

ELECTROMYOGRAPHY AS A METHOD OF INVESTIGATION
OF THE FUNCTIONAL STATUS OF THE
NEUROMUSCULAR APPARATUS

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(Received March 19, 1958).

In the classical studies by N. E. Wedensky (1901 a) it has been already shown that the study of the character of the electrical potential of a muscle may enable one to solve the question of the condition of the nerve elements ensuring its functions. More than 50 years have elapsed since that time. Electromyography has won broad application in physiology as well as in the clinic. It is also true that at present electromyography is not essential to study the condition of the nerve elements — both nerve cells and peripheral nerves — since, now more perfect methods of investigation are also available. However, electromyography may help one to reveal certain disturbances in the whole complex — neuron, end-plate, and muscle fibre. It is of a great interest for two reasons, firstly it provides knowledge about the activity of a motor unit, and secondly it provides information about disturbances of normal relationship among different components of this complex. Clinicians are in great need of correct understanding and interpretation of pathological disturbances of the activity of the muscular apparatus. Physiologists should help clinicians in this respect, and therefore, there is no wonder that at present, physiological journals of many countries publish much material on these questions. In this paper action potentials from muscles have been studied and different patterns analysed as to their significance.

Electromyographic investigations were performed on children with two kinds of neuromuscular disturbances—poliomyelitis and Little's disease at Kiev, U. S. S. R. In all these cases same methods of recording were used. Electromyograms were recorded simultaneously on an oscillograph from two muscles; either same muscles from both the extremities were taken or antagonistic muscles were used, depending upon the nature of disorder intended to be revealed. For recording electromyograms, superficial electrodes were placed on the skin overlying the belly and the tendon of the muscle, the electrodes being placed along the muscle fibres as far as was possible. Amplification used was 80 mv/mm., and time record was 1/50".

Superficial electrodes were chosen for recording potentials, because needle electrodes, although having a number of advantages, are themselves sources of excitation and to a certain extent distort the pathological picture.

In our opinion, to get a correct idea of the activity of a neuromuscular apparatus it is important to take a number of electromyograms under different conditions of excitation of the elements under investigation.

In a normal muscle at rest there is no electrical discharge, but in muscles with disturbed innervation there can be various kinds of electric potentials even during the state of rest. In a muscle deprived of innervation there appear spontaneous fibrillations. Electric potentials accompanying these fibrillations are of low voltage i. e. 50-100 mv, and very rarely reach 500 mv. Disappearance of fibrillations is a sign of re-innervation (Herbert Jasper and Gwen Ballem, 1949).

The origin of fibrillation is not clear yet, but there is no doubt that it is associated with disturbed excitability of the denervated muscle fibres. Choh-Luh Li and Milton Shy (1957) point out the possibility of the appearance of fibrillation potentials independent of end-plate potentials and from sites in the muscle further away from the location of end-plates.

Besides fibrillation, there is another kind of spontaneous muscle activity observed. During the rehabilitation period of poliomyelitis, spontaneous

