

ELECTROMYOGRAPHIC INVESTIGATIONS OF THE INTERCOSTAL MUSCLES IN EXPERIMENTAL POLIOMYELITIS

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The most dangerous form of poliomyelitis is that complicated by a disturbance of respiratory function. Clinico-physiological [2, 4] and histological [6] investigations have shown that the primary causes of respiratory disorders in poliomyelitis is a disturbance of the innervation of the intercostal muscles. Meanwhile it has been found that the excitability of the respiratory center is increased in the early stages and depressed in the late period of experimental poliomyelitis [1].

The object of the present investigations was to study the rhythm and intensity of the process of excitation of the intercostal muscles in experimental poliomyelitis and also to examine the capacity of the nervous centers of the respiratory muscles to react to stimulation.

EXPERIMENTAL METHODS

Poliomyelitis was reproduced experimentally in albino mice, inoculated intracerebrally with type II poliomyelitis virus (Lansing strain). Four stages may be distinguished in the course of this disease: incubation, preparalytic, paralytic, and terminal. The disease always ends in death of the animal; visible respiratory disorders are observed in the terminal stage of the disease and are outwardly similar to a disturbance of the rhythm of the respiratory movements.

In order to solve the various problems the method of recording the action potentials of the intercostal muscles of the fixed animal was used: during natural respiration and during the action of specific respiratory stimulants — CO_2 and corconium (dicholine ester of suberic acid). Both substances were given in low and high concentrations: CO_2 — 3 and 10%, corconium — 1 and 10 mg/kg.

Action potentials were recorded with bipolar needle electrodes in the 4th or 5th right intercostal space. Electrical potentials of one of the limb muscles were recorded at the same time. The investigations were carried out on 14 intact mice and 24 infected animals during the period of development of experimental poliomyelitis.

EXPERIMENTAL RESULTS

The electrical activity of the intercostal muscles of intact animals during natural respiration is related to inspiration and consists of batches of potentials with a rhythm of 240-300/min. Each batch consists of, on the average, 15-20 potentials with a frequency of 150-200/sec and an amplitude of 100-300 μB . Between inspirations the electrical activity of the intercostal muscles consisted of solitary action potentials or was absent altogether (Fig. 1a). During inhalation of air containing 3% CO_2 or after administration of corconium in a dose of 1 mg/kg, the reaction of the intercostal muscles took the form of increased electrical activity between the respiratory complexes. The rhythm of the respiratory complexes and of their electrical pattern remained largely as before (Fig. 1b). During strong stimulation of the respiratory center (inhalation of air containing 10% CO_2 or injection of corconium in a dose of 10 mg/kg) the electrical activity of the intercostal muscles was greatly intensified during expiration, so that these muscles were in a state of constant excitation. At the same time, distinct action potentials unaccompanied by any visible movement of the animal also appeared in the tibialis anterior muscle (Fig. 1c).

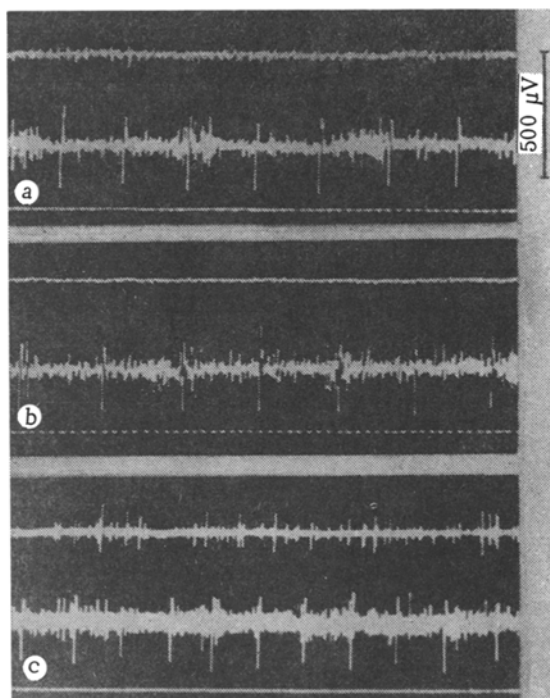


Fig. 1. Electrical activity of the tibialis anterior and intercostal muscles of an intact mouse during natural respiration (a) and after administration of corconium in a dose of 1 mg/kg (b) and 10 mg/kg (c). Significance of the curves (from top to bottom): electromyogram (EMG) of limb muscle; action potentials of intercostal muscles of the same animal (in this case the ECG also is recorded, but is not considered in the analysis) time marker (0.02 sec).

