# EFFECT OF LOW INTENSITY INFRARED SHORT-RANGE LASER RADIATION ON METABOLIC FUNCTION OF THE ISOLATED RAT MYOCARDIUM IN HYPOXIA

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Low-energy infrared semiconductor lasers, operating in the near infrared region, possess high biological activity and have deep penetrating powers into the tissues. With their appearance, new prospects have been opened up for the practice of medical physiotherapy. They have been shown to be highly effective in various branches of internal medicine, the surgery of infection, traumatology, neurology, etc. There have been isolated publications on the beneficial use of infrared laser radiation (IRLR) in cardiology, especially under conditions of coronary insufficiency [1, 2, 5, 6]. The use of IRLR also is promising because of the extreme simplicity of its use. However, the mechanism of its biological and therapeutic action has not yet been adequately studied. The targets for IRLR have not yet been explained: whether it acts at the molecular, subcellular, or cellular levels. These problems are best studied on relatively simple models of metabolic functions, which would allow direct and indirect effects of IRLR to be separated and the sites of their application in the general regulatory system of the body located. In view of the positive cardiotrophic effect of IRLR in clinical practice, the study of its action on the ischemic myocardium is of particular scientific interest. Accordingly the aim of the investigation described below was to study the action of IRLR on parameters of metabolic function of the isolated contracting heart under conditions of acute oxygen deficiency. With the aid of this model it is possible to detect rapid quantitative changes in the specific contractile function of the cardiomyocytes under the influence of any external stimulating factor.

## EXPERIMENTAL METHOD

Experiments were carried out on noninbred male albino rats weighing 150-200 g, subdivided beforehand into animals with low (LR) and high (HR) resistance to hypoxia [4]. To obtain the isolated heart, the rats were anesthetized with ether, the thorax quickly opened the inferior vena cava cannulated, and the superior vena cava ligated, after which the heart was washed out for 10-20 sec with heparin solution (1000 U heparin to 1 liter physiological saline). The heart was then separated from the incoming blood vessels, removed, and placed in physiological saline with heparin on ice, after which it was suspended. The isolated heart was perfused by Langendorff's retrograde method in our own modification [3] with oxygenated Krebs–Henseleit solution (95% $O_2$ + 5% $CO_2$, pH 7.4, 37°C) containing glucose (11.0 mM). The optimal pressure of perfusion fluid in the aorta was 80-100 cm water. Acute hypoxia was induced by lowering the oxygen concentration in the perfusion fluid to 20% and replacing it with nitrogen (model of acute hypoxia – $H_{20}$). After a period of stabilization of the contractile function of the heart for 30-40 min, the test parameters were recorded (20 min), after which $H_{20}$ was produced (20 min). The perfusion fluid was then again replaced by the original solution (95% $O_2$ + 5% $CO_2$). Restoration of parameters of metabolic function of the myocardium were recorded in the posthypoxic reoxygenation period for 20-30 min. When the action of IRLR was studied, it coincided in

