ELECTROMYOGRAPHIC INVESTIGATIONS OF RESPIRATION IN DOGS WITH A REPLANTED LUNG

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In experiments on dogs with a replanted lung increased bioelectrical activity of the intercostal muscles was observed on the site of operation.

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With the extensive development of thoracic surgery, the problem of transplantation of organs and tissues, especially lung transplantation, has become increasingly important [10-12, 15].

Following experiments on animals, in recent years the first operations of replantation and homotransplantation of the lung have been carried out under clinical conditions [10, 14]. The comprehensive study of function of the replanted lung, essentially a model of the denervated organ with its humoral connections restored, is of considerable interest.

The results of general spirography and of separate bronchospirometry show that the replanted lung begins to perform its function of gas exchange within a few hours after the operation [10-14, 16, 17].

The function of the replanted lung is increased 2-3 weeks after the operation, as can be clearly demonstrated by excluding the intact lung [10, 11]. The blood flow in the replanted lung is somewhat retarded in the early period after the operation but it quickly begins to catch up to the blood flow in the intact lung [2, 10, 12].

The object of the present investigation was to study the regulation of respiration in dogs with a replanted lung.

EXPERIMENTAL METHOD

Replantation of the lung was carried out in experiments on 60 dogs by complete division of all structures at the hilus of the left lung followed by anastomosis of the blood vessels and bronchii [11].

The principal electromyographic investigations were carried out on 9 dogs at various times (from 2 to 250 days) after replantation of the left lung. The investigation was carried out in a waking state under superficial morphine-barbiturate anesthesia. Action potentials were recorded by disc electrodes (6 × 12 mm) from the intercostal muscles. The electrodes were applied symmetrically on the right and left sides in the 8th and 9th intercostal spaces. The integrated electrical activity of the right and left intercostal muscles was recorded as two curves. Potentials were recorded on a "Disa" 3-channel electromyograph.

EXPERIMENTAL RESULTS AND DISCUSSION

During quiet respiration in waking dogs and under light anesthesia action potentials were found in either the inspiratory or the expiratory intercostal muscles.

In the early periods after replantation of the lung action potentials were usually found in the expiratory intercostal muscles, and at later stages in the inspiratory muscles. Increased electrical activity of the

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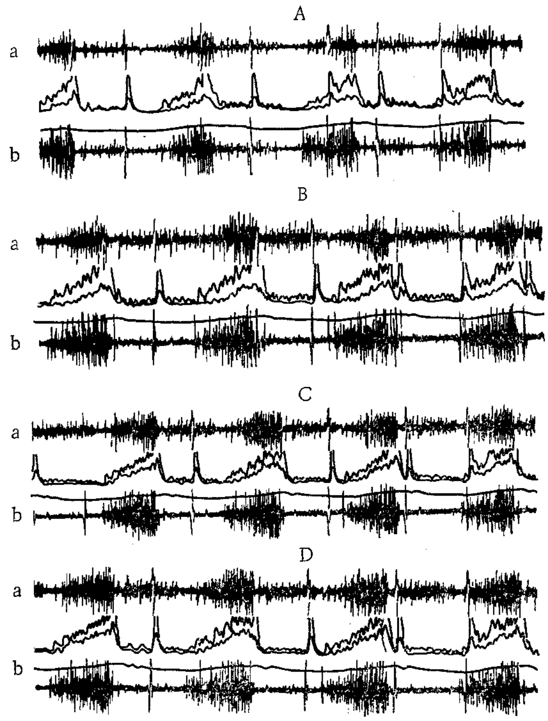

Fig. 1. Electromyograph (EMG) of inspiratory intercostal muscles during inhalation of air(A, C), 6% CO_2 (B), and 10% O_2 (D). a) EMG on side of intact lung; b) EMG on side of replanted lung. Two curves represent integrated electrical activity of intercostal muscles on right (intact) and left (replanted) sides. Pneumogram: above – inspiration, below – expiration. Same legend to all figures. EMGs recorded from dogs in a waking state.

muscles was found on the side of both the replanted and the intact lung. This indicates increased excitation of the respiratory center, for under normal conditions during quiet breathing the activity of the intercostal muscles in dogs is very weak and is found only in the inspiratory muscles.