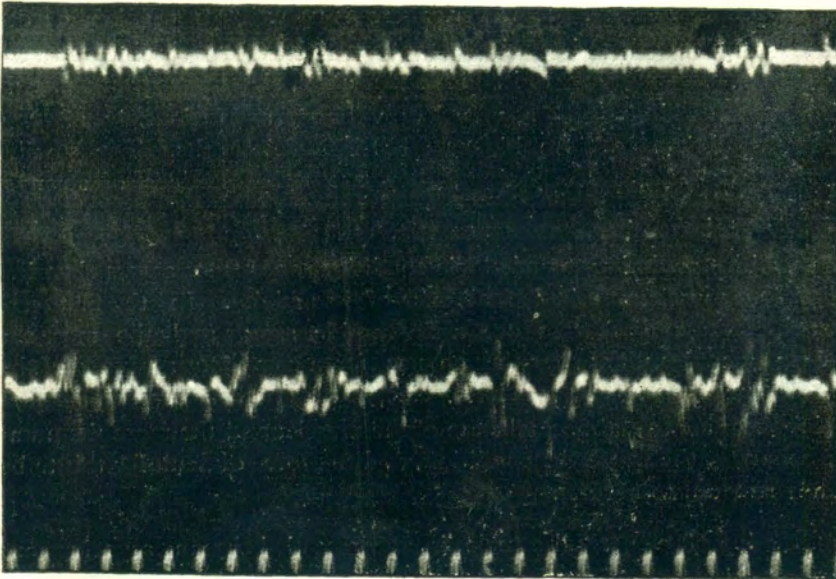


Fig. 1

REST. POLIOMYELITIS CASE:

I curve-m. biceps sinistra.

II curve-m. triceps sinistra.

twitchings of bundles of muscle fibre during rest were also observed. This fasciculation showed differences in frequency and strength which were

observed in muscle action potentials as well. Electromyograms No. 1 shows spontaneous activity of a biceps sinistral (the upper curve) and of triceps sinistral (the lower curve). In the biceps there were low discharges which occurred after short intervals of rest, in the triceps there were some discharges of higher potentials.

Similar spontaneous discharges were also observed in states of regeneration of nerve elements and they were indicative of an increased excitability of muscles associated with growing of new nerve fibres into the muscle. Similar discharges may appear not only during reinnervation, but also during rehabilitation of the functions of those motoneurons which were in a state of depression conditioned by oedema and the effect of toxins during the acute period of poliomyelitis. In any case, such a spontaneous activity of muscle fibres in poliomyelitis is always a favourable prognostic sign (Watkins *et al.*, 1939).

Another kind of electrical activity takes place in rigidity of muscles, as in Little's disease. In this case it is conditioned by an uninterrupted flow of impulses on the part of motoneurons. According to a number of authors (Hodes, 1953; Haagqvist, 1945), spastic contraction of the muscle is conditioned by small efferent nerve fibres of the diameter of 5-6 microns and of a low propagation velocity. However, there is no uniform opinion on this question. In any case there is no doubt that spasticity of muscles is supported by efferent impulses arriving to it. In such cases, electromyograms usually show incessant oscillations of a very low voltage, approximately of 40-80 microvolts, sometimes a little higher 120-126 microvolts. The smaller and more frequent the oscillations, they are manifestations of stronger muscular spasm.

Thus, with two different pathologic conditions one comes across electrical discharges in a muscle even in the absence of its activity. In the first case (poliomyelitis) these discharges are a favourable sign; and the more the number of discharges, the better the chance for a complete recovery of the muscle. In the second case (spasticity) electric potentials are an indication of muscle spasm i. e., an abnormal state of the muscle; and the more the number of discharges, the worse the condition, and so more difficult for this to be completely restored to normal.

Contraction of a normal muscle is accompanied by an asynchronous discharge of action potentials. In the antagonist muscle, with normal innervation either no activity or a low electrical activity conditioned by its tension is observed. This is seen in electromyogram No. 2 which is from a healthy man. The difference in the strength of action potentials is evident.

