Effect of Electroacupuncture on Systemic Hemodynamics in Rats with Postinfarction Cardiosclerosis

L. M. Belkina, S. A. Radzievskii*, D. D. Matsievskii, N. B. Korchazhkina*, V. A. Saltykova

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Electroacupuncture decreased total peripheral vascular resistance and increased cardiac output in 12-week-old postinfarction rats without cardiac insufficiency, while opposite changes were observed in rats with cardiac insufficiency. After the electroacupuncture course, norepinephrine decreased cardiac output in the rats with cardiac insufficiency, while acetylcholine increased it to a much higher extent than in the control rats that were not subjected to physiotherapy.

Key Words: *cardiac insufficiency; the pumping action of the heart; electroacupuncture*

Postinfarction cardiac insufficiency results mainly from disturbances of contractile and pumping action of the heart and of vascular tone regulation. Pharmacological and surgical correction of cardiac insufficiency are not always efficient, so nonmedicamentous treatment is gaining importance. Electroacupuncture (EAP) improves the performance of the ischemic heart [13,15]. EAP enhances cardiac tolerance to stressor, hypoxic, and ischemic damage [1,5]. In addition, EAP decreases the ischemic necrosis area [5] and moderates the responsiveness of myocardium [9] and blood vessels [6] to epinephrine.

The long-term effects of EAP on the cardiovascular system after myocardial infarction have not been adequately investigated. Our aim was to study the effect of EAP on systemic hemodynamics in rats with a long-term postinfarction cardiosclerosis (PICS).

MATERIALS AND METHODS

Experiments were carried out on male Wistar rats weighing 400-430 g. Postinfarction cardiosclerosis was modeled by ligating the descending left coronary artery according to the method of H. Selye. Systemic hemodynamics was studied under Nembutal narcosis (50 mg/kg) 12 weeks after myocardial infarction. Arterial pressure (AP) in femoral artery and cardiac output were recorded on-line. The latter was studied by noninvasive methods in the closed thorax, using a miniature piezo crystal [4] inserted into the right carotid artery and ascending aortic arch to measure the blood flow. The blood flow and AP signals were fed into an analogous electronic device which calculated the stroke volume, cardiac output, total peripheral vascular resistance (TPVR), and heart rate (HR). At the end of experiment the diameter of ascending aortic arch was measured under controlled AP and blood flow, which made it possible to calibrate the transducer in the units of blood flow. The data were recorded with an H3031 plotter (ZIP, Krasnodar). EAP was performed every day for 10 days [7] by bilateral auricular electrostimulation in the points near external acoustic meatus (0.8-2 mA, 1.5 msec, 3 Hz) with the help of a Lasper CS-504 electrostimulator (Kanaken Medical Instruments). Hemodynamics was studied immediately after the EAP course that was performed 10 weeks after experimental myocardial infarction.

Ischemic damage to the heart was evaluated by the cicatrical area in percentage to the free area of ventricular wall. Scattering in the cicatrix size was

Institute of General Pathology and Pathological Physiology, Russian Academy of Medical Sciences; *Institute of Rehabilitation and Physical Treatment Methods, Ministry of Health, Moscow

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pronounced, so the rats were divided into subgroups with relatively small and large size of the cicatrice: 20-33 and 33-59%, respectively. Therefore, the hemodynamics was investigated in 6 groups of rats: sham-operated rats (1st group, n=12) that were used as the control, since their cardiac parameters did not differ from that in intact rats; sham-operated rats subjected to EAP (2nd group, n=8); rats with small cicatrices (3rd group, n=7); rats with small cicatrices subjected to EAP (4h group, n=8); rats with large cicatrices (5th group, n=5); rats with large cicatrices subjected to EAP (6th group, n=5).

Cardiac insufficiency was assessed according to the end diastolic pressure measured in the left ventricle using a catheter inserted via the right carotid artery. This evaluation is based on our finding that the rats with small cicatrices had the same end diastolic pressure as the controls (4.5±0.4 mm Hg), while this parameter was 20-25 mm Hg in the rats with large cicatrices.

