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Effects of Vesical Distention on Parasympathetic Outflow to the Colon of Dogs

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ABSTRACT. The vesico-colonic reflex transmitted via the pelvic nerve was studied in dogs and it was found that the reflex consists of four elemental components. 1. Vesical distention produced an inhibition of rectal parasympathetic outflow without eliciting any vesical parasympathetic outflow in decerebrated and spinal dogs. 2. An afterdischarge usually followed the inhibition. These results show that the sacral defecation reflex center is inhibited by vesical afferents, and produces a rebound excitation eliciting the afterdischarge. 3. An inhibition of the rectal outflow occurred simultaneously with waxing of the vesical outflow during constant afferent stimulation of the vesical and rectal branches of the pelvic nerve in dogs from which the colon and urinary bladder had been removed. This inhibition may be produced by an efference copy from the pontine micturition reflex center. Most recto-colonic branches of the nerve responded to vesical distention with these inhibitions and afterdischarge. Corresponding to these responses colonic motility was inhibited and/or enhanced. 4. Eleven of 26 recto-anal branches of the nerve responded to vesical distention with an enhanced outflow elicited simultaneously with an enhanced vesical outflow. This enhancement was abolished by transection of Cl, which indicates that it may be caused by an efference copy from the pontine micturition reflex center.

Key words : defecation — micturition — vesico-colonic reflex — parasympathetic outflow — colonic motility

Discharge of pelvic efferent fibers to the urinary bladder of cats is inhibited by colonic distention or afferent stimulation of the rectal branches of the pelvic nerve[1,2]. Inhibition of rectal outflow of the pelvic nerve by distention and contraction of the bladder has also been briefly reported in cats[3]. Old works on the vesico-colonic reflex, however, indicated that colonic motility was enhanced reflexly via the pelvic nerve by distention of the bladder in dogs[4,5]. In our preliminary experiments on dogs, two kinds of inhibition and two kinds of enhancement of the rectal outflow of the pelvic nerve were seen as the result of the vesico-colonic reflex. This study investigates the origins of these reflex effects and aims to resolve the inconsistent results of the works mentioned above[3-5].

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METHODS

This study used 30 dogs, each weighing 5–12 kg. Sixteen dogs were anesthetized with intravenous α-chloralose (100 mg/kg), then decerebrated precollicularly. The other 14 dogs were decerebrated similarly under electrical narcosis[6]. Dogs were paralyzed with intravenous gallamine triethiodide (1 mg/kg), then artificially ventilated through a tracheal cannula at a rate of 30 to 35 strokes/min and a tidal volume of 50 to 150 ml. Body temperature was maintained at about 36°C by the light from two 100 W tungsten lamps.

To exclude sympathetic reflexes from the bladder, the lumbar colonic nerve and the bilateral hypogastric nerves were previously severed in all dogs. The dorsal surface of the lst cervical cord was exposed by a laminectomy for transection of the spinal cord. The pelvic nerves and their branches innervating the colon and urinary bladder were exposed bilaterally by a mid-line incision, and prepared for recording of efferent discharges and for afferent stimulation. Bipolar platinum wire electrodes were used for the stimulation and recording. The exposed nerves were covered with warmed mineral oil.

The anal mucosa was stimulated electrically with a specially shaped electrode. Ten lengths of silver wire 0.7 mm diameter and 20 mm length were attached in parallel with the same intervening spaces to the surface of an acrylic resin rod (12 mm diameter). The tips were connected alternatively to two lead wire. The electrode was inserted into the anal canal during stimulation of the anal mucosa. The anal mucosa was mechanically stimulated by manual rotation of the electrode in the anal canal.

