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Distribution of Neurons in the Lateral Reticular Nucleus Projecting to Cervical, Thoracic, and Lumbar Segments of the Spinal Cord in the Rat

Hyun Sook Lee*

Department of Premedical Science, School of Medicine, Konkuk University, Chungju 380-701, Korea

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Location of the neurons in the lateral reticular nucleus projecting to dorsal horn of the cervical, thoracic, or lumbar spinal cord was investigated in the rat using the technique of retrograde transport of horseradish peroxidase. The projection was bilateral with ipsilateral predominance. Neurons projecting to the cervical spinal cord were located near the medial, dorsal, and lateral perimeter of the magnocellular division of the lateral reticular nucleus, whereas cells projecting to the thoracic and lumbar spinal cord were localized in the medial and dorsal boundaries of the magnocellular division. The labeled neurons were distinctly multipolar in shape and measured approximately 10-15 μm in their greatest transverse diameter. A few neurons were also observed in the subtrigeminal nucleus, whereas few cells were in the parvocellular division. These observations provide an anatomical substrate for the functional implication of the lateral reticular nucleus in the regulation of spinal nociceptive transmission and vascular hemodynamics via the descending pathway into the spinal cord.

The lateral reticular nucleus (LRN) is one of the precerebellar nuclei that provide significant mossy fiber projections to the cerebellum of the rat (Payne, 1987). The LRN receives massive sensory input from the spinal cord via two monosynaptic pathways, the bilateral ventral flexor reflex tract and the ipsilateral forelimb tract (Ekerot, 1990a; 1990b). The ascending projection is somatotopically organized, where the dorsomedial aspect of the LRN is the site of preferential termination of the cervical spinal projection, whereas the lumbar spinal projections terminates preferentially in the ventrolateral region of the nucleus (Shokunbi et al., 1985).

A large number of electrophysiological studies have reported that the LRN in the caudal medulla is involved in the regulation of spinal nociceptive transmission and vascular hemodynamics via the descending pathway into the spinal cord (Ciriello and Calaresu, 1977; Gebhart and Ossipov, 1986; Sotgiu, 1986; Janss and Gebhart, 1988a; 1988b; Liu et al., 1990; 1993). The existence of several endogenous opioids within the LRN has been demonstrated using immunocytochemical methods. A few substance P or methionine-enkephalin immunoreactive, spinally-projecting neurons were identified in the LRN of the rat; in contrast, no spinally projecting dynorphin-immunoreactive neurons were found (Menetrey and Basbaum, 1987). In addition, a small number of leucine-enkephalin immunoreactive neurons were identified in the LRN of the squirrel monkey (Edwards et al., 1987). In addition to these neuropeptides, glutamic acid decarboxylase (GAD)-immunoreactive neurons were observed adjacent to the LRN (and partially overlapping the A1 area), which have been implicated in the descending control of blood pressure by modulating vasoconstriction at several arterial branches of the abdominal aorta (Ruggiero et al., 1985).

In relation to antinociceptive and hemodynamic function of this descending fiber projection, the present study was aimed to define the anatomical distribution of the projections from the LRN to the dorsal horn of cervical, thoracic, or lumbar spinal cord and to investigate whether the pathway might be somatotopically organized. A retrograde tracer, wheatgerm agglutinin-conjugated horseradish peroxidase (WGA-HRP), was injected into the dorsal horn of each level of the spinal cord and the distribution of retrogradely-labeled neurons within the LRN was investigated.

Materials and Methods

Nineteen Sprague-Dawley rats, including both sexes and ranging in weight from 300 to 350 g, were used in this study. Prior to surgery, each rat was anesthetized with an intraperitoneal injection of chloral hydrate (3.6 % in distilled water, 1 ml/100 g body weight).

* Tel: 82-43-840-3723, Fax: 82-43-851-9329
E-mail: Hyunsook.Lee@kku.edu

1. Tracer injection

After inducing anesthesia, the animal was placed in a stereotaxic apparatus, with thoracic and abdominal portions firmly fixed to the base. The mid-cervical (C_{4-5}), mid-thoracic (T_{6-7}), or upper lumbar (L_{1-2}) portion of the spinal cord was exposed by laminectomy, which was followed by the incision of dura mater. Lower lumbar (L_{3-5}) injections could not be performed because branches of spinal nerves located on top of the spinal cord prevent the micropipette from approaching the spinal cord stereotaxically. The injection system consisted of a glass micropipette (10-20 μm tip diameter) hydraulically linked to a 2.0 microliter Hamilton syringe. A total volume of 0.12-0.14 μl of 1% WGA-HRP (Vector Lab. PL-1026) was injected into the dorsal horn of the spinal cord over a 30 min period.

