Electrophysiological Study on Medullospinal Tract Cells Related to Somatosympathetic Reflex in the Cat

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= ABSTRACT =

It is well established that neurons in ventrolateral medulla play a key role in determining the vasomotor tone. The purpose of present study is to identify sympathetic related, medullospinal tract neurons in ventrolateral medulla and to show that these mediate somato-sympathetic reflex.

Medullospinal tract cells were identified by antidromic stimulation to intermediolateral nucleus (IML) of the second thoracic (T_2) spinal cord in anesthetized cats. Peripheral nerves were stimulated for orthodromic activation of these cells and peripheral receptive fields were determined. Post R-wave histogram of unit and spike triggered averaging of sympathetic nerve discharge (SND) were used to define sympathetic related cell.

A total of 113 neurons was recorded in ventrolateral medulla that had the axonal projections to T_2 spinal cord. Thirty-four of these medullospinal cells showed spontaneous discharges and the others not. Between these two groups, rostro-caudal coordinate of the distribution from obex [4.7±0.2 (mean S.E.) mm, 4.1 0.1 mm], depth from dorsal surface (5.5±0.2 mm, 4.9±0.1 mm) and conduction velocity (9.9±1.7 m/sec, 16.7±1.9 m/sec) were significantly different (p<0.05). In spontaneously discharging group, characteristics of rostral and caudal groups were significantly different and we demonstrated that cells in rostral group mediate somatosympathetic reflex.

From these results, we conclude that a certain portion of spontaneously discharging medullospinal tract cells in rostral ventrolateral medulla comprise the efferent outputs of somatosympathetic reflex to sympathetic preganglion neurons.

Key Word: Medullospinal tract cell, Rostral ventrolateral medulla, Somato-sympathetic reflex, Post R wave unit interval histogram, Spike triggered averaging of sympathetic nerve discharge.

INTRODUCTION

When the nociceptive information reaches the central nervous system by the parallel pathway, there are different kinds of responses depending upon the changes in the physical state of the body or its internal organ. For example, nociceptive information evoked by peripheral nerve stimulation starts the somatosympathetic reflex and the change in arterial blood pressure is representative of the somatosympathetic reflex after peripheral nerve stimulation (Chung et al, 1979; Johansson, 1962; Morrison & Reis, 1989; Stornetta et al, 1989). For this kind of change in blood pressure, it is known that the afferent inputs inducing the somatosympathetic depressor response are mediated by A-fibers and ascend in the spinal dorsolateral funiculus bilaterally, while those inducing somatosympathetic pressor response are mediated by C-fibers and ascend in the dorsolateral sulcus area bilaterally

(Chung & Wurster, 1976; Chung et al, 1979; Kozelka et al, 1981). These changes in blood pressure appears different aspects according to stimulated nerves, status of aneasthesia and the levels of the decerebration (Khayutin et al, 1986; Stornetta et al, 1989), so the mechanism can be understood when the cardiovascular control center is fully explored.

Recently, many evidences have been accumulated that the rostral ventrolateral medulla (RVLM) is the cardiovascular system control center. There are many names for RVLM and all of them are descriptive names for the small part of ventrolateral medulla (Brown & Guyenet, 1984; McAllen, 1986c; Reis et al, 1989). This small part extends from the rostral margin of the facial nucleus to the rostral one third of the inferior olive, dorsal border is the nucleus ambiguus and bordered medially by the inferior olive.

Electrical stimulation of this part increases blood pressure; since injection of amino acids also produces a similar effect, it is proven that the increase in blood pressure is not from nerve stimulation (Lovick et al, 1985; McAllen, 1986a; McAllen, 1986b). The microinjection of glycine causes a decrease in blood pressure similar to cervical cord dissection suggesting that RVLM is not just important for the pressor response but may also be required in sustaining normal blood pressure. In order for RVLM to perform its central role, it needs to receive and integrate the information from other centers. It is proven by the electrophysiological and neuroanatomical methods that the nucleus tractus solitarius (Ciriello & Caverson, 1986), lateral hypothalamus (Ciriello et al, 1985; Sun & Guyetnet, 1986) and the buffer nerves provide the information to RVLM and the electrical or chemical damages to RVLM abolish the cardiovascular responses to the brain ischemia (Guyenet & Brown, 1986), the peripheral nerve stimulation (Stornetta et al, 1989), carotid chemoreceptor stimulation(Dean & Coote, 1986) and defense area stimulation (Dean & Coote, 1986; Hilton et al, 1983; McAllen et al,1982).

The information from the spinal cord, which is affected by sciatic nerve (Stornetta et al, 1989; Lee et al, 1990), is sent to the RVLM. The damage done on this part eliminates somatosympathetic reflex and the nerve branches of RVLM reach sympathetic nerve preganglionic cells present in the intermediolateral nucleus of spinal cord. These facts provide evidence for the central role of RVLM in somatosympathetic reflex. However there are not so many reports that associate the cell activity with blood pressure change.

