VARIETIES OF TONIC MUSCLE FIBERS IN THE OCULOMOTOR APPARATUS OF THE RABBIT

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The extrinsic muscles of the mammalian eye are known to possess tone of central origin, associated with a considerable and constant electrical activity [1, 2, 3].

Our analysis of this electrical activity, using the technique of intracellular recording of the potentials of individual muscle fibers [4], showed that it is determined principally by special tonic muscle fibers, exhibiting relatively weak, slow waves of potential during excitation and incapable of conducting the excitation process. It has been found [5] that these tonic fibers possess a multiple innervation (of γ motor neurons), displayed in the electrogram of the fiber during natural activity by the presence of waves of potentials of different amplitude (large "principal" and small "accessory" potentials), in a succession of independent rhythms. Other specific features of the motor innervation of these particular tonic fibers have also been discovered.

In the present report we describe the two principle varieties of tonic fibers of the eye muscles of the rabbit, as distinguished in the course of later research.

EXPERIMENTAL METHOD

Experiments were carried out on 16 rabbits. The animals were fixed securely to a special frame, and the cerebral hemispheres removed under ether anesthesia. The orbit was widely exposed, and the lens and vitreous body detached from the eyeball*. The superior oblique muscle of the eye was then isolated for its full length and gently stretched out in an ebonite bath, filled with a semi-liquid mixture of vaseline oil and paraffin wax at 39°. The small portion of the muscle not covered with this mixture was irrigated with warm Ringer's solution. Neither the innervation nor the blood supply of the muscle was disturbed. Anesthesia was not used for the experiment.

The natural activity of the tonic units and their reactions to single stimuli, applied to the nucleus of the trochlear nerve in the form of rectangular electrical impulses, were studied. The electromyogram of the individual muscle fibers was recorded using intracellular glass microelectrodes filled with 2.5-3.0 M KCl (tip diameter 0.5-1.0 μ). The microelectrode was inserted into the part of the muscle lying outside the mixture. The indifferent electrode was applied to the skin of the head. The potentials were recorded on a cathode-ray oscillograph, supplied by a symmetrical alternating-current amplifier and a symmetrical cathode follower. The combined electromyogram recorded by means of needle electrodes, with high amplification, was also investigated (Fig. 1).

EXPERIMENTAL RESULTS

In the course of the experiments intracellular recordings were made of the electrical activity of 21 tonic fibers of the eye muscle in nine animals. The waves of potential (principal and accessory), found in individual tonic fibers, were approximately constant in their amplitude and duration. They were regular in shape, with a rapid rise and an exponential fall. The half-decay period of the potential in each fiber was approximately constant, and practically equal in the principal and accessory potentials. The waves of potential induced in the individual tonic fibers by stimulation of the nucleus of the trochlear nerve had a constant latent period. The rhythm of the "tonic" activity in some fibers was constant and regular, while in others it varied in a wave-like manner.

*Two control experiments were carried out on intact animals without enucleation of the eyeball. The results of these experiments did not differ from the others, so that they will not be discussed seperately.

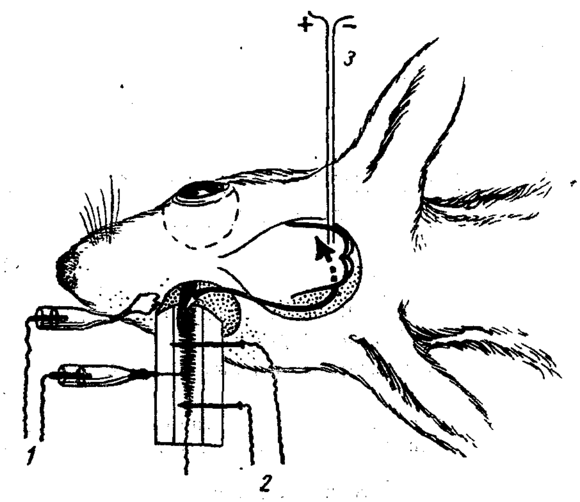

Fig. 1. Scheme of the experimental method. 1) Intracellular recording of the potentials of individual fibers of the superior oblique muscle of the eye; 2) recording of the combined electromyogram; 3) stimulation of the nucleus of the trochlear nerve.

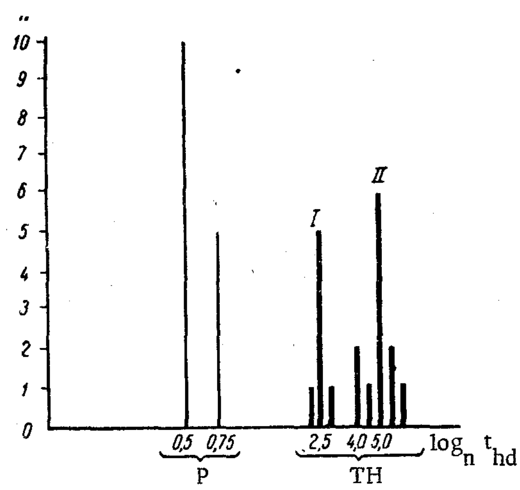

Fig. 2. Variation in tonic fibers of the superior oblique muscle of the eye in duration of the half-decay period (t_{hd}) of the potential (TH) and variation of phase fibers in the same parameter (P). I) First group; II) second group. A logarithmic scale of t is used to demonstrate the relationship between values.