2. Perfusion and fixation

After recovery period of 24 to 48 h, the animal was perfused with 150 ml of saline followed by 600 ml of fixative containing 1% paraformaldehyde and 1.25% glutaraldehyde in 0.1 M phosphate buffer solution (pH 7.4, 4℃). A post-fixation wash with 100 ml of 10% sucrose in the same buffer was also performed in order to block excessive depression of the enzyme activity, which might be caused by aldehydes remaining in the brain tissue. The brain was then removed and placed in 30% sucrose solution in the buffer overnight (4℃).

3. WGA-HRP histochemistry

Serial transverse sections of the LRN as well as injection sites were prepared on a cryostat at the thickness of 40 μm. Every seventh section through the LRN and every tenth section through the injection site were collected in tissue-culture plates. Sections were then incubated according to the combined method of nitroprusside-stabilized tetramethylbenzidine (TMB) reaction and cobalt/nickel-intensified diaminobenzidine (DAB) reaction described by Rye et al. (1984). Sections were washed with saline and incubated for 90 min in 100 ml of solution containing 10% ethanol, 1% DMSO, and 0.005% gelatin in 0.001 M acetate buffer (pH 4.3), which was mixed with 0.0085% TMB and 0.05% sodium nitroferricyanide. About 0.26 ml of 0.3% H_2O_2 was added six times at 15-minute intervals during the incubation period. Sections were rinsed with saline and then transferred to a stabilization bath at 4℃ containing 0.05% DAB, 0.003% H_2O_2, 0.16% $CoCl_2$, and 0.16% $Ni(NH_4)_2SO_4$. Sections were washed with saline, mounted on gelatin-coated glass slides, and counterstained with 1% neutral red.

Results

Among 19 animals, cases showing highly-localized injection sites were utilized for the present analysis. At least three well-defined injection cases were obtained at cervical, thoracic, or lumbar spinal levels. A substantial number of retrogradely-labeled neurons was observed in each subdivision of the LRN. The distribution of labeled cells was somewhat variable depending on the segmental level where the tracer was injected.

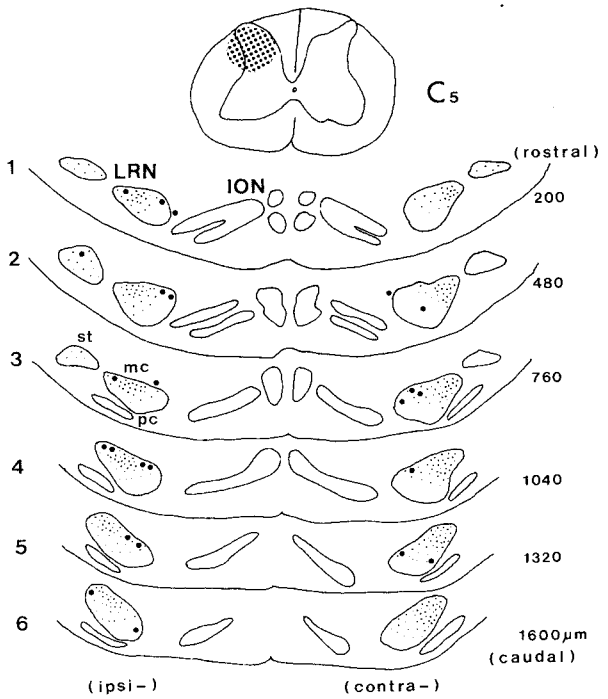

Fig. 1. The injection site of WGA-HRP within dorsal horn of the cervical (C_5) spinal cord was depicted on the top (rat No. 5). The others represent a rostro-caudal series of transverse sections (1-6) demonstrating the location of retrogradely-labeled neuronal somata (large dots) within the lateral reticular nucleus (LRN) ipsilateral (ipsi-) or contralateral (contra-) to the injection site. Small dots represent orthogradely-transported terminal labeling by the spino-reticular projection. ION, inferior olivary nucleus; mc, magnocellular division; pc, parvocellular division; st, subtrigeminal division.

Cervical injections

A labeling pattern with the tracer injection into a mid-cervical (C_5) level was shown at a rostro-caudal series of LRN sections (Fig. 1, rat No. 5). Retrogradely-labeled neurons were observed bilaterally with ipsilateral predominance. Cells were located at medial, dorsal and lateral perimeters of the magnocellular division at the ipsilateral side (Fig. 1, sections 1-6). A few cells were observed in the subtrigeminal nucleus (Fig. 1, section 2), whereas few cells were in the parvocellular division. In the contralateral side, the majority of labeled cells were located in the magnocellular division (Fig. 1, sections 2-5). Labeled neurons were not observed either in the parvocellular or in the subtrigeminal divisions.