Therefore, in this report the following facts will be proven. First, the electrophysiological characteristics of medullospinal tract cell, starting from the medulla to the spinal cord axons, will be explored. Additionally, cell bodies located in RVLM and their nerve terminals located in intermediolateral nucleus (IML) of spinal cord will be also proven. Second, it will be discussed that RVLM cells are connected to the cardiovascular system and these directly or indirectly control sympathetic nerve firing. Finally, the control of blood pressure by changes in cell activity whose changes are caused by peripheral nociceptive information will be discussed.

METHODS

Anesthesia and preparation

Forty adult cats of either sex (2-3 kg, body weight) were used. After pre-anesthetic treatment with atropine (0.1 mg/kg) and the sedation with single doses of ketamine (Ketalar, 20 mg/kg, i.m.), animal was anesthetized with α-chloralose (60 mg/kg, i.p.). Trachea, femoral artery and vein were cannulated and used for artificial ventilation, blood pressure monitoring and intravenous injection of drugs, respectively. Animal was paralyzed by intravenous administration of pancuronium bromide (Mioblock, Organon, initial dose 0.4 mg, maintaining dose 0.4 mg/ hour). End-expiratory CO_2 concentration was maintained at 3-4% and rectal temperature was maintained at $37 \pm 1°C$. Hartmann solution was infused continuously throughout the experiment (10-15 ml/hour).

The upper thoracic spinal cord was exposed by a laminectomy on T_2 vertebrae. The stellate ganglion and the inferior cardiac nerve were isolated for sympathetic nerve activity recording, and then an occipital craniectomy was performed. To expose the floor of the fourth ventricle, the cerebellum was removed by suction. The sciatic, common peroneal and tibial nerves were isolated and exposed for electrical stimulation in the left hindlimb.

After the operation, the animal was mounted on a stereotaxic apparatus and mineral oil pools were made with incised skin flaps over exposed areas. A water circulating heating coil was used in the thoracic pool to prevent heat loss through exposed area.

Recording of medullospinal tract cells

After a recovery period of at least an hour, exposed thoracic dura mater was opened and bipolar tungsten stimulating electrodes (0.5 mm

Fig. 1. Confirmation of stimulating site. A. Blood pressure increase after electrical stimulation of ipsilateral second thoracic spinal cord IML for 10 sec. Stimulus: 1 mA, 0.1 ms duration, 20 Hz. B. Compound action potential of inferior cardiac nerve SND evoked by single electrical stimulation of contralateral second thoracic spinal cord IML. Stimulus: 1 mA, 0.1 ms duration at 20 sec. Latency is 76 ms.

diameter and 0.1 mm tip diameter) were placed at the dorsolateral sulcus bilaterally. Electrodes were lowered ventrally to the depth(usually 1.5-2.0 mm) where the intermediolateral nucleus of sympathetic preganglion cell was assumed to exist and the site was confirmed by the largest arterial pressor response and a compound action potential with short latency in the inferior cardiac nerve to brief square pulse stimulation (Fig.1). Tripolar platinum electrodes were placed under the exposed peripheral nerves for stimulating them.

Single cell activity in the ventrolateral medulla was recorded with carbon filament recording electrodes (tip resistance: 1-2 MΩ). A recording electrode was positioned at the dorsal surface of the medulla, 3-7 mm rostral to the obex, and 2.5-4.5 mm from midline. Electrode was lowered down step by step with micromanipulator (Narishige, PC-5N) until single cell activities were discernible. Usually single cell activities were picked up at depth between 3-7 mm from the dorsal surface. Each track was separated by 0.25-0.5 mm. For the identification of a medullospinal tract cell with conventional criteria of antidromic activation, brief square pulses (0.1 msec, 500 μA, 2-3 Hz) were applied through the concentric electrodes to thoracic spinal cord. The electrical activities were amplified (WPI, DAM-80; band path 0.3-10 kHz; gain 10,000) and displayed and stored in digital oscilloscope (Nicolet, 4094C) and analyzed in personal computer using interface (CED 1401).

Confirmation of the cardiovascular cells

Sympathetic nerve discharges (SND) were recorded under mineral oil from the inferior cardiac nerve with bipolar platinum electrode. Amplification with band path of 1-1,000 Hz enabled us to view the synchronized discharges of the sympathetic nerve fibers in the form of slow wave. When the medullospinal tract cell was confronted, the following methods of analysis were employed to confirm and characterize the cell as the cardiovascular cell, recording SND in the form of slow wave.
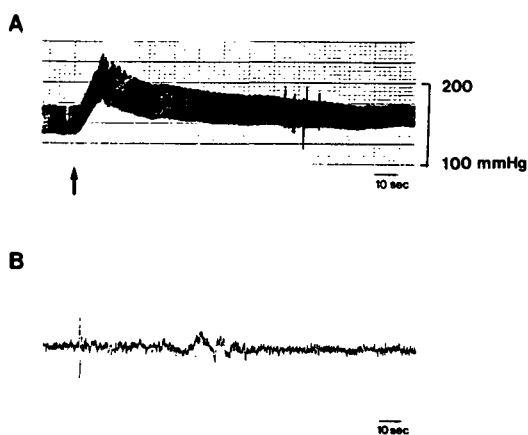
First, spike triggered averaging of SND was

used to show the correlation between the cell
and SND. The changes in inferior cardiac SND
following the naturally occurring spikes of the
cell were averaged. For this purpose, output
pulses from a window discriminator triggered
individual computer sweeps.

