Absence of coherence between cervical and lumbar spinal cord dorsal surface potentials in the anaesthetized cat

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Abstract

Recordings of spontaneous cord dorsum potentials (CDPs) along the longitudinal axis of the spinal cord were made. These recordings were obtained from the surface of the dorsal horn at different points along the spinal cord caudally and cranially in relation to the point giving spontaneous potentials of maximal amplitude. We found two curves (lumbar and cervical) for the longitudinal distribution of the area of the power spectra of these recordings. Each of these curves had a symmetrical decrement on both sides of the position of the point for the maximal area of power. Such points were discovered on the L5–L7 and C3–C4 spinal segments. Spectral analysis of the spontaneous CDPs simultaneously recorded in both regions indicates no evidence of coherence, thus suggesting that the spontaneous CDPs recorded in the lumbar and cervical regions of the pentobarbitone-anaesthetized cat are generated by two independent populations of neurones not functionally interconnected between them. © 2002 Elsevier Science Ireland Ltd. All rights reserved.

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A previous study [9] has shown that in the anaesthetized cat the neuronal ensemble involved in the generation of the lumbar spontaneous negative cord dorsum potentials (CDPs) is located in laminae III–VI (see also Refs. [5–8]). It was not clear, however, the extent to which this neuronal ensemble is distributed along the longitudinal axis of the lumbar [9,13] and cervical spinal cord. The purpose of the present report was to present evidence that the neurones producing the spontaneous CDPs are independently distributed in the lumbar and cervical spinal segments. Disclosure of these distributions along the longitudinal axis of the spinal cord could be important since the spontaneous activity of the neurones producing the lumbar spontaneous negative CDPs sets a background level of transmission regulation in the Ia-motoneuron pathway [9], and in the cortical responses elicited by tactile stimuli [11,12].

Guidelines contained in the NIH publication (Guide for the Care and Use of Laboratory Animals, U.S. Department of Health and Human Services, National Institutes of Health, Publication No. 85-23, Revised in 1985) were followed throughout. Briefly, experiments were carried out in adult cats (2.5–3.5 kg) initially anaesthetized with pentobarbitone (35 mg kg\(^{-1}\) of weight, intraperitoneally), supplemented during the dissection and recording periods with additional doses of 10 mg kg\(^{-1}\), intravenously as necessary to maintain deep anaesthesia. Blood pressure was recorded from a cannula inserted into the right femoral artery. Adequacy of anaesthesia was assessed by verifying that the pupils were constricted, and that blood pressure was stable (between 100 and 120 mmHg) and was not affected by noxious stimulation to the skin. After the surgical procedures, the animal was fixed in a metal frame using spinal and pelvic clamps. The head was fixed in a stereotaxic apparatus. The animals were paralyzed with pancuronium bromide (Pavulon, Organon) and artificially ventilated. The lumbo-sacral, low thoracic, and cervical spinal segments were exposed. Pools were formed with the skin around the exposed tissues, filled with mineral oil and maintained at a constant temperature (37 °C) by means of radiant heat. Spontaneous CDPs were recorded from the surface of the dorsal horn with two silver ball electrodes against indifferent electrodes placed on the near paravertebral muscles. Simultaneous recordings were made along the longitudinal axis of the cervical and lumbar segments. Spontaneous
potentials were recorded with the pre-amplifier filters set to 0.3 Hz in the low range and 10 kHz in the high range. Data acquisition of spontaneous CDPS was performed with a sampling rate of 500 Hz. Spectral analysis was performed with a frequency resolution of 0.5 Hz. Power spectra and the coherence function [1] between cervical and lumbar spontaneous CDPS was calculated from records of 2 min for the frequencies in the range from 0 to 30 Hz. The coherence function provides a normalized measure of the linear correlation between two signals as a function of frequency, $f$ [1]. Coherence is bounded between 0 and 1, where a value of 1 at the frequency $f$ indicates a perfect linear relation between both signals at the frequency $f$. It is commonly taken as a measure that quantifies the functional coupling between two signals. At the end of the experiment, each animal was killed with a pentobarbitone overdose and perfused with 10 % formalin, and the spinal cord was removed while leaving marks of the recording sites. After complete fixation and dehydration, the spinal cord was photographed.