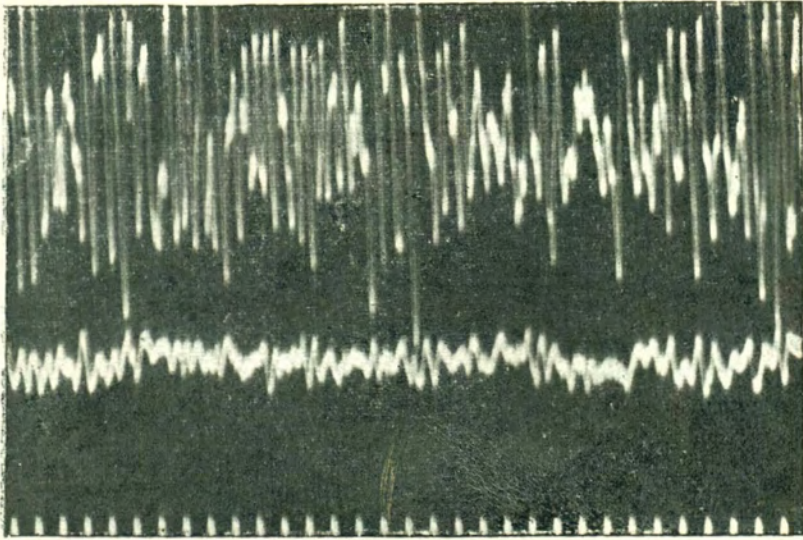


Fig. 2

HEALTHY MAN. FLEXION OF KNEE JOINT

I m. biceps femoris sinistra

II m. rectus femoris sinistra

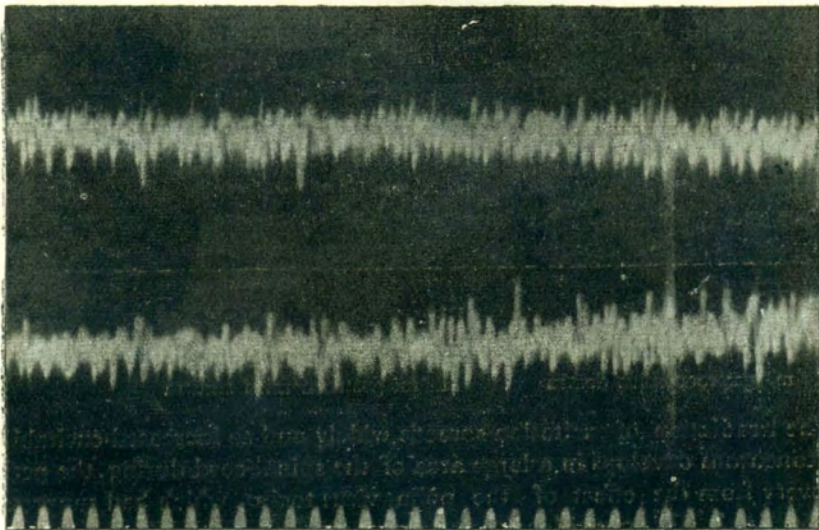


Fig. 3

A CASE OF LITTLE'S DISEASE. SPASTICITY. FLEXION OF KNEE JOINT.

I m. biceps femoris sinistra

II m. rectus femoris sinistra

Electromyogram No. 3 was taken from the same muscles under similar conditions, in a patient with Little's disease, i. e. with a rather evidently manifested muscular spasm. One can see that action potentials from both the antagonistic muscles are equal in strength, and looking at the electromyogram it is difficult to say which of the muscles is functioning. Hence, in this case reciprocal innervation is disturbed and in the spinal cord there is a state of increased excitability (Fudel - Ossipova and Mezhenina, 1955). The state of increased excitability of nerve centres may be conditioned by incessant flow of exciting impulses to them and the absence of inhibiting influence. This is probably what takes place in muscular spasm (Little's disease).

As a result of increased excitability of motoneurons there is irradiation of the process of excitation, and therefore in addition to the appearance of electrical activity in the contracting muscle, it also appears in the same muscle of the other extremity. A characteristic feature of this activity in the muscles of both the extremities (Fig. 4) is that besides weak oscillations, there also appear higher action potentials after certain periods of time.

