MYELINATED FIBERS OF A CAT CUTANEOUS NERVE WITH SLOW CONDUCTION VELOCITY

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Low-voltage potentials belonging to thin myelinated fibers were differentiated from instrumental noise by the use of a photoelectric coherent storage method and by the method of averaging evoked potentials of a cutaneous nerve in the cat using a BÉSM-3M computer. The thresholds of excitation of these fibers are higher than for group Aδ fibers. The conduction velocity in them ranges from 14 to 2.5 m/sec.

Stimulation of mammalian cutaneous nerves in sufficient strength to produce excitation of all group A myelinated nerve fibers leads to the appearance of two clearly differentiated complexes of evoked potentials on the recording. The first consists of high-amplitude potentials of the group Aβ nerve fibers, whose conduction velocity varies from 80 to 30 m/sec. The second consists of a more compact potential of the Group Aδ nerve fibers with a conduction velocity of 30–15 m/sec.

Gasser and Grundfest [8] showed that the range of conduction velocities in nerve fibers of the Aδ group lies between 23 and 19 m/sec. Using the relationship between conduction velocity and diameter of the nerve fiber [7], in their reconstruction of the potentials of the Aβ fibers they showed that nerve fibers from 4 to 3.3μ in diameter conduct impulses at a velocity of 23–19 m/sec. However, histological investigations of the saphenous nerve of the cat demonstrated the existence of nerve fibers from 1 to 5μ in diameter. These workers postulated that because of temporal dispersion the action potentials of small groups of the thinnest nerve fibers could escape the attention of the investigator.

Some workers described fibers conducting excitation at a velocity of 4-9 m/sec, but only by recording potentials under particularly favorable conditions from the whole nerve trunk [6, 11].

The results of electrophysiological and histological investigations of single nerve fibers of the saphenous nerve of the cat confirmed the existence of myelinated fibers 1-2μ in diameter, and the range of conduction velocities in the Aδ group was widened to 3.3 m/sec [4, 5, 9, 10].

Differences in the ranges of velocities of conduction of nervous impulses determined by recording potentials from the intact nerve and the single fiber could be due to two causes. The first is that when recordings are taken from the whole nerve trunk action potentials of small groups of thin nerve fibers are bypassed by unexcited fibers, the connective-tissue sheaths of the nerve, and blood vessels. The second possible cause is the high level of intrinsic noise of the electronic instruments, in which low-amplitude potentials of the nerve fibers are lost.

The object of this investigation was to attempt to detect myelinated nerve fibers with a slow conduction velocity by recording evoked potentials of the whole nerve trunk.

EXPERIMENTAL METHOD

Adult cats were anesthetized with hexobarbital (200 mg/kg), and a cutaneous nerve of the hind limb (saphenous) was dissected from the inguinal fold to the knee joint. The proximal segment of the nerve was

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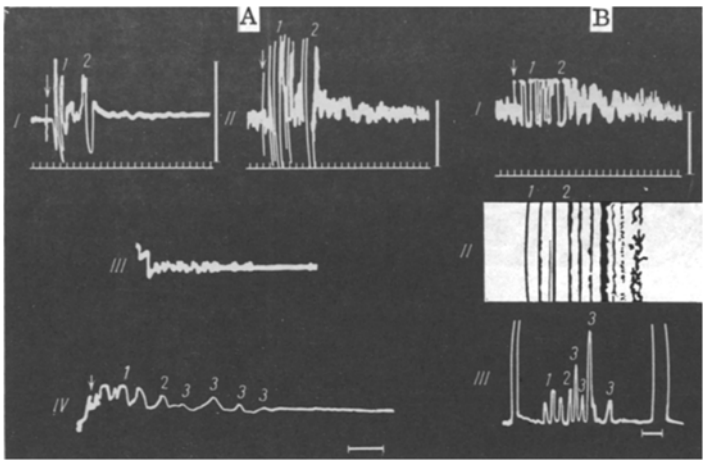

