RESPIRATORY ELECTROMYOGRAMS IN PULMONARY DAMAGE BEFORE AND AFTER VAGOTOMY

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Many clinical and laboratory investigations have shown that the dyspnea of pulmonary disease or trauma develops reflexly [1, 3, 7, 14]. In the above investigations, disturbance of respiratory movements was measured chiefly by pneumographic recording of respiratory movements. It is only recently that electrophysiological methods have become available for studying these movements. However, comparatively few electromyographical investigations have been made of the altered function of individual muscles following damage to the respiratory system, and they have been mainly clinical [10, 11, 13, 15-17].

The present investigation was made in the laboratory, and we have studied the mechanism of breathlessness by recording the electromyograms of respiratory muscles in cases of pulmonary damage before and after vagotomy.

METHOD

The experiments were carried out on 12 unanesthetized dogs in whose muscles plate electrodes were implanted by the method described by T. I. Goryunova [5]. Potentials were recorded from the diaphragm and internal intercostal muscles (from the intercartilaginous portion of the fifth intercostal space and from the internal oblique muscles of the belly); a three-channel amplifier was used in conjunction with a cathode ray oscillograph, the combination having a sensitivity of from 30 to 100 μv/mm.

Pulmonary damage was inflicted by injecting 10-20 ml of hot water at about 90° through the thoracic wall. In some experiments the potentials were recorded from muscles on the damaged side, and in other experiments from muscles on the opposite side. In one set of experiments the damage was inflicted before vagotomy, and in another, after.

RESULTS

We have previously described (1960) how the normal dog electromyogram shows a set of impulses at inspiration which gradually increase in rate and then diminish (diaphragm and intercostal muscles); at expiration (oblique muscles), impulses are recorded from the diaphragm, and there is an overlap of the volleys from the diaphragm and from the oblique muscles of the abdomen. The electromyograms of vagotomized dogs show a sharp cutoff to the impulses at input, and a gradual fading or disappearance of the potentials from the oblique muscles and diaphragm at inspiration, without any overlap.

I. Changes in the Electromyograms after Pulmonary Damage in Dogs with the Nervous System Intact

Unilateral thermal pulmonary damage produced regular changes in the electrical activity of the respiratory muscles. During the infliction of the damage and immediately after it, there was a marked increase in activity, both on the damaged and the undamaged side. After only a few seconds or minutes, in most cases, an asymmetry was observed between the electrical activity of the respiratory muscles on the two sides.

On the undamaged side, the amplitudes of the potentials from the diaphragm and intercostal muscles at inspiration were increased (Fig. 1, a, b). On the damaged side, on the contrary, there was a reduction of activity, both of the diaphragm and of the intercostal muscles (Fig. 1 c, d).

The increased rate of impulses from the unoperated side ceased after $\frac{1}{2}$-2 hours, and the activity returned to the original level. Normal conditions were not restored on the operated side for several hours. No such asymmetrical behavior was found in the oblique muscles of the abdomen. After the damage had been inflicted, there was an increased rate of impulses in both obliques, and the activity easily returned to the original level after a few minutes. These experiments confirmed our previous findings concerning the asymmetry of the electrical activities of the right and left arches of the diaphragm following damage to one lung [4], and also the