The distal colon was isolated from the proximal colon by transection at the point where the caudal mesenteric artery joins. A balloon of 5 cm length was inserted into the distal colon through the severed end. Another balloon of 3 cm length was inserted into the urinary bladder through a small incision made in the fundus. Intraluminal pressures in the colon and bladder were recorded on a pen-recorder via pressure transducers connected with the balloons. The bladder was distended with warmed water (about 36°C) injected with a 100 ml syringe connected to the balloon and pressure transducer via a T-cannula. Efferent discharges of the rectal and vesical branches of the pelvic nerve were amplified with RC coupled amplifiers and displayed on an oscilloscope. These discharges were led to spike counters in parallel with the oscilloscope and the counted output in bins of 500 msec was recorded by the pen-recorder.

RESULTS

The relationship between the efferent discharges of a rectal and a vesical branch of the pelvic nerve are shown in Figs. 1 and 2. Slight vesical distention that was subthreshold in regards to the initiation of reflex discharges from the vesical branch caused inhibition (the lst type inhibition) of the outflow in the rectal branch (Fig. 1B and 2A). Another kind of inhibition (the 2nd type inhibition) of the rectal outflow was elicited by moderate vesical distention.

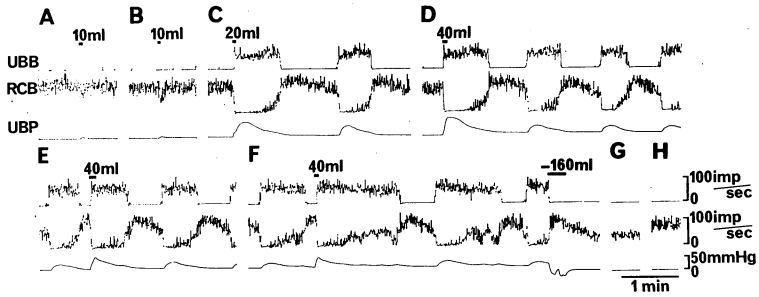

Fig. 1. Effects of vesical distention of efferent discharges in the vesical and rectal branches of the pelvic nerve.
Upper trace (UBB) : vesical branch. Middle trace (RCB) : rectal branch. Lower trace (UBP) : intravesical pressure. The urinary bladder was distended by stepwise injections of 10 ml water in A and B, 20 ml in C, and 40 ml in D, E and F. All of the water was removed in F at-160 ml. Records were interrupted for 2 min between A and B, B and C, C and D, and F and G, for 3 min between E and F, and for 4 min between G and H.

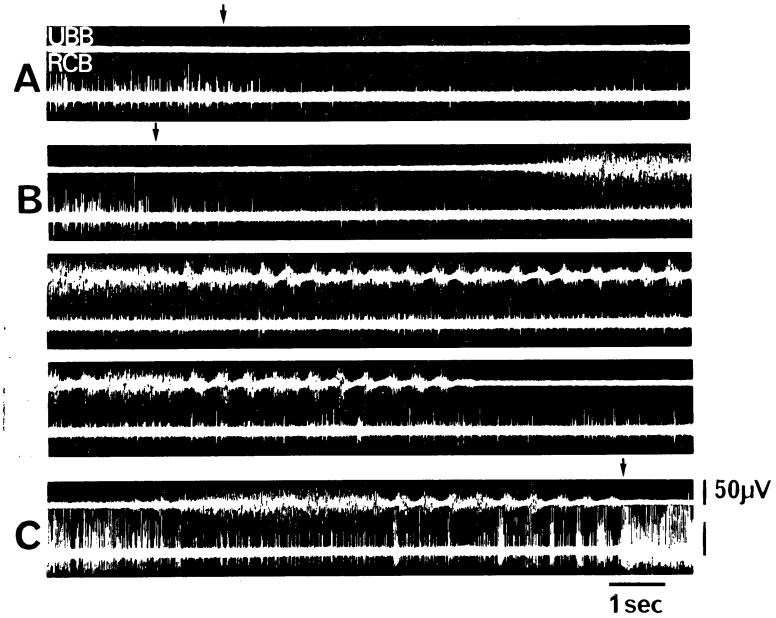

Fig. 2. Relationships between both efferent discharges in the vesical and rectal branches of the pelvic nerve.
Upper trace : vesical branch. Lower trace : rectal branch. At the arrow in A, the bladder was first distended by injection of 17 ml water. The bladder was then distended by an additional 3 ml at the arrow in B 3 min after the lst injection. Three photographs in B were a continuous record. Four min after the 2nd injection the bladder was distended with a further 5 ml. Traces in C were obtained 3 min after the 3rd injection. At the arrow in C, all of the water injected was removed from the bladder.