Second, information of post R-wave unit in-
terval histogram is provided on whether the cell
activity is timely related to the cardiac activi-
ty. Trigger pulses coincident with the R-wave
of the ECG were used for the construction of
the time interval histogram between the cell and
R-wave.

After confirming the cell as cardiovascular
cell with above mentioned two methods,
epinephrine or ephedrine was injected in-
travenously to demonstrate whether the unit is
sympathoexitatory or sympathoinhibitory. The
unit whose activity decreases after the arterial
blood pressure elevation is sympathoexitatory
and the unit whose activity increases is sym-
pathoinhibitory.

Histology and statistics

At the end of the experiment electrolytic le-
sions were made to mark the recording site in
the medulla as well as the stimulating sites at
the spinal cord. DC currents of 100-200 μA
were applied for 20 seconds through the recor-
ding and stimulating electrodes. The brainstem
and the spinal cord were taken out and fixed
in a 10% formalin solution for at least a week.
After then the tissues were frozen, cut and
stained for histological identification. Mean
values are expressed with their standard errors
(mean S.E.). Statistical comparisons were per-
formed with the use of Student's t-test. P-values
< 0.05 were considered significant.

RESULTS

The medullospinal tract (MST) cells satisf-
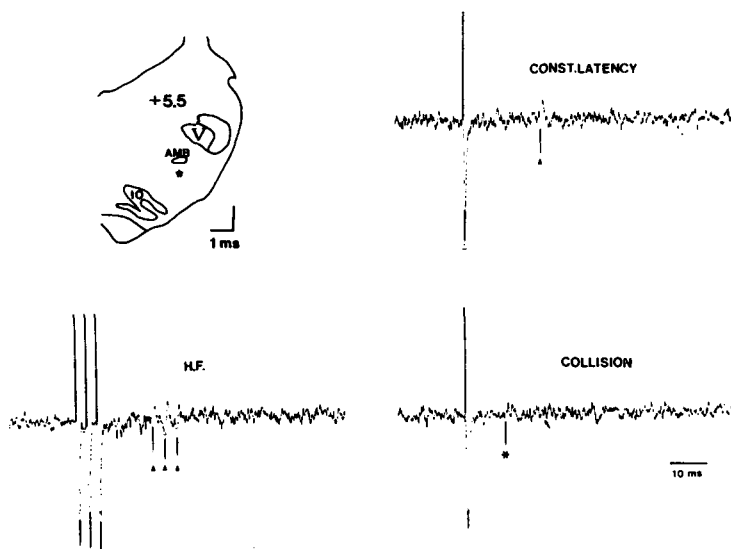ed the antidromic stimulation requirement. The

Fig. 2. *An example of medullospinal tract cells identified by collision with spontaneous activity. In upper left,
the recorded site of the cell is shown as a star. Arrow head indicates the time of expected action poten-
tial which was missed due to collision with spontaneous activity (asterisk). Const. latency: 19.7 ms,
H.F. (high frequency): 333 Hz.*

cell in Fig.2 represents the medullospinal tract cell. The cell body was located 5.5 mm rostal from the obex, 3.75 mm lateral from the midline and 5.8 mm in depth from the dorsal surface of the medulla (5.5-3.75-5.8). The cell was activated by ipsilateral spinal cord stimulation. The threshold of the all or none principle was 140 μA with 19.7 ms constant latency. It faithfully responded to 333 Hz high frequency triple pulse. Also, the spontaneous activity of this cell collided with the activity evoked by electrical stimulation. In this case, the conduction distance was 10 cm and the calculated conduction velocity was 5.07 m/sec, in the range of B-nerve fibers. A considerable number of cells showed no spontaneous activity, so the collision was confirmed with the cell activity activated by peripheral nerve stimulation. For the cells which were not stimulated by peripheral nerve electrical stimulation, they were considered as medullospinal tract cells if short refractory period between double pulse observed. Along with this, faithful responses to high

frequency electrical stimulation and constant latency were also confirmed. To observe the absolute refractory period, we used double pulses: the first pulse of which was two times the threshold while the second was four to six times the threshold.