Systemic hemodynamics was studied at relative physiological rest and under the functional loads that increased or decreased vascular tone: respectively, by norepinephrine (5 μg/kg) or acetylcholine (5 μg/kg) infused into the femoral vein via a catheter. The results were statistically analyzed using Student's t test and Wilcoxon-Mann-Whitney's nonparametric U test.

RESULTS

The basic parameters of systemic hemodynamics under relative physiological rest in rats with PICS are given in Table 1. It shows that the rats with small cicatrices (3rd group) had the basic parameters identical to those of the control rats with a single exception of a strongly increased HR. The values of AP, TPVR, and HR were significantly decreased by, respectively, 24, 37, and 12% in the rats with large cicatrices (5th group). By contrast, the stroke volume and cardiac output were significantly increased in this group by 42% (p<0.05) and 18% (p<0.05), respectively. Therefore, these rats had cardiac insufficiency combined with increased cardiac output that resulted probably from pathologically increased end diastolic pressure.

EAP did not affect the basic parameters of systemic hemodynamics and produced qualitatively different effects in rats with small and large cicatrices. The EAP course did not affect AP in the rats with small cicatrices, while it decreased TPVR by 19% (p<0.05). In these rats, HR significantly decreased by 37 beats/min, which is probably related to an increase in stroke volume (29%, p<0.05) and to a tendency of the cardiac output increase.

In rats with large cicatrices, AP and TPVR increased after the course of EAP by, respectively, 18 and 46%, while HR increased significantly by 23 beats/min. The increase in TPVR led to a decrease in the stroke volume by 23% (p<0.05) and in cardiac output by 19% (p<0.05). Therefore, EAP course increases cardiac afterload in the rats with cardiac insufficiency, which decreases cardiac output to the control level.

A certain decrease in the vascular tone in rats with small cicatrices by EAP is consistent with the data on the hypotensive effect of acupuncture [2,10], which results from moderation of the ongoing activity of the vasomotor center due to activation of the opioid- [8, 11] and GABAergic systems [3]. The mechanism of hypertensive effect of EAP in animals with cardiac insufficiency needs further experimental analysis.

EAP slightly restricted the rise in AP and TPVR caused by norepinephrine: the difference between the control (1st) group and the 2nd group (subjected to EAP) was detected 30 sec postinjection (p<0.05, Fig. 1). These data are consistent with a decrease in vasal catecholamine responsiveness in animals during adaptation to EAP [6]. In this period the control rats demonstrated a tendency to a small increase in the cardiac output, while an opposite tendency was observed in EAP-treated rats. This difference was not related to

TABLE 1. Effect of EAP on the Basic Parameters of Systemic Hemodynamics in Rats with PICS at Relative Physiological Rest (M±m)

Group	AP, mm Hg	HR, beat/min	Stroke volume, ml	Cardiac output, ml/min	TPVR, mm Hg/ml/min
1	148±3.2	385±5	0.19±0.009	78±3.2	1.98±0.23
2	137±5.0	378±11	0.20±0.015	74±3.8	1.92±0.133
3	143±6.8	418±10*	0.17±0.015	73±5.0	2.01±0.153
4	138±7.5	381±11+	0.22±0.01+	86±5.7+	1.63±0.101
5	112±6.0***	339±11*	0.27±0.020*	92±6.7*	1.24±0.106**
6	132±4.0++	362±15	0.21±0.015+	75±5.4+	1.81±0.164++

Note. *p<0.05, **p<0.02, ***p<0.001 with respect to the first group; +p<0.05, ++p<0.02 with respect to the previous group according to Student's t-test. [1]Significance of the differences was calculated according to the Wilcoxon-Mann-Whitney's nonparametric U test.

the value of HR which increased similarly (by 12-13 beats/min) in both groups.