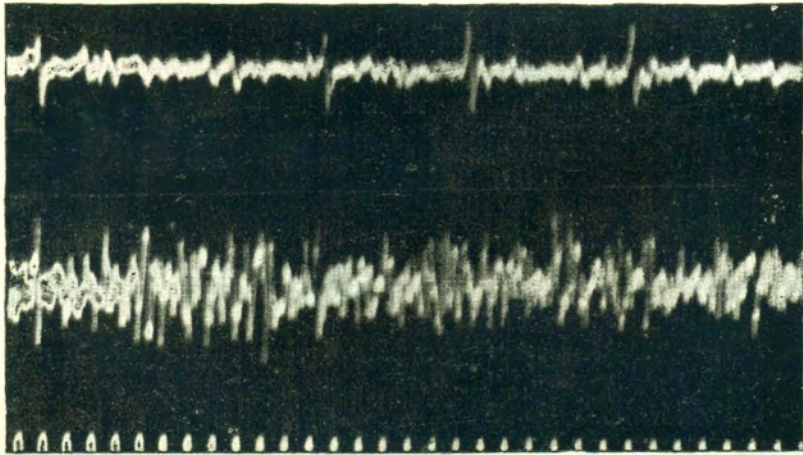


Fig. 4

POLIOMYELITIS CASE. FUNCTION OF GASTROCNEMIUS SINISTRA

I m. gastrocnemius dextra

II m. gastrocnemius sinistra

The irradiation of excitation spreads widely and so increased excitability of motoneurons develops in a large area of the spinal cord during the period of recovery from the effect of the polio virus toxins, which had suppressed their function. This conditions the appearance of discharges in them.

Action potentials, recorded through electrodes placed on the skin, present in themselves a combination of many potentials of motor fibres and motor

units. The strength of an action potential is defined, as is known, by the number of active units. Since contraction of separate units takes place at different time, a characteristic feature of a normal muscle is asynchronism. In normal electromyograms we come across different voltages of action potentials—from 300 microvolts to 1-2 millivolts; in intensive voluntary contraction there usually prevail high-voltage potentials. A change in the voltage of electric potentials—either for the lower or for the higher—is observed in cases of various disturbances of innervation and degenerative changes in the muscles. Decrease in the number of active units and an increased asynchronism of their contraction will give on an electromyogram a picture of action potentials of low voltage—80-160 microvolts rapidly following one after the other—and potentials of 300-400 microvolts will be only occasionally observed.

Frequency of impulses can be increased by an excessive flow of afferent impulses on the part of proprioceptors. A number of authors (Wachholder 1925, Schaefer 1940, Dusser de Borene 1923, Richter, 1927 and others) are of the opinion that high potentials on an electromyogram reflect the flow of impulses to a muscle on the part of motoneurons, and weak oscillations belong to proprioceptive impulses. With muscular spasm, there is undoubtedly an increased excitability of receptors in Golgi's tendon organ and muscle spindles.

Electromyograms of spastic muscles have a peculiar character that differentiates them greatly from electromyograms of healthy people. The presence

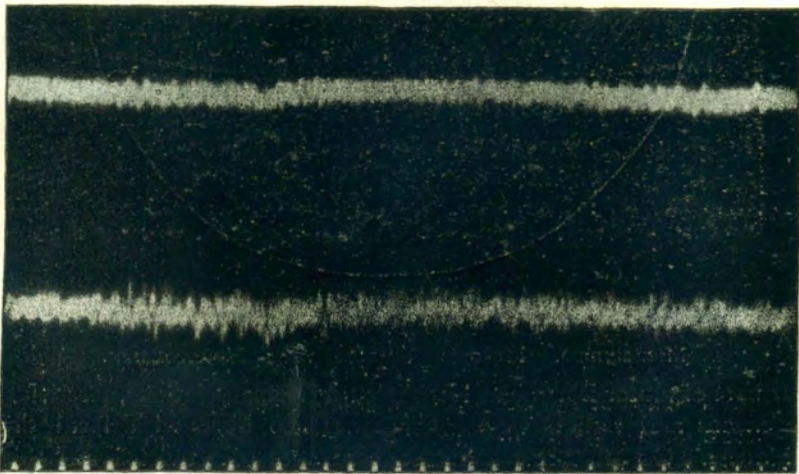


Fig. 5

SPASTIC CASE. FUNCTION OF M. GASTROCNEMIUS SINISTRA.