At a representative section in a cervical injection case (rat No. 5), labeled cells were located at the

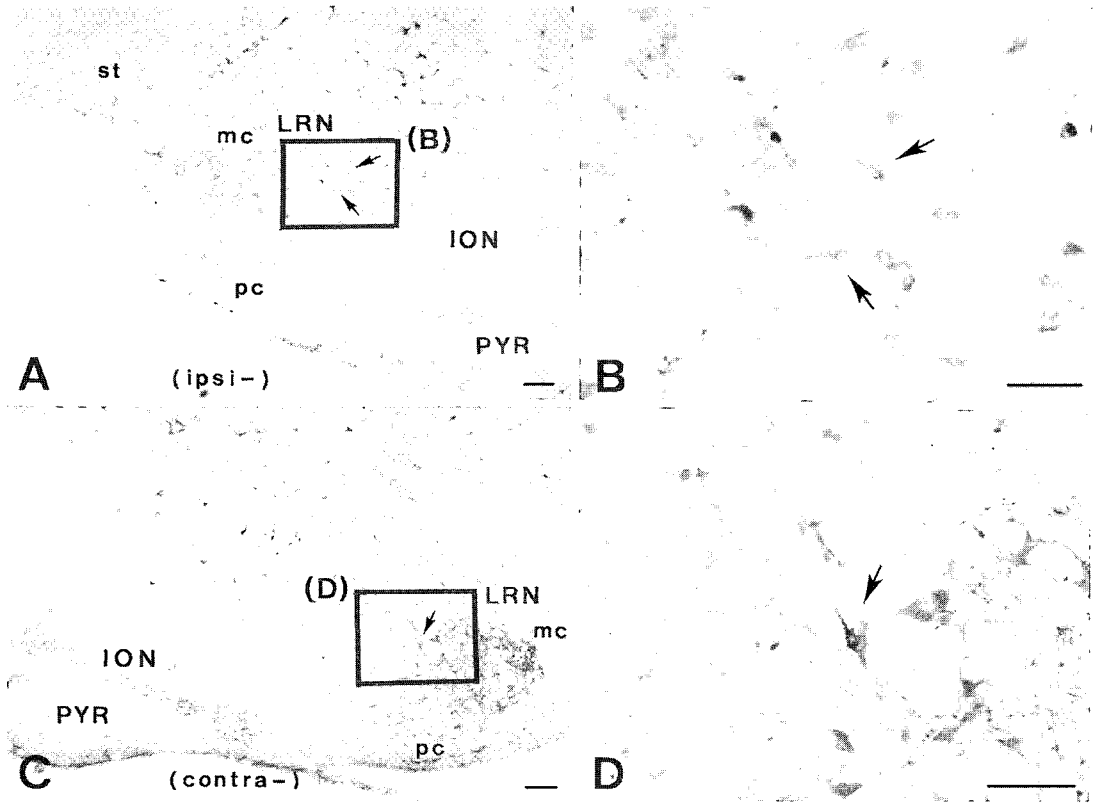

Fig. 2. Retrogradely-labeled neurons (arrows) in the lateral reticular nucleus (LRN) ipsilateral (ipsi-) or contralateral (contra-) to the injection site were shown at low (A and C) and high (B and D) magnifications in a representative case (rat No. 5). ION, inferior olivary nucleus; mc, magnocellular division; pc, parvocellular division; PYR, pyramid; st, subtrigeminal division. Scale bars = 100 μm.

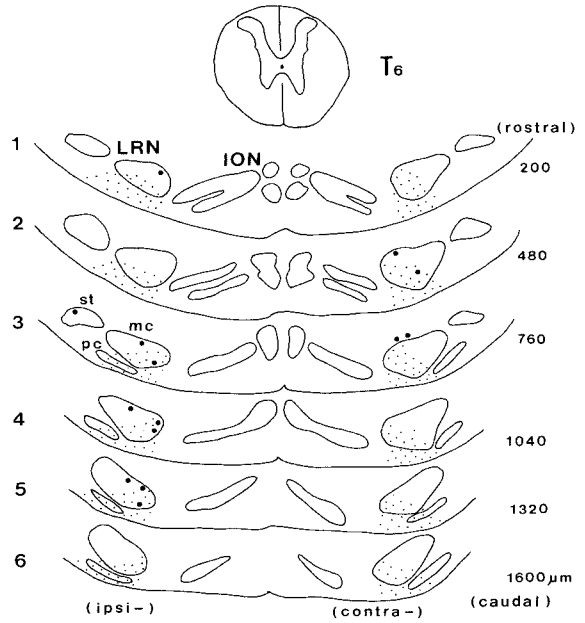

Fig. 3. The injection site of WGA-HRP within dorsal quadrant of the thoracic (T_6) spinal cord was shown on the top (rat No. 12). The others represent a series of the lateral reticular nucleus (LRN) sections (1-6) with retrogradely-labeled cells (large dots) at ipsilateral (ipsi-) or contralateral (contra-) to the injection site. Small dots represent terminal labeling by the spino-reticular projection. ION, inferior olivary neucleus; mc, magnocellular division; pc, parvocellular division; st, subtrigeminal division.

medial border of the ipsilateral magnocellular division at the ipsilateral side (Fig. 2A and B). Labeled cells were also observed at the dorsal boundary of the contralateral magnocellular division (Fig. 2C and D). The morphology of the labeled cells was mainly multipolar and the size was in the range of 10-15 μm in their greatest transverse diameter (Fig. 2B and D).