This inhibition occurred simultaneously with outflows from the vesical branch preceding vesical contractions and was followed by an enhanced discharge (the afterdischarge, the lst type enhancement) in the rectal branch during the resting phase of the outflows in the vesical branch (Fig. 1C–F and 2C). Fig. 2B shows that the discharge of the smaller spikes in the rectal branch was enhanced simultaneously with the outflows of the vesical branch (the 2nd type enhancement). These reflex effects were recognized in both anesthetized and non-anesthetized decerebrated dogs, therefore, the results obtained under such conditions will be presented together.

The origins of the lst and 2nd type inhibitions, the afterdischarges and the 2nd type enhancement in the outflow of the rectal branch were studied in the following experiments.

The 1st and 2nd type inhibitions and the afterdischarge

A suprathreshold vesical distention with a duration less than a few minutes usually brought about a serial discharge on the vesical branch, whereas the spontaneous outflow in the rectal branch was reciprocally inhibited during the serial discharges of the vesical branch (Fig. 3). When the vesical distention

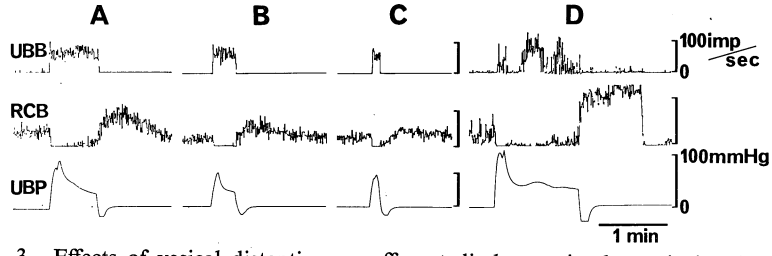

Fig. 3. Effects of vesical distention on efferent discharges in the vesical and rectal branches of the pelvic nerve.
Upper trace : vesical branch. Middle trace : rectal branch. Lower trace : intravesical pressure. The bladder was distended by injection of 100 ml water with different periods in A, B and C. D : another dog. The bladder was distended by 80 ml. Afterdischarges in the rectal branch caused a propulsive rectal contraction.

was ceased, the serial discharges disappeared suddenly and the inhibited outflow in the rectal branch recovered abruptly and was frequently followed by an enhanced afterdischarge, which gradually returned to the prestimulation level (Fig. 3A). The colonic motility usually decreased simultaneously with the inhibition. Sometimes, the afterdischarge developed into an excessive discharge causing a propulsive colonic contraction in defecation (Fig. 3D). Such an inhibition of the outflow was observed in 33 rectal branches of 17 dogs, and the inhibition was followed by an afterdischarge in 23 of the 33 rectal branches (Table 1). The grade of the afterdischarge decreased with shortening of the distending period (Fig. 3A–C). Three rectal branches of three dogs showed similar results.

TABLE 1. Types of response of rectal branches to the vesical distention in 18 decerebrated dogs. Numbers of the branches are shown.

Branch type / Response type	Inhibition with afterdischarge	Inhibition	Enhancement	Total
Recto-colonic	14	4	4	22
Recto-anal	9	6	11	26
Total	23	10	15	48

Similar inhibition and afterdischarge in the rectal branch were induced by afferent electrical stimulation of the vesical branches of the dogs from which the whole colon and urinary bladder had been removed (Fig. 4A). After transection of the spinal cord at Cl, the discharges in the vesical branch disappeared completely and the spontaneous outflow in the rectal branch decreased, although this outflow was enhanced reflexly by electrical stimulation of the anal mucosa[7,8] (Fig. 4B). No reflex outflow in the vesical branch was elicited by afferent stimulation of the contralateral vesical branches ; however, the enhanced outflow in the rectal branch was inhibited. This inhibition was followed by an afterdischarge weaker than that before the spinal transection. These results were confirmed by similar experiments in three decerebrated dogs from which the colon and urinary bladder had been removed.