This constant contraction of the intercostal muscles in the presence of distinct respiratory movements by the animal may be associated with the dichotomy of the function of pulmonary ventilation between the diaphragm and the muscles of the thoracic cage, as was observed [3] during the study of the action of large doses of corconium. In this case the intercostal muscles take no part in the act of respiration, which is performed exclusively by the excursions of the diaphragm.

The investigation of the intact animals revealed a direct relationship between the electrical reaction of the intercostal muscles and the strength of the applied stimulus and demonstrated that irradiation of excitation could take place from the respiratory center to the centers of the limb muscles.

The study of the electrical activity of the intercostal muscles of the infected animals yielded the following results. In the incubation period of the disease the electromyographic picture of the respiratory muscles remained within normal limits. The strength, duration, and rhythm of the excitation corresponded to those in the intact animals. The reaction of the respiratory center to stimulation was normal and the strength relationships were correct.

With the appearance of the initial symptoms of the disease strong excitation of the respiratory center was sometimes observed in the resting state. This was shown by a change from phased to constant electrical activity of the intercostal muscles during natural respiration. The degree of excitation was probably limiting, for subsequent weak and strong stimulation had a depressant action, lowering the frequency and amplitude of the potentials of the intercostal muscles.

With the further development of the disease, when only the spinal centers for the limbs were involved in the pathological process, this picture became a regular feature. Constant electrical activity of the intercostal muscles during natural breathing was observed in most animals and was intensified by the action of a weak stimulus. As a rule this raising of the level of excitation was maximal. An increase in the strength of stimulation caused no further changes, although the electrical activity of the intercostal muscles did not exceed the mean normal indices. Sometimes a further increase in the strength of stimulation led to the development of a "pessimal" reaction of the respiratory center. These changes are illustrated in Fig. 2, showing the EMG of an infected mouse in the paralytic stage of poliomyelitis. In curve *a*, complexes of waves can be seen, corresponding to a respiration rate of 300/min. Each complex consists of 12-15 potentials with a frequency of 150/sec and an amplitude of 300 μ V. During expiration the intercostal muscles did not relax completely, and showed electrical activity with a frequency of 150/sec and with a somewhat smaller amplitude. Infrequent potentials with an amplitude of 500 μ V were recorded from the parietic tibialis anterior muscle. After injection of a small dose of corconium (Fig. 2b) the electrical activity during expiration increased and the respiratory complexes became difficult to distinguish, while the impulses from the parietic muscle of the hind limb became weaker. A large dose of corconium (Fig. 2c) caused no significant change in the electrical activity of the intercostal muscles and slightly strengthened the activity of the parietic tibialis anterior muscle.

In the terminal stage, before death of the animal, when severe and widespread motor disturbances developed and the rhythm of respiration was appreciably disturbed, the EMG indicated a marked depression and change in the character of the reaction of the respiratory center to stimulation (Fig. 3). The recordings of the potentials of the dying animal during natural respiration (Fig. 3a) demonstrate that the intercostal muscles and their nerve supply

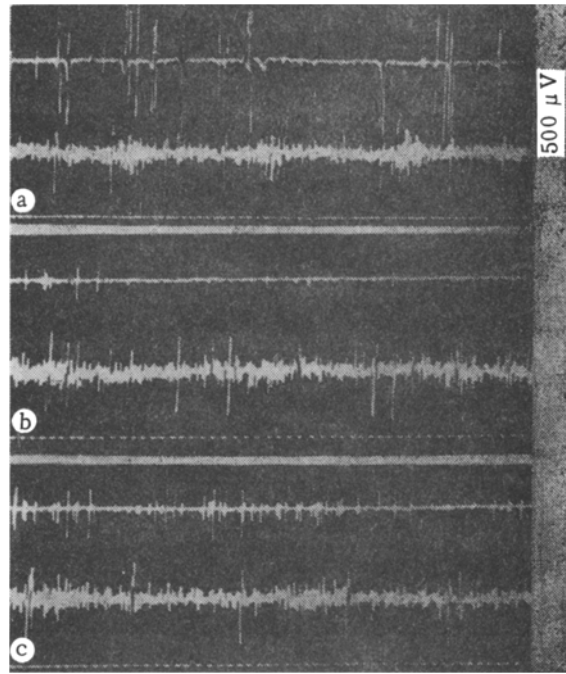


Fig. 2. Electrical activity of the tibialis interior and intercostal muscles in the paralytic stage of the disease during natural respiration (a) and after injection of coronium in doses of 1 mg/kg (b) and 10 mg/kg (c). Significance of curves as in Fig. 1.

