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LATERAL THALAMIC NOCICEPTION: THE EFFECTS OF INTERRUPTION OF TRANSMISSION THROUGH THE VENTROLATERAL AND THE DORSOLATERAL SPINOTHALAMIC TRACTS

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The recurrence of clinical pain associated with the return of nociception that can occur following anterolateral spinal cord damage (White & Sweet, 1969) has prompted the hypothesis that alternate nociception signaling ascending spinal pathways exist outside the confines of the classical spinothalamic tract. Candidate alternate pain pathways considered include the spinocervical tract, the post synaptic dorsal column pathway and propriospinal pathways (Willis, 1985). Little attention has been given the possibility of a direct spinothalamic pathway existing outside the ventral quadrant. Recent evidence using retrograde transport of horseradish peroxidase (HRP) has, however, demonstrated the existence of a dorsolateral spinothalamic tract (DSTT) in cat and squirrel monkey (Jones et al., 1985a,b). The DSTT consists nearly exclusively of lamina I spinal neuron axons while the ventral spinothalamic tract (VSTT) consists of axons of spinal neurons located in laminae IV-X. Both pathways cross segmentally and have widespread thalamic terminations. Within the lateral thalamus, both pathways have terminals in the ventral posterior lateral nucleus (VPL) and the posterior nucleus (PO) (Apkarian et al., 1986b). This paper describes the changes in the response characteristics of nociceptive neurons of the cat lateral sensory thalamus following interruption of transmission through either the DSTT or the VSTT.

METHODS

Cats initially anesthetized with nembutal (35 mg/kg) and maintained with 2/3 nitrous oxide, 1/3 oxygen and supplemental halothane (0.1-0.2%) were used for these experiments. The thoracic spinal cord was exposed over two segments and a small craniectomy was done for thalamic access. Single unit recordings were made from the lateral sensory thalamus using parylene coated tungsten microelectrodes with impedances of 4-10 megohms. Only units responsive to noxious cutaneous inputs form the basis of this report. Following isolation, the response properties of the unit to innocuous and noxious (pinch and temperature >45 degrees C) stimuli were determined. Two methods of interrupting transmission through the thoracic ventral quadrant (VQ) or the dorsolateral funiculus (DLF) ipsilateral to the recording site were used. In some experiments, following characterization of the unit responses, microsurgical lesions of the DLF and/or the VQ were made. More commonly transmission through the DLF or the VQ was reversibly blocked by cooling the quadrant of interest to 1-3 degrees centigrade using 0.6 mm stainless steel tubing, in contact with the appropriate area of the thoracic spinal cord, through which cooled methanol was pumped. The contact temperature was monitored and could be set to any level by adjusting the methanol pump speed (Salsbury & Horel, 1983). The changes in the response properties of the thalamic units following interruption of transmission through the DLF or VQ were then determined. Each thalamic recording site was marked with an electrolytic lesion for later histologic localization.

RESULTS

Eighteen units responding to noxious cutaneous stimuli were studied. The receptive fields of all these units included the contralateral hindlimb. The locations of the units within the thalamus are shown in figure 1. Thirteen recording sites were in the shell region of the anterior lateral portion of the VPL nucleus, and two were located in PO. One of these units responded exclusively to noxious stimuli, while the remainder responded in a graded fashion to innocuous and noxious stimuli. Two units did not respond to noxious thermal stimulation, yet increased their ongoing activity when the receptive fields were

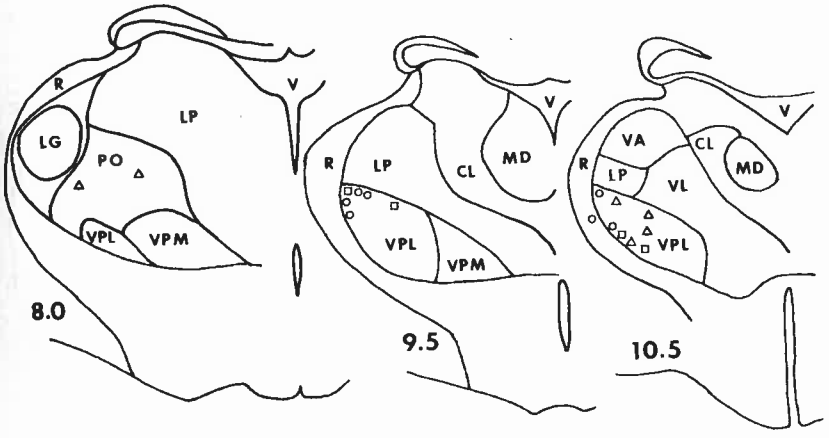

Figure 1. Locations of thalamic recording sites. The AP level of each thalamic section is indicated. The circles represent units unaffected by either DLF or VQ block. The triangles represent units whose responses were decreased by DLF block. The squares represent units whose responses were altered by VQ block.

