Selection of Intact Fine Nerve Strands Using Power Spectrum of Their Electrical Noise

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Experiments on narcotized cats demonstrated a decrease in noise factor determined as the ratio of power spectrum maximum of electrical noise in a fine nerve strand to the corresponding value of the equivalent resistor in neurofilaments isolated from the sciatic nerve with blocked conduction in comparison with intact control. Noise factor can be used as a criterion for selection of intact fine nerve strands.

Key words: *fine nerve strand*; *C-fiber*; *electrical resistance*; *power spectrum*; *noise factor*

Recording of signals from isolated fine nerve strands (FNS) is an important, although arduous method to study the nervous system, because spikes in the isolated neurofilament can be absent due to damage to nerve caused by preparation. However, the absence of tonic discharges is not sufficient for sorting out such "passive" FNS, so additional long-term procedures are needed for determining their state, such as the search for receptive tissue terminals of sensory fibers using various local stimuli [4,6] or electrical stimulation of the hypothalamus for initiation of discharges in vasodilator fibers that have no baseline activity [5]. In many cases FNS are sorted out due to the absence of induced discharges. Low efficiency of searching for intact FNS necessitates elaboration of a special method for rapid functional assessment of FNS. To this end we measured electrical resistance and calculated power spectrum of electrical noise in intact FNS with tonic activity and in passive FNS isolated from the nerve with blocked conduction.

MATERIALS AND METHODS

Electrical signals in FNS isolated from the sciatic nerve were recorded in 9 cats anesthetized with chloralose and urethane (40+600 mg/kg). Isolation of FNS and recording of individual C-fiber spikes were described previously [2,3]. FNS were attached to a platinum wire electrode and cut distally, which ensured recording of efferent discharges only. Signals were amplified with a low-noise PARC-113 amplifier (input resistance and capacity are 100 MW and 15 pF, respectively), filtered through a four-pole KH3500 filter (85-2000 Hz), digitized with a 12-bit ADC-12m digitizer (Biola, Moscow), and processed using an original software. We analyzed electrical parameters of passive FNS of nonconducting nerve, in which only the electrical noise was recorded, and active FNS, in which tonic discharges were recorded together with electrical noise. In experiments with passive FNS, the conduction block was performed by crushing the nerve trunk proximally and distally at the distance of 1 cm from the cut epineurium.

FNS resistance was measured with sinusoidal test waveform signal fed via a calibrated resistance (R= 339 kΩ) to an amplifier with connected and disconnected FNS (Fig. 1). The amplitude of the test waveform signal (5 mV) far surpassed the amplitude of electrical noise and spikes in FNS (microvolts and tens microvolts, respectively), but was lower than the amplitude irreversibly suppressing spike activity in FNS [7].

At the test waveform frequency (520 Hz), the amplifier input impedance (20 MΩ) far surpassed the resistance of calibrated resistor (R) and FNS (r), so the latter can be calculated by the formula:

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$$r=R/(A/a-1),$$

where A and a are the output amplitudes of sinusoidal waveform with disconnected and connected FNS, respectively.

To compute the power spectra of FNS electrical noise, the neurograms (Fig. 2) were divided into 102.4-msec fragments containing 512 successive points. If a fragment contained spikes, it was not used in spectral computation. In each spike-free fragment, the noise power spectrum was calculated using fast Fourier transform algorithm, and the resultant spectra were averaged. The total duration of analyzed fragments was 1-3 min.

FNS noise power spectrum was compared with power spectrum of thermal noise of a resistor equivalent to FNS resistance.

