EFFECT OF CIRCULATION IN THE LUNGS ON FUNCTIONAL STATE OF THE LUNG STRETCH RECEPTORS

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Acute experiments on cats under chloralose–urethane anesthesia showed that the number and frequency of impulses in the volley generated by the lung stretch receptors is greater when the pressure in the pulmonary artery is high (25-30 mm Hg) than when it is low (5-10 mm Hg). If the arterial pressure exceeds 30-40 mm Hg, falls to zero, or undergoes sharp fluctuations, spike activity of the lung receptors diminishes or disappears.

In acute ischemia, changes in the function of the lung receptors are the resultant of a series of successive changes. The severity, duration, and order of the postischemic changes depend on the type of lung receptors and on their physiological state. Stretch receptors are most resistant, ceasing to function 30-60 min after the arterial pressure falls to zero. Regional perfusion of the lungs with blood from a donor after ischemia for 20 min restores spike activity of the receptors. Later, destructive changes evidently takes place in the receptors.

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Adrian [16], who first described the stretch receptors of the lungs, found that they closely resemble muscle stretch receptors in their physiological properties: the frequency of their impulses rises and falls smoothly to correspond with inspiration and expiration, the intensity of the impulses in a volley depends on the degree of stretching of the lungs, their threshold of stimulation is low, they are slow to adapt, and very resistant to changes in the gas composition. They function for 30-60 min after arrest of the heart.

It was thus considered firmly established that the function of stretch receptors consists entirely of informing the central nervous system about the degree of expansion of the lungs and is independent of the state of the circulation in the lungs [16, 20]. Investigators have concentrated mainly on developing new methods of investigation and study of the physiological properties of different lung receptors innervated by A-, B-, and C-fibers and on the study of their participation in reflex responses under normal and pathological conditions [1,3-8, 11, 13, 14, 16-19, 21-23]. Little attention has been paid to the relationship between the lung receptors and the circulation.

The object of the present investigations was to study the extent to which the function of the lung stretch receptors is dependent on the arterial pressure in the pulmonary circulation and to examine its changes in ischemia.

EXPERIMENTAL METHOD

Under combined anesthesia (50 mg/kg chloralose + 0.5 g/kg urethane) 70 experiments were carried out on cats. Spike activity was investigated in thin bundles and single afferent fibers of the vagus nerves, split up in the neck, during measured stretching of the lungs with air through a DP-5 apparatus. Drying and cooling of the nerve fibers was prevented by immersing them in a mineral oil bath at 37°, the temperature being maintained by a miniature heater. To maintain the pressure in the lungs at a fixed level, regional perfusion of the humorally isolated lungs in situ with blood from a donor was carried out. Humoral isolation of the lungs in situ was obtained by ligation of the ascending aorta, the superior and inferior venae cavae, and the azygos vein. For regional perfusion of the lungs, blood from the donor's right carotid artery was passed through a pressure stabilizer into the pulmonary artery, and the outflowing blood was passed through a catheter from the left atrium into the donor's right jugular vein. Ischemia was produced by total exsanguination through the femoral artery. The vagus nerve was divided beneath the root of the lungs. The

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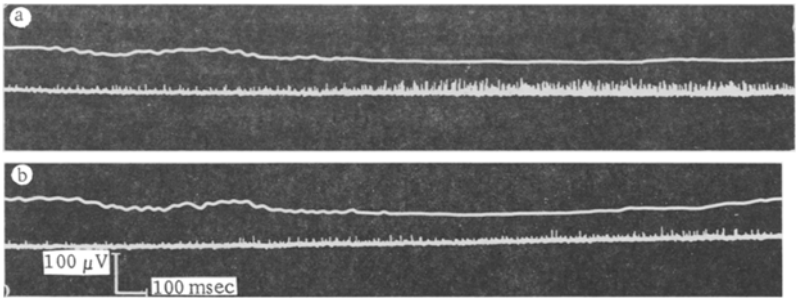

Fig. 1. Spike activity of lung receptors at different levels of perfusion pressure (PP) during stretching the lungs at a pressure of 500 mm water. Experiment No. 239. a) PP 30 mm Hg; b) PP 5 mm Hg. From top to bottom: pneumogram (downward deflection of line corresponds to inspiration), neurogram.

neurogram was recorded by means of bipolar platinum electrodes. Besides potentials in the vagus nerve, the pneumogram and the systemic and perfusion pressures were also recorded.

EXPERIMENTAL RESULTS

Activity of the stretch receptors at different levels of pressure in the pulmonary artery was investigated in the experiments of series I. Typical results are shown in Fig. 1a, b. When the arterial pressure was maintained at a high level (25-30 mm Hg) for 30-60 min, the stretch receptors of the lungs generated more impulses, with shorter intervals between individual spikes in the response to stretching of the lungs than when the arterial pressure was low (5-10 mm Hg). In the last case the number and frequency of the spikes generated by the same stretch receptors were reduced.

A similar relationship between receptor activity and the arterial pressure was observed in most experiments. However, because of the anatomical and physiological properties of the lungs and the nature of the pulmonary circulation, this relationship is limited in degree [10]. If the perfusion pressure exceeded 30-40 mm Hg or fell to zero, and also if it underwent sharp fluctuations, the ability of the lung receptors to generate spreading impulses diminished or disappeared.

In the experiments of series II the physiological state of the lung receptors was investigated in acute ischemia.

When the systemic arterial pressure was lowered to 20-0 mm Hg, in 50% of experiments the stretch receptors of the lungs responded by a slight increase in the number of impulses, by about 5-10 spikes per respiratory cycle. This state of slight excitation of the receptors persisted for 2-10 sec. In 50% of the experiments, when the arterial pressure was lowered the stretch receptors did not change their function.

