OPTIMAL PARAMETERS OF ELECTRICAL DEFIBRILLATION OF THE ATRIA

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In acute experiments on dogs thoracotomy was performed and atrial flutter and fibrillation induced. The threshold levels of current, energy, and charge required to abolish these arrhythmias were determined in the case of direct application of a monopolar square pulse ranging in duration from 1 to 15 msec were determined. The values of the current and energy defibrillating the atria when the electrodes were applied directly to them were minimal if the duration of the pulse was 8 msec: 113 ± 13.7 mA and 10.4 ± 2.6 mW · sec, respectively, to abolish flutter and 275 ± 18.2 mA and 62.3 ± 9.0 mW · sec to abolish fibrillation. The strength of the current restoring the nomotopic rhythm by direct strial defibrillation was only one-fiftieth of the strength of the current previously established for transthoracic atrial defibrillation in dogs. The effectiveness of direct atrial defibrilation under experimental conditions points to the need for development of an adequate method for its clinical application.

KEY WORDS: atrial arrhythmias; direct atrial defibrillation.

The basic principle of defibrillation of the heart is synchronization of excitation of the individual cells of the myocardium by means of a powerful electrical impulse [2]. This method has become widely used not only to abolish ventricular fibrillation, but also for the treatment of atrial fibrillation [2, 7, 8]. However, during atrial defibrillation, single impulses of the same parameters as those used to abolish ventricular fibrillation continue to act on the whole heart [2, 6, 8, 11]. Yet there is abundant evidence to show that the application of a strong current (20-50 A), especially if repeated pulses have to be applied, can give rise to serious complications [4, 9, 12].

In the present writers' opinion, during atrial defibrillation it is possible to apply electrical pulses not to the whole heart, as is the current practice, but directly to the atria.

In the investigation described below values of the current (I), energy (E), and charge (Q), essential for abolishing atrial fibrillation and flutter when a square electrical pulse between 1 and 15 msec in duration was applied directly to the atria, were determined in experiments on dogs.

EXPERIMENTAL METHOD

Experiments were carried out on nine dogs weighing 12-20 kg and anesthetized with pentobarbital (30 mg/kg, intravenously). The animals were artificially ventilated, thoracotomy was performed, the pericardium opened, and the heart exposed. Atrial fibrillation and flutter were induced by short electrical stimulation of the atria after mechanical destruction of the sinoatrial node [1]. For stimulation, square pulses 2 msec in duration, with a frequency of 20 Hz, and with a voltage 2.5 times above the diastolic threshold were applied by bipolar electrodes. In some experiments, to maintain atrial fibrillation, two or three drops of 0.1% methacholine solution were applied to the surface of the atria or 1 ml of 0.05% neostigmine solution was injected intravenously. Cardiac activity was monitored by recording the ECG in standard lead II.

Electrical atrial defibrillation was carried out by means of two electrodes made from soft thin wire gauze. The shape and size of the electrodes were chosen individually and they were applied directly to the right or left atrium so that the greater part of the atria was beneath them. The electrodes were securely

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TABLE 1. Threshold Values of Square Pulse, 8 msec in Duration, Abolishing Atrial Flutter (A) and Fibrillation (B) by Direct Atrial Defibrillation in Nine Dogs (M ± m)

	Voltage (V)*, in V	Current (I)*, in mA	Charge (Q), in mA · sec	Energy (E), in mW · sec
Atrial flutter	11,6±1,2 (7,6—16,6)	113±13,7 (74—173)	0,9±0,11 (0,59—1,38)	10,4±2,6 (4,4—22,9)
Atrial fibrillation	28,3±1,7 (24—32,6)	275+18,2 (230—320)	2,2±0,14 (1,84—2,56)	62,3±9,0 (44,1—83,4)

*The resistance of the atria during application of the pulse varied between 83 and 120 Ω, mean 103 ± 2Ω.