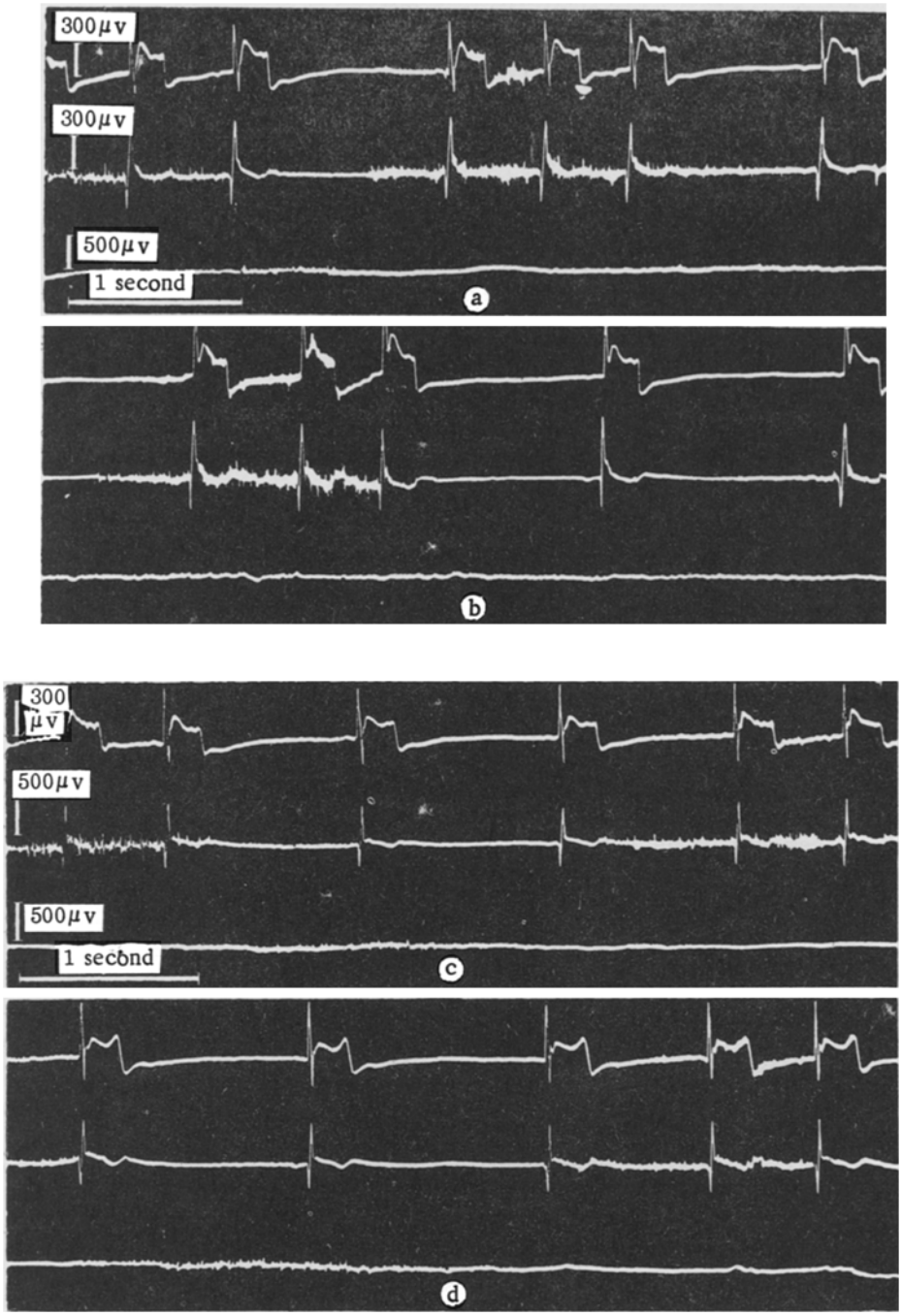

Fig. 1. Electrical activity in the respiratory muscles after unilateral pulmonary damage in dogs with the nervous system intact. a) Knopik, before damage; b) same dog, two minutes after damage to opposite side; c) dog Faithful, before damage; d) same dog, five minutes after damage to same side. Curves, from above downward: electromyogram of the intercostal muscles, diaphragm, and oblique muscles of belly.

results of E. L. Golubeva, who showed that after unilateral pulmonary damage the rates of flow of impulses in the two phrenic nerves are different [2].

II. Changes in the Electromyogram of the Respiratory Muscles Following Pulmonary Damage in Vagotomized Dogs

Just as when the nervous system was intact, after vagotomy, damage to one lung caused an asymmetry in the electrical activity of the diaphragm and intercostal muscles.