pinched with serrated forceps. The activity of the units studied by thermal stimulation usually showed response saturation at receptive field temperatures above 50 degrees centigrade (figure 2). The nociceptive response properties of the units in PO were similar to those in VPL, though the receptive fields of the PO units were generally larger, at times consisting of the entire lower half of the body.

Six of eighteen units had their responses to noxious stimulation blocked by cooling or lesioning the DLF as shown in figure 2. The locations of these units are indicated in figure 1. When effective, DLF cooling or lesioning was able to completely abolish the thalamic response to noxious thermal cutaneous stimulation (figure 2). DLF blocking did not alter the responses or receptive field sizes of thalamic units elicited by innocuous skin stimulation, even when the responses to noxious stimuli were abolished. Two thalamic units showed an increase in responsiveness to noxious cutaneous stimulation during DLF cooling.

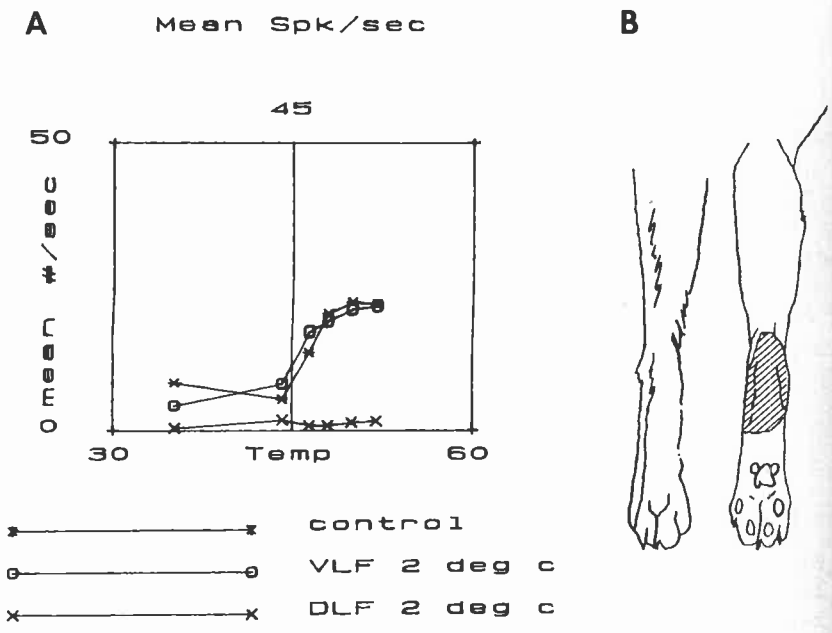

Figure 2. Effects of DLF and VLF blocks on a VPL unit responses to noxious cutaneous stimuli. A. Illustrates the mean number of spikes/second plotted against the cutaneous temperatures used to elicit the responses. In both the control state and when the VLF is cooled to 2 degrees C, the unit responds briskly to skin temperatures over 45 degrees C. When the DLF is cooled to 2 degrees C, the response to skin heating is lost. B. Shows the contralateral lower extremity receptive field to pinch of this unit. The heat stimulus was applied within this receptive field.

Four of sixteen units studied had their responses to nociceptive thermal cutaneous stimulation altered by cooling or lesioning the VQ. Of these, one showed a decrease (but not loss) to noxious cutaneous thermal stimulation, one showed an increased response to noxious thermal cutaneous stimulation, one showed an increase in background resting activity that masked any temperature response and one showed loss of response to pinch after VQ section which had been preceeded by an ineffective DLF