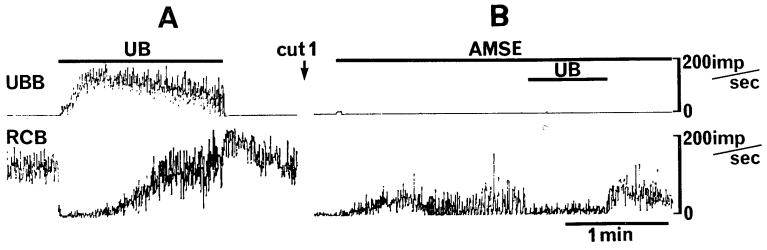

Fig. 4. Effect of afferent stimulation of the vesical branches on efferent discharges in the vesical and rectal branches of the pelvic nerve.
The whole colon and the bladder were removed in this dog. A : control. B : response at 30 min after transection of the spinal cord at Cl. Upper trace : vesical branch. Lower trace : rectal branch. During the horizontal bar indicated by UB, the central cut-ends of the contralateral vesical branches were stimulated with pulses of 0.5 msec duration, 6 volts and 5 Hz. During the horizontal bar indicated by AMSE, the anal mucosa was stimulated with pulses of 1 msec duration, 10 mA and 10 Hz.

Similar inhibition in the outflow of the rectal branch of spinal dogs were elicited by vesical distention (Fig. 6C). In this case, outflow in the rectal branch was elicited reflexly by mechanical stimulation of the anal mucosa. Such reflex outflow, as well as the spontaneous outflow, was inhibited in all eleven rectal branches examined in nine spinal dogs. The inhibition was followed by an

afterdischarge in six of the eleven rectal branches, although the afterdischarge in the spinal dogs did not develop to the extent of causing the propulsive colonic contraction of defecation.

The records shown in Fig. 5 were obtained using a dog from which the whole colon and urinary bladder had been removed. In this case, the spontaneous outflow of the rectal and vesical branches was absent, although the outflow in the rectal branch could be elicited reflexly by continuous afferent stimulation of the contralateral rectal branches with a fixed frequency[9,10]. The reflex outflow was promptly inhibited by additional afferent stimulation of the contralateral vesical branches with another fixed frequency (Fig. 5B), after which the outflow in the rectal and vesical branches appeared. The outflow in the rectal branch was, in this stage, inhibited simultaneously with waxing of the discharges in the vesical branch as shown in Fig. 5C (the 2nd type inhibition). An inverse relationship was recognized. This reciprocal relationship between the discharges of the rectal and vesical branches was confirmed in three dogs prepared similarly.

