

# EFFECT OF PAIRED ELECTRICAL STIMULATION OF THE HEART ON ITS HEMODYNAMICS

V. I. Shumakov, A. E. Kuvaev,  
V. E. Tolpekin, and G. P. Itkin

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Paired electrical stimulation of the heart slows its contractions and increases their strength. Strengthening of the cardiac contractions by paired stimulation is more marked in animals in a state of cardiac decompensation.

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The method of paired stimulation of the heart [1-5, 8] consists essentially of the successive application of paired electrical pulses to the heart. The pulses of each pair are applied in time so that each second impulse is applied immediately after the end of the absolute refractory phase caused by the first pulse. As a result of this spacing, electrical depolarization of the myocardium arises from each second ("early or premature") pulse, with continuation of the absolute refractory state, and unaccompanied by mechanical systole of the ventricles. The cardiac contraction developing after the refractory period prolonged in this manner is strengthened, and the earlier the second ("premature") pulse is applied in the relative refractory phase, the stronger the "postextrasystolic" contraction.

Double depolarization lengthens the duration of the absolute refractory phase of the heart and thus slows the rate of its contractions.

This paper describes the results of experiments to determine the working efficiency of a paired stimulator of our own design and to study some problems connected with the effect of paired stimulation of the heart on the hemodynamics in experimental animals.

## EXPERIMENTAL METHOD

Experiments were carried out on 20 dogs weighing from 8-25 kg under endotracheal anesthesia (morphine, listhenon, ether). The chest was opened in the 5th intercostal space. After incision of the pericardium, electrodes for paired stimulation and a pick-up for recording the intramyocardial pressure (IMP) were sutured to the heart (in the middle 3rd of the left ventricle). The method of measurement of the IMP suggested by Kreuzer and Schoeppe [6] and improved by Shenderov and co-workers [1] was used.

The pressure in the left ventricle, thoracic aorta, and left and right atria, and also the ECG were recorded. In addition, the volume blood flow in the femoral (5 experiments) and carotid (3 experiments) arteries was measured by means of a continuous blood flow-meter. In two experiments the coronary sinus was catheterized. Stimulating pulses (2-6 V, 2-3 msec) were applied to the left ventricle from the stimulator through ordinary wire electrodes.

## EXPERIMENTAL RESULTS

In all experiments changes in the frequency of cardiac contractions, in the tone of the myocardial wall, and in the hemodynamics were observed under the influence of paired electrical stimulation (Fig. 1).

Depending on the time after which the second ("premature") pulse in each pair was applied, the heart rate was reduced by 25-50% below its initial level. The duration of continuous paired stimulation of the heart in these experiments did not exceed 2-3 h, but the rhythm could be imposed in this way for a longer period.

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Combined Laboratory of the Artificial Heart and Valves, Institute of Clinical and Experimental Surgical Research, Ministry of Health of the USSR; Institute of Cardiovascular Surgery, Academy of Medical Sciences of the USSR, Moscow. (Presented by Academician B. V. Petrovskii.) Translated from *Byulleten' Éksperimental'noi Biologii i Meditsiny*, Vol. 67, No. 6, pp. 13-16, June, 1969. Original article submitted May 22, 1968.

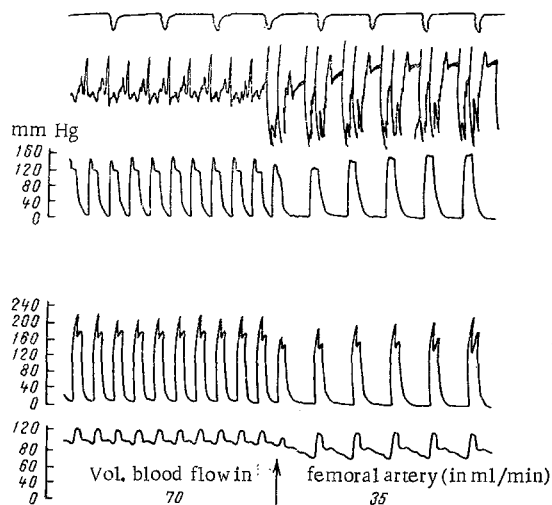


Fig. 1. Changes in hemodynamic indices during paired stimulation of the heart (beginning marked by arrow) in animal with healthy heart. From top to bottom: time marker 1 sec, ECG, curve of intramyocardial pressure in middle third of left ventricle, pressure inside left ventricle, pressure in abdominal aorta.