Lumbar (L5–L7) spontaneous negative CDPS generated by dorsal horn spinal neurones (laminae III–VI) were identified according to their characteristic amplitudes of about 40–150 µV and durations of about 25–80 ms [7,9,10,13]. The results described here were derived from experiments in which spontaneous potentials with the same characteristics were recorded in the cervical (C3–C4) segments. Spontaneous potentials were recorded from the surface of the dorsal horn at different points along the longitudinal axis of the lumbar and cervical spinal cord. Fig. 1A–D shows power spectra computed from continuous recordings of cervical spontaneous CDPS lasting 2 min. As seen in Fig. 1E, the area of the power spectra of this type of recording is highest at the junction between C3 and C4 segments. The curve for the longitudinal distribution of the area of power spectra (Fig. 1E, five experiments) was obtained by plotting such areas against the distances between the recording electrode and the point for maximal area of the power spectra. The point at which the area of power spectra was maximal is marked by zero and the distances are designated minus in the cranial direction and plus in the caudal direction. The areas of the power spectra are given in percentages of the maximal area. Below the horizontal axis of Fig. 1E are marked (with horizontal lines) the entry zones of the dorsal roots (C3–C4). The description of Fig. 1F–J is similar to that of Fig. 1A–E, except that the data were obtained from recordings of the lumbar L5–L7 segments (five animals). Note that Fig. 1J also shows a distribution of areas of the power spectra that falls on both sides of the maximum point. These findings suggest that the sets of neurones involved in the generation of the spontaneous negative CDPS are located in the lumbar (L5–L7) and in the cervical (C3–C4) spinal segments. This possibility raised the question of whether the two neuronal sets belong to the same or to different populations. This question was approached by examining the synchrony between activity in both sets of neurones by testing the coherence function between the spontaneous CDPS recorded at L5–L7 and at C3–C4. The upper traces in Fig. 2A illustrate typical spontaneous CDPS simultaneously

![Graphs and images showing power spectra and coherence function.](image-url)
recorded from the surface of the C3–C4 and L5–L7 segments in one animal. Fig. 2B,C shows the corresponding power spectra obtained from continuous recordings of such cervical and lumbar spontaneous CDPs lasting 2 min. The graph in Fig. 2D shows the coherence between lumbar and cervical spontaneous CDPs versus the frequency. No evidence of statistically significant coherence was found (namely absence of coherence). Similar results were obtained in the other four experiments.

The present report has indicated that in the lumbar L5–L7 and cervical C3–C4 segments of the cat spinal cord, there are two sets of neurones producing spontaneous CDPs. These sets of neurones appear to be located in the same longitudinal region as neurones receiving monosynaptic inputs from low threshold cutaneous afferents [9]. As shown in Fig. 1, these regions correspond to the lumbar L5–L7 and the cervical C3–C4 spinal segments, in confirmation of electrophysiological studies performed on the lumbo-sacral region [2–4,9,13,14]. In this context, Bernhard [2,3] made a thorough analysis of the distribution of cutaneous evoked potentials along the longitudinal axis of the lumbar spinal cord. Bernhard found that the lumbo-sacral longitudinal distribution of the amplitude of negative CDPs elicited by stimulation of cutaneous nerves follows a bell shape, very similar to the distribution of the area of power spectra of spontaneous CDPs illustrated in Fig. 1J.

Our data also indicate that spontaneous CDPs recorded from the L5–L7 segments are not synchronized with the spontaneous CDPs recorded at the C3–C4 segments (absence of coherence, Fig. 2D). This suggests that the sets of neurones located at C3–C4, versus the group of neurones located at L5–L7, are not functionally interconnected in the anaesthetized cat. In this context, a relevant question would be the extent to which both sets of neurones are coupled during the locomotion or during the execution of specific motor tasks in the intact, non-anaesthetized behaving cat. It thus seems reasonable to anticipate that in the behaving cat the synchronization of the ‘spontaneous’ activity of the cervical and lumbar dorsal horn neurones could result from activity in common propriospinal or descending inputs. We conclude that in the spinal cord of the anaesthetized cat there are two independent groups of neurones, whose area of the power spectra of their spontaneous CDPs is distributed in a bell-like form along the longitudinal axis of the lumbar and cervical levels of the spinal cord.

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