Thoracic injections

A series of rostro-caudal sections exhibiting the pattern of labeled cells were shown in a representative injection case at a mid-thoracic level (T_6, rat No. 12). The majority of labeled neurons was located at the dorsal, medial and ventral boundaries of the magnocellular division at the ipsilateral LRN (Fig. 3, sections 3-5). A few neurons were also found at the subtrigeminal division (Fig. 3, section 3), whereas few cells were at the parvocellular division. At the contralateral side, a limited number of cells was observed at the magnocellular division (Fig. 3, sections 2 and 3). Labeled neurons were not observed either in the parvocellular or subtrigeminal divisions.

At a representative rostral section in a thoracic injection case (rat No. 12), labeled neurons were observed in the magnocellular division of the ipsilateral LRN (Fig. 4A and B). In the more caudal section, cells were found at the medial and dorsal boundaries of the

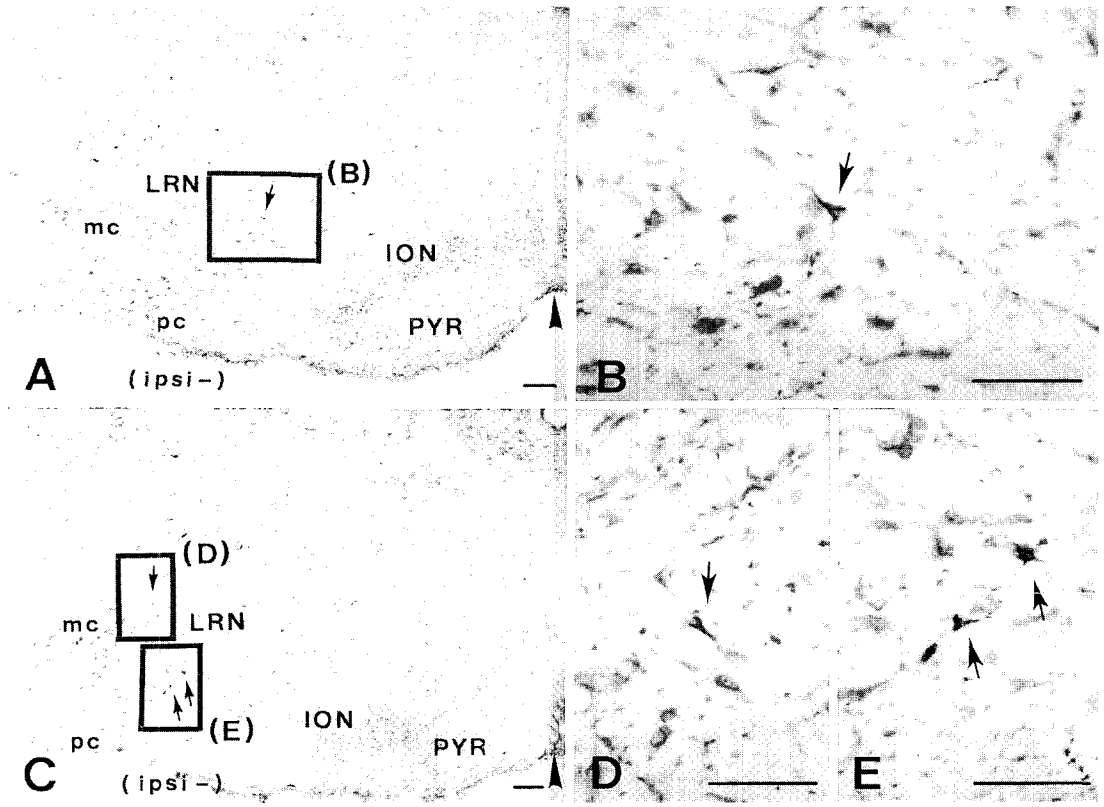

Fig. 4. Retrogradely-labeled neurons (arrows) were depicted at rostral (A and B) and caudal (C-E) sections of the lateral reticular nucleus (LRN) ipsilateral (ipsi-) to the injection site (rat No. 12). Arrowheads represent midlines. ION, inferior olivary nucleus; mc, magnocellular division; pc, parvocellular division; PYR, pyramid. Scale bars = 100 μm.

