EXPERIMENTAL METHODS FOR CLINICAL PRACTICE

Bioelectric Activity of Spinal Cord in Patients with Vertebrospinal Pathologies

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A method for functional evaluation of spinal cord conducting systems in patients with vertebrospinal diseases is proposed. The method is based on the analysis of changes in electrospinoneurogram recorded with epidural electrodes below the injury during an attempt at voluntary activation of foot muscles. The degree of changes in electrospinoneurogram frequency during voluntary command addressed to motoneurons of the lumbar enlargement reflect the state of descending spinal systems.

Key Words: *spinal cord; electrospinoneurogram; power spectrum*

Diagnosis and therapy of spinal injuries require differential evaluation of all components and systems of the spinal cord (SC); specifically, it is important to evaluate the state of descending tracts conducting the regulatory signals from the brain to spinal neuronal structures activating muscles of the lower extremities. The state of spinal descending systems can be tested by means of evoked spinal potentials recorded below the level of involvement during electrical stimulation of the cervical enlargement [8]. The state of the proprio- and reticulospinal systems is evaluated by H-reflex changes during conditioned stimulation of the ulnar nerve [7] or using the Jendrassik maneuver, respectively [4]. However these methods have certain limitations. The first method can detect only the absence/presence of stimulus conduction through the injury, but does not allow differentiation of the status of individual SC, as the evoked potential reflects both the orthodromal activity of the descending tracts and the antidromal activity of ascending tract fibers. The second method can be used only in patients with intact reflectory monosynaptic excitation of the SC, which is rare in spinal patients.

In the present study conduction of a natural voluntary signal from the brain to motoneurons of foot muscles via spinal descending systems was analyzed by the method of electrospinoneurography. We investigated spectral characteristics of electrospinoneurograms (ESNG) recorded at rest and during an attempt to send a voluntary signal to foot muscles, as we suggested that the signal transfer would be paralleled by rearrangement of the temporal structure of spinal impulse activity.

MATERIALS AND METHODS

Eleven patients (19-44 years) with complete (n=5) or partial (n=6) intermission of the SC in the thoracic or cervical portions were examined. The history of spinal injury was at least 1 year. ESNG was recorded by electrodes implanted into the epidural space near the lumbar intumescence below injury [5]. Bi- and monopolar modes of registration were used. For monopolar

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registration the indifferent electrode was positioned on *m. rectus abdominis*. After the experimentator's command, the patient send a voluntary signal to muscles of the lower extremity with an intention to stand on toes. Power spectra were obtained using Fourier transformations from autocorrelation functions. To exclude the influence of cardiac rhythm on power spectrum, the estimations were made for 400-msec ESNG fragments between heart contractions. ESNG was digitized at a frequency of 1-5 kHz. Low (10-20 Hz), medium (20-50 Hz), and high (50-100 Hz) frequencies were distinguished in the power spectra. For evaluating the degree of signal power redistribution between different frequency ranges, the ratio of medium and high frequency power to 10-20 Hz power was estimated [7]. Spectral characteristics of spontaneous electrical activity (BEA) and ESNG recorded during patient's attempt at voluntary activation of the foot muscles were compared. Activity of spinal muscles was monitored electromyographically during this task in order to rule out flowing onto electrodes.

RESULTS

Analysis of ESNG in patients with different neurological status showed that changes in the spinal BEA frequency reflect the function of the descending tracts. Figures 1 and 2 present the ESNG of two patients with different severity of spinal involvement and the corresponding spectral powers. Analysis of the spectra of patient K. (incomplete involvement of the spinal cord: Th_{IX-XII} fracture/dislocation, inferior deep proximal paraparesis, distal paraplegia) showed that during an attempt at voluntary activation of foot muscles (no real movements) the main spectral peaks shifted from 10 Hz (frequency characteristic of spontaneous activity) to higher frequency, the spectrum power in the 20-100 Hz range increasing 1.5-2.5 times. In patient R. with clinical picture of complete involvement (Th_X fracture-compression, spinal compression, myeloischemia from Th_{VIII} level, inferior spastic paraplegia) the power spectra of spontaneous ESNG and ESNG during an attempt at voluntary movements were the same. The ratio of