I m. tibialis ant. Sinistra.

II m. gastrocnemius Sinistra.

of a great number of weak oscillations and almost complete absence of strong oscillations are typical of Little's disease. Thus, on the lower curve of electromyogram No. 5 action potentials from the gastrocnemius are of low voltage—80-150 microvolts—and occur at the frequency of 150 per second. In this patient spasm was strongly marked and voluntary contraction was performed with difficulty.

Such a type of electromyogram makes one suppose that there is a considerable decrease in the number of actively contracting motor units, and there is striking asynchronism of impulses coming to them and considerable proprioceptive signaling. This supposition is confirmed by a pathomorphological investigation of that muscle, a bit of which was taken during an orthopedic operative interference. On microphoto of the gastrocnemius (Fig. 6) marked dystrophic processes are seen, involving considerable areas of the muscle. A

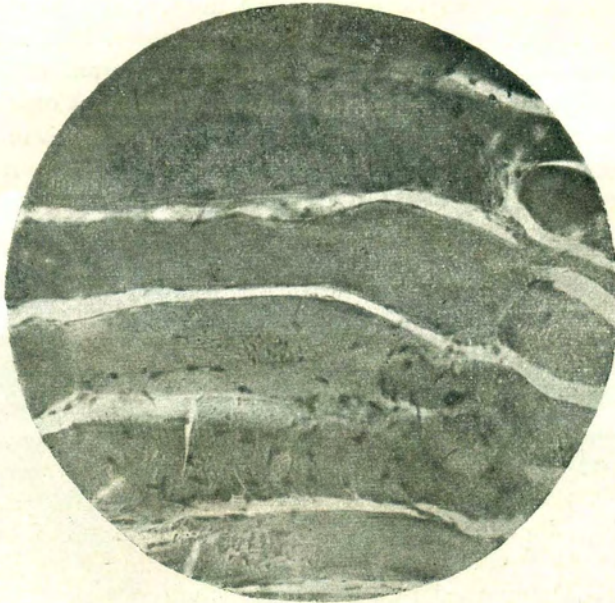


Fig. 6

MICROPHOTO. MUSCLES STAINED WITH HEMATOXYLIN.

greater part of motor fibres had lost their transverse striations, sarcoplasm was homogeneous and structureless. There are also fibres with focal thickness and thinness. On other microphotoes there were seen twisted and thickened nerve fibres which were fragmented in places.

Action potentials of a muscle, according to Rosenbleuth, consist of (1) excitation potential, (2) conduction potential and (3) contraction potential.

With ordinary methods of recording used in this investigation too, it is conduction potential that is apparently recorded. A great majority of authors are of the opinion that duration of an action potential of a muscle in man is 3.5 – 4.6 milliseconds (Petersen and Kugelberg, 1949). But along with this, in normal muscles they also observe more durable action potentials of 5 – 10 milliseconds (Wedell *et. al.*, 1943; Buchtal, 1947) due to interference of a number of electric potentials.

Monophasic potentials are not met with; the common type of potentials are the diphasic spike potentials, but in 2–4 percent of cases they came across polyphasic potentials as well (Petersen and Kugelberg, 1949). Appearance of polyphasic potentials is probably the effect of polyinnervation of a number of motor fibres, as it was experimentally shown by Katz and Kuffler in the sartorius of a frog.