Fig. 1. Differentiation of low-voltage potentials of myelinated fibers from instrumental noise by averaging on a computer (A) and by photoelectric coherent storage (B) during superoptimal stimulation of Aδ fibers. In A: I and II) potentials of saphenous nerve with different degrees of amplification. Amplitude of stimulating pulse 20 V, duration 0.1 msec, time marker 0.5 msec, calibration for I) 250 μV, for II) 50 μV; III) the same potential after recording on magnetic tape; IV) result of averaging 17 responses of the nerve. Time marker 2 msec. In B: I) potential of nerve after clipping. Time marker 0.5 msec, calibration 100 μV; II) recording of 150 sweeps of oscilloscope beam with brightness modulated by action potential of A fibers of the nerve; III) result of photometry of record II. Time marker 2 msec. Arrow indicates stimulation artefact. 1) Potential of Aβ fibers; 2) potential of Aδ fibers; 3) potentials differentiated from noise and belonging to fibers with conduction velocities of: for AIV) 11.0, 9.0, 7.1, and 5.9 m/sec, for BIII) 10.6, 8.3, 7.5, and 5.8 msec.

placed on stimulating electrodes and the distal segment on platinum recording electrodes. The tissues surrounding the dissected portion of the nerve were sutured to a metal frame. The hollow thus formed was filled with warm aerated mineral oil. The temperature of the nerve was kept constant between 36 and 36°C.

The nerve was stimulated with square pulses 0.1 msec in duration. The amplitude of the stimulating pulse was chosen at the threshold, optimal, and superoptimal levels for excitation of group Aδ nerve fibers. From the recording electrodes the nerve potentials were led to the input of a type UBP 1-02 amplifier.

To differentiate the low-amplitude action potentials of the nerve from instrumental noise two methods of coherent storage of signals with subsequent averaging were used. The first method was by averaging the evoked responses of the nerve with the BÉSM-3M computer. The principle of an analogous method of differentiating low-amplitude action potentials of unmyelinated fibers of the inferior cardiac nerve by means of a specially modified computer from instrumental noise was described previously [3]. Evoked potentials from the nerve were amplified (Fig. 1A : I and II) and recorded on magnetic tape (Fig. 1A : III) with a certain delay after the signal which served as the reference point for synchronous triggering of the computer. After conversion of the whole record from the analogue to the discrete form with a quantization frequency of 50 kHz each consecutive signal from the nerve was added to its predecessor. The resultant data stored in this way were divided by the number of nerve potentials fed into the computer. The curve of the averaged results was recorded on the screen of a cathode-ray oscilloscope (Fig. 1A : IV).

The second method of differentiating potentials from noise was optical, using a photoelectric coherent storage device [1] used in conjunction with a type Sl-18 cathode-ray oscilloscope. After maximal amplification with the UBP 1-02 instrument the high-voltage evoked potentials from the nerve were clipped in amplitude (Fig. 1B : I) and led to the beam brightness modulation input of the oscilloscope. With each

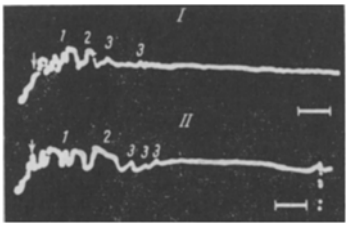

Fig. 2

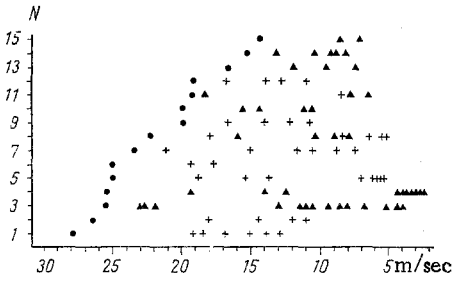

Fig. 3

Fig. 2. Low-voltage potentials of cutaneous nerve distinguished from noise by means of a computer: I) in response to threshold (0.1 V) and II) to optimal (1 V) stimulation of Aδ fibers. Arrow is artefact of stimulation: 1) potential of Aβ fibers; 2) potential of Aδ fibers; 3) potentials of fibers with velocities of 14.8 and 10.0 m/sec for I and 10.4, 9.0, and 8.1 m/sec for II, distinguished from noise.