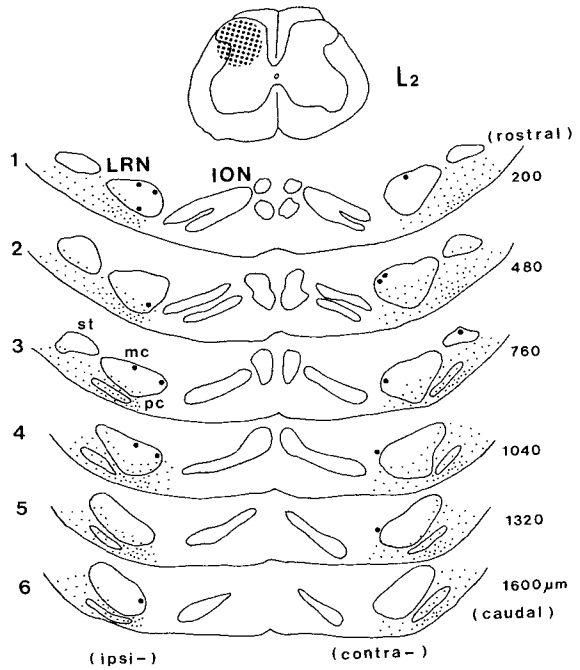

Fig. 5. The injection site of WGA-HRP within dorsal horn of the lumbar (L_2) spinal cord was shown on the top (rat No. 17). The others represent a series of lateral reticular nucleus (LRN) sections (1-6) with retrogradely-labeled cells (large dots). Small dots represent terminal labeling. ION, inferior olivary nucleus; mc, magnocellular division; pc, parvocellular division; st, subtrigeminal division.

magnocellular division at the ipsilateral side (Fig. 4C-E). The morphology of the labeled cells was either pyramidal or multipolar and the size was in the range of 10-15 μm in their greatest transverse diameter (Fig. 4B, D, and E).

Upper lumbar injections

The distribution of labeled cells in the rostro-caudal series of transverse sections was shown in a representative lumbar injection case at L_2 level (rat No. 17). At the ipsilateral side, labeled neurons were located in the dorsal, medial, and ventral borders of the magnocellular division (Fig. 5, sections 1-4). Labeled cells were not found either in the subtrigeminal or in the parvocellular divisions. In the contralateral side, cells were observed in the dorsal and medial boundaries of the magnocellular division (Fig. 5, sections 1-5). A few labeled neurons were also observed in the subtrigeminal nucleus, whereas few cells were in the parvocellular division (Fig. 5, section 3).

In a representative section, labeled cells were observed at the medial and dorsal boundaries of the magnocellular division at the ipsilateral side (rat No. 17, Fig. 6A-C). At the contralateral side, cells were found at the medial border of the magnocellular division (Fig. 6D and E). Labeled cells were either multipolar- (Fig. 6B and C) or bipolar-shaped (Fig. 6E) and the size was in the range of 10-15 μm.

Discussion

It has long been known that the lateral reticular nucleus, located at the medullary reticular formation, is one of the major precerebellar nulcei that relay information to the cerebellum (Payne, 1987). It receives massive sensory- or motor-related inputs from the spinal cord as well as the red nucleus and the cerebral cortex (Shokunbi et al., 1986; Wiesendanger and Wiesendanger, 1987). It has been recently reported that the LRN has a substantial amount of descending inputs to the spinal cord (Liu et al., 1993). A number of physiological studies further proposed that descending projections from the LRN to the spinal cord might be specifically involved in pain suppression and hemodynamic control (Janss and Gebhart, 1988a, b; Liu et al., 1990). The central system that modulates pain and blood pressure involves the periaqueductal gray, the solitary nucleus, and the nucleus raphe magnus (Lovick, 1985).

In spite of a large number of electrophysiological studies, the anatomical and neurochemical identification of this descending pathway was less characterized. Since the ascending projection from the spinal cord to the LRN is somatotopically organized, it was interesting to investigate whether the descending projection was also topographically organized (Shokunbi et al., 1985). As mentioned, the ascending projection was organized in such a way that the dorsomedial aspect of the LRN was the site of preferential termination from the cervical spinal cord, while the ventrolateral region was the termination site from the lumbar spinal cord. Based on the present study, a similar type of topographic organization was not observed in the descending projection from the LRN to the dorsal horn of the cervical, thoracic, or lumbar spinal cord (Figs. 1, 3, and 5). Labeled cells in the medial and dorsal borders of the magnocellular division were overlapped in each injection case of cervical, thoracic, or lumbar spinal cord (Figs. 1, 3, and 5), whereas the labeled cells in the lateral border of the magnocellular division were observed only in the cervical injection cases (Fig. 1).

The overlap of retrogradely-labeled neurons in the medial and dorsal perimeters of the magnocellular division at each injection case could be explained in part by the fact that bulbospinal fibers generally give off axon collaterals to multiple levels of the spinal cord (Kausz, 1991). Physiological experiments also indicated that a large proportion of reticulospinal neurons projecting to the lumbar and thoracic spinal cord provides collateral axonal branches into the cervical cord (Martin et al., 1981).