A total of 113 medullospinal tract cells was recorded and the cells showed constant latency and faithful response to high frequency electrical stimulation. The electrical characteristics are listed in Fig. 3. Of these MST cells, 34 showed spontaneous discharges, 10 showed collisions with evoked activity by peripheral nerve stimulation, and 69 were identified by their constant refractory periods. Bilateral IML of the spinal cord were electrically stimulated as described in the methods. 85 of the MST cells had axonal projections to the ipsilateral IML while 29 of these projected to contralateral IML. In these two groups, there were no significant differences in conduction velocity, refractory period and threshold. For the medullospinal tract cells identified by refractory
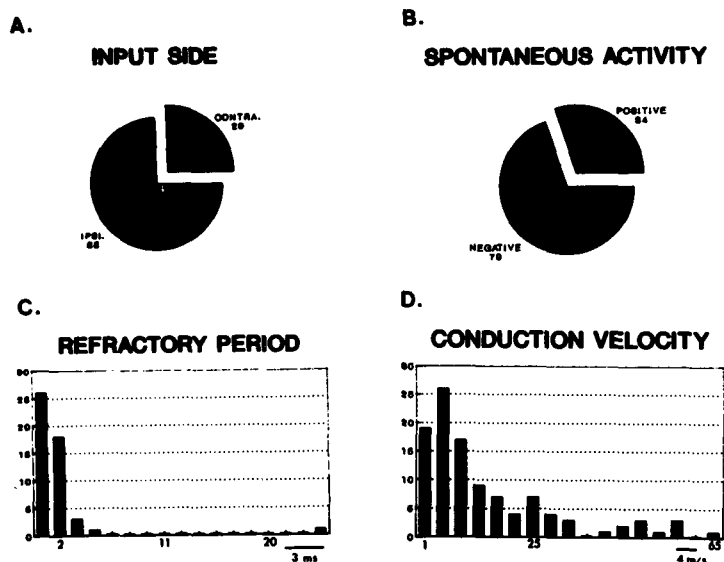

Fig. 3. Descriptive figures of 113 medullospinal tract cells. A. Pie of axonal projection side in T_2 spinal cord. Ipsi: ipsilateral, contra: contralateral side of cell body. B. Pie according to spontaneous activity. Positive: unit of spontaneous activity, negative: quiescent unit. Values under the label mean number of units. C. Histogram of refractory periods. D. Histogram of conduction velocity.
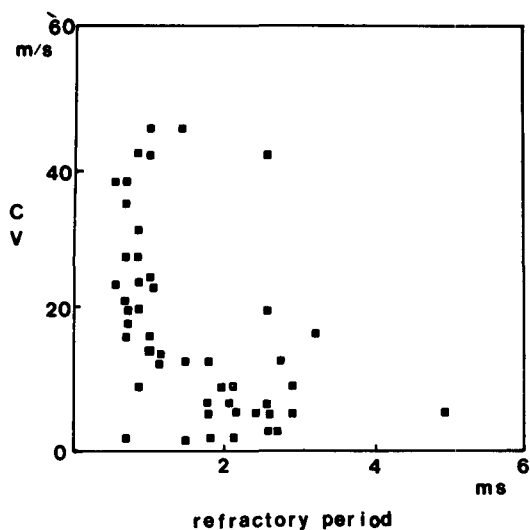
Fig. 4. Refractory period of medullospinal tract cells
inversely correlates with conduction veloci-
ty (CV).

Table 1. Comparison of rostro-caudal coordinate
(RCC), depth from the dorsal surface of
medulla (DEPTH) and conduction velocity
(CV) of medullospinal tract cells according
to spontaneous activity.

	Spontaneous Activity	
	Positive	Negative
RCC	4.7 ± 0.2mm	4.0 ± 0.1mm
DEPTH	5.5 ± 0.2mm	4.9 ± 0.1mm
CV	9.8 ± 1.7m/sec	16.6 ± 1.9m/sec

Fig. 5. Anatomical distribution of cat medullospinal
tract cells ; composite histographs of the
recording sites in consecutive medulla levels
cross-sectioned with 1 mm interval. Left
panel:quiescent units, right panel: units with
spontaneous activity. Numbers in the each
figures represent levels from the obex in mm.

periods, most of their refractory periods were
within 2 msec and the refractory period has
reverse correlation with the conduction veloci-
ty (Fig. 4) which corresponds well with the
general characteristics of unit nerve fiber. The
conduction velocities varied over a wide range.
They were distributed from C-fiber cell group
with 4 m/sec conduction velocity to Aβ-fiber
cell group with 70 m/sec conduction velocity
(Fig. 3.D). This means that there are func-
tionally different cell groups among the

medullospinal tract cells.

In order to maintain the cardiovascular tone,
RVLM cells should display spontaneous activi-
ty. Therefore the anatomical and the elec-
trophysiological characteristics were compared
between the spontaneously active group and the
quiescent group. As shown in table 1, the
characteristics were significantly different, and
it could be concluded that the group with the
spontaneous activity is located in the more
rostral and ventral part of the medulla and has
slower conduction velocities. The anatomical
distributions of these two groups were plotted

Table 2. Comparison of distance from the median line (ML), depth from the dorsal surface of medulla (DEPTH) and conduction velocity (CV) of medullospinal tract cells with spontaneous activity according to rostro-caudal coordinate +5 mm from the obesx.