However, there are probably other causes that may condition the appearance of polyphasic potentials. Thus, during the period of recovery from poliomyelitis in paretic muscles we came across a great number of polyphasic potentials. During recovery of function of affected neurons, there take place considerable ramifications of growing nerve fibres which penetrate into motor fibres, formerly innervated by other, now dead, motoneurons (Jasper and Gwen Ballem, 1949; Hertz *et. al.*, 1954). Consequently in such cases polyphasic potentials are a result of some dispersion of the impulse arriving in this case to many motor fibres with different thresholds of excitability. Besides that,

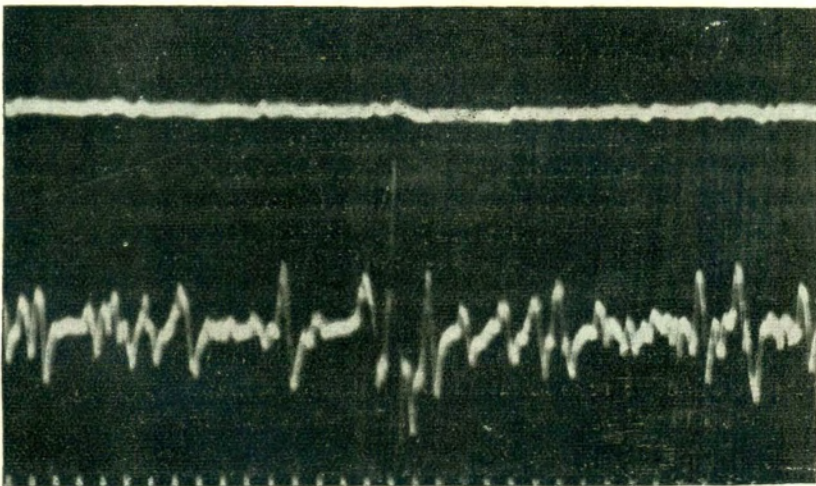


Fig. 7

POLIOMYELITIS CASE. EXTENSION, THE LEFT KNEE.

I m. quadriceps femoris dextra

II. m. quadriceps femoris sinistra

the speed of conduction of excitation in certain motor fibres may be different too. Duration and strength of electric potentials increases due to a simultaneous contraction of many motor units.

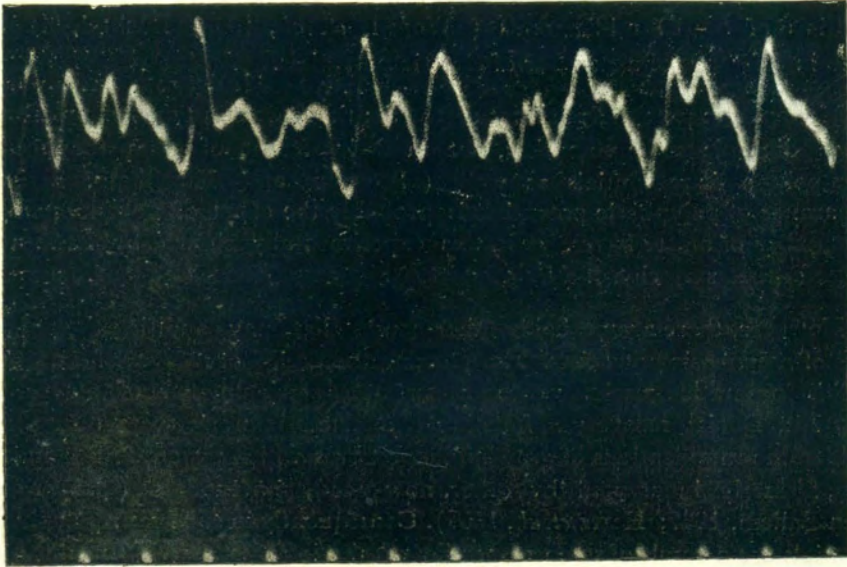


Fig. 8

POLIOMYELITIS CASE. REST.

I m. biceps brachii dextra Speed—100 mm/sec.

In electromyogram No. 7 (Fig. 7) are seen high and big sized potentials of irregular form as if consisting of several potentials merged into one. Polyphasic potentials of a similar character were discovered in the biceps brachii during spontaneous activity (Fig. 8). This photo was taken at a higher speed of the film, not 50 mm. per second, but 100 mm. Here we can see action potentials consisting of 3 and 4 phases. Duration of such potentials was 15-18-20 milliseconds, i.e. 5-6 times more than that of normal.