The reaction of systemic hemodynamics to norepinephrine was similar in rats with small and large cicatrices: therefore, the features of this reaction are exemplified in rats with large cicatrices (Fig. 1). Norepinephrine increased AP and TPVR in the 5th group to a lesser extent than in the 1st group ($p<0.05$), which implies a decrease in the vasal catecholamine responsiveness in the animals with PICS. Cardiac output slightly and similarly increased in these groups due to a small increase in HR and stroke volume.

Since the course of EAP induced approximately equal changes in the cardiovascular system reaction to norepinephrine in rats with small and large cicatrices, these data are also demonstrated on rats with large cicatrices (Fig. 1). EAP did not affect the pressor response to norepinephrine in rats with PICS. However, instead of small rise in the cardiac output caused by norepinephrine in the 5th group, this index decreased to a small but statistically significant value in the 6th group ($p<0.05$). Since EAP does not modify vascular reaction to norepinephrine in rats with PICS, a small drop in the stroke volume, which occurred against the background of a small and similar increase in HR in both groups, causes this effect. Some decrease in the stroke volume is probably related to potentiation of the norepinephrine-induced myocardial inotropic effect in rats with PICS.

Acetylcholine caused nearly similar drops in AP and TPVR in control rats and in rats subjected to EAP. The maximum drop in TPVR was observed 10 sec postinfusion (respectively, 53 and 60% of initial level, Fig. 2). At the same time, AP was more rapidly restored in EAP-treated rats than in the control rats. The EAP-induced acceleration of vascular tone restoration