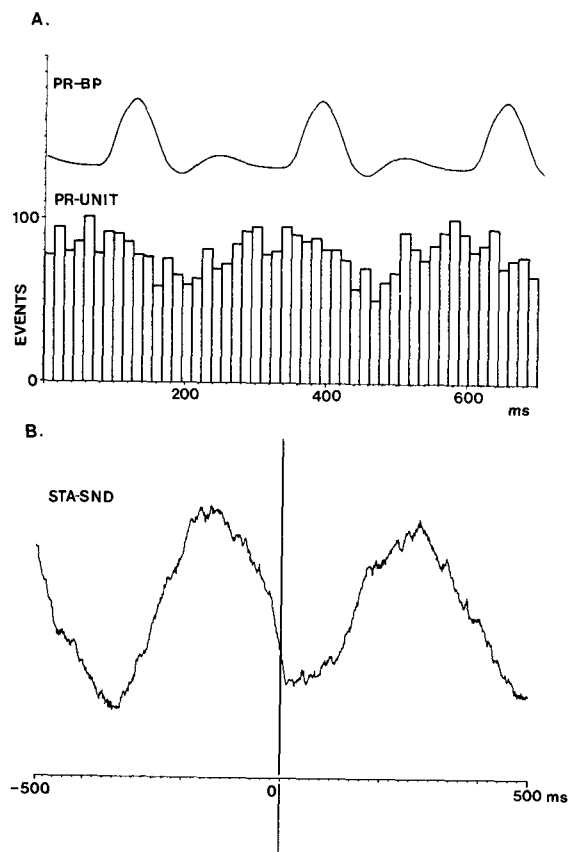|	Rostral (>5mm)	Caudal (<5mm)
ML	3.8 ± 0.04mm	3.2 ± 0.18mm
DEPTH	6.0 ± 0.12mm	5.2 ± 0.27mm
CV	6.0 ± 1.2m/sec	12.0 ± 2.4m/sec

Fig. 6. The definition of 'cardiovascular cell'. A. Post R-wave averages of arterial pulse (BP) wave (top) and histogram of unit spikes (bottom). Number of trials is 50 for BP and 1000 for UNIT. Bin width for unit histogram is 14 ms. Number of bins is 50. B. Spike triggerd averaging of SND. Unit spikes are at zero lag. Number of trials is 500. Sampling frequency is 1000 Hz.

on Mueller's stereotaxic atlas (Reinoso, 1961) as shown in Fig. 5. The quiescent units were distributed around rostral +4 mm. But spontaneously active units had two groups, one around +4 mm and the other around +6 mm, and the rostral group around rostal +6 mm from obex was located in a more lateral and ventral area of medulla and its anatomical location and conduction velocity well corresponded to established data of RVLM cells (Table 2). Thersefore, the spontaneously active rostral medullospinal trct cells were judged to be RVLM cells.

To confirm the relation with cardiovascular system and their pivotal role in the control of SND, post R-wave unit interval histogram and spike triggered averaging of SND were performed. Fig.6 is an example of these operations. Fig.6A is the post R-wave unit histogram; the interval time of cell activity after R-wave was expressed in the form of histogram using EKG R-wave as trigger. The aspect of the histogram showed a regular period that was in accord with that of blood pressures averaged after R-wave. This meant that the unit activity changes according to cardiac rhythm. Fig.6B is the spike triggered averaging of SND. SND triggered by spontaneous activity of medullospinal tract cell were averaged 500 times. This procedure implies that SND is under control of this cell and that a portion of the activity is generated by this unit in the SND component, and the cell that satisfied these two criteria was defined as the cardiovascular cell. The cell

shown in Fig.7 was the cardiovascular cell and had axonal projection to IML. It had a constant latency of 23ms, according to the all or none principle, and faithfully responded to high frequency stimulation. Located in 6-4-6.25, the activity of the cell changed after peripheral nerve stimulation. When the stimulation was given in A intensity at 500 msec, there was a 100 msec activation phase and 900 msec silent
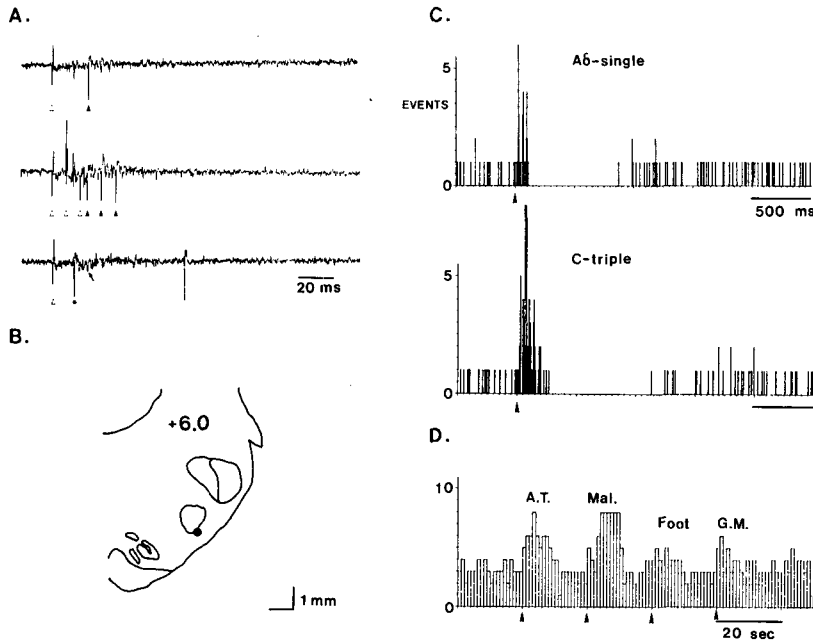
Fig. 7. An example of 'cardiovascular cell'. A. The unit satisfies the criterior of single unit antidromic stimulation; constant latency (top) high frequency (middle) and collision (bottom). Empty triangle means stimulus artifact; filled triangle, unit activity; asterisk, spontaneous unit discharge. B. Anatomical location; 6.0-4.0-6.25. C. Response of unit to common peroneal nerve stimulation. Upper: Aδ-single pulse at 500 msec, lower: C-triple pulses at 500 msec. Number of bins is 1500 and time per bin is 2 msec. Number of trials is 20. D. Rate of unit firing to squeeze of achilles tendon (A.T.), malleolus (Mal), foot and gastrocnemius muscle (GM). for 10 sec.