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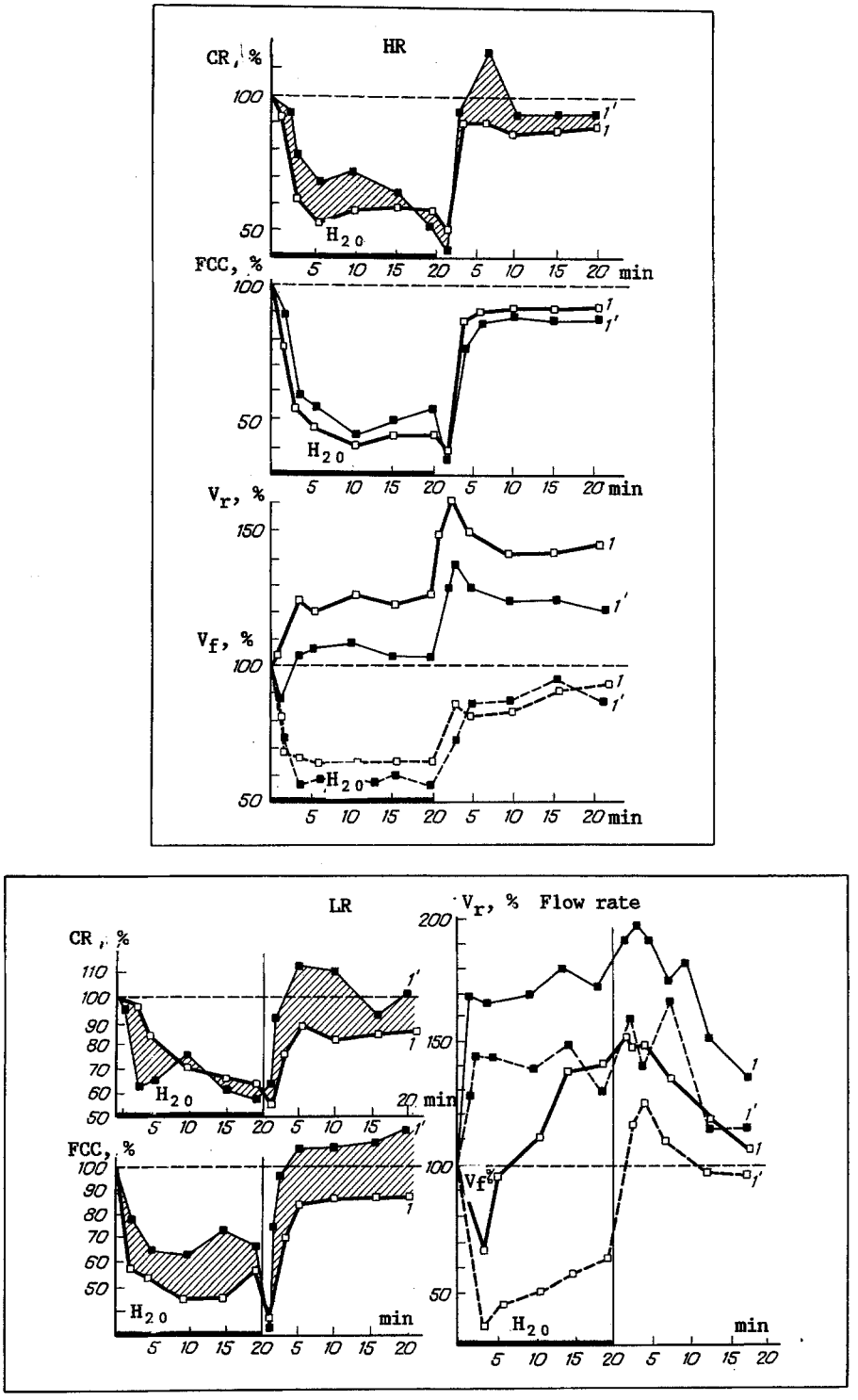


Fig. 1. Action of IRLR on FCC, myocardial $V_r$ and $V_f$ in HR and LR animals during hypoxia (20% $O_2$ – $H_{20}$) and in period of reoxygenation. 1) without IRLR, 1') with IRLR during $H_{20}$.

time with the action of $H_{20}$ (20 min). Irradiation was carried out with the AML T 01 design of semiconductor infrared laser with $\lambda = 0.89\ \mu$, pulse power 3 W, pulse following frequency 400 Hz, and exposure 20 min.

The mechanical contractility of the heart was measured under isometric gauge conditions by means of a strain gauge transducer. Optimal stretching of the myocardium (by 1.5 times) was achieved with the aid of a vernier device. The rate (CR) and force (FCC) of the cardiac contractions were recorded. The rate of oxygen consumption (respiration rate $V_r$) was determined

TABLE 1. Relative Changes in CR and FCC under the Influence of IRLR (in percent of their values without IRLR)

| Time, min | CR | | FCC | |
|---|---|---|---|---|
| | LR | HR | CR | HR |
| | Hypoxia (20% $O_2$) | | | |
| 3 | 110 | 120 | 180 | 110 |
| 5 | 116 | 120 | 150 | 115 |
| 10 | 147 | 120 | 190 | 120 |
| 15 | 145 | 100 | 220 | 120 |
| 20 | 106 | 80 | 210 | 130 |
| | Reoxygenation | | | |
| 3 | 130 | 80 | 150 | 100 |
| 5 | 130 | 120 | 120 | 100 |
| 10 | 130 | 105 | 120 | 108 |
| 15 | 110 | 105 | 120 | 108 |
| 20 | 120 | 105 | 120 | 108 |

polarographically [3] by means of a Clark's electrode. The volume of the continuous-flow polarographic cell was 1.0 $cm^3$. The flow rate ($V_f$) of the perfusion fluid was determined by measuring the volume of fluid flowing from the heart in unit time.