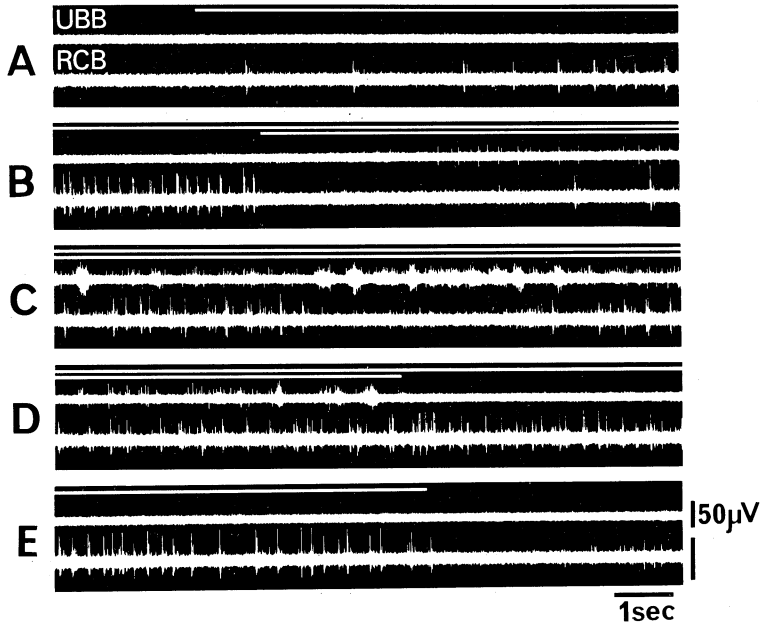

Fig. 5. Effects of afferent stimulation of the rectal and vesical branches on efferent discharges in these branches.
The whole colon and the urinary bladder were removed in this dog. Upper trace : vesical branch. Lower trace : rectal branch. Records were interrupted for 35 sec between A and B, 55 sec between B and C, 68 sec between C and D, and 20 sec between D and E. During the upperhorizontal bar, the central cut-ends of the contralateral rectal branches were stimulated with pulses of 0.5 msec duration, 10 volts and 20 Hz. During the lower horizontal bar, the central cut-ends of the contralateral vesical branches were stimulated with pulses of 0.5 msec duration, 6 volts and 3 Hz.

Co-activated outflow in the rectal and vesical branches

The rectal branches of the pelvic nerve could be divided into two groups on the bases of where they invaded rectal wall in the dog. The major group consisted of large numbers of rectal branches invading the rectal wall at the part where the rectum was attached by peritoneum (the recto-colonic branch). The minor group consisted of four to five strands invading the rectal wall near the part joining with the anococcygeal muscle (the recto-anal branch).

In some rectal branches especially the recto-anal one, during vesical distention, an enhanced reflex discharge (the 2nd type enhancement) was induced simultaneously with discharges of the vesical branch in spite of the simultaneous occurrence of inhibition of spontaneous discharges in the recto-colonic branch (Fig. 6A). This 2nd type enhancement was observed in four of 22 recto-colonic

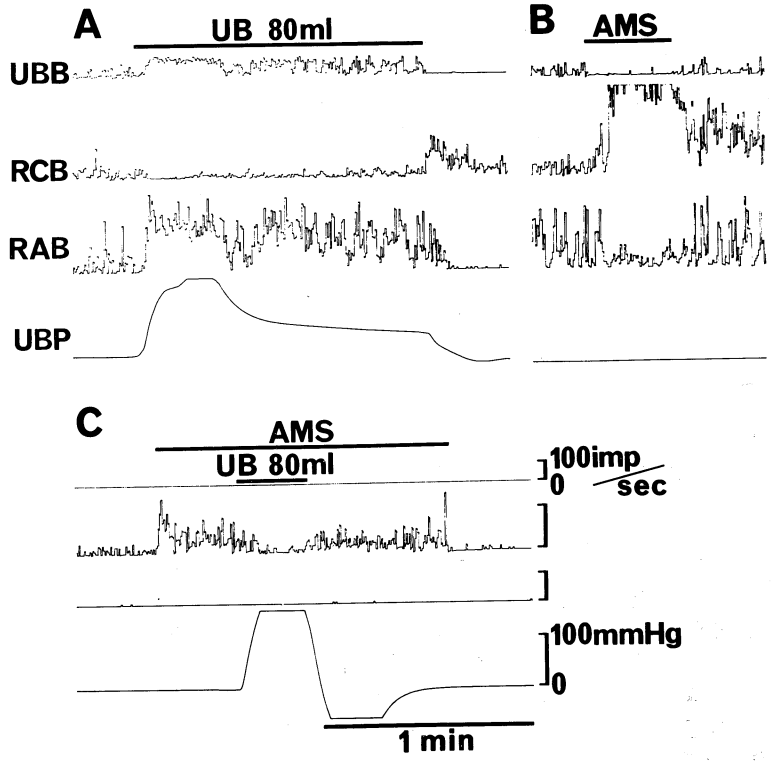

Fig. 6. Effects of vesical distention on efferent discharges in the vesical and rectal branches of the pelvic nerve.
Traces from above down are discharges in the vesical branch, the recto-colonic branch, the recto-anal branch and the intravesical pressure. The bladder was distended with 80 ml injection during the horizontal bars indicated by UB in A and C. The anal mucosa was stimulated mechanically during the horizontal bars indicated by AMS in B and C. A and B: control responses before transection of the Cl spinal cord. C : responses at 40 min after the transection.