On the undamaged side the activity was increased, and returned to the original level after 24 hours (Fig. 2, a, b). On the damaged side the reduction in activity was more pronounced than in the animals with intact nervous systems, and more time was required for restoration to the original level of activity, sometimes even several days (Fig. 2, c, d).

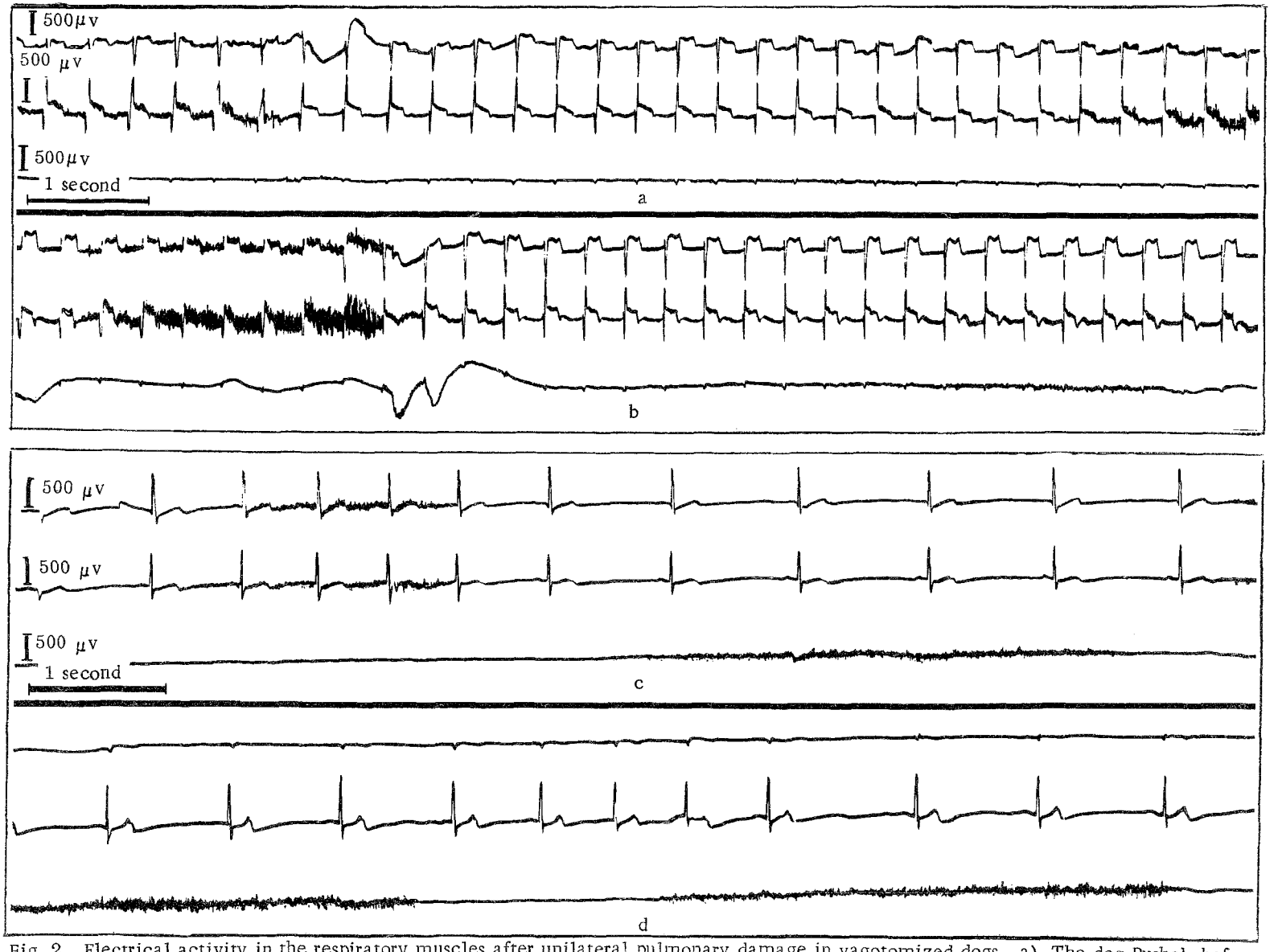

Fig. 2. Electrical activity in the respiratory muscles after unilateral pulmonary damage in vagotomized dogs. a) The dog Pushok, before damage; b) same dog, three minutes after damage to opposite side; c) dog Volchok, before damage; d) same dog, two minutes after damage to same side. Conditions as in Fig. 1.

A typical feature of the electrical activity in the vagotomized animals was the disappearance of impulses from the oblique muscles. Pulmonary damage caused a reappearance or an increase in the strength of pulses from these muscles (Fig. 2), which was maintained for several days, and sometimes increased.

Our experiments have established the following facts: 1. In unilateral pulmonary damage, there is an asymmetrical electrical activity not only in the diaphragm, but also in the internal intercostal muscles. 2. In the oblique muscles of the abdomen, there is no such asymmetry. 3. Asymmetry of the electrical activity of the diaphragm and intercostal muscles following unilateral pulmonary damage occurs in vagotomized animals, and is more marked, and the effect is more prolonged than in animals with intact vagi.

We must inquire into the reason for the asymmetry.

There are two possible explanations: the first is that impulses arising from the damaged pulmonary area cause an asymmetrical activity in the respiratory center itself [2]. The second is that pulses from the damaged pulmonary area cause an asymmetrical change in the excitability of the spinal motoneurons of the different respiratory muscles, with the result that there is a change in their responses to impulses originating in the respiratory center [4].

Direct experiments are required to decide between these two possibilities. However, many indirect observations lead us to support the second of the two alternatives.

