CONTROL OF RESPIRATION AFTER A SUDDEN INCREASE IN THE RESISTANCE TO INSPIRATION

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Responses of the diaphragm and changes in the pneumogram of adult unanesthetized rabbits in response to a sudden increase in resistance to inspiration are described. Activity of the diaphragam does not change at the time when the resistance is increased, but the final effort developed by the diaphragm is increased by the prolongation of inspiration. The volume of inspiration is reduced after the sudden increase in resistance, and the degree of the reduction depends both on the magnitude of the resistance and on the phase of the respiratory cycle at which the resistance is increased. It is concluded from the results of these experiments that the duration of inspiration is a function, not only of the volume of inspiration (Hering — Breuer reflex), but also of activity of the respiratory muscles.

Data in the literature concerning the effect of a sudden increase in the resistance to respiration on parameters of external respiration are few in number and contradictory in nature [2]. It has been shown [2] that a sudden increase in the resistance to respiration in man leads to an immediate increase in activity of the intercostal muscles. However, in experiments on rabbits no changes could be found under these circumstances in the activity of single respiratory neurons [3]. The respiratory volume is usually increased immediately after an increase in the resistance. Since each inspiration is regarded as lasting until an "assigned" respiratory volume has been reached [1, 5], the participation of higher cortical centers in the regulation of respiration can be postulated in such cases. Meanwhile, in special experiments on subjects knowing nothing about their character, the effect of an increase in resistance was to produce a decrease in the volume of the first inspiration [4].

The object of this investigation was to study the effect of a sudden increase in the elastic resistance (of varied magnitude) to inspiration on the activity of the respiratory muscles (diaphragm) and on the respiratory volume immediately after its inclusion.

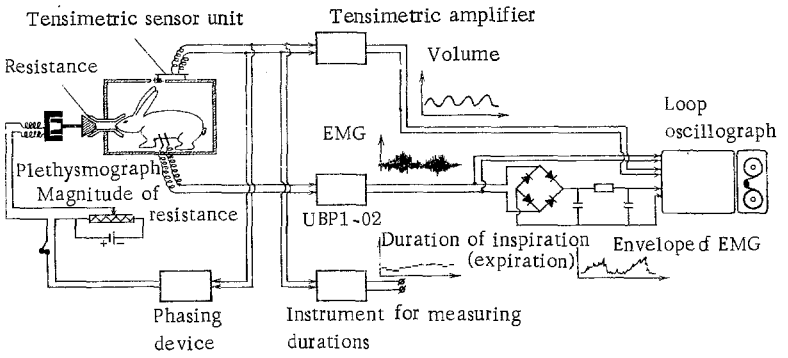

Fig. 1. Scheme of experimental system.

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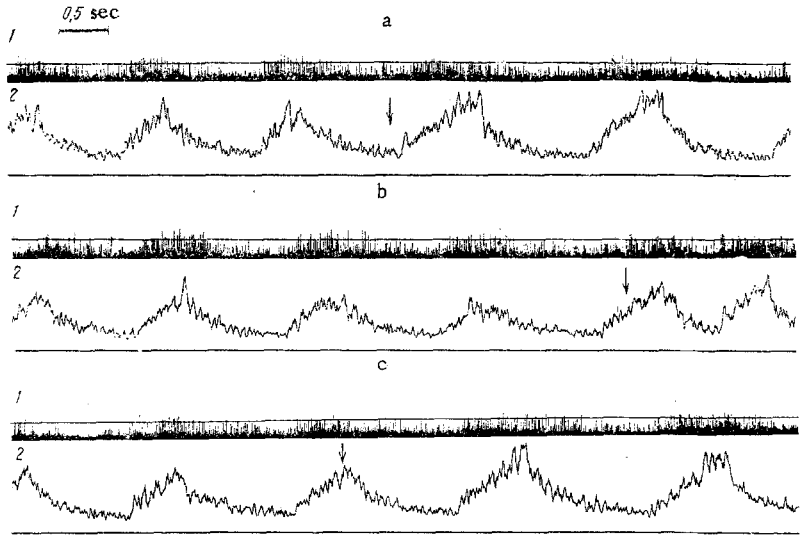

Fig. 2. Response of diaphragm to sudden increase of resistance to inspiration in rabbits at different phases of the respiratory cycle. Arrows indicate different (a, b, c) times of increasing resistance. 1) Rectified EMG of diaphragm; 2) envelope of EMG.

