# RESTORATION OF HEART RHYTHM DURING FIBRILLATION BY A CONDENSER DISCHARGE

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THE MOSCOW INSTITUTE OF PHYSIOLOGY under L. S. Stern has investigated a method for checking cardiac fibrillation due to electric shock.

The use of a strong alternating sinusoidal current of low frequency, which has been widely applied in physiologic experiments since the time of Prevost's and Battelli's classical investigations, is connected with difficulties which will be discussed below. They attempted also to use an electrostatic discharge for the same purpose but this could not be applied in clinical practice.

In 1938-1939 the authors developed a condenser method for terminating cardiac fibrillation caused by electric shock. They used a condenser battery with a capacity of some 3-4 microfarads. The condensers were charged by a small step-up transformer, with the aid of a rectifier (kenotron). The first experiments on dogs proved that this method was effective. In order to restore the heart function the condenser had to be charged with more than 2000 volts, depending upon the size of the animal and upon other conditions. Later, Gurvich conducted a series of experiments for the purpose of studying in detail the physical and physiologic conditions which terminated cardiac fibrillation by a condenser discharge.

## MATERIALS AND METHODS

Six hundred and fifty dogs, sheep, and goats were used. In the majority of cases no narcotics were given. In a small number, narcosis was used in the form of morphine, magnesium sulphate, and chloralose.

Metal electrodes, covered by gauze moistened with salt solution, were placed on both sides of the thorax in line with the position of the heart. The surface area of the electrodes varied from 30 cm.$^2$ (for dogs) to 120 cm.$^2$ (for sheep). Cardiac fibrillation was produced by passing the electrode through an alternating current of 0.1 amperes or of greater intensity. Adrenalin injections were given in cases in which chloroform or potassium salts were used for narcosis. Fibrillation was stopped by condenser discharges. Capacity fluctuated between 0.5 and 52 micro-

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farads; the tension which was applied reached as high as 6000 volts. In the last series of experiments, inductive resistance (up to 0.5 henrys) was introduced into the discharge circuit.

The cardiac condition was registered by recording blood pressure and by electrocardiography.

*Threshold of tension of condenser discharges necessary for the termination of cardiac fibrillation:* The threshold of tension usually remained at the same level in repeated tests in the course of the experiment, as well as in experiments repeated after a few days. In different subjects the height of the threshold varied according to the size of the animal and its state of nutrition. The threshold heights determined in 37 dogs in which cardiac fibrillation was terminated by condenser discharges with a capacity of 12-17 microfarads are given in the following graph. This shows, despite considerable individual variations, a definite direct relation between the degree of heightening of the threshold and the weight of the animal. (The change of capacity from 12-17 microfarads exerted only a slight influence upon the height of the threshold, as shown below.)

Similar results were obtained when the threshold tension necessary for the termination of cardiac fibrillation was measured in sheep and goats (150 animals) with a capacity of 14 microfarads when auto-induction in series equalled 0.5 henrys. In these experiments the individual fluctuations from the average threshold values usually did not exceed 10-15 percent and only in some animals reached 25-30 percent. The average threshold of tension of animals weighing 15-25 kg. was 3200 volts, that of animals weighing 25-35 kg. was 3800 volts, of those weighing 35-45 kg. 4500 volts, and of the group which weighed more than 45 kg. the average threshold tension was 5000 volts.

*Dependence of threshold tension upon the capacity of the condensers in the termination of cardiac fibrillation by condenser discharges:* The height of the threshold tension was in inverse proportion to the capacity. However, when capacity increased, the threshold was lowered only until capacity reached a certain limit, beyond which the threshold remained at a constant level. In the author's experiments, when the resistance of the object equalled 80-100 ohms, this limit was reached with 25-35 microfarads. Thus the dependence of tension upon capacity in the termination of cardiac fibrillation can be represented by a curve. When there is an increase in capacity as recorded along the axis of the abscissa, the ordinates indicating the tension rise to a certain limit, and when the limit is reached, the curve continues parallel to the axis of the abscissa.