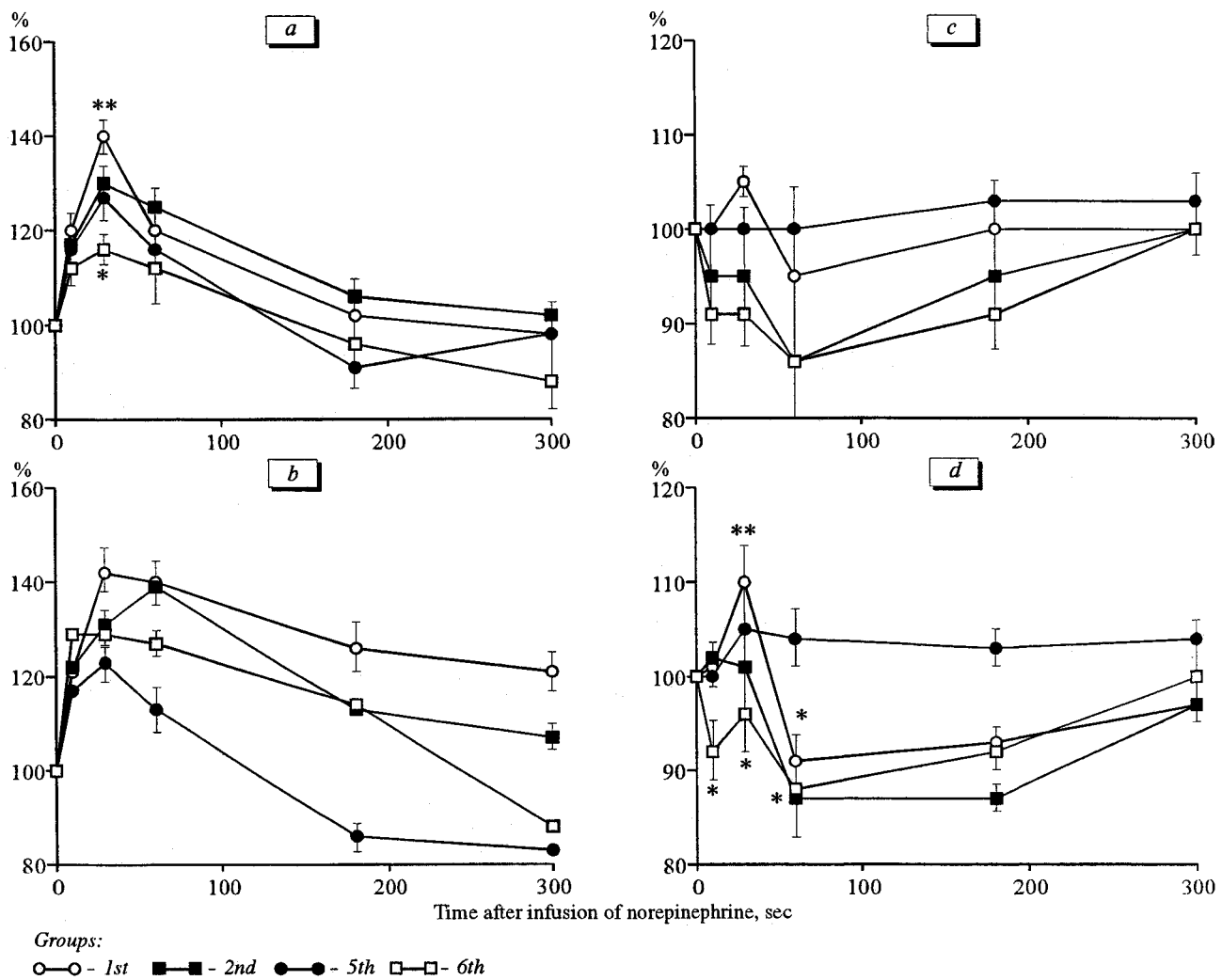

Fig. 1. Effect of norepinephrine on the parameters of systemic hemodynamics in rats with cardiac insufficiency after an electroacupuncture course. $p<0.05$: *comparison of the 5th and 6th groups; **comparison of the 1st and 2nd groups according to the Wilcoxon-Mann-Whitney's test. Here and in Fig. 2: *a*) arterial pressure, *b*) total peripheral vascular resistance; *c*) stroke volume, and *d*) cardiac output. Zero number corresponds to the start of infusion. Ordinate: parameters of hemodynamics are expressed in percentage of the initial level.