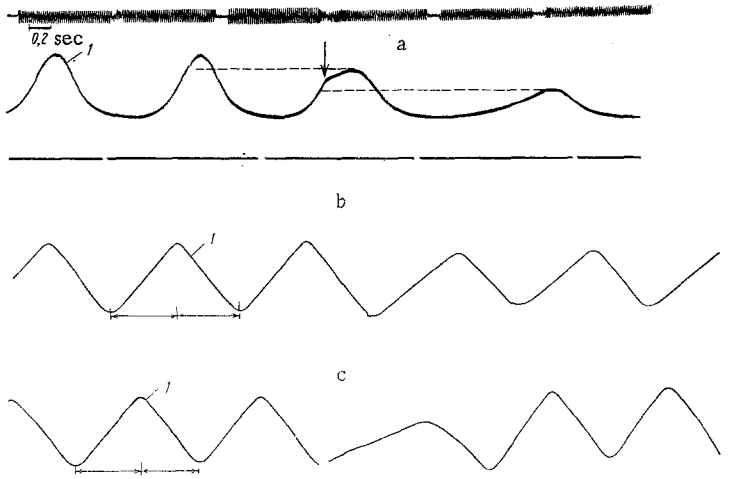

Fig. 3. Changes in pneumogram of rabbit following increase in resistance. Arrows indicate times of increasing and decreasing resistance. 1) Pneumogram (inspiration upward); a) resistance increased during inspiration, magnitude of increase in resistance 100 mm H_2O/2 liters/min; b) magnitude of resistance 40 mm H_2O/2 liters/min); c) magnitude of resistance 100 mm H_2O/2 liters/min.

EXPERIMENTAL METHOD

Chronic experiments were performed on adult unanesthetized rabbits. The resistance to inspiration was produced by means of a system of two cones (one moving, the other stationary), placed inside the inspiratory valve of the respirator mask. The position of the moving cone relative to the stationary cone, determining the resistance to inspiration, was varied by means of a permanent magnet system.

The electromyogram (EMG) of the diaphragm was recorded by means of loop electrodes implanted near the pedicles of the diaphragm, and the potentials were amplified by means of UBP1-0,2 amplifiers. Recordings were made of the EMG and its "envelope," obtained by rectification and subsequent filtration of the EMG.

The animal's pneumogram was recorded by means of a whole-body plethysmograph into which the rabbit was placed. The inspiratory and expiratory valves of the respirator mask had outlet tubes from the plethysmograph to the atmosphere. Changes in pressure inside the plethysmograph were measured by a tensimetric sensor unit.

The apparatus provided for a sudden increase in resistance at a particular moment of the respiratory cycle (by means of a phasing device) and for continuous measurement of the duration of each inspiration and expiration. The voltage at the output of the instrument measuring duration at any moment of time was proportional to the duration of the preceding inspiration (expiration). The experimental system is shown schematically in Fig. 1.

Changes in the EMG of the diaphragm and pneumogram in only one or two respiratory cycles immediately after the increase of resistance were studied in the experiments. To preclude the possibility of temporal conditioning, the times of increasing the resistance were chosen at random.

The total number of experiments was 28.

EXPERIMENTAL RESULTS

The results of the experiments of series I (effect of resistance on diaphragmatic activity) showed that a sudden increase in the resistance caused no change in the rate of inspiration (shown by the slope of the EMG envelope), and in some cases it actually produced a slight decrease (at least in one or two inspirations after the increase of resistance). However, because of the increase in duration of inspiration the maximal ordinate of the envelope toward the end of inspiration was greater than before the resistance was increased. The same pattern was observed when the resistance was increased at different times of the respiratory cycle. If the resistance was increased immediately before the end of inspiration, no changes in diaphragmatic activity took place during the current inspiration (Fig. 2).

Two types of experiments were included in series II (effect of resistance on the pneumogram): an increase of resistance by a constant amount at different times of inspiration (before the beginning of and during inspiration) and an increase of resistance by different amounts before the beginning of inspiration. The results of these experiments were as follows.

Increasing the resistance caused an increase in the duration of the first inspiration, but its depth did not reach the initial level. The greater the fraction of inspiration taking place against increased resistance, the greater the decrease in its volume (the resistance remaining constant). For instance, increasing the resistance for the beginning of inspiration led to a greater decrease in volume and a greater increase in the duration of inspiration than increasing the resistance during inspiration (Fig. 3a). These effects also depended quantitatively on the magnitude of the resistance: the greater the resistance, the greater the decrease in volume and increase in duration of inspiration (Fig. 3b, c).

The decrease in the rate of inspiration immediately after increasing the resistance could be due, as in the stretch reflex, to a momentary increase in electrical activity of the diaphragm. The absence of this effect indicates that spinal mechanisms evidently do not play an essential role in these phenomena. Lengthening of the phase of inspiration must have continued until the original depth of inspiration had been reached if the time of ending of inspiration were determined entirely by the Hering – Breuer reflex. The fact that after the increase of resistance inspiration stopped when its volume was less than initially, but when the amplitude of the EMG envelope was greater, suggests that the respiratory center stops the phase of inspiration in response to the receipt of information not only concerning the volume of the lungs (Hering – Breuer reflex), but also of the increased activity of the respiratory muscles.

The deepening of respiration described in the literature in man immediately after an increase in the resistance to respiration [1, 5] is possibly due to influences of the higher levels of the central nervous system which did not come into play under the experimental conditions described above.

LITERATURE CITED

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