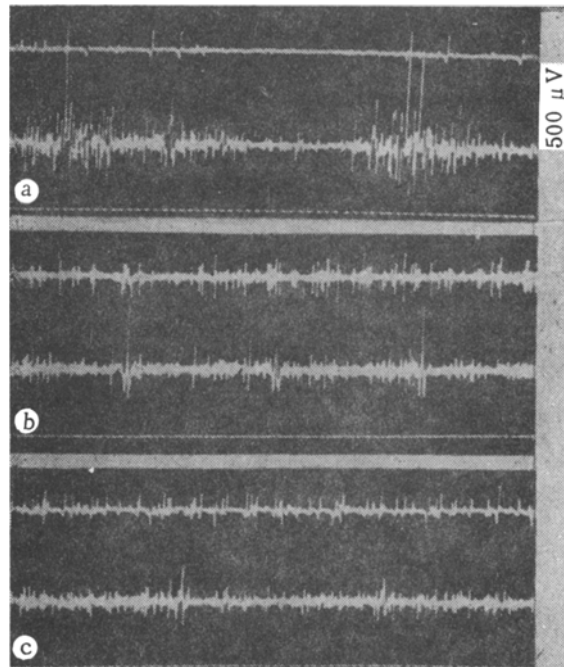


Fig. 3. Electrical activity of the tibialis anterior and intercostal muscles in the terminal stage of the disease during natural respiration (a) and during inhalation of air containing 3% CO₂ (b) and 10% CO₂ (c). Significance of curves as in Fig. 1.

remained capable of developing excitation; the respiratory complexes consisted of 27-30 potentials of relatively high frequency (100/sec) and amplitude (300 μ V). During inhalation of air with 3% CO₂ the frequency and amplitude of the potentials of the intercostal muscles fell sharply. The muscles were in a state of weak and prolonged contraction. Inhalation of air containing 10% CO₂ depressed their electrical activity still further, in association with a disturbance of the periodic activity of the respiratory muscles. In the remaining experiments the same pattern was regularly observed. In some cases neither weak nor strong stimulation had any effect. Sometimes during stimulation of the respiratory center depression of its activity was observed; in some cases very weak activation caused by a weak stimulus gave way to still weaker activity when the strength of the stimulus was increased. It must be pointed out that these changes sometimes took place against the background of slight depression of the respiratory function.

The experimental results show that during the development of experimental poliomyelitis the relationships between excitation and inhibition are disturbed in the central nervous system — in the respiratory center and the corresponding segments of the spinal cord. The nerve cells are readily excitable and capable of falling rapidly into a state of inhibition. The distortion of the reaction to weak and strong stimuli (a balancing or paradoxical reaction), and also the complete absence in many cases of a reaction of stimulation suggest that a paralytic process may develop in certain nervous centers. These experimental findings are in agreement with clinical observations [5] showing a disturbance of the respiratory function in all forms of acute poliomyelitis even in the absence of clinically apparent respiratory disorders. In our experimental model, judging by the action potentials of the intercostal muscles, a disturbance of the respiratory function was observed before the appearance of visible respiratory disorders. This was seen more frequently in association with the development of generalized paralysis, but it was sometimes found in the preparalytic stage of the disease.

The results of our investigations are in full agreement with the hypothesis put forward by B. P. Doroshchuk [4] on the basis of clinical observations, according to which a functional paralysis of the intercostal muscles may be present in certain cases. In our experiments death of the animals took place, as a rule, against the background of a depressed, but not completely lost, ability of the intercostal muscles to contract, with a well marked tendency for paralytic inhibition to develop in the nervous centers. This suggests that one possible cause of death of the animals is a functional depression of the respiratory muscles.

SUMMARY

A study was made of the electrical activity of the intercostal muscles during the development of experimental poliomyelitis.

Action potentials were recorded with animals breathing naturally and also during action of specific respiratory stimulants — CO₂ (3 and 10%) and coronium (1 and 10 mg/kg). In the incubation period of the disease the electromyographic picture of the intercostal muscles, was normal, both during natural respiration and during the action of respiratory stimulants. With further progress of the disease there was a rise of the excitation of the intercostal muscle centers and of their regular reaction in response to weak and strong stimuli. The results obtained could be explained by the capacity of the corresponding nerve centers to become rapidly inhibited, the latter state presenting features of a paralytic character.

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