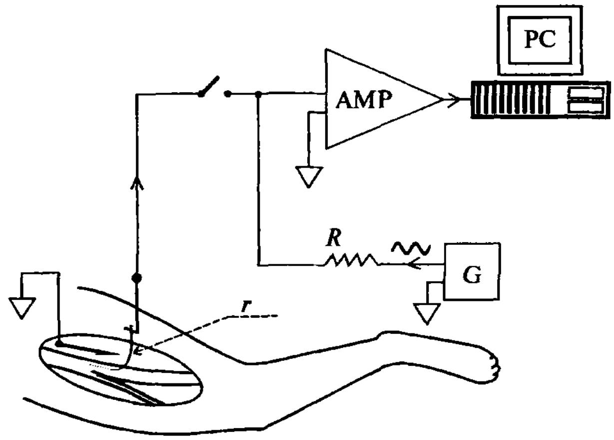

Fig. 1. Experimental setup for recording the neurograms and measuring resistance of fine nerve strands, which includes generator (G), low-noise amplifier (AMP), and calibrated resistor (R=339 kΩ).

RESULTS

The resistance of intact (520±300 kΩ, n=17) and passive (630±500 kΩ, n=11) FNS was measured with 5% accuracy. The differences were insignificant (p>0.3), so FNS resistance cannot be a selection criterion for intact neurofilaments.

Noise power spectra of passive FNS (Fig. 3, *a*) coincided with the spectra of equivalent resistors (Fig. 3, *b*). By contrast, the noise power of intact FNS significantly surpassed that of equivalent resistors (Fig. 3, *c*).

A resistor is a source of electrical noise with the power proportional to absolute temperature and its resistance [1]. In addition to this thermal noise, there are other sources of stochastic signals. Their contribution to the total noise is assessed by a noise-factor (NF) calculated as the ratio of total noise power to the power of its thermal component [1]. We calculated NF of FNS as the ratio of maxima in the power spectra of electrical noise of FNS and equivalent resistor.

NF of passive FNS was 0.99±0.04 (mean value and the standard deviation). Therefore, the noise in passive FNS of non-conducting nerve is thermal. NF of intact FNS was 1.58±0.60. Difference in NF of intact and passive FNS was significant (p<0.03).

Thus, the intact FNS generate not only thermal, but also an additional noise. This noise is probably induced by nerve impulses in fibers with tonic activity located near the isolated FNS. In intact FNS these impulses cannot be visually distinguished from thermal noise because of their low amplitude. From this viewpoint, NF of FNS characterizes impulse activity in nerve fibers located in the immediate proximity to FNS. If NF significantly (by more than 5%) differs from 1, the fibers with background activity are located near the isolated FNS, which enhances probability that this FNS is intact. Even if there are no spike activity in this FNS, it may appear in response to adequate stimulation. Therefore, NF can serve as a criterion of FNS intactness.

Great variations in NF and resistance values of intact FNS can be related to their individual structural and functional characteristics [8]. In this case, these parameters can serve as additional markers for identification of individual FNS. The proposed method of testing of FNS functional state can be used in the development of microneurographic diagnostic methods for clinical studies.

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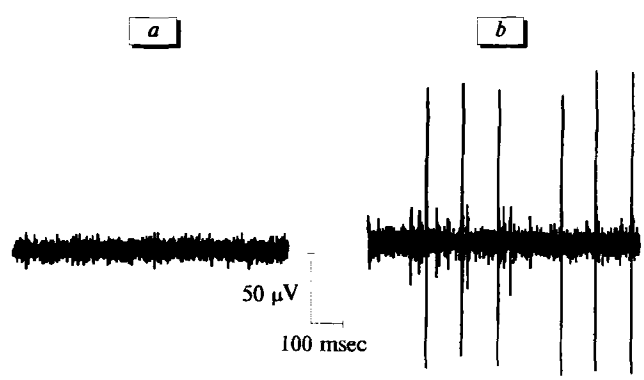

Fig. 2. Neurograms of a passive fine nerve strand (*a*) and a strand with tonic activity (*b*).