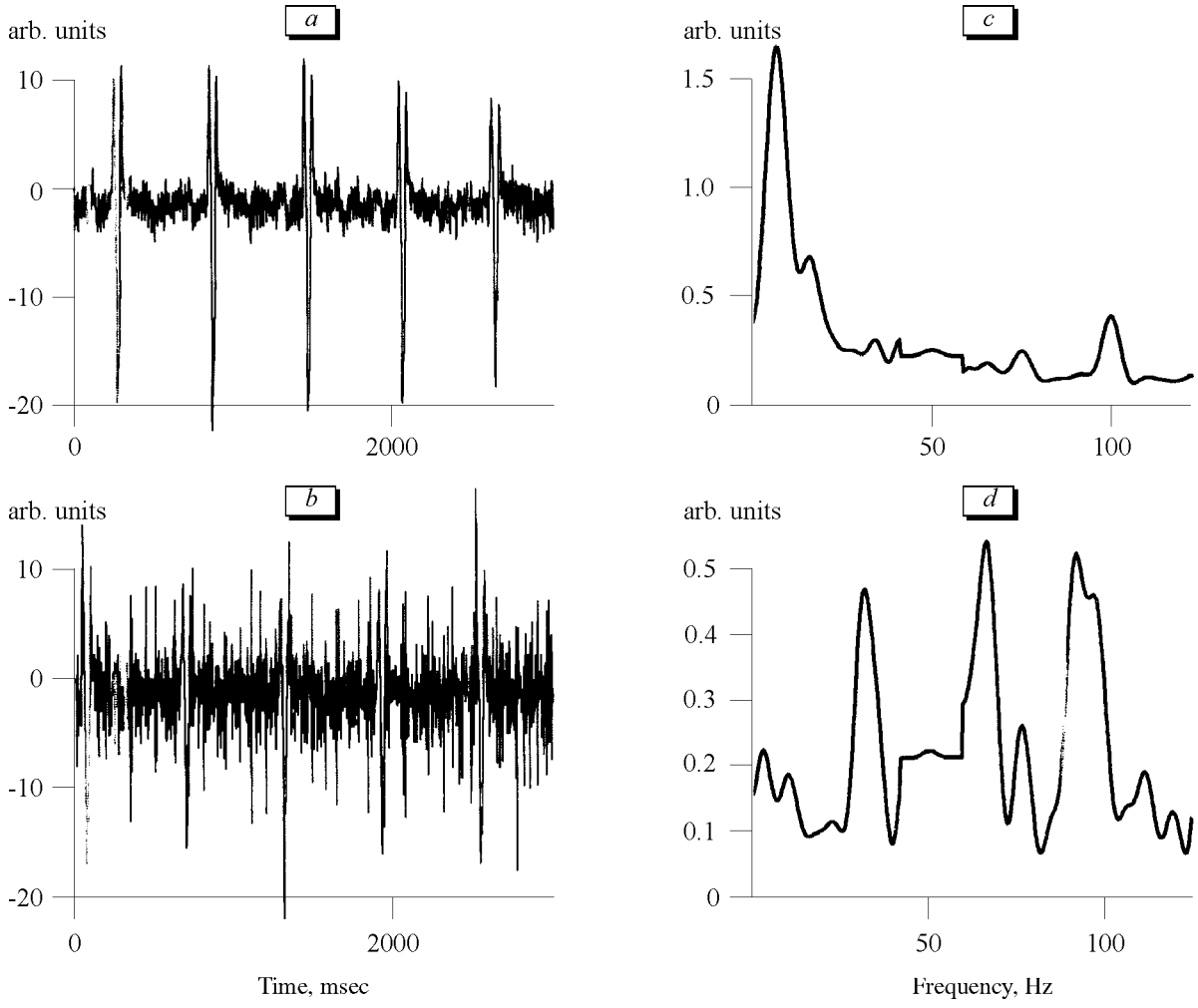

Fig. 1. Electrospinograms (*a, b*) and power spectra (*c, d*) of spontaneous (*a, c*) and voluntary (*b, d*) activity in patient K.