branches and eleven of 26 recto-anal branches (Table 1). The outflows in two such rectal branches responded inversely to mechanical stimulation of the anal canal mucosa (Fig. 6B). Neither the 2nd type enhancement nor reflex discharge of the vesical branch was induced by vesical distention after transection of the spinal cord at C1, although the outflow in the recto-colonic branch was still increased reflexly by stimulation of the anal canal after the transection. This reflex outflow was inhibited by vesical distention as before the transection (Fig. 6C). Similar effects of spinal transection on the 2nd type enhancement were confirmed in seven of the nine rectal branches examined in seven dogs. The outflow in the remaining two rectal branches was inhibited by vesical distention after transection of the spinal cord.

DISCUSSION

It was found in this study on the vesico-colonic reflex via the pelvic nerve that, in its rectal branch, there are at least two kinds of efferent fibers. Their responses to vesical distention differ profoundly, the outflow of one group being inhibited during vesical distention or contraction while that of the other is enhanced (the 2nd type enhancement). Inhibition in the former fibers is classified into two types by its origin : elicited without outflow in the vesical branch and of spinal origin (the 1st type inhibition) ; and accompanied by outflow in the vesical branch with its origin being due to a mechanism concerned with the supraspinal brain stem level (the 2nd type inhibition). The excessive after-discharges (the 1st type enhancement) following such inhibitions were elicited at the cessation of a vesical distention and/or a contraction.

Origins of these reflex effects

The 1st type inhibition could be elicited by weak vesical distention that was subthreshold for reflex activation of the vesical parasympathetic nerve (Fig. 1 and 2). This was true of both decerebrated dogs and acute spinal dogs, in which vesical distention did not elicit any reflex activity on the vesical parasympathetic nerve (Fig. 4). It was concluded from these results that the 1st type inhibition is mediated by a spinal reflex pathway.

The rectal parasympathetic outflows were further inhibited reciprocally during the discharging phase of the vesical parasympathetic nerve (the 2nd type inhibition). This inhibition occurred simultaneously with spontaneous waxing of the vesical parasympathetic outflow even in a dog with its whole colon and bladder removed, when the rectal and vesical parasympathetic outflows were elicited by constant afferent stimulation of the rectal and vesical branches of the pelvic nerve (Fig. 5). In this dog, because afferent activity in the vesical and rectal branches were only constant inflows elicited by constant afferent stimulation, neither of the afferent activities could drive directly waxings of the discharge in the vesical parasympathetic outflow. So, it may be concluded that the 2nd type inhibition depends directly not on the vesical afferent activity,

but on the descending activity from the pontine micturition reflex center[11,12]; therefore, it shows a reciprocal relationship with the vesical parasympathetic outflow. The lst type inhibition was followed by an afterdischarge in decerebrated dogs as well as in spinal dogs. The longer inhibition was followed by a larger afterdischarge (Fig. 3). The afterdischarge is probably caused by rebound excitation elicited on the spinal parasympathetic neurons or some interneurons composing the pathway of the defecation reflex[6].

The 2nd type enhancement was brought about on the outflow in some rectal branches of the pelvic nerve simultaneously with discharges of the vesical parasympathetic nerve. The 2nd type enhancement was abolished after transection of the Cl spinal cord (Fig. 6). It is concluded from these results that the 2nd type enhancement is elicited by an efference copy of the descending activity from the pontine micturition reflex center[12].