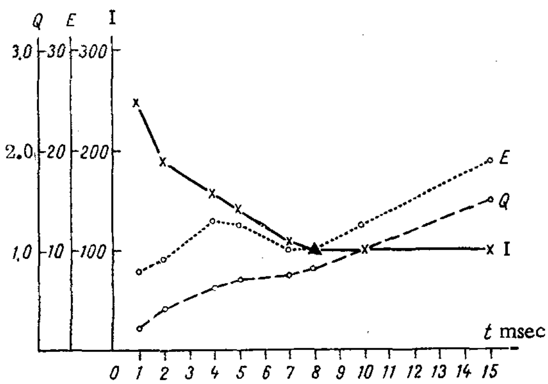

Fig. 1. Curves showing threshold strength of current (I), energy (E), and charge (Q) as functions of duration of monopolar square pulse (t), abolishing atrial flutter in a dog weighing 13 kg. Abscissa, pulse duration (in msec); ordinate, threshold values of current (in mA), energy (in mW · sec), and charge (mA · sec) during direct application of pulse to atrium.

fixed to the myocardium. Square monopolar pulses with a duration of between 1 and 15 msec were used for defibrillation. The experimental apparatus consisted of a square pulse generator, an emitter follower, and a dc source, so that square pulses up to 600 mA could be obtained, with a load of 100 Ω.

Threshold values of current (I) and voltage (V) were established during application of pulses of stepwise-increasing strength. The results were recorded on a two-channel S1-17 oscilloscope. The current was determined by measuring the voltage drop on a 1Ω resistor, connected in series with one of the electrodes. The voltage was determined by connecting the oscilloscope in parallel into the electrical circuit. The values of the current and voltage stopping atrial flutter and fibrillation for each pulse duration (t) were used to calculate the charge (Q) by the equation $Q = It$, and the energy (E) by the equation $E = IVt$.

EXPERIMENTAL RESULTS

The experiments showed that electrical pulses of suitable parameters, if applied directly to the atrium, abolished atrial fibrillation and flutter and restored the nomotopic rhythm of the animals' cardiac activity. Repeated measurements of the defibrillating current during application of a pulse of the same duration gave the minimal threshold values of the current abolishing atrial flutter and fibrillation. Individual differences in threshold values of the current were observed in different animals. The limits of variation of the values of the current, voltage, energy, and charge for an 8-msec pulse abolishing atrial fibrillation and flutter in dogs are given in Table 1. They show that much lower values of current, voltage, charge, and energy are required to abolish atrial flutter than fibrillation.

Determination of the threshold defibrillating values of the current, charge, and energy with a change in the duration of the pulse from 1 to 15 msec showed how they depend on the duration of action [$I = f(t)$, $Q = f(t)$,

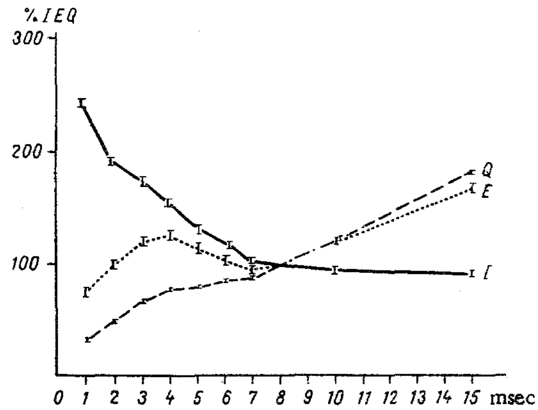

Fig. 2. Curves showing threshold strength of current (I), energy (E), and charge (Q) as functions of duration of monopolar pulse (t) based on averaged data of direct atrial defibrillation in nine dogs. Abscissa, pulse duration (in msec); ordinate, threshold strength of current (I), energy (E), and charge (Q) in % of corresponding values for a pulse 8 msec in duration.