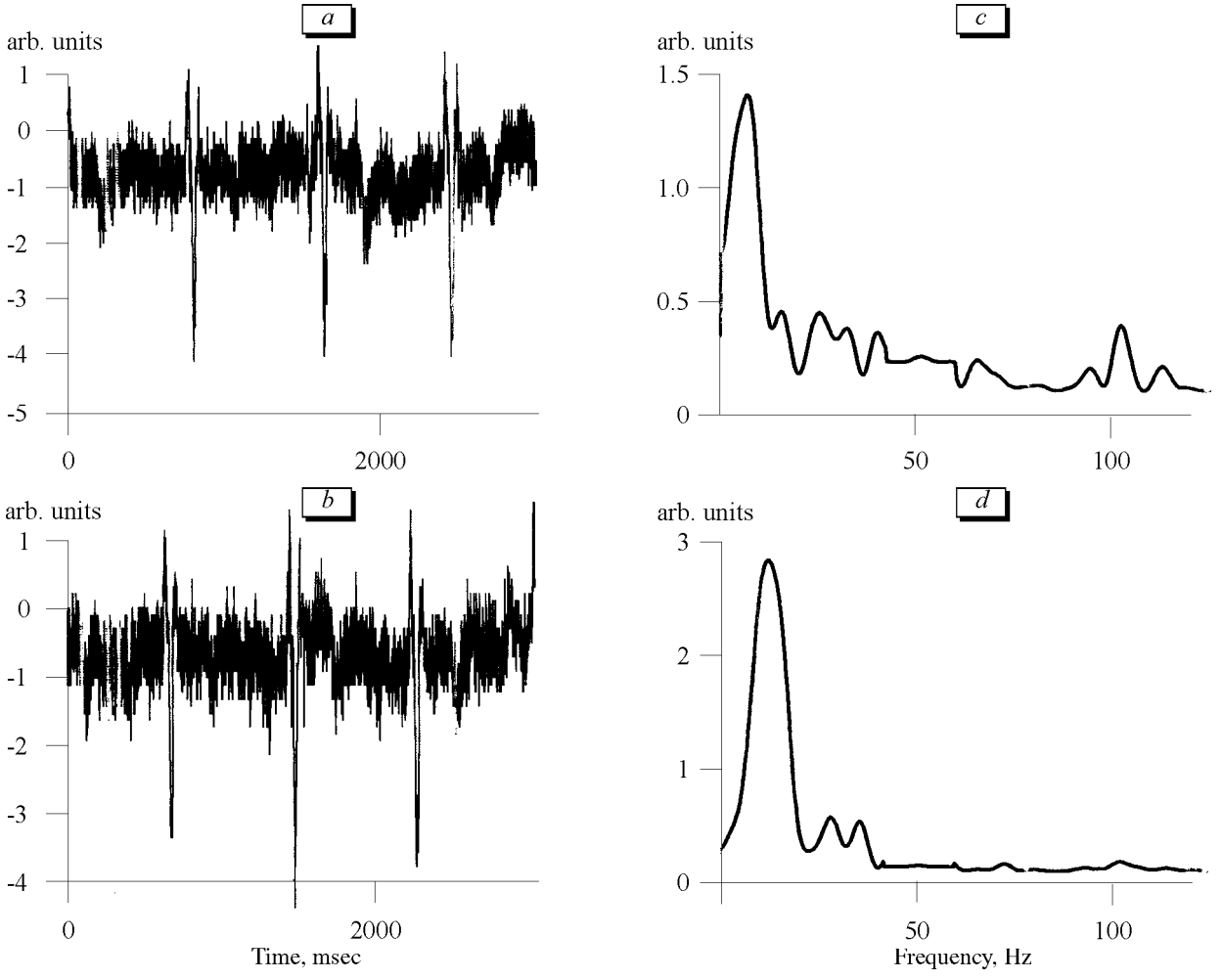

Fig. 2. Electrospinograms (*a, b*) and power spectra (*c, d*) of spontaneous (*a, c*) and voluntary (*b, d*) activity in patient R.

high-frequency component of the spectrum to the low-frequency component depended on the neurological status of the patient (Table 1). The effect of spectrum power redistribution was observed in all patients with incomplete spinal involvement. On the other hand, in 2 of 5 patients with the clinical diagnosis of complete spinal involvement spectral characteristics slightly changed duringan attempt at moving, which indicated that stimulation conduction was retained in part of the descending fibers.

The signal in the electromyelograms of patients with spinal injuries presents in two ranges: 0.5-2.0 and 10-20 Hz [6]. Changes in BEA appeared only after electric stimulation of the brain; no spontaneous changes in the components were observed. No relationships between the appearance of changes of the components' amplitude-time characteristics and the parameters of stimulation were detected. This suggests that these components are not generated in the zone of the electrode implantation, but reflect the supraspinal effects. Presumably, BEA in the 20-100 Hz range reflects the degree of conduction of the natural voluntary command of the patient to activate foot muscles through the level of involvement along the descending tracts. As the electrode was placed on the dorsal surface of the SC, the recorded BEA reflected primarily the conduction of the signal along the lateral corticospinal tract, one of the main tracts in signal transfer

TABLE 1. Changes in Spontaneous/Voluntary Activity Power Ratio in Different Spectral Ranges (*M*±*m*)

Patient	Spontaneous activity		Voluntary activity	
	20-50 Hz	50-80 Hz	20-50 Hz	50-80 Hz
K.	0.48±0.19	0.26±0.05	1.24±0.374	1.05±0.29
R.	0.47±0.25	0.21±0.08	0.60±0.1	0.26±0.12

from the brain to spinal motor neurons. Hence, alteration of ESNG frequency during an attempt at voluntary activation of foot muscles helps to evaluate the status of the descending systems along which voluntary orders reach the elements mediating the motor function.

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