Fig. 3. Distribution of conduction velocities in thin myelinated fibers of cutaneous nerve by evoked potentials. Circles show conduction velocity in modal group of Aδ fibers; plus signs show conduction velocity in fibers distinguished with the aid of the photoelectric storage device; triangles show the same distinguished by a computer. In all cases nerve stimulated at superoptimal strength. Abscissa, conduction velocity (in m/sec); ordinate, No. of experiment.

successive stimulation of the nerve the oscilloscope beam was displaced in a vertical direction. Up to 150 sweeps of the beam, the brightness of which was modulated by the evoked action potentials of the A fibers of the nerve, were thus recorded on the screen (Fig. 1B : II). The stored data were processed by photometric examination of the image using a narrow vertical split moving in the plane of the time axis (Fig. 1B : III).

The conduction velocity in the nerve fibers was determined by calculating the distance from the stimulating cathode to the first recording electrode and the latent period from the artefact of stimulation to the maximal deflection of the action potential studied.

EXPERIMENTAL RESULTS AND DISCUSSION

Using the ordinary method of recording potentials (Fig. 1A : I) the conduction velocity in the modal group of myelinated Aδ fibers of the cat saphenous nerve in these experiments lay between 28 and 14 m/sec.

During stimulation of the nerve by pulses of threshold strength for Aδ fibers, one or two potentials with conduction velocities of about 10 m/sec could be distinguished from noise (Fig. 2 : I). If the nerve was stimulated at optimal strength for excitation of group Aδ fibers (amplitude of stimulating pulse 5-8 times above threshold), potentials of the nerve fiber with conduction velocities below 10 m/sec were distinguished from noise (Fig. 2 : II). Stimulation of the nerve at superoptimal strength (15-20 times above threshold) resulted in the differentiation of action potentials from fibers with conduction velocities of 5 m/sec or below from noise (Fig. 1A : IV). In some experiments potentials of nerve fibers with conduction velocities as low as 2.5 m/sec were distinguished (Fig. 3). The precise values of the threshold of excitation of nerve fibers of smaller diameter than the Aδ group were not investigated. However, with an increase in the strength of stimulation of the nerve the number of nerve fibers of smaller diameter involved in the excitation increased, and this points to differences in the threshold of excitation.

The considerable scatter of the conduction velocities in the modal groups of Aδ fibers (Fig. 3) can be explained by differences in the age and individual characteristics of the animals [2]. The results of differentiation of low-amplitude action potentials from instrumental noise also indicate considerable scatter of the conduction velocities and evident disagreement between the method of averaging of the computer and the optical method.

One reason for disagreement between the conduction velocities obtained may be drift of the potentials during processing. The drift with the computer averaging method is caused by unavoidable instrumental error: delay of the stimulating pulse behind the pulse synchronizing triggering of the computer, and errors arising during analogue-digital conversion with transformation of the signal from the analogue to the discrete form. Drift of action potentials distinguished from noise by the optical method is also due to unavoidable instrumental errors, errors of measurement, and nonlinearity of storage on the photographic method.

Since a large quantity of initial data is used with both methods, despite these unavoidable errors mentioned above, the final results are statistically significant.

LITERATURE CITED

1. V. A. Kozhevnikov and R. M. Meshcherskii, Modern Methods of Analysis of the Electroencephalogram [in Russian], Moscow (1963).
2. N. A. Timko, Fiziol. Zh. SSSR, No. 4, 552 (1970).
3. V. M. Khayutin, V. L. Shur, and E. V. Lukoshkova, Dokl. Akad. Nauk SSSR, 197, No. 6, 1456 (1971).
4. A. G. Brown and A. Iggo, J. Physiol. (London), 193, 707 (1967).
5. P. R. Burgess, D. Petit, and R. M. Warren, J. Neurophysiol., 31, 833 (1968).
6. J. H. Coote and J. F. Perez-Gonzales, J. Physiol. (London), 208, 261 (1970).
7. J. Erlanger and H. S. Gasser, Electrical Signs of Nervous Activity, University of Pennsylvania, Philadelphia (1937).
8. H. S. Gasser and H. Grundfest, Am. J. Physiol., 127, 393 (1939).
9. C. C. Hunt and A. K. McIntyre, J. Physiol. (London), 133, 66 (1960).
10. A. Iggo, Acta Neuroveg. (Vienna), 24, 225 (1963).
11. W. Koll, J. Haase, R. M. Schütz, et al., Pflüg. Arch. ges. Physiol., 272, 170 (1961).