On the side of the replanted lung the electrical activity of the intercostal muscles was considerably increased. The amplitude and duration of volleys in both the inspiratory and the expiratory muscles and the integrated electrical activity were greater on the side of the replanted lung (Figs. 1 and 2). The differences observed indicate that replantation of the left lung leads to asymmetry in the work of the respiratory center as a result of its partial deafferentation caused by denervation of one lung.

To examine the compensatory powers of the apparatus of external respiration and the reactivity of the respiratory center in dogs with a replanted lung, the animals were made to inhale hypercapnic (6% CO_2) and anoxic (10% O_2) gas mixtures for a period of 3-5 min. The dogs in a waking state inhaled the gas mixture through a mask with breathing valves, the anesthetized dogs inhaled it through an endotracheal tube.

Regardless of the time after the operation all the animals responded actively to hypercapnia. This could be judged not only from the dynamics of the electrical activity of the intercostal muscles, but also from the increase in minute volume of the combined lung ventilation. Taking the initial lung ventilation as 100%, by the end of the 5th minute of inhalation of the hypercapnic gas mixture it was increased by 250-400%. This increase in the lung ventilation of dogs with a replanted lung indicates that the respiratory center possesses considerable reactivity and the external respiratory system possesses large compensatory reserves.

However, a more accurate idea of the state of function of the respiratory center in hypercapnia is given by the dynamics of electrical activity of the intercostal muscles. In hypercapnia the electrical activity of the inspiratory intercostal muscles increased sharply on the intact and the replanted sides (Figs. 1 and 2), causing a marked increase in the amplitude of the action potentials. Volleys of impulses either were shortened, corresponding to rapid respiration, or lengthened, corresponding to flow and deep respiration (Figs. 1 and 2). The configuration of the volleys approximated to rectangular or triangular, indicating increased excitation of the respiratory center [4-6]. Characteristically, in dogs in the earlier stages after replantation of the lung, the electrical activity of the expiratory intercostal muscles was not reduced in hypercapnia and did not disappear, as it does normally, but on the contrary it was sharply increased (Fig. 2). Often under these conditions, as well as an increase in electrical activity of the expiratory intercostal muscles, a similar marked increase in electrical activity of the inspiratory muscles was observed at inspiration (Fig. 3).

Similar changes in electrical activity of the intercostal muscles took place in these dogs when they inhaled the anoxic gas mixture. During anoxia, the amplitude of the action potentials and the duration of the volleys were greater on the side of the replanted lung. Asymmetry in the work of the respiratory center persisted and was even more marked than during inhalation of atmospheric air. Analysis of the electromyographic data obtained in anoxia and hypercapnia showed that in the dogs with a replanted lung the coordination relationships between the electrical activity of the inspiratory and expiratory intercostal muscles under these conditions frequently differed in character from those found in normal animals. Marshak and

