OPTIMAL TYPE OF IMPULSES FOR THE ELECTROSTIMULATION OF THE HEART

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In recent years electrostimulation of the heart has found employment in clinical practice in cases of its arrest due to a complete block of atrioventricular conductivity, or the absence of automatsim [4, 10, 11, 12]. The effectiveness of electrostimulation in various causes of cardiac arrest has been extensively studied experimentally [6, 7, 10]. However, the problem of optimal form and duration of electric impulses used in electrostimulation has been much less elucidated. As regards the duration of impulses, it should be pointed out that there are considerable variations (from one to 100 milliseconds) in the experiments of various authors [3, 5, 6, 8, 9].

In studying the effectiveness of stimulation of the heart in the arrest of its activity in dogs, poisoned with proserine or cooled to 20°, we investigated the liminal voltage which induces an extrasystole at various lengths and forms of electric impulses. The results of these measurements are described in the present article.

METHODS OF EXPERIMENTS

Experiments were carried out on dogs under usual thermal conditions (18 tests) and under hypothermia (10 tests). The animals of the first group were given a preliminary subcutaneous injection of a 2% pantopone solution, eight mg of the dry substance per kg body weight. Within 40 minutes we separated the femoral vessels under local novocaine anesthesia—the artery for recording arterial pressure, and the vein for the injection of proserine. Proserine was given in the form of a 0.05% solution at 0.5 ml, repeatedly until the onset of considerable retardation of the cardiac rhythm. In four experiments we did not inject proserine, because the cardiac rhythm proved to be sufficiently retarded after pantopone administration.

The animals of the second group received simultaneously with pantopone 0.1 mg/kg of atropine subcutaneously. Prior to, and during the cooling period, a nembutal solution (0.2%) was administered intravenously. The cooling was effected by immersing the dogs into an ice bath. When the body temperature reached 20°, the cooling was terminated and the animals were placed into a water bath of 45° temperature. The warming was stopped when the body temperature reached 33°.

After the cardiac rhythm had been retarded under the effect of proserine or cooling, we carried out electrostimulation of the heart. Needle-electrodes were inserted subcutaneously on the right and left side of the thorax along the location of the heart. We tested isolated monophasic rectangular impulses (from one to 100 msec) and serrated (5 to 10 msec) electric impulses with the aid of a GRAKh-1 apparatus (universal stimulator manufactured by the experimental construction bureau of the AMN SSSR in 1954). We also tested isolated bi-phasic impulses of rectangular and sinusoidal forms. The first were obtained from a source of continuous current (an anode battery with voltage up to 100 V) by means of a mechanical commutator; the other—by means of a discharge of a condenser of 500, 1500, and 3000 miorofarads through a special induction coil without an iron core, calculated for an impulse duration up to 10 msec.

The effectiveness of the electric stimuli was determined by the appearance of an extra pulse wave on the recorded arterial pressure curve.

RESULTS OF EXPERIMENTS

The experiments demonstrated that the magnitude of liminal voltage which produces an extrasystole depends on the form of the electric impulse and on its duration. The lowest threshold was obtained in acting upon the heart with monophasic impulses of rectangular form. At 10 msec duration, the threshold for a monophasic impulse of rectangular form was approximately 1.7-2-fold lower than the threshold for a serrated or sinusoidal form (Tables 1 and 2).