Another location with labeled neurons was the lateral border of the magnocellular division of the LRN, which was obtained when the injection was made at the dorsal horn of the cervical spinal cord (Fig. 1). It is consistent with the previous observation that a few cells located at the most lateral portion of the ventrolateral reticular formation between the lateral reticular nucleus and the caudal pole of the spinal trigeminal nucleus project to the superficial or deep dorsal horn of the cervical spinal cord in the rat (Tavares and Lima, 1994). It should be emphasized that the lateral cap of the magnocellular division overlapped the medial portion of the A1 group at caudal LRN sections where the subtrigeminal divisions do not exist (Fig. 1, sections 4-6). It has been postulated that the majority of cells in the A1 group provide noradrenergic fibers to the solitary nucleus, the dorsal motor nucleus of the vagus nerve, the locus coeruleus, and the parabrachial nucleus in the pons (Woulfe et al., 1990). The noradrenergic system plays an important role in the descending control of pain transmission and various other autonomic functions (Satoh et al., 1977; Janss et al., 1987). A previous immunocytochemical study indicated that noradrenergic neurons were found mostly in the region immediately dorsal and lateral to the LRN, along with a few scattered neurons near the ventral surface of the medulla in and around the parvocellular division of the LRN (Ciriello et al., 1986).

Descending projections from the LRN into the thoracic spinal cord also need further investigation (Figs. 3 and 4). As mentioned earlier, electrophysiological studies have reported that the LRN is involved in two different functions involving the regulation of spinal nociceptive transmission as well as vascular hemodynamics via a descending pathway into the spinal cord (Janss and Gebhart, 1988a, b; Liu et al., 1990). If the injection method used in the present study can be modified such that tracer material injected at thoracic levels can be deposited in the dorsal horn but not the lateral horn and vice versa, then it may be possible to distinguish between tactile processing and autonomic function of the descending circuitry.

Labeling pattern in the LRN at the lumbar injection case was similar to the thoracic injection case (Figs. 5 and 6). Labeled neurons were mainly observed at the medial, and dorsal perimeter of the magnocellular region. A recent study indicated that descending projection neurons at these locations also send axon collaterals into the ventrolateral portion of the midbrain periaqueductal gray matter (Lee and Mihailoff, 1999). These observations confirmed that the descending projection system from the LRN to the spinal cord plays an important role in somatosensory or autonomic function such as pain suppression and hemodynamic control.

In all three injection cases at cervical, thoracic, or lumbar spinal cord, a scanty number of cells were observed in the subtrigeminal nucleus, whereas few cells were in the parvocellular division. It was reported in the rat that neurons in the subtrigeminal region of the LRN send efferent fibers to various lobules of the vermis and cerebellar hemispheres, whereas those in