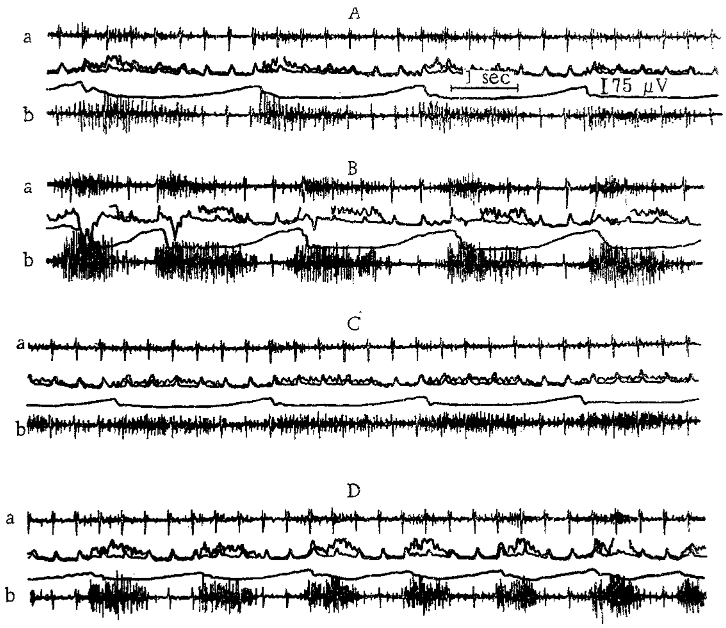

Fig. 2. EMGs of expiratory intercostal muscles during inhalation of air (A, C), 6% CO_2 (B), and 10% O_2 (D). Significance of curves as in Fig. 1.

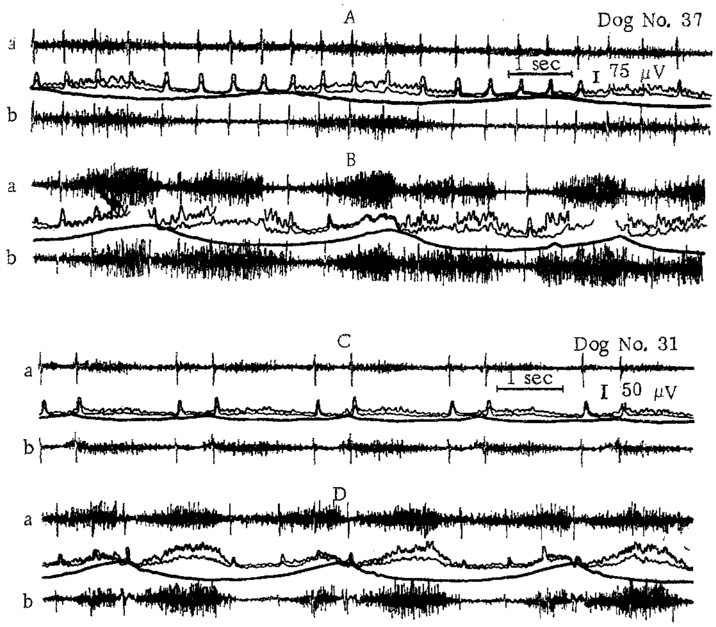

Fig. 3. EMGs of expiratory and inspiratory muscles during inhalation of air (A, C) 6% CO_2 (B), and 10% O_2 (D). In hypercapnia and anoxia increased activity is recorded both in the phase of inspiration and of expiration. Significance of curves as in Fig. 1.

co-workers [7-9] reported that during hypercapnia and anoxia in animals and man the increase in electrical activity of the inspiratory muscles is accompanied by a decrease or even the total inhibition of electrical activity of the expiratory muscles. In many dogs with a replanted lung (especially soon after operation), during hypercapnia and also during anoxia, the increased electrical activity of the inspiratory muscles at inspiration was associated with a sharp increase in the electrical activity of the expiratory muscles at expiration (Fig. 3).

The increase in electrical activity of the expiratory muscles in the dogs soon after replantation of the lung is an important compensatory reaction of the respiratory center. Active involvement of the expiratory muscles in the act of respiration helps to promote expiration with the replanted lung, whose elasticity could have been disturbed after replantation.

These adaptations are possibly based on proprioceptive reflex reactions of the intercostal muscles arising through changes in volumes of the intact and replanted lungs [3, 9]. The asymmetry in working of the respiratory center developing after replantation of the lung may result from the same causes as are observed after pneumonectomy: inhibitor afferent information from the replanted lung no longer reaches the respiratory center [1, 4-6].

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