TABLE 1

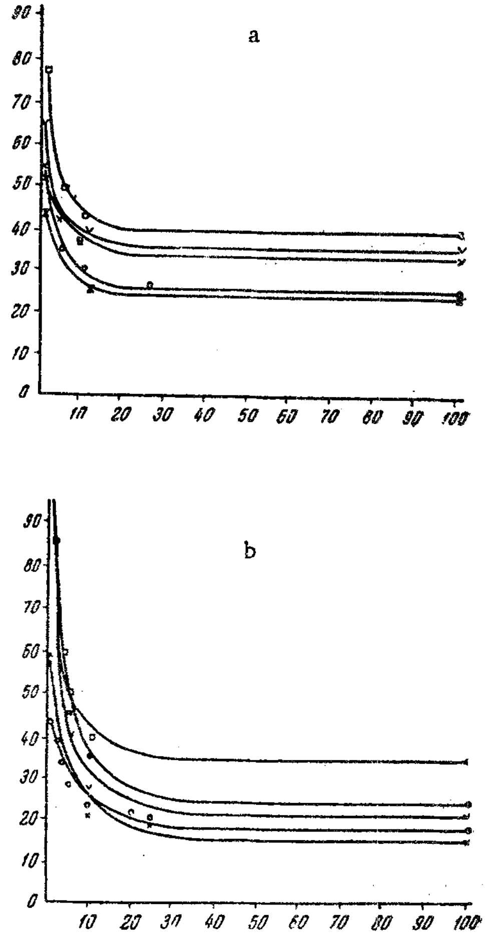
Liminal Voltage for Rectangular Monophasic and Serrated Electric Impulses

No. of experiment	Liminal voltage (in V)			
	for rectangular impulses lasting		for serrated impulses lasting	
	5 msec	10 msec	5 msec	10 msec
6	31	22	90	60
9	91	70	100	100
12	45	31	70	70
13	–	27	–	45

TABLE 2

Liminal Voltage for Rectangular Monophasic and Bi-phasic Electric Impulses of 10 msec Duration

No. of experiment	Liminal voltage (in V)	
	for rectangular monophasic impulses	for rectangular bi-phasic impulses
14	25	24
15	26	30
16	37	48
17	30	33
18	38	53



Dependence of liminal voltage on the impulse duration. a) Curves prepared according to the data of five experiments carried out under usual thermal conditions; b) curves prepared according to the data of five experiments carried out under hypothermia conditions. Along the axis of abscissa—time (in milliseconds), along ordinate axis—voltage (in V).

The liminal voltage for a bi-phasic impulse of rectangular form proved to be equal to a monophasic impulse of the same form.

The liminal voltage for monophasic rectangular impulses was in inverse ratio to their duration. This relationship is graphically presented in the figure.

The figure shows that the point of inflexion of the curves, prepared according to the data of experiments conducted under usual thermal conditions, corresponds to the impulse duration of 7-10 msec (see Fig., a). The inflexion point of curves prepared according to the data of experiments conducted under conditions of hypothermia (see Fig., b) corresponds to impulse duration of 10-13 msec).

The greater effectiveness of monophasic rectangular impulses as compared to sinusoidal and serrated impulses, which we had observed in our experiments, finds its explanation in a certain regular dependence of the electric stimulation effect on the rate (gradient) of increase of the strength of current. As regards the isolated electric impulse effects on the heart, the greater effectiveness of rectangular as compared to sinusoidal impulses was pointed out by Callaghan and Bigelow [3].

In the conducted experiments we were unable to achieve any added stimulating cardiac effect of both phases in the action of isolated bi-phasic impulses of a rectangular current; the liminal voltage for such an impulse proved to be equal to that of a monophasic impulse. In a previously conducted study of the comparative action of an alternating sinusoidal and a rectified (monophasic pulsating) current, under prolonged and continuous cardiac stimulation, we observed the summary effect of both phases—the threshold for the alternating current was twice as low as the one for a rectified current [1]. The stronger stimulating action of an alternating sinusoidal current can be explained apparently by the fact that each of its periods exerts a stimulating effect corresponding to its full amplitude voltage. The absence of a summary effect with an isolated bi-phasic impulse indicates the peculiarities of adaptation changes in the tissues under the effect of stimuli of various duration and quantity.

The dependence of liminal voltage on the duration of the impulse was determined in an indirect stimulation of the heart. Nevertheless, the dependence relationship of this curve is analogous to the one obtained under conditions of direct cardiac stimulation. The need of more prolonged cardiac stimulation in producing an extrasystolic contraction under hypothermia conditions corresponds to the dependence of the duration of the stimulation process on the temperature [2].

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