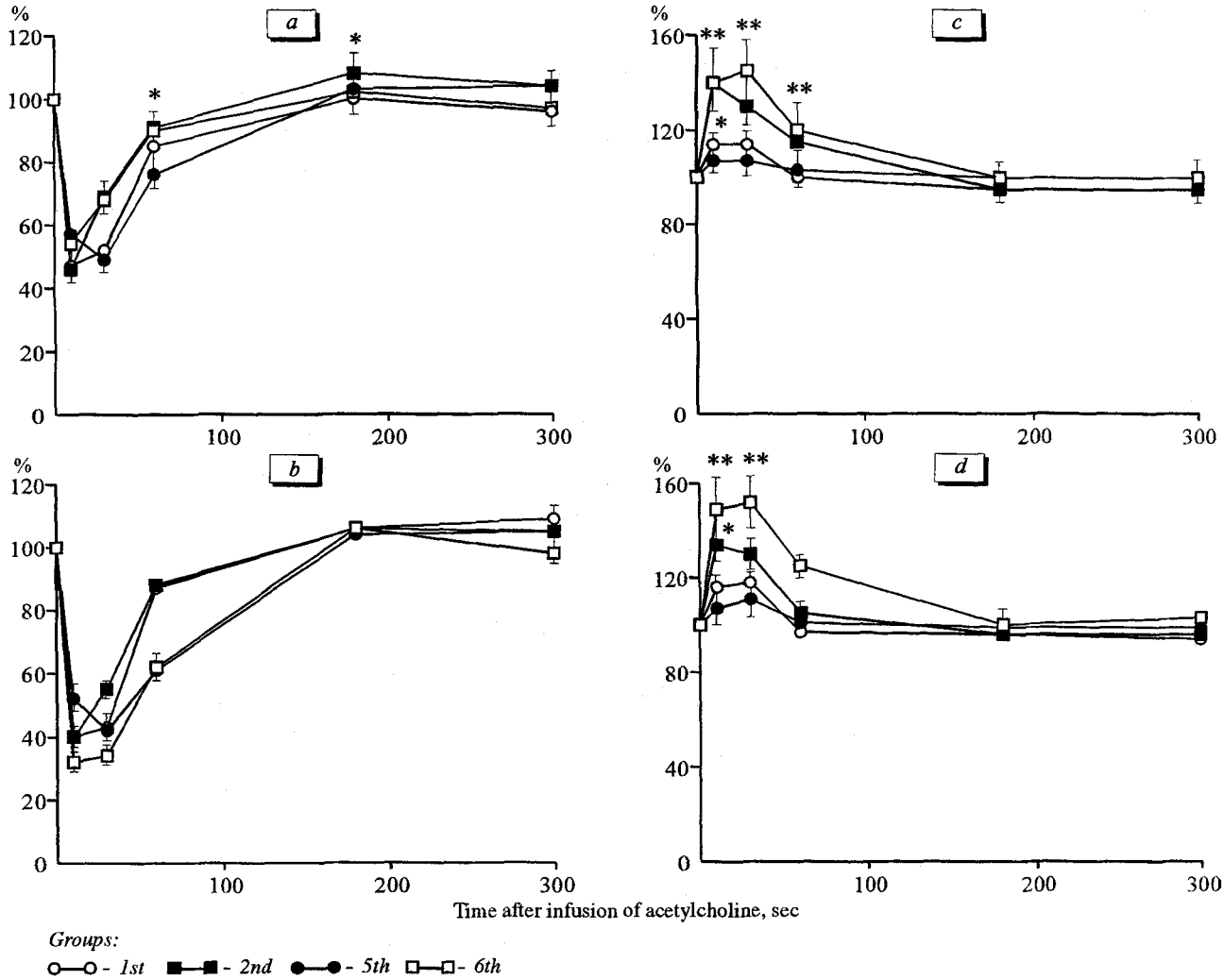

Fig. 2. Effect of acetylcholine on systemic hemodynamics in rats with cardiac insufficiency after course of electroacupuncture. $p<0.05$: *comparison of the 5th and 6th groups; **comparison of the 1st and 2nd groups according to the Student's t test.

is probably related to an increase in the cholinesterase activity.

The pumping action of the heart became more sensitive to acetylcholine after the course of EAP. Ten seconds postinfusion the increase in cardiac output was 2-fold in the 2nd group in comparison with the 1st group. Primarily, it is related to much greater increase of the stroke volume in the 2nd group in comparison with the 1st group against the background of similar drops in TPVR and HR (by 2-6 beats/min).

Our findings show that EAP does not produce pronounced effect on the acetylcholine-induced drop of vascular tone but accelerates its restoration. In addition, acetylcholine intensifies the pumping action of the heart after EAC.

The response of systemic hemodynamics to acetylcholine was almost identical in the control and in PICS rats. At first glance, it contradicts the data on inhibition of acetylcholine-induced endothelium-dependent vascular dilation [14] which is mediated by nitric oxide. Although we did not study the dose-response reaction of hemodynamics to acetylcholine, the lack of inhibition of the vascular system reaction to the vasodilator in PICS rats (our findings) is most probably related to the fact, that under cardiac insufficiency the endothelium-dependent dilation is not disturbed in every vascular region. For example, inhibition of dilation occurs in pulmonary vessels but not in abdominal aorta and in peritoneal vessels [12]. Evidently, in PICS animals the disturbances of endothelium-dependent dilation in some vascular regions could be compensated by normal responses of endothelium in other regions resulting in a stable responsiveness to acetylcholine of the whole body.

It should be stressed that PICS rats subjected to EAP demonstrated a greater increase in cardiac output in response to acetylcholine than rats not subjected to EAP: in the 5th and 6th groups the increments were 7-11 and 49-52%, respectively ($p<0.001$, Fig. 3). The pronounced difference in cardiac output in these groups