For instance, unilateral pulmonary damage causes asymmetrical activity in the intercostal muscles and diaphragm. The electromyogram of the oblique muscles of the abdomen shows no such asymmetry. Such a result cannot be explained on the basis of unequal activity of the left and right halves of the respiratory center. It must be pointed out that there may be some asymmetry in the activity of the respiratory muscles of the abdomen themselves, as is observed in unilateral peritonitis. It is interesting that the explanation given is that there is an asymmetry in the activity of the spinal motoneurons [6, 8].

Some support for the idea that spinal mechanisms are concerned in the respiratory asymmetry is given by the fact that it occurs also in vagotomized animals.

Nevertheless, we certainly do not deny that the changes are brought about reflexly through the action of impulses from the damaged zone affecting the respiratory center. This mechanism has been studied in our laboratory for many years [3, 9, 12, 14], and its importance is shown in our experiments. Actually, after vagotomy the electrical activity of the oblique abdominal muscles becomes much reduced or disappears entirely. After unilateral pulmonary damage, the symmetrical activity of the left and right oblique muscles again develops. The appearance or increase in the activity of the oblique muscles in vagotomized animals after pulmonary damage is evidently due to the fact that stimulation from the damaged zone constitutes additional afferent stimulation of the respiratory center.

SUMMARY

The electrical activity of the respiratory muscles, including those of the diaphragm, and the intercartilaginous part of the internal intercostal and internal oblique abdominal muscles, was recorded by means of chronically implanted electrodes in dogs.

After unilateral injury to the lungs, the electrical activity of the diaphragm and intercostal muscles was asymmetrical, being reduced on the side of the injury and intensified on the opposite side. There was no asymmetry in the oblique muscles. Injury to the lungs caused a similar but more prolonged reaction in vagotomized animals. It is suggested that this asymmetry results from asymmetrical changes in the excitability of spinal motoneurons of individual respiratory muscles, which alter their response to impulses from the respiratory center.

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