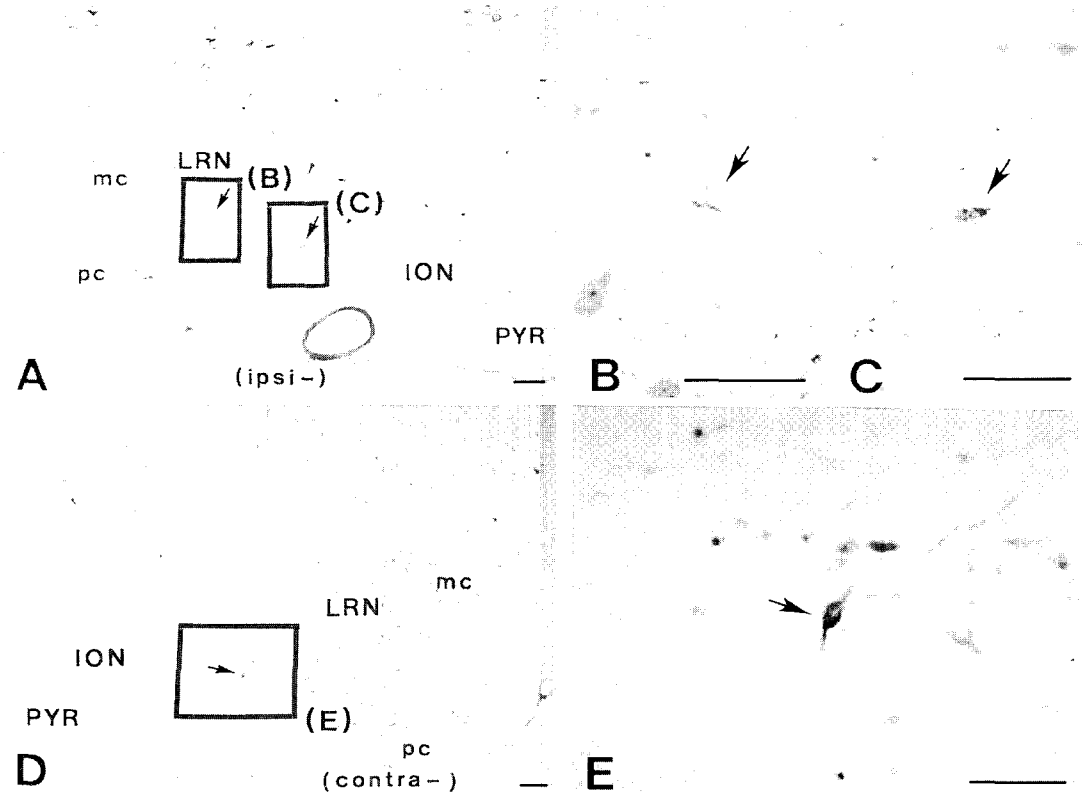

Fig. 6. Retrogradely-labeled neurons (arrows) were depicted within the lateral reticular nucleus (LRN) ipsilateral (ipsi-, A-C) or contralateral (contra-, D and E) to the injection site (rat No. 17). ION, inferior olivary nucleus; mc, magnocellular division; pc, parvocellular division; PYR, pyramid. Scale bars = 100 μm.

the parvocellular division specifically do to the pyramis and copula pyramidis of the cerebellum (Eisenman, 1982; Payne, 1987).

The relative paucity of labeled neurons in each injection case at cervical, thoracic, or lumbar spinal levels is consistent with the previous anatomical study indicating that only a few endogenous opioid immunoreactive LRN neurons have descending projections to the spinal cord (Menetrey and Basbaum, 1987). However, it seems to contradict physiological studies that have demonstrated regulation of spinal nociceptive transmission from multiple sites along LRN electrode penetrations (Janss and Gebhart, 1988a, b; Liu et al., 1990). It is possible that only a few cells at the perimeter of an electrically-stimulated zone might have been responsible for antinociceptive effects. Although massively parallel connections involving large numbers of neurons are characteristic of many sensory, motor and association pathways in the brain, there is increasing evidence that important physiological functions can also be mediated by discrete projections from relatively small numbers of neurochemically specific neurons.

Neurochemical identities of these descending pathways need to be further characterized in the future using the double-labeling method. It has been suggested that a moderate number of GAD-immunoreactive neurons in the caudal ventrolateral medulla might be involved in the regulation of blood pressure by modulating vasoconstriction at several arterial branches of the abdominal aorta (Ruggiero et al., 1985). Gamma-aminobutyric acid (GABA)-containing cells in rostral medullary region have also been implicated in pain suppression circuits (Cho and Basbaum, 1991). In addition, several opioid substances were identified in the LRN. It has been reported that methionine-enkephalin immunoreactive neurons occupy a peripheral location in the magnocellular division of the rat LRN (Murakami et al., 1987). It has also been suggested that substance P- and enkephalin-immunoreactive neurons in the LRN contribute to the bulbospinal pathway that reaches the cervical or lumbar enlargements (Fallon and Leslie, 1986). The differential distribution within the LRN or co-localization of these opioid neurotransmitters, norepineprine, or GABA within each subregion of the LRN would facilitate the understanding of the role of the LRN in somatosensory and autonomic functions of the animal.

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References

Cho HJ and Basbaum AI (1991) GABAergic circuitry in the

rostral ventral medulla of the rat and its relationship to descending antinociceptive controls. *J Comp Neurol* 303: 316-328.

Ciriello J and Calaresu FR (1977) Lateral reticular nucleus: a site of somatic and cardiovascular integration in the cat. *Am J Physiol* 233: R100-R109.

Ciriello J, Caverson MM, and Park DH (1986) Immunohistochemical identification of noradrenaline- and adrenaline-synthetizing neurons in the cat ventrolateral medulla. *J Comp Neurol* 253: 216-230.

Edwards DL, Poletti CE, and Foote WE (1987) Evidence for leucine-enkephalin immunoreactive neurons in the medulla which project to spinal cord in squirrel monkey. *Brain Res* 437: 197-203.

Eisenman LM (1982) The reticulocerebellar projection to the pyramis and copula pyramidis in the rat: An experimental study using retrograde transport of horseradish peroxidase. *J Comp Neurol* 210: 30-36.

Ekerot CF (1990a) The lateral reticular nucleus in the cat. VII. Excitatory and inhibitory projection from the ipsilateral forelimb tract (iF tract). *Exp Brain Res* 79: 120-128.

Ekerot CF (1990b) The lateral reticular nucleus in the cat. VIII. Excitatory and inhibitory projection from the bilateral ventral flexor reflex tract (bVFRT). *Exp Brain Res* 79: 129-137.

Fallon JH and Leslie FM (1986) Distribution of dynorphin and enkephalin peptides in the rat brain. *J Comp Neurol* 249: 293-336.

