.2%, p < 0.05), CAU (−19.1 ± 8.4%, p < 0.01). Stimulation of SPM caused slight acceleration or inhibition in some cases and no change in other cases, with no clear tendency noted. Stimulation of HPC, PUT and GP caused little change in intestinal movement.

2. Effect of 8 Hz stimulation
When the frequency of stimulation was changed to 8 Hz, recruiting response−like waves appeared in the cortical and hippocampal EEG in all cases. Stimulation of c−AMYG caused either inhibition or acceleration of intestinal movement. Fig. 1−b shows an example of inhibition. Fig. 2 shows the changes in intestinal movement induced by electrical stimulation to various nuclei. Stimulation of c−AMYG caused either inhibition or acceleration of intestinal movement. Fig. 1−b shows an example of inhibition. Fig. 2 shows the changes in intestinal movement induced by electrical stimulation to various nuclei. Stimulation of c−AMYG caused either inhibition or acceleration of intestinal movement. Fig. 1−c shows a representative example. In nine rabbits, c−AMYG stimulation was performed. In all cases, the amplitude of INTEST MOV decreased after sti
Fig. 1—a Effect of 3 Hz stimulation to c—AMYG on EEG, EMG and intestinal movement.
FC = EEG derived from frontal cortex
HPC = EEG derived from hippocampus
FEMG = EMG derived from forelimb flexor muscles
HEMG = EMG derived from hindlimb extensor muscles
INTEST. MOV. = intestinal movement (internal pressure of balloon)
INTEG = integrated wave of INTEST. MOV.

Fig. 1—b Effect of 8 Hz stimulation to c—AMYG on EEG, EMG and intestinal movement.
Fig. 1—c Effect of 100 Hz stimulation to c—AMYG on EEG, EMG and intestinal movement.

Fig. 2 Changes in intestinal movement induced by 3 Hz, 8 Hz and 100 Hz stimulation to various sites of the limbic system and basal ganglia. The ordinate indicates changes in the number of peaks of the integrated wave against the pre—stimulative value expressed as a percentage. The circles, triangles and squares indicate mean value, and vertical bars indicate standard deviation.

*P<0.05, **P<0.01 compared with pre—stimulative value.

mutation, continuing for about 25 – 60 seconds. Fig. 2 shows the changes in intestinal movement induced by 100 Hz stimulation to various nuclei. A significant inhibition of intestinal movement was noted with stimulation to c—AMYG (−32.2 ± 16%, p< 0.01). A significant acceleration was seen with stimulation to b—AMYG (14.4 ± 11.8%, p< 0.05), and CAU (25.4 ± 15.4%, p< 0.01). Stimulation to other nuclei caused no consistent changes.

4. Effect of Vagotomy

After the bilateral vagus nerves were cut in five rabbits, the same experiment was performed. The site of electrical stimulation was c—AMYG, CPY or CAU. Fig. 3 shows the changes in intestinal movement in the same manner as in Fig. 2. The data were compared with those of a group not subjected to vagotomy. With 3 Hz stimulation to c—AMYG, CPY and 100 Hz stimulation to CAU, the acceleration effect, which was found when vagotomy was not performed, almost disappeared in the vagotomy group. On the other hand, the inhibitory effect, which was seen with 100 Hz stimulation to c—AMYG and 3 Hz stimulation to CAU in the non—vagotomy group, persisted in the vagotomy group.

5. Effect of Adrenalectomy

The effect of adrenalectomy on the inhibition of intestinal movement was examined. In five rabbits the same experiment was performed after adrenalectomy. Fig. 4 shows the changes in intestinal movement in the same manner as in Fig. 2, with the values compared with those of a group not subjected to adrenalectomy. The site of stimulation
was c—AMYG or CAU. Acceleration and inhibitory effects were also recognized after adrenalectomy in the same way as in the group not undergoing adrenalectomy. However, with 100 Hz stimulation to c—AMYG, the inhibitory effect of the adrenalectomized group (−15.3 ± 4.7%) was less marked than that of the non—adrenalectomized group (−32.2 ± 16.0%).