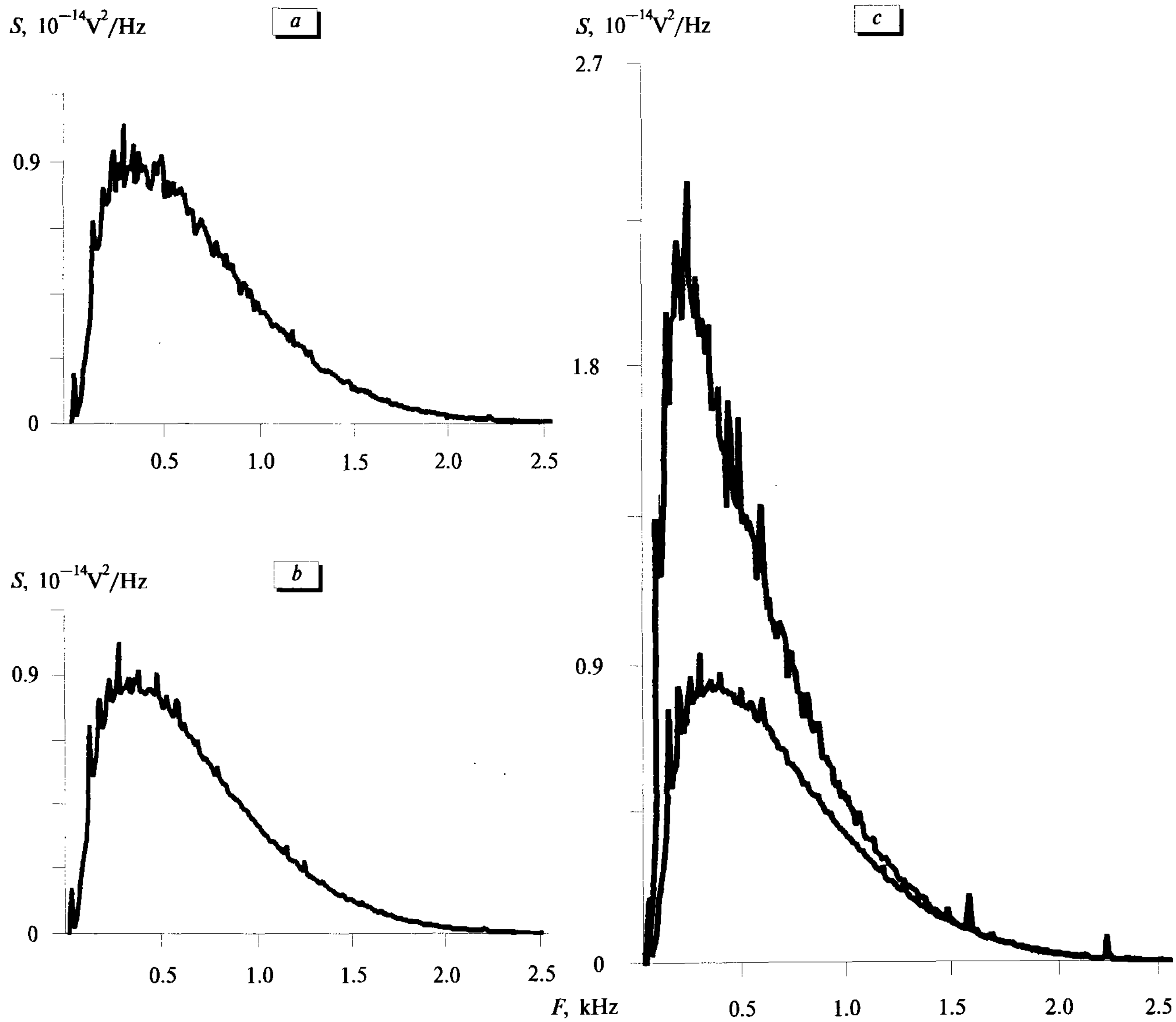

Fig. 3. Noise power spectra of passive neurofilament (the same as shown in Fig. 2) (*a*), its equivalent resistor 550 kΩ (*b*), neurofilament with tonic activity (*c*, upper curve), and its equivalent resistor 500 kΩ (*c*, lower curve). Noise power spectrum of active neurofilament (*c*, upper curve) was calculated in the spike-free intervals. Ordinate is calibrated at 400 Hz.

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