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MECHANISM OF THE ANTIARRHYTHMIC EFFECT OF LASER IRRADIATION

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KEY WORDS: laser; myocardial ischemia; ventricular arrhythmias; vagus nerve; myelinated and unmyelinated fibers

The antiarrhythmic effect of intracardiac laser irradiation in myocardial ischemia is associated mainly with reduction of the coagulability and viscosity of the blood, inhibition of lipid peroxidation, and activation of mast cells, releasing vasodilators and improving the blood supply to the myocardium [2, 3]. In the ischemic heart these factors change not only the biochemical composition of the blood, but also excitability of the receptors, and this must inevitably be reflected in the functional state of the afferent innervation of the heart, whose role in the antiarrhythmic action of laser irradiation is not yet clear. Meanwhile, activation of the parasympathetic nervous system is known to lead to an increase in electrical stability of the myocardium [11, 13].

The aim of this investigation was to study the role of afferent information reaching the CNS along fibers of the vagus nerves from the receptor structures of the heart during intracardiac laser irradiation.

EXPERIMENTAL METHOD

Experiments were carried out on 65 male and female cats weighing 2.5-4 kg, under pentobarbital anesthesia (40 mg/kg, intraperitoneally) and artificial respiration. Myocardial ischemia was induced by compression of the circumflex branch of the left coronary artery for up to 15 min. The development of ischemia in the myocardium was recorded during 15 min after compression of the coronary artery and 15 min after release of the guide loop on the coronary artery. The following idioventricular disturbances of the cardiac rhythm were taken into consideration in the analysis: grouped ventricular extrasystoles, ventricular tachycardia, and ventricular fibrillation. Laser irradiation of the right atrium was carried out with light from an LG-75 helium–neon laser (power at the end of the light guide 3-5 mW,

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λ = 632.8 nm). The role of afferent information transmitted from receptors of the heart along different types of fibers in the antiarrhythmic effect of laser irradiation in myocardial ischemia along different types of fibers was studied by cooling the vagus nerves. Lowering the temperature of the nerves to 6°C led to selective blocking of information along thick myelinated fibers [12, 14], whereas cooling to 0°C blocked the transmission of information along thin, unmyelinated fibers also [15]. The temperature of the nerves was controlled by changing the flow rate of the liquid by means of the screw of a vacuum pump. Laser irradiation of the right atrium began 5 min after the temperature of the vagus nerves had reached the assigned level with stabilization of the blood pressure (BP) [6]. The temperature of the vagus nerves, the ECG, and BP in the femoral artery (by means of a "EMT-35" transducer ("Elema") were recorded on a "Biocomp-8" polygraph (Hungary). Analysis of BP and heart rate (HR) was undertaken at the 20th minute of each period of laser irradiation. The significance of the results was assessed by Student's t test and the chi-square test.

EXPERIMENTAL RESULTS

In the past the choice of optimal conditions for laser therapy in order to prevent ischemic cardiac arrhythmias has been basically empirical in character. Consequently, it was first necessary to study the antiarrhythmic effect of laser irradiation in myocardial ischemia when given in one and two applications. The coronary vessel was compressed after preliminary laser irradiation of the right atrium for 20 min, i.e., the time required not only to increase the microcirculation of the myocardium, but also to increase the excitability of its nervous structures [1, 8]. Myocardial ischemia was observed after compression of the coronary vessel for 20 min against the background of continuing laser irradiation of the right atrium and for 10 min after switching off the laser.

In the control series of (18) experiments ligation of the circumflex branch of the left coronary artery in cats led to the appearance of idioventricular cardiac arrhythmias in 72.27% of cases, including grouped ventricular extrasystoles in 50%, ventricular tachycardia in 27.75%, and ventricular fibrillation in 55% of experiments.

Preliminary single irradiation of the right atrium under the conditions specified above did not reduce the frequency of development of ischemic cardiac arrhythmias: grouped ventricular extrasystoles were observed in 60%, and ventricular fibrillation in 50% of the experiments.