In the interval between volleys from the stretch receptors, as in other investigations impulses were recorded which were difficult to identify. Since in the present experiments the vagus nerves were divided beneath the root of the lungs and the branches innervating the heart were severed, it was concluded that these impulses reflect the activity of the lung receptors. When the arterial pressure was reduced to 0-20 mm Hg, the activity of these receptors increased (Fig. 2a and b). This suggests that these receptors belong to the pulmonary vessels.

Against the background of continued bleeding, after the excitation noted above or in its absence, inhibition of activity both of the stretch receptors of the lungs and of receptors which are considered to be receptors of the pulmonary vessels developed. The stretch receptors of the lungs showed the greater resistance to blood loss in this inhibitory phase. The frequency of spikes in each discharge fell on the average by only 8-15. Spike activity of receptors functioning between respiratory cycles was inhibited to a greater degree (Fig. 2b). Depression of receptor function was expressed as a decrease in the total number of spikes discharged and it began between 15 sec and 45 min after the arterial pressure reached zero. The duration of this period varied from 1 to 40 min in different experiments.

As the duration of ischemia increased, a period occurred when the function of the lung stretch receptors was considerably depressed – by 3-5 times compared with the control. In this period receptors

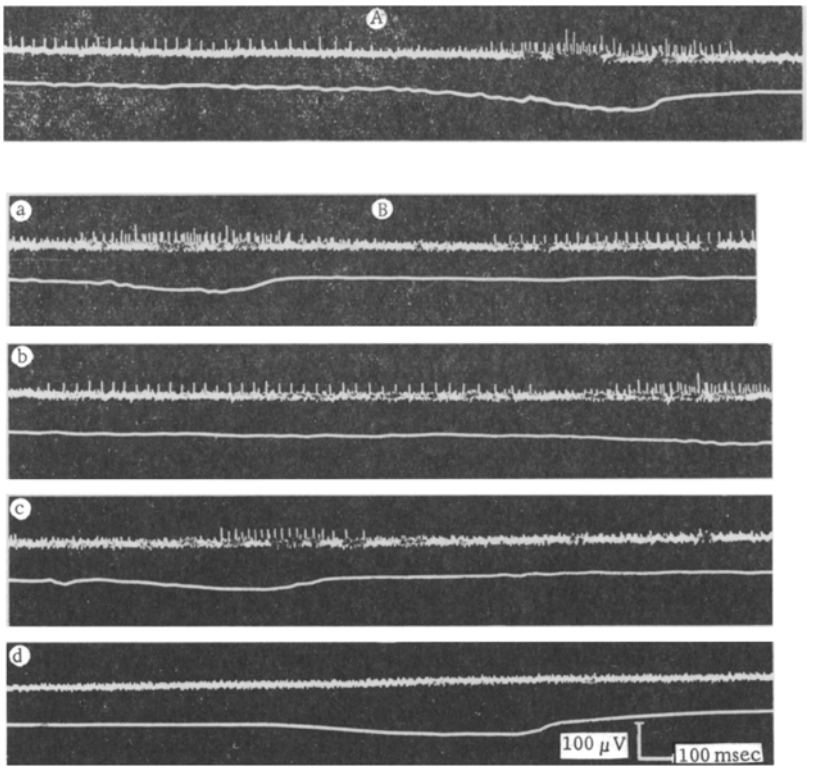

Fig. 2. Function of lung receptors during ischemia. Experiment No. 168. A) Control (before bleeding). Spike activity of stretch receptors (on the right) and receptors functioning in the interval between respiratory cycles (on the left); B) after bleeding; a) increase in discharge frequency of receptors functioning in interval between respiratory cycles (on the left); b) decrease in discharge frequency of receptors functioning in interval between cycles (on the left). Slight decrease in discharge frequency of stretch receptors (on the right); c) considerable decrease in discharge frequency of lung stretch receptors. Cessation of spike activity of receptors functioning in interval between respiratory cycles; d) disappearance of spike activity of lung receptors. From top to bottom: neurogram, pneumogram (down-ward deflection of line indicates inspiration).

functioned between the respiratory cycles stopped generating spikes. This period reflects a certain dysfunction in the activity of the various receptor structures of the lung. The duration of this phase varied from 4 to 52 min (Fig. 2c).

Later, as a result of ischemia, all the lung receptors, including the stretch receptors, ceased to function. This period began 15-20 min after the arterial pressure had fallen to zero (Fig. 2d). Disappearance in this period does not imply death of the receptors, because receptor function recovered after adequate perfusion of the lungs. It was therefore concluded that this period is anabiotic.

The intensity of afferent spike activity from the lungs restored by perfusion depended on the duration of ischemia. Restoration of receptor function was possible if the ischemia did not exceed 20-25 min in duration. After longer periods impulse activity could not be restored, evidently because of destructive changes which develop in the receptors.

These results confirm Adrian's findings indicating that the stretch receptors of the lungs can function for up to 1 h after arrest of the heart and for this reason show considerable similarity to the stretch

receptors of skeletal muscles. However, the lung receptors functioning between the respiratory cycles are less resistant to ischemia. The stretch receptors of muscles are much more resistant to ischemia. Their function can be restored 1 h or longer after the arterial pressure falls to zero, and also after repeated periods of ischemia [12].

It can be concluded from the data described above, concerning the relationship between function of the lung receptors and the pressure in the pulmonary artery, that a normal circulation provides for a definite level of metabolic activity. Reduction or cessation of the pulmonary circulation is known to depress the metabolic activity of the cells and, in particular, phospholipid metabolism, to disturb oxidative processes, and to inhibit enzyme systems [2]. These changes subsequently lead to structural disturbances. The oxygen deficiency existing in ischemia likewise causes destructive changes in the receptors [9, 15].

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