6. Effect of Propranolol Administration

After propranolol (0.3mg/kg) was administered to five rabbits, the same experiment was performed. Fig. 5—(a) shows the changes in intestinal movement in the same manner as in Fig. 2. The inhibitory effect seen in the control group almost disappeared in the group administered propranolol.

7. Effect of Splanchnicotomy

After bilateral splanchnicotomy in five rabbits the same experiment was performed. The site of stimulation was c—AMYG. Fig. 5—(b) shows the changes in intestinal movement in the same manner as in Fig. 2. The inhibitory effect seen in the control group with 100 Hz stimulation disappeared in the splanchnicotomized group.

8. Histological examination

Fig. 6 shows the sites of stimulation (black circles) in c—AMYG, b—AMYG, CPY and CAU, which were confirmed histologically after completion of the experiments.

Discussion

The irritable bowel syndrome (IBS) is a functional disease of the gastrointestinal system. Despite complaints such as constipation, diarrhea or abdominal discomfort, it occurs in the absence of

**Fig. 4** Effect of adrenalectomy:
Changes in intestinal movement induced by stimulation to c—AMYG and CAU with and without adrenalectomy.

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○ without adrenalectomy
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any organic abnormality. According to the diagnostic criteria of the National Institutes of Health (NIH) of the United states in 1982, IBS is defined as diarrhea or constipation accompanied by abdominal pain, with painless diarrhea or constipation not included in the definition of IBS. Therefore, at present IBS is classified as follows: 1) the constipation type (constipation with abdominal pain), 2) the diarrhea type (diarrhea with abdominal pain), and 3) the alternating diarrhea and constipation type (diarrhea and constipation with abdominal pain).

Concerning the pathophysiology of IBS, Peters reported in 1944 that constitutional factors are also responsible for the onset, but mainly mental stresses induce the abnormality of tonus of the autonomic nervous system, and especially the state of tonus of the para-sympathetic nervous system is strongly related as the cause. It has generally been believed ever since that IBS is closely related to the autonomic nervous system. It is clinically and experimentally recognized that motility, secretion, and blood flow of the digestive tract are influenced by emotions such as tension, anxiety, and anger. Since the digestive system is controlled by the autonomic nervous and endocrine systems,
it is vulnerable to emotional changes. The autonomic nervous system cooperates with the endocrine system to maintain homeostasis, mainly at the level of the hypophyseal system. In order to prevent the breakdown of this cooperation the cerebral limbic system controls both of these systems.\textsuperscript{12}

In the present study, various nuclei of the limbic system and the basal ganglia were electrically stimulated in rabbits in order to clarify the relationship between the central nervous system and the digestive tract.

In EEG, there was no specificity with the site of stimulation. With 3 Hz stimulation, spike and wave complexes—like waves appeared, while 8 Hz stimulation caused a recruiting response—like pattern to appear. Regarding the mechanism of the spike and wave complexes and recruiting response, Jasper et al.\textsuperscript{13} and Morison and Dempsey\textsuperscript{14} have reported that these reactions are induced by electrical stimulation of the nucleus centromedianus (CM) or nucleus ventralis anterior (VA), both of which are nonspecific nuclei of the thalamus. Both spike and wave complexes and the recruiting response have been reported to have suppressor activity in the central nervous system by Yasuhara,\textsuperscript{15} Nasu,\textsuperscript{16} Akiyoshi,\textsuperscript{17} and Hayashi.\textsuperscript{18} Stefens and Droogleever Fortuyn,\textsuperscript{19} Mettler,\textsuperscript{20} Powell,\textsuperscript{21} and Cowan\textsuperscript{22} have noted that there are anatomical fiber connections between nonspecific nuclei and GP, PUT, and CAU. There are also connections between nonspecific nuclei of the thalamus and limbic system, which is the higher center of the thalamus.\textsuperscript{23} The results of the present experiment suggest that stim-

\textbf{Fig. 6} Histological sites of stimulation to c—AMYG, b—AMYG, CAU and CPY(black circles).
mulation of the various nuclei of both the limbic system and basal ganglia caused the excitation of CM or VA, resulting in EEG reactions such as spike and wave complex-like or recruiting response-like patterns. On the other hand, with 100 Hz stimulation, an arousal reaction was observed.