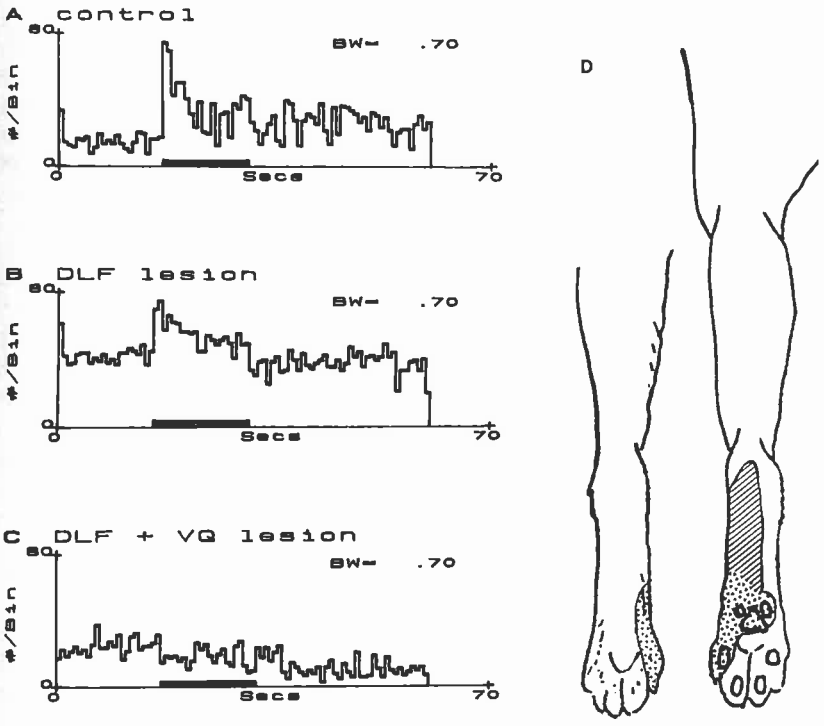

Figure 3. The effects of DLF and a combined DLF and VQ lesion on the responses of a VPL unit to pinch. A, B and C are peristimulus time histograms with binwidth of 0.7 seconds. The time of the occurence of the pinch is marked by the heavy black bar above the time axis. B. The effect of the DLF lesion ipsilateral to the recording site is to increase the spontaneous activity without altering the magnitude of the response to pinch. C. The response to pinch is abolished only when a VQ lesion ipsilateral to the recording site is added to the DLF lesion. D. The contralateral lower extremity receptive field to touch (stippled) and pinch (diagonal lines). Following the VQ lesion, the responses to both noxious and innocuous cutaneous stimuli are abolished.

lesion (figure 3).

In three units, where the response to noxious cutaneous stimulation could not be blocked by cooling either the VQ or the DLF, progressive surgical lesions of the spinal cord demonstrated that the input to these thalamic units traveled through multiple ascending pathways distributed bilaterally in the spinal cord.

DISCUSSION

These preliminary results indicate that information concerning the occurence of noxious peripheral stimulation ascends through the spinal cord in both the VQ and the DLF. It is impossible on the basis of this study to differentiate between the effects of interruption of direct spinothalamic pathways (DSTT, VSTT) and interruption of spinoreticulo-thalamic pathways or other multisynaptic pathways traveling in the VQ or DLF. The increase in responses to noxious peripheral stimulation that occurred with transmission block of either DLF or VQ were likely the result of loss of descending inhibition. The inability to block transmission to some of the units that were studied might indicate that the fibers traveling in the quadrant being cooled were too distant from the cold probe to be lowered to a blocking temperature, since when the contact probe is at 0 degrees centigrade, the effective blocking range is about 0.5 mm (Apkarian et al., 1986a). However, information concerning noxious peripheral events can also reach the thalamus through areas outside of the ipsilateral spinothalamic tracts.

Since the DSTT in the DLF is comprised almost entirely of lamina I cell axons (Jones et al., 1985a), it is clear that the nociceptive responses of some thalamic units is mediated by lamina I cell input. Based on the limited number of units in this study, it is uncertain whether there is a topographic preference in the lateral thalamus of units activated by lamina I cell input. Since there are essentially no lamina I cell axons traveling in the cat VSTT, it is apparent that lamina I cell input is not necessary for the nociceptive responses of all thalamic units.

This data is consistent with the work of Kennard (1954) who demonstrated the importance of the DLF for behavioral

nociception in cats. Similarly, Vierck (1979) has shown that lesions of the DLF in macaque monkeys can, at least transiently, interfere with nociception. Interestingly, human pathologic specimens obtained following successful anterolateral cordotomy, indicate that some of the lesions were limited to the DLF (Sweet, 1973). It is possible, then, that the return of pain perception following anterolateral cordotomy or spinal trauma is a reflection, in part, of the spared lamina I cell input to the thalamus. The severe burning dysesthetic pain, typical of the post cordotomy syndrome, likewise is probably due in part to the activity in the thalamus elicited by lamina I cell nociceptive specific input. The role that the DSTT plays after long term denervation remains uninvestigated at present.

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