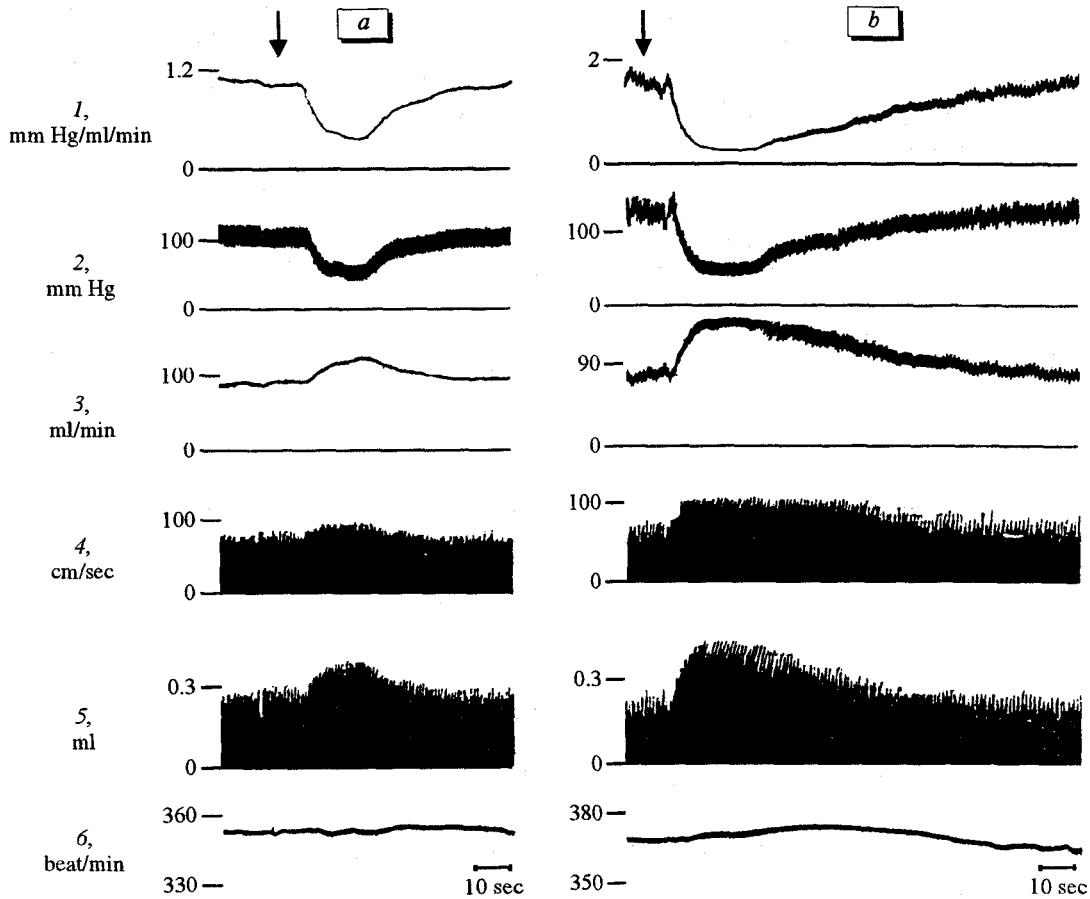

Fig. 3. Effect of acetylcholine on systemic hemodynamics in rats with cardiac insufficiency that (*a*) were or (*b*) were not treated by electroacupuncture. *1*) total peripheral vascular resistance; *2*) arterial pressure; *3*) cardiac output; *4*) blood flow; *5*) stroke volume; and *6*) heart rate. The arrow indicates the start of acetylcholine infusion.

was primarily caused by a more drastic increase in the stroke volume in the 6th group in comparison with the 5th group, because HR did not change markedly in both groups. At the same time, this effect is not related to different variations in AP and TPVR, which changed approximately in a similar way in these groups, with exception of their intensified restoration in rats subjected to EAP. Thus, under a decreased afterload, the course of EAP intensifies the pumping action of the heart both in intact and PICS rats. This effect is probably caused by greater blood inflow to the heart due to EAP-induced increase in the vascular response to acetylcholine in the smaller circulation. This hypothesis is confirmed by the data on EAP-induced increase of vascular responsiveness to acetylcholine in isolated segments of rat tail artery [6].

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