E = f(t)]. The character of this relationship for abolition of atrial flutter and fibrillation was the same. Curves reflecting the values of the threshold strength of current (I), energy (E), and charge (Q) as a function of duration of a monopolar square pulse (t), plotted from the absolute data of one experiment, are given in Fig. 1. Averaged curves based on data of nine experiments are illustrated in Fig. 2. Threshold values of current, charge, and energy corresponding to a definite pulse duration are given in this figure as percentages of the current, charge, and energy corresponding to a pulse with a duration of 8 msec. As Figs. 1 and 2 show, the threshold strength of current (I) was greatest for a pulse 1 msec in duration. With an increase in the pulse duration from 1 to 8 msec the strength of the current gradually fell, but with a further increase in pulse duration, the strength of the current remained practically unchanged. The function has two minima: the energy was minimal for pulses with durations of 1 and 8 msec. The charge (Q) increased with an increase in pulse duration.

The reciprocal relationship between current strength and pulse duration between 1.25 and 8.3 msec was discovered previously during ventricular defibrillation by monopolar and bipolar sinusoidal pulses [2, 5, 10]. The results of the present investigation indicate a similar relationship during the abolition of atrial flutter and fibrillation by direct action of a monopolar square pulse on the atria. It can accordingly be concluded that electrical defibrillation of the atria, like defibrillation of the ventricles, obeys a strength–duration of stimulation law.

The criteria for determining the optimal pulse duration must be the minima of the functions I = f(t), E = f(t), and Q = f(t). The risk of injury to the myocardium is reduced at the energy minimum because of a decrease in the thermal effect. At the charge minimum the effect of tissue electrolysis is reduced. The minimum of current amplitude must be regarded as the most important criterion, because of a high current strength, even with minimal energy and charge, can cause injury to the myocardium and impair its contractile power [5, 8, 10].

According to the results of this investigation, the optimal duration of the monopolar square pulse for direct atrial defibrillation is 8 msec. Atrial defibrillation with a pulse of this duration corresponds to minima of current and energy, but the charge is very high. One possible way of overcoming the electrolysis effect is by using bipolar pulses [3, 5, 11].

As a result of these investigations the optimal duration of the monopolar square pulse and threshold values of current, energy, and charge required for the abolition of atrial fibrillation and flutter by direct application of electrodes to the atria were thus determined. Atrial fibrillation by this method requires a much smaller current than transthoracic defibrillation. According to the writers' data, transthoracic atrial defibrillation in dogs by means of a bipolar sinusoidal pulse with a duration of 10 msec was effective if the strength of the current was 13.1 ±1.2 A, and flutter was abolished by a current with a strength of 5.2 ± 0.3 A. These values of the current are almost 50 times greater than the mean current required for direct atrial defibrillation (Table 1).

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FUNCTIONAL AND MORPHOLOGICAL CHARACTERISTICS OF THE ENDOCRINE SYSTEM IN THE PROGENY OF ADRENALECTOMIZED RATS

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Signs of premature maturation and activation of the pituitary-adrenocortical system were observed in the early postnatal period (70-90 h) in the progeny of rats adrenolectomized 1-3 and 7-9 days before parturition. The stronger response to stressor action than in the control (progeny of rats undergoing mock adrenalectomy and intact rats) was evidence of premature maturation of their suprahypophyseal regulatory mechanism also. Signs of functional exhaustion in the pituitary-adrenocortical system and also in the thyroid gland were found in sexually mature (6-10 months) rats obtained from adrenalectomized females.

KEY WORDS: adrenalectomy; progeny; adrenals; functional exhaustion.

Experimental investigations and clinical observations have demonstrated the effects of pathology of the maternal endocrine glands on the development and formation of the functions of the fetal glands [2, 4, 5, 8, 13]. In the postnatal period the consequences of these effects have been inadequately studied. Yet data on this problem could help to promote a better understanding of the mechanism of origin of some congenital endocrinopathies, and would be important for the choice of tactics in prevention and treatment.

In the investigation described below the effect of adrenalectomy on pregnant rats on the state of the pituitary-adrenocortical system of their progeny was studied.

EXPERIMENTAL METHOD

Altogether 420 animals of the first generation obtained from noninbred albino rats, either adrenalectomized 1-3 and 7-9 days before parturition, subjected (at the same time) to mock adrenalectomy, or intact, were investigated. The state of adrenocortical function was assessed in the newborn (70-90 h) and sexually

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