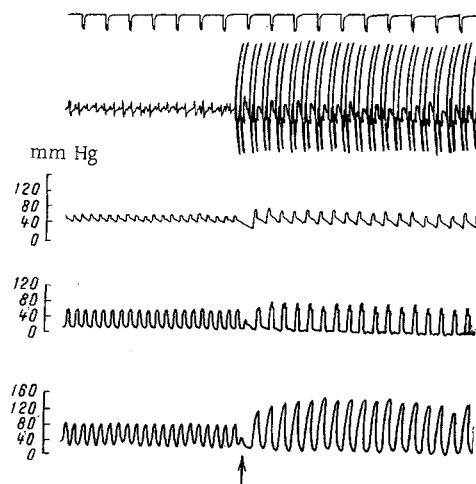


Fig. 2. Changes in hemodynamic indices during paired stimulation of the heart (beginning marked by arrow) in animal with low initial pressure. From top to bottom: time marker 1 sec, ECG, pressure in thoracic aorta, and in left ventricle, intramyocardial pressure.

Immediately after application of paired electrical pulses to the heart, the systolic and diastolic pressures inside the wall of the myocardium of the left ventricle changed. The greatest increase in IMP (up to 150%) was observed when its initial level was low (Fig. 2). Under these circumstances an increase in pressure in the left atrium and in the diastolic pressure in the left ventricle also were observed. Conversely, the IMP was never increased by more than 10-15% if the initial systolic IMP was high. Hence, the tension in the myocardial wall can be increased to a greater degree by means of paired stimulation if signs of cardiac failure are present.

The diastolic IMP more commonly was reduced slightly or remained at its initial level. In 14 of 20 experiments it was lowered (by 25-75%), in two cases it was unchanged, and only in 4 was it raised to some degree (by 10-15%).

These results suggest that paired stimulation causes greater relaxation of the myocardium in diastole, and with an increase in the duration of diastole, this leads to an increase in diastolic filling of the heart. So far as the causes of the periodically observed increase in diastolic IMP are concerned, they require further study.

The IMP is known to reflect to some degree the tension in the myocardial wall [1], and this is closely correlated with the oxygen consumption of the myocardium.

Despite a considerable increase in tone of the myocardial wall under the influence of paired stimulation, the pressure inside the left ventricle did not change significantly. In 9 of 20 cases the systolic pressure in the left ventricle was unchanged, in 4 it was reduced, and only in 7 was it increased (by 5-25%). It is not yet possible to explain fully the reasons for these conflicting results. All that can be said is that an increase in systolic pressure in the left ventricle was nearly always observed if the initial level of this index was low (not exceeding 100 mm Hg).

In most cases the diastolic intraventricular pressure fell.

In the femoral artery both the systolic and diastolic pressures showed a tendency to decrease. Only in one case was an increase in systolic pressure in the femoral artery (by 38%) observed.

The blood flow in the femoral artery in animals with no signs of cardiac failure as a rule fell (sometimes by 50% of its initial value). Conversely, the blood flow in the carotid artery showed a tendency to decrease only immediately after the beginning of stimulation, and to a much lesser degree than in the

femoral artery, after which it returned rapidly to its initial level. In two experiments in which paired stimulation was carried out on animals with signs of heart failure, the volume blood flow in the femoral artery increased.

It can thus be concluded from these results that paired electrical stimulation of the heart leads to a considerable increase in tone of the myocardial wall during systole and to a decrease in tone during diastole, indicating an increase in the contractile activity of the myocardium associated with slowing of the heart rate. It is considered that the fullest positive inotropic effect of paired stimulation can be expected if it is used against the background of reversible cardiac failure.

#### LITERATURE CITED

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