Gebhart GF and Ossipov MH (1986) Characterization of inhibition of the spinal nociceptive tail-flick reflex in the rat from the medullary lateral reticular nucleus. *J Neurosci* 6: 701-703.

Janss AJ, Jones SL, and Gebhart GF (1987) Effect of spinal norepinephrine depletion on descending inhibition of the tail flick reflex from the locus coeruleus and lateral reticular nucleus in the rat. *Brain Res* 400: 40-52.

Janss AJ and Gebhart GF (1988a) Quantitative characterization and spinal pathway mediating inhibition of spinal nociceptive transmission from the lateral reticular nucleus in the rat. *J Neurophysiol* 59: 226-247.

Janss AJ and Gebhart GF (1988b) Brainstem and spinal pathways mediating descending inhibition from medullary lateral reticular nucleus in the rat. *Brain Res* 440: 109-122.

Kausz M (1991) Arrangement of neurons in the medullary reticular formation and raphe nuclei projecting to thoracic, lumbar and sacral segments of the spinal cord in the cat. *Anat Embryol* 183: 151-163.

Lee HS and Mihailoff GA (1999) A fluorescent double label study of lateral reticular nucleus projections to the spinal cord and periaqueductal gray in the rat. *Anat Rec* 256: 91-98.

Liu RR, Tang JS, Hou ZL, and Jia H (1990) Responses of reticulospinal neurons in the lateral reticular nucleus area of the rat to cutaneous noxious and non-noxious stimulation. *Neurosci Lett* 109: 92-96.

Liu RH, Tang JS, and Hou ZL (1993) Effect of systemic morphine on neurons in the lateral reticular nucleus area of the rat. *Brain Res Bull* 32: 179-184.

Lovick TA (1985) Ventrolateral medullary lesions block the antinociceptive and cardiovascular reponses elicited by stimulating the dorsal periaqueductal gray matter in rats. *Pain* 21: 241-252.

Martin GF, Cabana T, and Humbertson AO (1981) Evidence for collateral innervation of the cervical and lumbar enlargements of the spinal cord by single reticular and raphe neurons: studies using fluorescent markers in double-labeling experiments on the North American opossum. *Neurosci Lett* 24: 1-6.

Menetrey D and Basbaum AI (1987) The distribution of substance P-, enkephalin-, and dynorphin-immunoreactive neurons in the medulla of the rat and their contribution to bulbospinal pathways. *Neuroscience* 23: 173-187.

Murakami S, Okamura IL, Yanaihara C, Yanaihara N, and Yasuhiko I (1987) Immunocytochemical distribution of met-enkephalin-Arg^6-Gly^7-Leu^8 in the rat brainstem. *J Comp Neurol* 261: 193-208.

Payne JN (1987) Cerebellar afferents from the lateral reticular nucleus in the rat. *Neuroscience* 23: 211-221.

Ruggiero DA, Meeley MP, Anwar M, and Reis DJ (1985) Newly identified GABAergic neurons in regions of the ventrolateral medulla which regulate blood pressure. *Brain Res* 339: 171-177.

Rye DB, Saper CB, and Wainer BH (1984) Stabilization of the tetramethyl benzidine reaction product. *J Histochem Cytochem* 32: 1145-1153.

Satoh K, Tohyama M, Yamamoto K, Sakumoto T, and Shimizu N (1977) Noradrenaline innervation of the spinal cord studied by the horseradish peroxidase method combined with monoamine oxidase staining. *Exp Brain Res* 30: 175-186.

Shokunbi MT, Hrycyshyn AW, and Flumerfelt BA (1985) Spinal projections to the lateral reticular nucleus in the rat: a retrograde labeling study using horseradish peroxidase. *J Comp Neurol* 239: 216-226.

Shokunbi MT, Hrycyshyn AW, and Flumerfelt BA (1986) A horseradish peroxidase study of the rubral and cortical afferents to the lateral reticular nucleus in the rat. *J Comp Neurol* 248: 441-454.

Sotgiu ML (1986) Inhibition of the nociceptive jaw opening reflex by the lateral reticular nucleus (LRN) in the rabbit. *Neurosci Lett* 65: 145-148.

Tavares I and Lima D (1994) Descending projections from the caudal medulla oblongata to the superficial or deep dorsal horn of the rat spinal cord. *Exp Brain Res* 99: 455-463.

Wiesendanger R and Wiesendanger M (1987) Topography of the corticofugal projection to the lateral reticular nucleus in the monkey. *J Comp Neurol* 256: 570-580.

Woulfe JM, Flumerfelt BA, and Hrycyshyn AW (1990) Efferent connections of the A1 noradrenergic cell group: A DBH immunohistochemical and PHA-L anterograde tracing study. *Exp Neurol* 109: 308-322.

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