Parameters of the Electrical Activity of the Tonic Fibers

Serial No. of experimental animal	Fiber No.	Caliber of micro-electrode (in μ)	Amplitude of principal potentials (in μV)	Half-decay period of potential (in millisec)	Natural rhythm of activity (No. of principal action potentials in 1 sec)	Latent period of reaction to stimulation of nucleus (in millisec)
33	I	1.5	20-22	2.5		5
62	I	0.5	20	5.0	50	
	IV	0.5	24	4.5	50	
	V	1.0	20	6.0	–	5.5
64	I	0.5	20	4.0	30-40	
	II	0.5	10		40	
	III	0.5	23	2.3	20	
	V	1.0	28	4.0	40-50	
65	I	0.8	20	5.0	15	
	IV	0.8	10	3.0	–	5.7
68	II	–	10	5.0	50-60	
	III	–	10-12	5.0	30	
69	I	–	15	2.5	20	
	III	0.5	18	2.5	15-20	
	IV	0.5	13	6.5	12	
	VII	0.5	15	5.0	30	
76	VI	0.5	14-16	6.0	25-35	5.5
77	III	–	26	2.5	30	
98	III	0.5	10-15	5.0	–	
	IV	0.5		5.0	20	
	V	0.5	28	2.5	17-18	

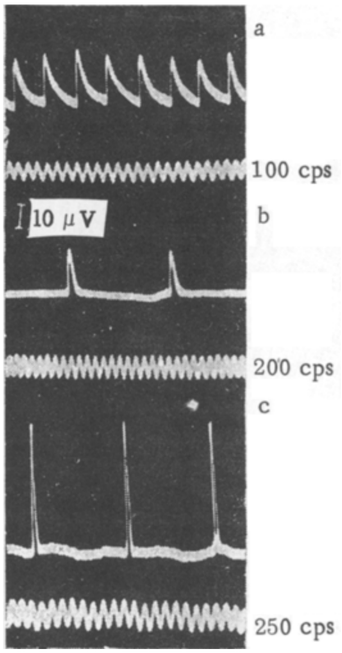

Fig. 3. Waves of potential during rhythmic activity of individual fibers of the superior oblique muscle (intracellular recording). a) Tonic muscle of the second group; b) of the first group; c) phase fiber. Calibration unit 10 μV.

Comparison of the electrical activity of the various tonic fibers (of the same or different animals) revealed some differences in all its parameters: the amplitude and duration of the principal waves of potential, the relative magnitude of the accessory waves of potential, the natural rhythm of activity and the latent period of the "induced" potentials. Certain parameters of the electrical activity of the tonic fibers which were investigated are given in the table.

The differences between the amplitude of the waves of potential in the individual tonic fibers, and also the differences in the relative magnitude of the accessory potentials, could be related to a difference, not so much in the properties of these fibers, as in the position of the microelectrode in the fiber in relation to the neuromuscular plates generating these potentials*.

The considerable differences in the time parameters of the waves of potential in the individual fibers, frequently when tapped by the same microelectrode, cannot be attributed to differences in the conditions of recording. They were due to differences in the properties of the muscle fibers tested. The variations in the time parameter of the potentials (half-decay period) in the tonic fibers investigated are illustrated graphically in Fig. 2.

Two variants were most frequently observed in the magnitude of the half-decay period of the potential of the tonic fibers: 5 and 2.5 millisec. The remaining variants were grouped around these two, forming two corresponding groups: the first (t_{hd} = 2.3-3 millisec) and the second (t_{hd} = 4.0-6.5 millisec). Two groups of tonic fibers may thus be assumed: faster (first group) and slower (second group). The slower fibers are more common.

In Fig. 3 we show the activity of the tonic fibers of the two groups. For purposes of comparison we also show the action potentials of a phase fiber, recorded during a brief burst of its rhythmic activity. It may be recalled that the phase fibers, in contrast to the tonic fibers, do not as a rule show constant rhythmic activity.

From the available data we can compare the other parameters of the electrical activity of the tonic fibers of the two groups (see table). The amplitudes of the waves of potential in these two groups of fibers were, on the average, equal (about 20 μV). The latent periods of their "induced" potentials were also practically equal. Acessory waves of potential were either present in or absent from the electrogram of natural activity of the two groups of fibers. The rhythm of the principal (and acessory) potentials in the two groups of fibers varied within close limits, although the mean rhythm of the activity in the fibers of the second group ($\approx$30 in 1 sec) was slightly faster than in the fibers of the first group ($\approx$ 20in 1 sec).

Analysis of the combined electromyogram recorded with needle electrodes showed that in a tonic state slow single-phase waves were also present, correponding in their parameters to the potentials described above in the second and first groups of fibers. Sometimes it could also be seen that the tonic component of the electrical response of the muscle to strong stimulation of the nucleus of the trochlear nerve (the combined potential of the tonic fibers) consisted of more or less slow elementary potentials.

The results described thus demonstrate that two groups of tonic fibers (a slower and a faster) are present in the superior oblique muscle of the rabbit's eye, identical in their innervation. It must be pointed out that among the intrafusal muscle fibers of "tonic type" in the skeletal muscles of mammals possessing a γ innervation two groups are also found, differing in the character of their reaction to the nervous impulse [6].

*The nearest neuromuscular plate generates the principal, and the more distant the accessory potentials.

SUMMARY

With the aid of the method of intracellular leading of action potentials a study was made of the tonic muscular fibers of the obliquus oculisuperior (the general characteristics of which was given in the previous reports). Two groups of tonic fibers were distinguished which differed by the duration of their action potentials.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.