phase. With C intensity electrical stimulation, the activation phase was about 250 msec and the silent phase was about 1000 msec. The activity of cell was not considerably altered by natural stimulation to the superficial tissue like the skin, but the activity was changed considerably by stimulation to deep tissues like the Achilles tendon and the maleolus (Fig.7.D). The effect on the arterial blood pressure that was induced by this change in the cell activity is displayed in Fig.8. Fig.8A is the case of the cell demonstrated in Fig.7 and Fig.8B is the case of cardiovascular cell that had no axonal projection in the IML of T_2 spinal cord . In the upper part of Fig.8A, a 1 Hz stimulus was applied to the common peroneal nerve at 50 sec and 200 sec for 20 sec duration with A intensity, and the cesation of stimulation reduced the

activity of the cell and the blood pressure. In the lower part of Fig.8A, the same nerve is stimulated at 100 sec and 200 sec for 20 sec with C intensity 20 Hz stimulus. The activity of the cell and blood pressure increased simultaneously with the stimulus; this decreased gradually during the time of the stimulus. After the stimulus, the cell activity resulted in a lower value compared to that of the control period. These facts suggest that the change in the arterial blood pressure directly reflects the activity of the cell. In the upper portion of Fig.8B, the common peroneal nerve was stimulated at 100 sec and 200 sec for 20 sec with a 1 Hz stimulus (Aδ intensity) and with a 20 Hz stimulus (C intensity) in the lower part of Fig.8B. In contrast to Fig.8A, the change in the arterial blood pressure did not indicate any correlation
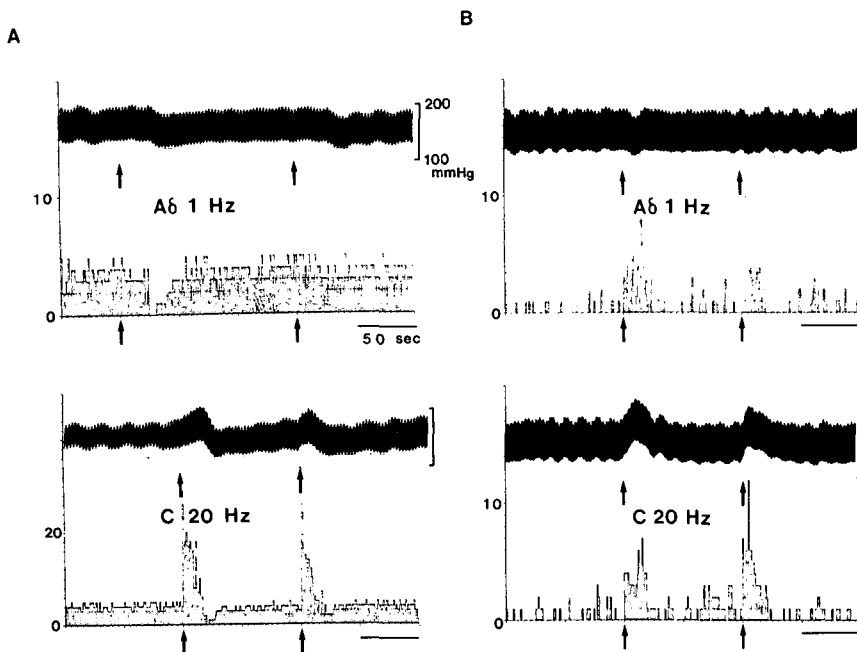
Fig. 8. Dependency of arterial blood pressure on unit activity variation to common peroneal nerve stimulation. A. Unit of Fig. 7. Upper: A 1 Hz for 20 sec at 50 sec and 200 sec, lower: C 20 Hz for 20 sec at 100 sec and 200 sec. Arrow indicates the starting point of stimulation. B. Unit of 'cardiovascular cell' but has spinal cord axon. Upper: A 1 Hz for 20 sec at 100 sec and 200 sec, lower: C 20 Hz for 20 sec at 100 sec and 200 sec.
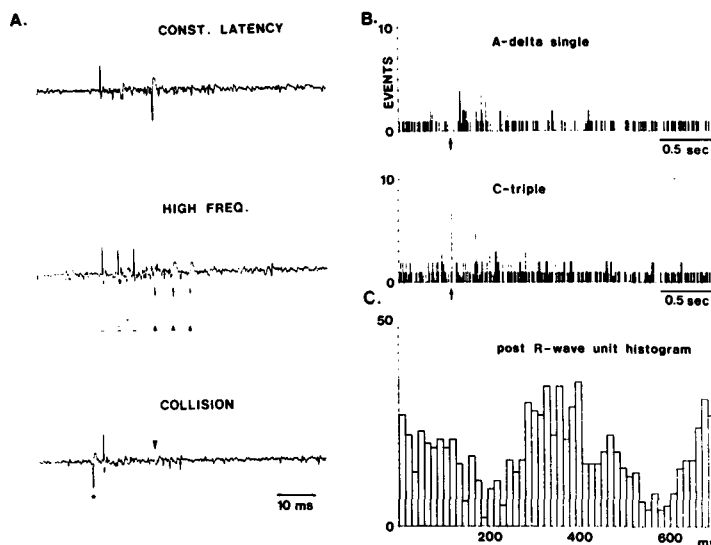