*Increase of effectiveness of condenser discharge for the termination of cardiac fibrillation:* The importance of the prolongation of discharge for the termination of fibrillation is indicated above. The importance of this factor increased in the later stages of fibrillation due to the decreased excitability of the myocardium in prolonged asphyxia. For the prolongation of the discharge, inductive resistance (0.3-0.5 henrys) was included in the discharge series. This also produced a certain

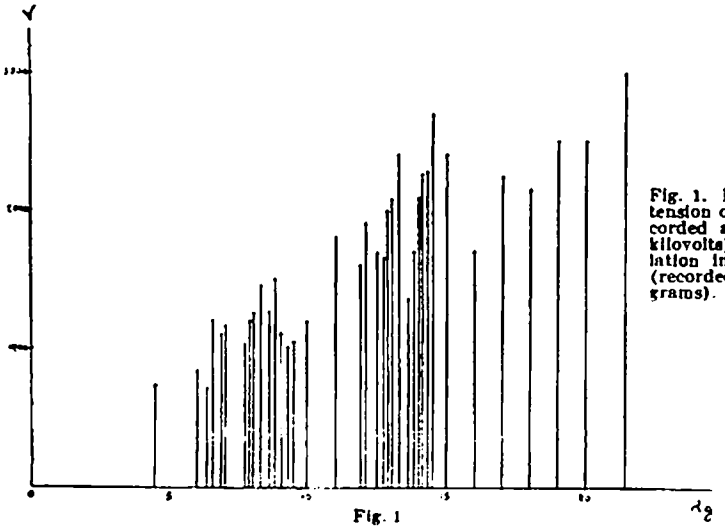

Fig. 1. Height of the thresholds of tension of condenser discharges (recorded along the ordinate axis in kilovolts) which check cardiac fibrillation in dogs of different weight (recorded along the abscissa in kilograms).

Fig. 1

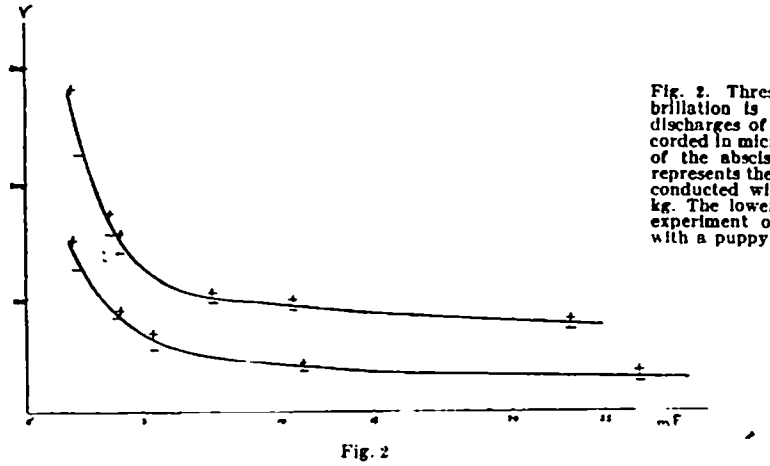

Fig. 2. Threshold tension when fibrillation is checked by condenser discharges of different capacity (recorded in microfarads along the axis of the abscissa). The upper curve represents the experiment of 8/17/40 conducted with a dog weighing 6.5 kg. The lower curve represents the experiment of 8/21/40 carried out with a puppy weighing 1.2 kg.

Fig. 2

stabilization of the strength of the discharge current regardless of unavoidable and considerable fluctuation of the electric resistance (impedance) of the animal.

Tests have proven that such a modified form of the discharge current is practicable especially in cases where small capacities are applied (less than 10 microfarads): When auto-induction is included, the thresholds of tension are lowered (see graph).

As shown in the second graph, the inclusion of auto-induction greatly lowers the maximum amplitude of the discharge current that is needed for the termination of fibrillation.

*The use of massage for the restoration of cardiac function with the aid of condenser discharge in fibrillation:* The condenser discharge restored cardiac function