It is not clear whether the stimulation of these nuclei themselves generated the arousal reaction or whether the brainstem reticular formation was also stimulated by the same stimulation, causing excitation of the entire central nervous system.

It is known that the limbic system is closely related to autonomic function. MacLean\textsuperscript{24}) considered the limbic system to be the highest center on the autonomic nervous system, and called it the visceral brain. In the present study, AMYG, which is the largest nucleus in the limbic system, and HPC, CPY and SPM were particularly investigated with respect to their autonomic function.

Studies on AMYG in laboratory animals have appeared frequently, but most reports have focused on gastric movement, and little has been published about its effects on large bowel motility. The effects of stimulation on gastric movement are not uniform. Eliasson\textsuperscript{25}) and Gastaut\textsuperscript{26}) noted only an acceleration effect, while Shealy and Peele\textsuperscript{27}) and Fennegan and Puiggari\textsuperscript{28}) reported that both acceleration and inhibition are found depending on the site of stimulation.

In our department, the effects of AMYG on the autonomic nervous system have been intensively studied in rabbits.\textsuperscript{29, 30}) Considering both the results of the present and these other experiments, 100 Hz stimulation to AMYG seems to have the same effect on the intestine and the bladder, that is, inhibition by c—AMYG stimulation and acceleration by b—AMYG stimulation. On the other hand, opposite effects are found on uterine movement. With 3 Hz stimulation in the present study, acceleration and inhibition were observed by c— and b—AMYG stimulation, respectively, while this stimulation seemed to have no specific effects on bladder or uterine movement. With 8 Hz stimulation, no specific effects were observed on intestinal or uterine movement.

Since c— and b—AMYG often have opposing effects on the movement of the intestinal canal, bladder and uterus as discussed above, it seems that the effects of the entire AMYG on the autonomic nervous system are not uniform. Physiologically, the application of certain stimuli to c—AMYG produces a reaction only as a result of a complicated balance between excitatory and inhibitory reactions. Furthermore, there are individual differences in the response to similar stimulation or to the same degree of stress. Concerning intestinal movement, when a stress stimulation causes the entire AMYG to over react, the result appears to be IBS.

Among other nuclei in the limbic system, CPY produced a marked increase in intestinal movement with 3 Hz stimulation. As this structure is located close to c—AMYG, stimulation to this nucleus may have produced changes similar to those produced by stimulation to c—AMYG.

As for SPM, according to Kaada,\textsuperscript{31}) stimulation of the septal area generally suppresses autonomic functions, producing inhibition of respiratory motion, bradycardia, and a fall in blood pressure. He also reported that it is considered to be the site of suppressing emotions, since destruction of SPM promotes such functions as arousal, the startle response, and the flight or fight reaction. In the present experiment, however, no specific changes were observed in intestinal movement after electrical stimulation of the septal nucleus.

Concerning HPC, it is generally reported that no marked changes in autonomic function are induced by its stimulation in humans or animals. In this experiment, almost no change was found in intestinal movement.

Regarding the relation between the EEG changes and intestinal movement, various results were obtained depending on the site of stimulation even with the same stimulation frequency. It seems that there is no direct relation between the acceleration or inhibition of intestinal movement and EEG changes.