Fig. 9. A medullospinal 'cardiovascular cell' with scanty peripheral nerve input. A. shows medullospinal single unit. B. A single and C triple at 500sec. A little response to A input, no difference to C input. C. Post R-wave unit interval histogram: correlation of unit with cardiovascular system.
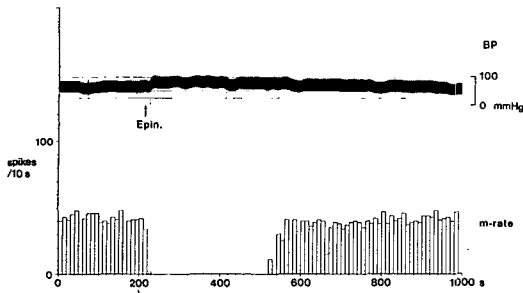
Fig. 10. Response of unit to baroreceptor reflex activation. Upper: trace of arterial blood pressure. Lower: unit activity rate per 10 sec. Arrows indicate the injection point of epinephrine (0.01%, 0.1 ml).

with the activity of cell.

The cardiovascular cell displayed in Fig.9 had axonal projections to the spinal cord and was not affected by peripheral nerve electrical stimulation. Fig.9A shows that the cell satisfies the criteria of antidromic stimulation, and the anatomical location was 5-3.5-5.8. As demonstrated Fig.9B, the cardiovascular cell had some input from A nerve stimulation but no input from C nerve stimulation. Fig.9C demonstrates that the activity of the cell was in accordance with the cardiac rhythm.

The activity-rhythm accordance resulted from the inhibition of cell activity by the baroreceptor activation (Fig.10). The upper trace is the arterial blood pressure and the lower one is the number of cell activities per second. When the arterial blood pressure was elevated by the injection of epinephrine at 200 sec, the activity of the cell disappeared. The activity returned after the normalization of the blood pressure. The baroreceptor activity by the increase in blood pressure inhibited the cell activity and the activity of the cell enhanced the SND.

Ninty per cent of the cardiovascular cells observed in RVLM were not activated by the antidromic stimulation and the most of cells with spontaneous discharge had the irregular nerve discharge pattern as shown in Fig.11. Upper trace of Fig.11 demonstrates the relation-
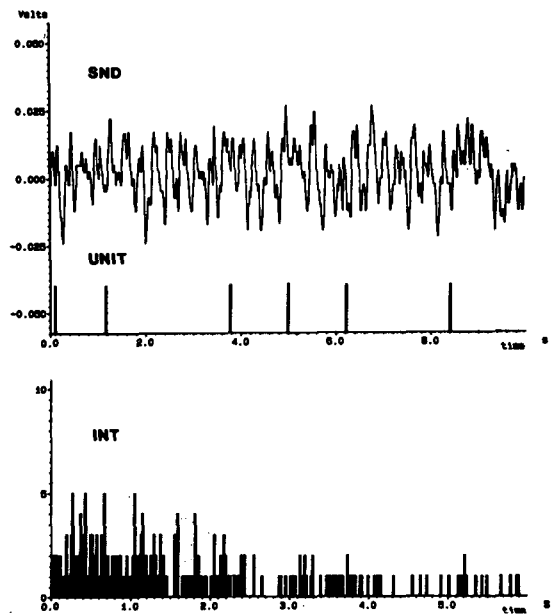

Fig. 11. Unit interval of Fig.9. cell. Upper: time relation of SND and standardized unit interval. Lower: unit interval histogram of 250 unit. Time per bin is 20 ms and number of bin is 300.

ship of SND and cell activity, and lower trace is the interval time histogram of 250 cell units. Unit discharge did not have 1:1 locking with SND and the unit interval time histogram showed wide spread pattern so these features mean that the unit discharged with irregular interval.