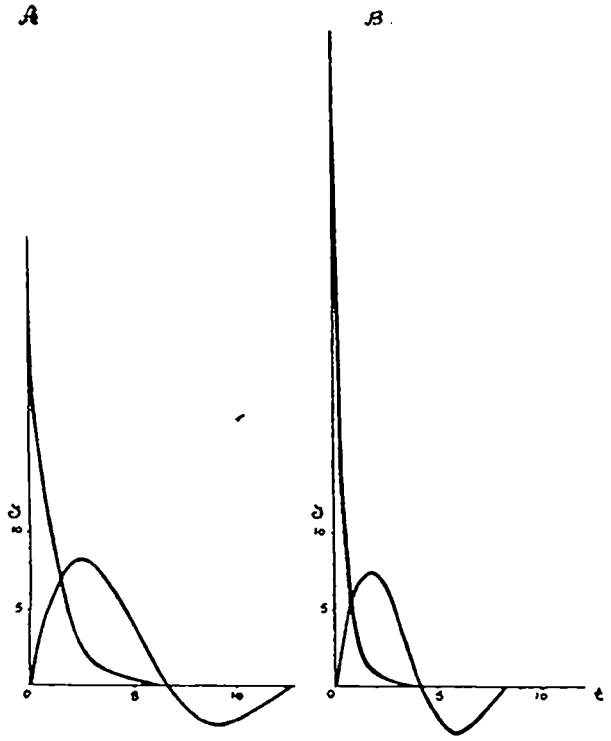


Fig. 8. Threshold strength of the current needed for checking fibrillation in different types of discharge current. A) Condenser discharges of 10 microfarads carried out with auto-induction of 0.85 henrys and without auto-induction. B) Same as above with a capacity of 4 microfarads. (The recorded resistance of the auto-induction coil was 48 ohms the resistance of the object was 100 ohms.) This represents the experiment of 1/20/48 carried out with dogs weighing 20 kg.

Fig. 8

if the discharge was applied not later than 1-1½ minutes after the onset of fibrillation. However, this interval of time does not constitute the limit. By means of preliminary massage of the heart, normal cardiac function may be restored by discharges applied after a rather long period of fibrillation.

The effectiveness of preliminary massage was observed by the author in more than 50 dogs in which cardiac fibrillation was produced by an alternating current (19 experiments) and intravenous injection of potassium chloride. The heart was massaged by pressure on the thorax and circulation re-established as shown by pulse waves recorded on a tonograph. The massage was started 1-2 minutes after fibrillation set in.

The above tests showed that after fibrillation lasting eight minutes, the animals were easily resuscitated. When it lasted 10-15 minutes 19 animals survived and 17 died. Thirteen of the latter had been weakened by previous operations.

## DISCUSSION AND CONCLUSIONS

1. The condenser discharge is effective in checking cardiac fibrillation in animals caused by electric shock as well as by certain poisons (chloroform, potassium chloride).

The cardiac rhythm returned and resembled the original rhythm which was recorded before the occurrence of fibrillation. The re-establishment of normal

heart action and of the function of the central and sympathetic nervous systems is lasting. The animals were observed from ten days to four months.

2. The experiments lead to the conclusion that the condenser method of re-establishing the normal heart action in ventricular fibrillation may be just as effective in cases of electric shock in man.

It has been mentioned that in animal experiments, it is absolutely necessary to resort to a preliminary massage of the heart in cases in which the condenser discharge was administered more than 1-1½ minutes after the onset of fibrillation. It is also possible to maintain an artificial blood circulation at a constant but considerably lowered level in clinical cases in which the heart has stopped by applying at rhythmic intervals considerable pressure to the abdominal walls and synchronizing this treatment with the movements of artificial respiration (K. A. Fries 1912). A respirator has been constructed for this purpose.

3. The condenser method of checking cardiac fibrillation offers certain practical advantages over the method based on the use of a very strong alternating current. a) In accordance with reports in the literature, and with the author's data, a strong alternating current generator with a tension exceeding 1000 volts (up to 2000-3000 volts) and of 25-30 amperes, is required to stop ventricular fibrillation in large animals. Such a strong transformer is very bulky and for technical reasons, cannot be plugged in to the ordinary lighting circuit. b) For the use of such strong current, it is absolutely necessary to have additional apparatus which would enable one to control the duration of the effect of the current upon the organism. c) Alternating current of high tension is dangerous for the technicians and in some cases even for the patient. If, as a result of some technical defect in the series, the tension of the current is considerably lowered at the surface of the patient's body, this current acquires the capacity of producing cardiac fibrillation.

It is essential to note that in the numerous control experiments carried out by the author, a single condenser discharge with threshold capacity for checking fibrillation which was made through the thorax of the animal never produced fibrillation in a normal physiologic state. A number of experiments tested the effect on normal heart action of condenser discharges with a tension exceeding 1-1½ or two times the threshold value, but no irreversible pathologic disturbance of heart action was noted.