In the next series of (13) experiments preliminary irradiation of the right atrium was applied twice with a gap of 20 min between the first and second sessions. Under these conditions the frequency of idioventricular arrhythmias was reduced to 30.7% ($p < 0.05$); grouped ventricular extrasystoles were observed in 23% of cases, ventricular tachycardia did not develop in a single experiment, and ventricular fibrillation was observed in only 7.7% of cases (Fig. 1).

A single application of laser irradiation thus does not affect the frequency of development of idioventricular cardiac arrhythmias, whereas after repeated laser irradiation a marked antiarrhythmic effect is observed; this evidently points to summation of the biological effect of laser irradiation in this particular case.

The course of the ischemic process in the myocardium is known to depend on the initial level of BP [9]. It can be tentatively suggested that the protective action of laser irradiation may be determined by this factor. Accordingly, we analyzed changes in BP and HR associated with different schedules of laser irradiation. Single preliminary irradiation of the right atrium could lower (in 40.9% of cases, by 13.57 ± 2.3 mm Hg), or raise (in 36.3%, by 18.18 ± 3.1 mm Hg) BP or leave it unchanged. HR could also be reduced (in 31.8% of cases, by 10.38 ± 1.2 beats/min), increased (in 27.2%, by 17.28 ± 3.4 beats/min), and also unchanged (in 41% of cases). Meanwhile changes in HR never correlated with changes in BP. These effects were still found in the animals after a second laser irradiation of the atrium. Data on changes in BP and HR in response to the first and second laser irradiations indicate absence of summation of the laser effect on the main parameters of the hemodynamics and on the independence of the antiarrhythmic action of the laser on BP.

It can be tentatively suggested that the antiarrhythmic effect of the laser may be associated both with improvement of the myocardial microcirculation, with enhanced oxygenation of the blood, and with antioxidant protection of the cells [2, 4], on the one hand, and with a change in excitability of the nervous structures of the heart, leading to a change in the functional state of the bulbar cardiovascular center, whose role in the development of ischemic cardiac arrhythmias was demonstrated in [5], on the other hand. Yet we know that afferent information transmitted along myelinated and unmyelinated fibers of the vasgus nerves, plays different roles in the development of ischemic cardiac arrhythmias [7].

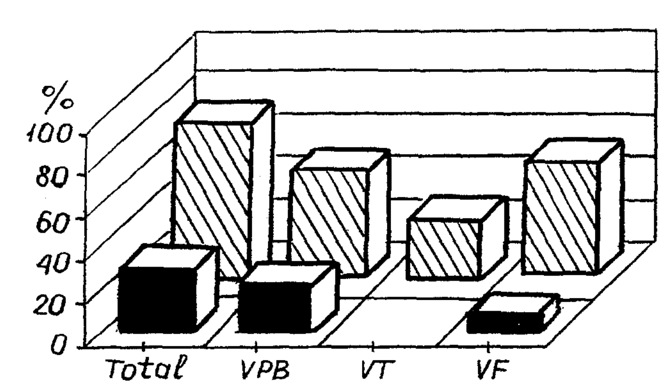

Fig. 1

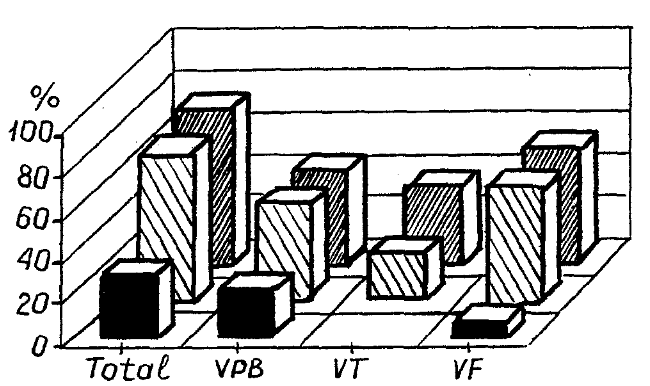

Fig. 2

Fig. 1. Frequency of development of idioventricular arrhythmias in myocardial ischemia in control (oblique shading) and with two sessions of laser irradiation (black columns). Legend: ordinate, frequency of development of idioventricular arrhythmias (in %); abscissa, types of idioventricular arrhythmias: total) idioventricular extrasystoles, including: VPB) grouped ventricular extrasystoles, VT) ventricular tachycardia, VF) ventricular fibrillation.

