DETERMINATION OF THE FRACTION OF THE MOTONEURON POOL RESPONSIBLE FOR THE MONOSYNAPTIC REFLEX IN MAN

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In healthy persons and patients with neurological diseases, with depression of the flow of supraspinal impulses and lowered excitability of spinal motoneurons the fraction of the motoneuron pool participating in the monosynaptic reflex was determined quantitatively. Using the ratio (in percent) between the maximum amplitudes of the H- and M-responses as one index, and the number of refractory motor units during conduction of H-reflex discharges, determined by the method of paired stimuli, as the other index, as a rule the same value was obtained for the fraction of the motoneuron pool. The two methods consequently are about equal in diagnostic value under both normal and pathological conditions.

When studying the function of the segmental apparatus of the human spinal cord many investigators have used the ratio (in percent) between the maximum amplitudes of reflex (H) and motor (M) responses of a skeletal muscle as an index of the fraction of the motoneuron pool responsible for the monosynaptic reflex, i.e., as a measure of excitability of the α-motoneurons [1, 4, 5]. However, if excitation of the neuromotor units during stimulation of motor axons arises synchronously, during stimulation of $1a$ afferent fibers definite desynchronization takes place because of synaptic transmission in the center and dispersion of the conduction velocity, found even in a functionally homogeneous group of afferent fibers. The question thus arises whether the amplitudes of the H- and M-potential are comparable. The method of determining the number of motor units participating in the conduction of H-reflex discharges by paired stimuli, suggested relatively recently [7], is therefore of considerable theoretical interest. Having demonstrated the participation of 100% of the cells of the motoneuron pool in the monosynaptic reflex in several subjects, the workers cited conclude that this method is to be preferred as being more accurate.

The object of the present investigation was to compare the accuracy of the two methods when studying monosynaptic excitability of human spinal motoneurons under normal conditions and also to determine the degree of synchronization of motoneuron activation when the flow of supraspinal impulses is deficient under pathological conditions.

EXPERIMENTAL METHOD

Tests were carried out on ten healthy subjects and on 22 patients with the cervicothoracic form of syringomyelia (nine patients), with vascular cervical myelopathy (seven patients), and with a spinal form of multiple sclerosis (six patients). Most of the healthy subjects and patients were tested repeatedly. The H-reflex was evoked by stimulation of the tibial nerve in the popliteal fossa with square pulses (0.1 Hz, 0.5 msec, 30-70 V) from a type ESU-1 two-channel electrical stimulator. Potentials of the reflex and motor responses of the soleus muscle were recorded by surface electrodes, amplified by a UBP1-01 amplifier, and photographed on the screen of a type S1-19 CRO with superposition of 3-5 sweeps of the beam.

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TABLE 1. Excitability of Spinal Motoneurons in Healthy Subjects and Neurological Patients (results obtained by two methods)

Indices studied	Healthy subjects (n = 28)	Patients with		
		syringomyelia (n = 13)	vascular cervical myelopathy (n = 21)	multiple sclerosis (n = 9)
H_{max} (in mV)	0,92±0,05	0,57±0,11	0,69±0,07	0,70±0,16
M_{max} (in mV)	1,38±0,09	1,36±0,21	1,28±0,10	1,32±0,21
M_{refr} (in mV)	0,42±0,04	0,74±0,12	0,53±0,08	0,57±0,03
$\frac{H_{max}}{M_{max}}$ (in %)	66,7±3,7	41,9±4,2	53,9±4,7	53,0±5,1
$\frac{M_{max}-M_{refr}}{M_{max}}$ (in %)	69,6±3,9	45,6±5,8	58,6±5,8	56,8±6,6

Legend: n is number of cases.

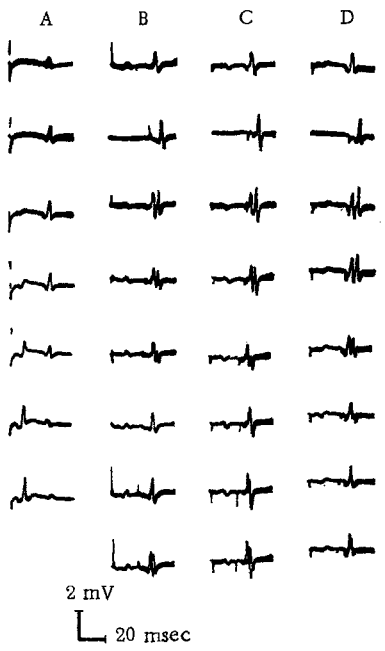

Fig. 1. H- and M-response of soleus muscle in healthy subjects to stimulation of tibial nerve by single and paired stimuli. From top to bottom: A) dynamics of H- and M-response during gradual increase in intensity of the single stimulus; B, C, D) conditioning maximum H-response, testing maximum M-response, dynamics of M-potential during stimulation by paired stimuli with a gradual decrease in the time interval (explanation in text).

To determine the relative number of neuromotor units in a refractory state during H-reflex discharges, the nerve was stimulated with paired pulses, the first of which evoked a maximum H-response (H_{max}) and the second a maximum M-response (M_{max}). By approximating the two stimuli in time, the test M-wave was gradually superposed on the conditioning H-potential and a reduced M-wave was recorded under refractory conditions (M_{refr}). In each observation the ratios H_{max}/M_{max} and $(M_{max} - M_{refr})/M_{max}$ were calculated in percentages and compared. The results of 71 tests were subjected to statistical analysis.