## EXPERIMENTAL RESULTS

Under conditions of acute hypoxia ($H_{20}$) changes in the contractile function of the myocardium of the LR and HR animals were virtually identical, both qualitatively and quantitatively. They took the form of a rapid fall in CR and FCC, from the first minute, and after only 5 min both had reached virtually the minimal values. The greatest decrease in CR averaged 40-50% and in FCC 55-60% (Fig. 1). There was a simultaneous fall of the myocardial $V_r$, which in HR rats was somewhat less marked than in LR (Fig. 1). The trend of the perfusion flow rate $V_f$ in the myocardium at $H_{20}$ differed in the HR and LR animals: in the former it was increased on average by 20% as early as by the 3rd minute (Fig. 1) and stabilized at that level, whereas in LR rats it initially fell by 20% before beginning to rise gradually, to exceed 40% by the end of $H_{20}$ (Fig. 1). Thus under conditions of acute oxygen deficiency ($H_{20}$) $V_f$ showed a compensatory increase, maintaining the oxygen supply to the myocardial cells and their respiration rate at a higher level. This is clear on analysis of the trend of $V_r$ and $V_f$ in the myocardium of HR and LR rats: lowering of the latter in the myocardium of LR during hypoxia led to stronger inhibition of myocardial respiration than in HR rats, where no reduction of flow was observed. A subsequent increase of flow led to strengthening of respiration.

During reoxygenation, CR and FCC began to recover after only a minute, and reach their maximal values of 3-5 min. However, recovery was incomplete, and in both cases did not exceed 80-90%. The flow rate was increased in the first 5 min of the posthypoxic period, but later it gradually fell, more so in LR than in HR (Fig. 1). $V_r$ in the posthypoxic period also increased. In the myocardium of HR it did not reach the initial values, even after 20-30 min, whereas in the myocardium of LR, after a temporary overshoot (the first 5 min), it virtually returned to normal at once.

When $H_{20}$ was combined with irradiation, the changes in CR in the myocardium of the HR and LR rats remained the same as during exposure to hypoxia alone. However, in the posthypoxic period recovery of CR was more complete and phases of its activation began to appear, and were especially well defined in the myocardium of LR, after which this parameter returned to normal (Fig. 1, Table 1).

Irradiation with IRLR weakened the inhibiting action of $H_{20}$ on FCC of the myocardium of LR and accelerated its recovery in the posthypaxic period; however, it had no protective action on FCC of the myocardium of HR (Fig. 1). IRLR sharply increased both $V_f$ and $V_r$, both during and after $H_{20}$ in the myocardium of LR, and depressed both these parameters in the myocardium of HR, i.e., its action on them was directly opposite (Fig. 1, Table 1).

Thus the strongest action of IRLR was associated with its positive effect on $V_f$ of the perfusion fluid in the myocardium of LR and $V_r$ of LR also. The fact that this effect was not present in the myocardium of HR suggests that fundamental differences exist in the regulatory systems of the HR and LR animals, controlling myocardial vascular tone. It must be recalled that oxidative metabolism of the myocardium of HR and LR also differs [3], a matter of decisive importance for the formation of its resistance to oxygen deficiency.

Since the protective action of IRLR on FCC, $V_r$, and $V_f$ of the myocardial perfusion fluid of HR was not present during hypoxia, and weakening of the disturbances of FCC in the myocardium of LR took place against the background of combined strengthening of $V_f$ and $V_r$, it must be assumed that it was connected with local vasodilatation of the isolated myocardium and, consequently, with an increase in the oxygen supply to the cardiomyocytes.

It can thus be predicted that the use of IRLR in acute oxygen deficiency may be effective in cases of coronary insufficiency more especially in patients with low resistance to hypoxia.

Activation of the microcirculation during low-intensity laser irradiation, arising on account of a local increase in blood flow, is independent of wavelength, as was shown by Kozlov et al. [2]. It may be associated with various factors, including a marked increase in the ratio of prostacycline thromboxane $B_2$ [1], and this must lead to weakening of the vasoconstrictor function of the myocardium and to elevation of the level of oxidative metabolism of the cell. In that case it can be tentatively suggested, first, that different metabolites of the arachidonic acid cycle may play the role of local regulators of the blood flow during hypoxia and, second, that regulation of this cycle as a whole differs in the cardiomyocytes of HR and LR animals.

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