Fig. 2. Frequency of development of idioventricular arrhythmias during action of laser in control (black columns) after blocking of myelinated (wide oblique shading) and unmyelinated (narrow oblique shading) vagus nerve fibers. Legend as to Fig. 1.

Consequently, in the next section of the research the antiarrhythmic action of the laser was studied during selective blockade of different types of fibers of the vagus nerves. In 13 experiments on cats, two sessions of intraatrial laser irradiation, against the background of blockade of the conduction of excitation along myelinated fibers did not affect the frequency of development of ischemic arrhythmias compared with the control series (Fig. 2). Idioventricular disturbances of the cardiac rhythm developed in 69.2% of experiments, including grouped ventricular extrasystoles in 46.15%, and ventricular tachycardia in 23.7% of experiments, whereas ventricular fibrillation was observed in 53.8% of experiments.

In the next series of experiments (II) intraatrial laser irradiation against the background of cooling of the vagus nerves to 0°C, leading to blocking of conduction not only of afferent, but also of efferent information, and along unmyelinated fibers [10], had no effect on the frequency of development of ischemic cardiac arrhythmias (Fig. 2). Idioventricular disturbances of the cardiac rhythm were observed in 72.7% of experiments: grouped ventricular extrasystoles occurred in 45.5%, ventricular tachycardia in 27%, and ventricular fibrillation in 54.54% of experiments. The results of this series of experiments are evidence that total blocking of the conduction of excitation along myelinated and unmyelinated fibers of the vagus nerves blocks the protective effect of laser irradiation on the frequency of development of ischemic cardiac arrhythmias by the same degree as selective blocking of the conduction of excitation along myelinated fibers.

One of the mechanisms of the antiarrhythmic effect of laser irradiation is thus a change in afferent information reaching the CNS from the receptors of the heart along myelinated fibers of the vagus nerves.

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INTERATRIAL DIFFERENCES IN MYOCARDIAL REACTIVITY AND ITS CHANGES FOLLOWING EXERCISE ADAPTATION

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KEY WORDS: reactivity; adaptation; exercise; myocardium; atrium

Considerable atrioventricular differences in reactivity of the rat myocardium have been described [1, 6]. However, interatrial differences in myocardial reactivity have still received only little study. Interatrial differences in changes in myocardial reactivity during adaptation of animals to exercise likewise have not been studied. Exercise adaptation of rats is known to increase the inotropic effects of adrenomimetics [5] and the chronotropic action of acetylcholine [2], and also to modify the chronoinotropic reactions of the myocardium [3, 4].

The aim of the investigation described below was to study interatrial differences in inotropic effects of adrenomimetics and acetylcholine and changes in the frequency of contractions, and also differences in the changes in myocardial reactivity in the left and right atria during adaptation of rats to physical exercise.

EXPERIMENTAL METHOD

Wistar rats initially weighing 200-230 g were trained beforehand to run on a treadmill, and were adapted to exercise five times a week for 10-45 min each time, with a gradual increase in the speed of movement of the belt from 10 to 19 m/min in the course of 3 weeks [4]. Animals tolerating a complete training course (6 weeks) were used in the experiments. Animals of the same age served as the control. The heart was removed after intraperitoneal general anesthesia of the animals with urethane (140-160 mg/100 g). After rinsing of the heart (retrogradely through the aorta) with oxygenated Krebs–Henseleit solution both auricles were amputated and strips of their ventral regions were fixed with silk ligatures between microscrews and force transducers (the 6M × 1c mechanotron in series with a rigid spring) in a thermostatically controlled (25°C) continuous flow (20 ml/min) chamber. After preliminary stretching of the preparations and stimulation for 1.5-2 h with a frequency of 0.5 Hz and with a voltage on the platinum electrodes of 1.5 times the threshold level, they were additionally stretched up to the suboptimal length. The reactivity of the preparations was assessed from relative (% of the initial level) changes in the developed force F, and the maximal and

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