The appearance of polyphasic potentials of a high voltage and duration is indicative of active rehabilitation of motoneurons and growing of nerve fibres into the muscle.

It is possible to detect the presence of intact motoneurons supplying the paretic muscle with nerve fibres by doing a passive flexion of the extremity. In this case stretching of the affected muscle brings about a discharge of action potentials. It has been found that these discharges are not irregular as in spontaneous activity, but these are group discharges. Such groups of

discharges during passive flexion are seen on electromyogram No. 9 which is from a patient during recovery from poliomyelitis with paresis of both lower extremities. Function of the tibialis is absent from both legs. Voluntary contraction does not take place. Impulses coming from the cortex do not excite motoneurons, as judged by the absence of electrical potentials in the muscles. Passive flexion of the foot brings about a flow of proprioceptive impulses to the spinal cord, and they act in an excitatory way at the intact motoneurons. As a result of this, there appear in the muscle group discharges alternating with weak oscillations (lower curve). The same muscle of the opposite leg, which was at rest, also showed group discharges whose rhythm was slower than in the active muscle. These potentials are very similar to the discharges of a single motor unit. One may think that in this electromyogram there were recorded spikes of two motor units, giving simultaneous periodical impulses after long intervals of time. At a simultaneous discharge of both the motor units there appears a high action potential. The appearance of action potentials in the protagonist of the contracting muscle is explained by irradiation of excitation in the spinal cord and increased excitability of motoneurons rehabilitating their function.

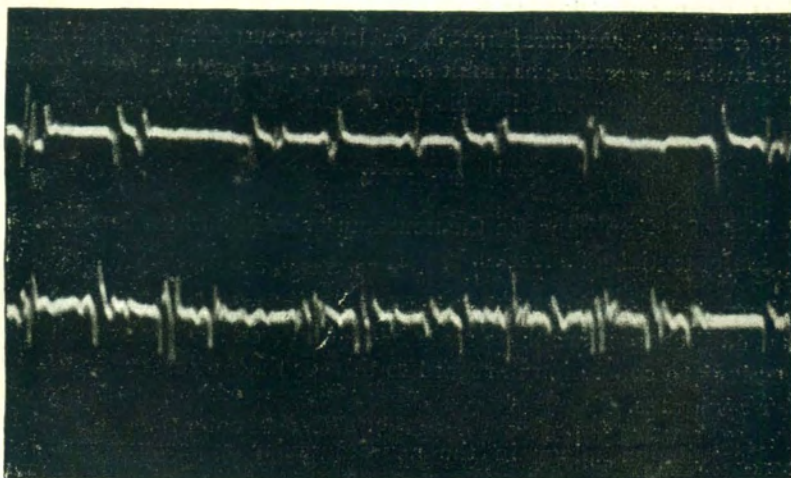


Fig. 9

POLIOMYELITIS CASE. FUNCTION M. TIB. ANT. SIN.

I m. tibialis anticus dextra

II m. tibialis anticus sinistra

The appearance of group discharges at passive contraction is indicative of the presence of motoneurons capable of activity, but if their number is small and they are not completely intact, they will not be able to ensure the full function of the muscle. A small number of contracting motor units cannot bring into action the big inert mass of the muscle.

Physiological explanation of such group discharges is difficult. There is no doubt that certain changes in the state of motoneurons condition the appearance of periodical discharges in them. As similar periodicity in the activity of motoneurons is observed in pathological states, especially with affection of a great number of motoneurons, it is more probable that in such cases there functions a small number of motoneurons, which after each excitation require a long period of time to restore their energy.