Roles of these reflex effects

Both inhibition and enhancement of colonic motility were induced by vesical distention in dogs in which the lumbar colonic nerve and bilateral hypogastric nerves had been severed. In several cases, a propulsive colonic contraction was elicited after cessation of the vesical distention (Fig. 3D). The changes induced in colonic motility corresponded to the lst and 2nd type inhibitions and the rebound discharge in the rectal parasympathetic outflow. These changes in the rectal parasympathetic outflow were observed in most of the recto-colonic branches (Table 1). Efferent stimulation of the recto-colonic branches caused a contraction of the whole rectum and colon (Fukuda and Fukai, unpublished result). These inhibitions and the afterdischarge in the rectal parasympathetic outflow mediate colonic motility changes caused by the reflex from the urinary bladder.

The 2nd type enhancement, in which the rectal parasympathetic outflow was enhanced simultaneously with the outflow in the vesical parasympathetic nerve, was observed mainly in the recto-anal branches of the pelvic nerve (Table 1). Efferent stimulation of the recto-anal branches caused relaxation of the internal anal sphincter as the effects of stimulation of the S2 ventral root and the pelvic nerve[13,14]. It is concluded from these results that the 2nd type enhancement participates in the sphincter relaxation mediated by the pelvic nerve during vesical contraction.

REFERENCES

1) Floyd, K., McMahon, S.B. and Morrison, J.F.B. : Inhibitory interactions between colonic and vesical afferents in the micturition reflex of the cat. J. Physiol. (Lond.) **322** : 45-52, 1982
2) McMahon, S.B. and Morrison, J.F.B. : Factors that determine the excitability of parasympathetic reflexes to the cat bladder. J. Physiol. (Lond.) **322** : 35-43, 1982
3) De Groat, W.C., Booth, A.M., Milne, R.J. and Roppolo, J.R. : Parasympathetic preganglionic neurons in the sacral spinal cord. J. Auton. Nerv. Syst. **5**: 23-43, 1982
4) Semba, T. and Mishima, H. : On the excitatory reflexes from the urinary bladder to the

discending colon. Sogoigaku **13** : 116–117, 1956 (in Japanese)
5) Hayashi, T. : On the effects of distension of the urinary bladder upon the colon. J. Physiol. Soc. Jpn. **21** : 380–385, 1959 (in Japanese)
6) Fukuda, H., Fukai, K., Yamane, M. and Okada, H. : Pontine reticular unit responses to pelvic nerve and colonic mechanical stimulation in the dog. Brain Res. **207** : 59–71, 1981
7) Okada, H., Yamane, M., Fukuda, H. and Fukai, K. : The ano-colonic reflex and parasympathetic outflow to the colon in the dog. Auton. Nerv. Syst. **14** : 267–276, 1977 (in Japanese)
8) Fukuda, H. and Fukai, K. : Convergence of visceral afferents on candidate units for the pontine defecation reflex center of the dog. Jpn. J. Physiol. **32** : 1007–1010, 1982
9) Okada, H., Fukuda, H. and Yamane, M. : The efferent activity in the pelvic nerves during the recto-rectal reflex of the dog. Auton. Nerv. Syst. **12** : 278–287, 1975 (in Japanese)
10) Okada, H., Fukuda, H. and Yamane, M. : On the localization of the pontine defecation reflex center of the dog. Auton. Nerv. Syst. **13** : 24–31, 1976 (in Japanese)
11) Barrington, F.J.F. : The effect of lesions of the hind- and mid-brain on micturition in the cat. Quart. J. Exp. Physiol. **15** : 81–102, 1925
12) Okada, H. and Yamane, M. : Unit discharges in the pons and the mid-brain with the rhythm of urinary bladder movements of the dog. Auton. Nerv. Syst. **11** : 46–57, 1974 (in Japanese)
13) Nakayama, S., Mizutani, M. and Neya, T. : Nervous control of the internal anal sphincter. Jpn. J. Smooth Muscle Res. **16** : 211–214, 1980 (in Japanese)
14) Bouvier, M. and Gonella, J. : Nervous control of the internal anal sphincter of the cat. J. Physiol. (Lond.) **310** : 457–469, 1981