FUNCTIONAL PROPERTIES OF SPINAL MOTONEURONS IN OLD RATS

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In old rats the mean membrane potential (MP) was shown not to differ significantly from the mean value of this parameter in young sexually mature rats (56.5±1.26 and 58.4±1.4 mV respectively), but at the same time the frequency of detection of motoneurons with MP of 70 mV or more was 18.6% lower in the old than in the young animals, and the frequency of motoneurons with MP of 50-59 mV was 14.2% higher. Thresholds of direct excitability in the old rats were lower in the old rats than in young sexually mature animals [$(2.0\pm0.2)\times10^{-9}$A compared with $(3.0\pm0.3)10^{-9}$A]. The number of discharges during polarization of the neuron for 50 msec reached 4-5, which corresponds to 80-100 spikes/sec. The frequency of action potentials (AP) determined for the first two intervals, reached 125/sec, compared with over 300/sec in young, sexually mature rats. The duration of the antidromic spike was increased (1.02±0.09 msec in young sexually mature animals, 1.65±0.14 msec in the old rats; P<0.001). Antidromic spikes from motoneurons of old rats as a rule had no late depolarization.

KEY WORDS: *Aging; motoneurons; membrane potential; excitability; multiple discharges; antidromic responses.*

The functional properties of spinal motoneurons during aging, unlike their structure [7, 14] and metabolism [12, 17], have received very little study. Yet such information could broaden our ideas of the mechanism of aging of nerve cells and could help to reveal the neurophysiological mechanisms of the change in spinal reflex activity during aging.

The object of this investigation was to study the membrane potential (MP), direct excitability, multiple discharges, and antidromic responses of motoneurons of old rats.

EXPERIMENTAL METHOD

Experiments were carried out on noninbred rats of two age groups (8-12 and 24-26 months) anesthetized with urethane (0.5 ml of a 10% solution/100 g body weight after brief induction with ether). In accordance with data in the literature [4] this dose of urethane does not depress motoneuron spike activity. The MP was determined in motoneurons of segments L5-6, identified by stimulation of the central ends of the divided ventral roots. Direct stimulation and recording of action potentials (AP) were carried out by means of a single-channel microelectrode connected to a bridge system [5, 6, 8]. To limit spontaneous activation of neurons leading to changes in their sensitivity to the polarizing current [15, 16], the corresponding roots were divided. Potentials were recorded by means of a type UBPI-02 dc amplifier with cathode follower at the input. The magnitude of the stimulating current was determined by means of a second amplifier by measuring the voltage drop across a resistor included in the circuit of the reference electrode.

EXPERIMENTAL RESULTS AND DISCUSSION

During aging no significant change took place in the MP of the motoneurons. In young sexually mature rats, for instance, its mean value was 58.4±1.4 mV and in the old rats 56.5±1.26 mV (P>0.2).

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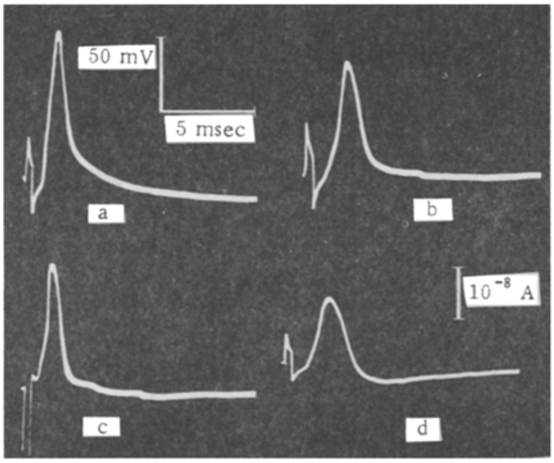