The basal ganglia were also subjected to the same experiment. Studies on GP, PUT and CAU
were performed to unveil the relationship between these nuclei and motor functions. Very little study has been performed so far about the relationship of GP, PUT, and CAU with the autonomic nervous system. White\textsuperscript{32} and Mitchell\textsuperscript{33} noted disturbances in perspiration, lacrimation, saliva secretion, body temperature control and other autonomic functions following destruction of the striatum, i.e. CAU and PUT, and suggested that these structures mediate autonomic nervous activity. It was reported recently that cerebrovascular disturbances in the striatum induce abnormalities of the autonomic reflexes as indicated by changes in blood pressure and heart rate.\textsuperscript{34, 35, 36} In our department, Isami\textsuperscript{37} investigated the effects of the basal ganglia on the cardiovascular system in rabbits. According to his report, stimulation of GP caused a fall in blood pressure, a decrease of the heart rate, and a reduction in blood flow of the common carotid artery. Stimulation of PUT only caused an increase in cerebral blood flow, and stimulation of CAU caused virtually no changes. In the present experiment, stimulation of PUT and GP had almost no effect on intestinal movement. However, as for CAU, which is the largest of the basal ganglia, inhibition with 3 Hz stimulation and promotion with 100 Hz stimulation were noted. Thus, stimulation of CAU induced effects similar to those obtained by stimulation of b—AMYG, and it is evident that CAU influences intestinal movement, albeit slightly.

We performed adrenalectomy to examine how the humoral element of the adrenal gland influence intestinal movement. Adrenalectomy did not suppress the inhibitory effect of c—AMYG and CAU on intestinal movement. But when c—AMYG was stimulated with 100 Hz, the inhibition was much less in the adrenalectomy group than in the group without adrenalectomy, suggesting that the inhibition of intestinal movement by c—AMYG may be partly mediated by the adrenal gland.

In order to clarify the afferent pathways of the effect of these subcortical nuclei on intestinal movement, we performed vagotomy, propranolol administration and splanchnicotomy. After vagotomy, the accelerating effect of CAU, c—AMYG and CPY totally disappeared while the inhibitory effect persisted. Hence, it was clear that the acceleration of intestinal movement is mediated through the vagus nerve. The promotion of intestinal movement is considered to be the main feature of IBS, and has been shown to be due to the tonic effect of the parasympathetic nerves. Our results are consistent with this explanation. On the other hand, both the injection of propranolol, which is a $\beta$—receptor blocking agent, and splanchnicotomy suppressed the inhibitory effect of c—AMYG and CAU on intestinal movement, while the promotive effect remained, demonstrating that the inhibitory impulses are mediated through the visceral nerves. Moreover, the effects of propranolol show that the role of the $\beta$—receptor is dominant in the regulation of the ascending colon.

In the present study, electrical stimulation was applied to only one specific site at a time. Physiologically, it is hard to suppose that a certain emotion, such as fear, anger, or anxiety, would effect only a specific portion of the limbic system, and more natural to consider that the effect would spread throughout the limbic system. For example, in AMYG which is said to be the site most vulnerable to emotional changes, stimulation propagates to both c— and b—AMYG. With 3 Hz stimulation, the balance of both promotive effect by c—AMYG and inhibitory effect by b—AMYG would determine the actual change in intestinal movement. Contradictory phenomena may appear in different individuals due to different balances of these two effects.

Paying special attention to the promotion of intestinal movement which is the main feature of IBS, clinical symptoms seem to develop when the promotion exceeds a certain limit. The pathogenesis of this condition depends on complicated relationships between the digestive hormones, the tonus of the autonomic nervous system and some other factors. The present experiment showed that even the stimulation of the central nervous system alone can produce a marked increase in intestinal movement depending on the site stimulated. There

is no doubt that IBS is also closely related to the central nervous system.

An outline of the present results was reported at the 30th and 31st International Congress of Physiological Sciences, at the 18th Japanese Congress of EEG and EMG.

Acknowledgements

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References