EXPERIMENTAL RESULTS

In the healthy subjects, in all tests except two, the threshold of the H-reflex was below that of the M-response. With an increase in the stimulus strength, the amplitude of the H-reflex increased. As a rule the maximum value of the H-potential was observed in response to stimulation of threshold magnitude for motor axons. With further growth in the stimulus strength the H-reflex was inhibited, while the M-response was increased (Fig. 1A). The ratio between the maximum amplitudes of the H- and M-responses varied from 46 to 90%. During stimulation of the nerve with paired stimuli the amplitude of the maximum M-potential evoked by the testing stimulus remained unchanged when this response was more than 7 msec away from the conditioning H-reflex. With a decrease in the time interval, there was a gradual decrease in amplitude of M_{max}. The greatest decrease in amplitude of the M-wave was observed when the interval was 0-1 msec (Fig. 2). In two cases total disappearance of the M-response was observed, indicating participation of 100% of cells of the motoneuron pool in the monosynaptic reflex, whereas the ratio H_{max}/M_{max} in these same experiments was 80 and 90%, respectively (Fig. 1B). However, in nearly all cases the ratios H_{max}/M_{max} and $(M_{max} - M_{refr})/M_{max}$ were equal (Fig. 1C, D). As a result, both methods of testing yielded very closely similar mean values for the number of motoneurons participating in the monosynaptic reflex (Table 1).

In must also be noted that when the time interval between the two stimuli was at a certain value, the testing M-response began to precede the conditioning H-reflex. The original M-wave recovered under these circumstances only when the interval between the potentials reached 2-3 msec (Fig. 2).

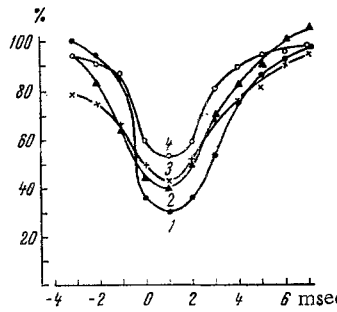

Fig. 2. Amplitude of M-potential plotted against time interval between conditioning H-reflex and testing M-response in healthy subjects (one) and in patients with vascular cervical myelopathy (two), multiple sclerosis (three), and syringomyelia (four) (mean values). Abscissa, time between conditioning H-reflex and testing M-response of soleus muscle, in msec (a minus sign denotes that the M-response precedes the H-reflex); ordinate, amplitude of testing M-response as a percentage of maximum M-potential.

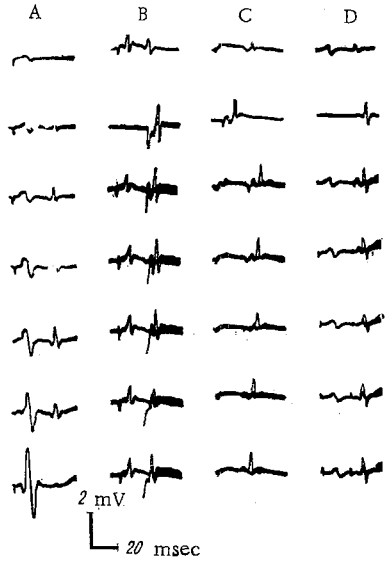

Fig. 3. H- and M-response of soleus muscle in patients with multiple sclerosis (A, D), syringomyelia (B), and vascular cervical myelopathy of traumatic origin (C) to stimulation by single and paired stimuli. Legend as in Fig. 1.

In some patients with a spinal form of multiple sclerosis [3], and also in some cases of the cervico-thoracic form of syringomyelia (on the side of the focus) and with vascular cervical myelopathy of varied etiology, the writer previously found lower thresholds for the M-response than for the H-reflex. This occured when the stimulus strength was increased against the background of an increasing M-wave (Fig. 3A). Both in these cases and in most cases with an ordinary ratio between the thresholds of the H- and M-potential, the reflex response of the muscle was reduced in amplitude. Briskness of the ankle jerks, with the presence of pyramidal signs observed in the patients, suggested that the low amplitude of the H-response is associated, not with a decrease in the number of activated motoneurons, but with their asynchronous participation in the monosynaptic reflex. Since the refractory period in the neuromuscular unit is 2-3 msec, it would be expected that more complete data would be obtained by the use of the method of paired stimuli. However, this hypothesis proved to be correct in only a few cases (Fig. 3B). In most tests quantitatively equal results were obtained for the function of the motoneurons both when the M-potential was determined in the period of refractoriness of the motor units and when the ratio between the maximum amplitudes of the H- and M-response was obtained (Fig. 3C, D). The possible reason is that, by contrast with a blow on the tendon, electrical stimulation of the nerve is accompanied by synchronized discharges in afferent fibers of group 1A [6].

The results thus show that when the excitibility of human spinal motoneurons is tested under normal conditions and when the supraspinal flow of impulses is deficient and atony of the nerve center is present [2] both methods are of approximately equal diagnostic value. Only in a few cases does the method of paired stimuli reveal a greater fraction of the motoneuron pool participating in the monosynaptic reflex.

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