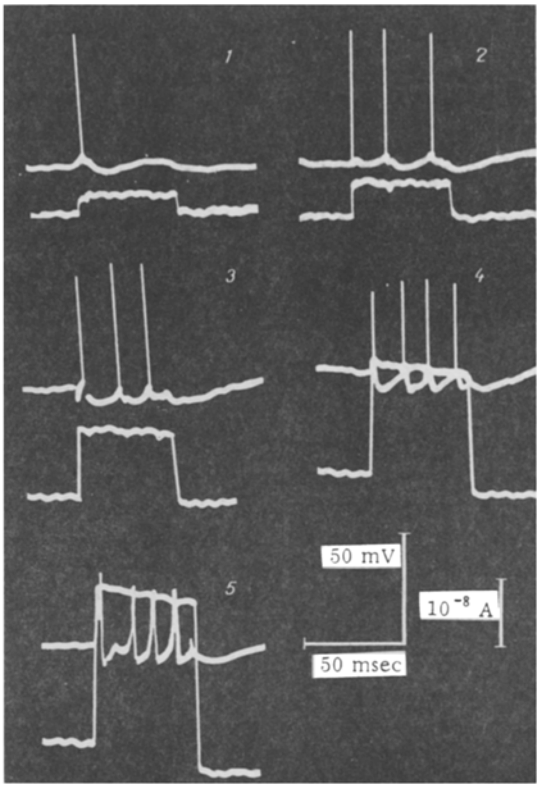

Fig. 1 Fig. 2

Fig. 1. Antidromic responses of motoneurons recorded intracellularly to a single discharge in ventral root L_6: a, b) in an adult rat with MP of 74 and 50 mV, respectively; c, d) in old rats with MP of 46 and 52 mV, respectively. Calibration: 50 mV, 6 msec. Records obtained by superposition of 10 sweeps of the beam.

Fig. 2. Multiple discharges of a motoneuron of an old rat during stimulation by square pulses. Strength of stimulation increased (1-5) from $0.25 \cdot 10^{-8}$ to $2 \cdot 10^{-8}$A. Top beam records unit responses, bottom beam records stimuli.

To determine the mean values, motoneurons whose MP was between 40 and 49 mV were chosen for the calculation, for they generated a complete antidromic spike (Fig. 1c). The ability of such motoneurons to preserve normal spike activity for a long time was demonstrated by Kostyuk [1]. Meanwhile, if the distribution of the motoneurons by their MP level is examined, a definite age difference can be seen. For instance, in young sexually mature rats, of 59 identified motoneurons 16.9% had an MP of 40-49 mV (Group 1), in 23.8% it was 50-59 mV (group 2), in 35.5% it was 60-69 mV (group 3), and in 23.8% it was 70-78 mV (group 4); in the old rats (58 motoneurons) the corresponding figures were 15.5, 38, 41.3, and 5.17%. The marked decrease in the proportion of motoneurons of group 4 and the increase in the proportion of motoneurons of group 2 will be noted.

The functional state of motoneurons can be judged to some degree from the levels of the thresholds of direct excitability, which were obtained from the minimal strength of the polarizing current in the outwards direction from the cell that evoked a single discharge from the neuron. In young sexually mature rats the thresholds of direct excitability ranged from $2.5 \cdot 10^{-9}$ to $5 \cdot 10^{-9}$A, with a mean value of $(3.0 \pm 0.3) \cdot 10^{-9}$A, whereas in old rats they ranged from $1 \cdot 10^{-9}$ to $3 \cdot 10^{-9}$A, with a mean value of $(2.0 \pm 0.2) \cdot 10^{-9}$A ($P<0.02$). The threshold levels for motoneurons of young sexually mature rats agreed with those given in the literature [10] and were lower than the thresholds for motoneurons of cats [5]. With an increase in the strength of the current the number of discharges increased to reach 4 or 5 per 50 msec of polarization of the neuron in the motoneurons of the old rats, or 80-100 spikes/sec (Fig. 2). The AP frequency when determined for the first two intervals was 125 spikes/sec. In the young sexually mature rats it was over 300 spikes/sec, also in agreement with data in the literature [9, 11].

An increase in the strength of the stimulating current to $2 \cdot 10^{-8}$A caused a marked decrease in amplitude and an increase in duration of the discharges as well as inactivation of the membrane, leading to blocking of APs of somatic-dendritic origin.

Besides motoneurons capable of generating multiple discharges others were frequently found in the old rats which responded to a current of 3-4 times above threshold strength by a single AP with marked afterhyperpolarization lasting 20-40 msec.

Discharges of the motoneurons of the old rats often were long in duration. The NS-SD duration of the antidromic spike in young sexually mature rats averaged 1.02 ± 0.09 msec, compared with 1.65 ± 0.14 msec in old animals ($P < 0.001$); this difference was due both to a change in the ascending phase and more especially to a slower decline of the descending phase.

The antidromic spike was followed by late depolarization (the small wave at the base of the spike in Fig. 1a, b), which is associated [10, 13] with the spread of the excitation wave toward the dendrites. Antidromic responses of motoneurons of the old rats as a rule did not have this wave (Fig. 1c, d), possibly indicating a change in dendrite function.

The results of this investigation of several physiological parameters of motoneurons of old rats (MP, excitability, lability, character, and duration of the antidromic spike) thus provide evidence of changes in the functional properties of the motoneuron that could be connected with structural and metabolic changes in the various formations of the motoneuron. These changes in motoneuron function could influence the reflex activity of the spinal cord [2, 3]. Furthermore, the investigator studying motoneuron physiology must take these age differences in its properties into consideration.

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