DISCUSSION

Control commands from ventrolateral medulla are generated by medullospinal tract cells: their cell bodies are in the medulla and their axons are located in the IML. Recently, it has been found in electrophysiological studies of animals such as rats, cats, and rabbits that the medullospinal tract cell has a slow conduction velocity (Brown & Guyenet, 1984, 1985; McAllen, 1986c). This cell group, however, is only one of diverse groups of cells which send axon from the ventrolateral medulla to the

spinal cord. The rest of the cell groups were reported to have different conduction velocities compared to that of cardiovascular cells (Barman & Gebber, 1985; Lovick, 1985). Lovick reported that the injection of excitatory amino acids to this part of a rat generates the pressor response on the cells of the sensory motor regulation resulting in an abrupt inhibition of the tail-flick reflex to nociceptive stimulation.

On the other hand, it was reported that the pain regulation system has a close relationship with the cardiovascular reflex system that stimulates the lateral hypothalamus, dorsal PAG and parabrachial complex. Their efferent terminals were in the RVLM, and they evoked the cardiovascular reflex and analgesic effect (Katayama et al, 1984; Lovick, 1985; Ward, 1988). But it was also reported that microinjection of excitatory amino acids into RVLM produced large increases in mean arterial pressure and the microinjection did not exert any control over nociceptive spinal reflexes (Siddall & Dampney, 1989). The possibility therefore exists that RVLM has no relationship with the antinociceptive system. We have confirmed that there is a spectrum of medullospinal tract cells which start from C-nerve cells and go to Aβ cells. Among these cells, only the RVLM cells that control the cardiovascular system were located in specific portion of rostal ventrolateral medulla and had conduction velocities under 10 m/sec with spontaneous activities. As cells without spontaneous activities showed fast conduction velocities which correspond to that of Aδ and Aβ nerve fiber, it is possible that their nerve terminals end some place other than in the IML. Barman & Gebber (1985) reported that the conduction velocities of non-cardiovascular cells were 24.4 ± 2.2 m/sec and that their axon terminals were not in the IML. In that report, the conduction velocities of the cardiovascular cells were 3.4 ± 3 m/sec and their axon terminals were in the IML.

The conduction velocities of cardiovascular cells were described somewhat differently between the reports. Some of the reports stated that the cell groups maintained velocities under

10 m/sec, represented in the single conduction velocity peak (Barman & Gebber, 1985; McAllen, 1986c), but Morrison's report showed two peaks in the conduction velocities in those for the rat medullospinal tract cells (morrison et al, 1988), and similar results were achieved for the study of the cat (Lebedev et al, 1986). Two peaks may represent two components of SND which is in response to electrical stimulation of the RVLM, and we cannot exclude the possibility that two groups exist in RVLM.

First, in order for RVLM cells to play a central role in the somatosympathetic reflex, they should receive somatic nociceptive information. Somatic nociceptive information can be evoked by peripheral nerve, e.g. the sciatic nerve, stimulation. Aδ (Group III) and C (Group IV) nerve fibers conduct such somatic nociceptive information (Chung et al, 1979; Kaufman et al, 1983; Swenzen et al, 1988); these evoke cardiovascular responses and activities of these nerve fibers are proportional to the actual somatic nociceptive stimulation (Abram et al, 1983). This fact therefore supports that the somatosyspathetic reflex follows the peripheral nerve stimulation, but there are negative opinions concerning the role of C-fiber in rats (Nosaka et al, 1980; Morrison & Reis, 1989). In our study, the recruitment of C-fibers was critical to the pressor response. Therefore, we consider that the activation of unmyelinated fibers is essential to the somatosympathetic reflex in the cat (Sato, 1973).

Some RVLM cells with spontaneous activity received information from peripheral nerves such as the baroreceptor. Their activities changed according to the cardiac rhythm. The peak of SND followed the cell activities after a constant interval. We considered these cells to be cardiovascular cells and we had confirmed that some of these cells receive A and C peripheral nerve input. It was confirmed by antidromic stimulation that the cardiovascular cells had an axonal projection to IML. These were considered to be the efferent pathway of somatosympathetic reflex in the spinal cord. The activities of these cardiovascular cells

preceded blood pressure change and they also were proportional to the blood pressure change in response to peripheral nerve stimulation. This means that the change in blood pressure is directly reflected by the cell activity. Whenever there was such a change, there was an increase in cell activity followed by a silent period. This silent period can be explained as characteristics of the cell itself or as the result of inhibition by the connected neural network, and we cannot overlook the fact that the activation of the baroreceptor through the nucleus tractus solitarius may play a part in the inhibition of cell activity.

A certain portion of cardiovascular cells in RVLM was not activated by antidromic stimulation and showed the original rhythm that had the time correlation with the R-wave. These cells fired irregularly so we consider that the irregularity is the statistical activity firing. This fact is in accordance with the statistical model of Barman & Gebber(Barman & Gebber, 1989; Gebber & Barman, 1989), but we cannot exclude the possibility that the network with other cardiovascular center generates the rhythm. In addition, RVLM had efferent and afferent connections with other cardiovascular regulation centers and the RVLM cells without axonal projection to the spinal cord may be connected to these areas(Dampney et al, 1987).

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