Knowing that the most labile link in the complex—neuron axon end-plate—is the latter, it is possible that they are responsible for periodicity (Wedensky 1903). There is no doubt that with poliomyelitis alongside with affection of the body of a motoneuron there is also a change in the functional condition of the end plates. (Hodes, 1948; Tchernov, 1950).

The material presented in this paper does not certainly exhaust all the variety of electromyograms that can be obtained in muscular disorders. It would appear from the present series of observations that the patterns of electric potentials in muscles with neuro-muscular disorders are very complex and present considerable difficulties for their correct interpretation. Every time that a electromyogram is examined there arises the question as to what might be the cause of distortion of motor impulse discharges; does it result from injury to neuron, peripheral nerve, or neuromuscular junction? These difficulties will be overcome as result of further experimental investigations by physiologists in conjunction with electromyographic observations on patients.

SUMMARY

An idea of a disturbance in the neuromuscular apparatus can be obtained from action potentials of muscles.

Voltage and frequency of electric potentials of muscles, their form and the character of discharges are those main indications, analysis of which enables one to arrive at a conclusion in regard to this or that disorder in the neuromuscular apparatus.

The existing pathology in the neuromuscular apparatus can be well revealed at simultaneous recording of electric potentials:

- (1) from antagonist muscles.
- (2) from muscles of the same name on both extremities.

In this paper are presented different patterns of electric potentials observed in cases of poliomyelitis and infantile spastic paralysis and they are analysed.

REFERENCES

1. Buchtal Fritz (1947): *An. Rev. Physiol.*, **9**, 119.
2. Hunt C. C. (1954): *J. Gener. Physiol.*, **38**, 117.
3. Choh—Luh Li, Milton Sky and Jay Wells (1957): *J. Physiol.*, **135**, 522.
4. Dusser J. G. De Borene (1923): *Scand. Arch., Physiol.*, **43**, 107.
5. Fudel—Ossipova, S. I. and Mezhenina (1955): *Ucrainian Jour of Physiol.*, **17**.
6. Haagqvist (1946): *Acta Med. Scand.*, **104**, 8.
7. Hertz, H., Madsen, A., Buchtal F. (1954): *Jour. of Bone & Joint Surgery 36-A*, 902.
8. Hodes, R. (1953a): *Annual Review of Physiol.*, **15**, 139.
9. Hodes, R. (1948b): *Arch. Neurol. & Psychiatr.*, **60**, 457.
10. Jasper, H. and Ballen, G. (1949): *J. Neurophys.*, **13**, 230.
11. Jusevitch, N. S. (1955): *J. Neurol. & Psychiatr. U. S. S. R.*, **55**, 89.
12. Katz, B. and Kufflar, S. (1941): *J. Neurophysiol.*, **4**, 207.
13. Petersen, J. and Kugelberg, E. (1949): *J. Neurol. Neurosurg. Psychiatr.*, **12**, 124.
14. Richter, J. (1927): *Amer. J. Physiol.*, **85**, 506.
15. Rosenblueth, A., Wills, A., and Hoogland, H. (1941): *Amer. J. Physiol.*, **133**, 455.
16. Schofer, H. (1940): *E. Electrophysiology B. II*.
17. Tchernov, I. D. (1950): *J. Neurol. and Psychiatr.*, **53**, 653, U.S.S.R.
18. Uphland, J. M. and others (1956): "Works of Leningrad Medic. Inst. of Sanitation and Hygiene," 176, Moscow.
19. Wachholder (1925): *Pfl. Arch.*, **210**, 646.
20. Watkins, A., Mary, M. Brazier and Swab, R. (1943): *J. Amer. Med. Assoc.*, **123**, 188.
21. Wedell, G., Feinstein, B. and Pattle, R. (1943): *Lancet*, **1**, 236.
22. Wedensky, N. E. (1901a): *Excitation, Inhibition and Narcosis*. S. Petersburg 1901.
23. Wedensky, N. E. (1903b): *Pflug. Arch. ges. Physiol.*, **100**, 1.