EFFECT OF DURATION OF COMPLETE CIRCULATORY ARREST ON RECOVERY OF BODILY FUNCTIONS DURING RESUSCITATION WITH THE HEART – LUNG APPARATUS

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Investigations on dogs have shown that an artificial circulation with a volume velocity of 80-100 ml/kg body weight/min, produced by the heart – lung apparatus, even without artificial respiration and cardiac massage can permanently restore the vital functions of animals whose circulation was completely arrested as a result of lethal electric shock for a period of 10-12 min under superficial omnopon-nembutal anesthesia. With an increase in the duration of circulatory arrest to a mean value of 15.3±0.6 min, the rate of restoration of functions is slowed, and the outcome of resuscitation considerably worsened.

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The artificial circulation using an apparatus of the heart – lung type is a promising method of resuscitation [2-6, 9].

The main purpose of most investigations using the artificial circulation for resuscitation has been to study the possibility of resuscitating animals after death from various causes and to determine the maximal duration of clinical death [1, 3, 7, 8, 10, 11].

In some cases it has been found that dogs can be resuscitated with permanent restoration of their functions after long periods of clinical death. However, the great scatter in the periods of clinical death and the use of different types of artificial circulation during resuscitation have complicated the systematic analysis of the results.

At V. A. Negovskii's suggestion and in order to make a detailed examination of the effect of duration of complete circulatory arrest on restoration of bodily functions, the present investigation was undertaken in which the animals were resuscitated by means of a heart – lung apparatus, with a specified and constant volume velocity of the artificial circulation.

EXPERIMENTAL METHOD

Altogether 18 experiments were performed on adult dogs weighing from 6 to 16 kg. Under omnopon-nembutal anesthesia (omnopon 8 mg, nembutal 10 mg/kg body weight), a catheter was introduced through the right jugular vein into the orifice of the venae cavae in order to aspirate blood into the heart – lung apparatus, and a cannula was inserted into the central end of the right common carotid artery for injecting the blood. To prevent the blood from clotting, heparin "Richter" (300 i.u./kg) was injected into the animals. Circulatory arrest was produced in the animals by electric shock, causing the heart to fibrillate. For this purpose an alternating current (50 Hz, 127 V) was applied for 3 sec to the animal's forelimbs through electrodes implanted beneath the skin. Resuscitation was carried out with the heart – lung apparatus equipped with type ISL-2 venous and arterial roller pumps and a type AIK-RP64 foam-film oxygenator. The apparatus was filled with 900-1000 ml heparinized donor's blood obtained from large dogs anesthetized with

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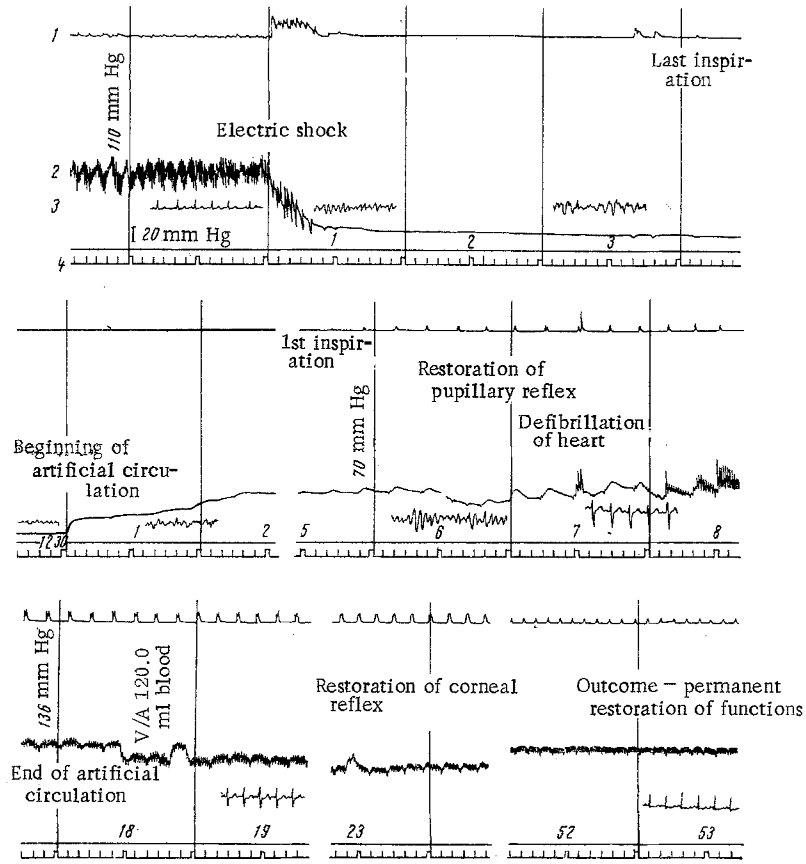

Fig. 1. Changes in respiration, arterial pressure, and ECG during death from lethal electric shock and resuscitation by means of an artificial circulation 12 min 30 sec after circulatory arrest. 1) Respiration; 2) arterial pressure; 3) ECG; 4) time marker (5 sec).

omnopon and nembutal. In the experiments of group 1 the artificial circulation with perfusion fluid heated to 30-32° was begun 10 min after electric shock, in those of group 2 after 11.4-12.5 min, and in those of group 3 after 14.5-18 min.

Oxygenation of the blood was carried out, checked by continuous-flow oxymetry, until the oxygenation saturation of the hemoglobin was 94-96%.

After a mean period of 10 min from the beginning of resuscitation, fibrillation of the heart was stopped by a 3000 V discharge from a pulse defibrillator, and the circulation continued to be assisted until the arterial and venous pressures became stabilized.

The arterial pressure in the left femoral artery, venous pressure in the inferior vena cava, pneumogram, ECG, and rectal temperature were recorded during the experiments. Observations were kept on changes in the pupillary and corneal reflexes and on the subsequent restoration of normal functions.

EXPERIMENTAL RESULTS

During the period of preparation for the experiment, lasting 2-2.5 h, the body temperature of the animals fell under the influence of anesthesia on the average from 38.5±0.2° in the initial state to 35.8±0.5° before electric shock ($P < 0.001$). By this time the anesthesia had become superficial. The animals responded to nociceptive stimulation by changes in the frequency and depth of respiration, and changes in the pulse rate and arterial pressure.

TABLE 1. Times of Recovery of Principal Vital Functions in Dogs Resuscitated by Extracorporeal Artificial Circulation after Cardiac Arrest for Different Periods

Group of expts.	No. of expts.	Statistical index	Duration of circulatory arrest (in min)	Time of recovery from beginning of resuscitation (in min) of respiration	of pupillary reflexes	of corneal reflexes	Mean arterial pressure during artificial circulation (in mm Hg)	Duration of artificial circulation (in min)
1st	6	$M \pm m$	10,0	3,6±1,2	8,6±1,0	13,7±1,2	87,5±7,4	21,1±0,5
2nd	6	$M \pm m$	12,2±0,2	4,7±0,3	10,9±0,6	20,2±0,6	80,2±6,7	21,2±1,3
		P_1	<0,001	<0,5	<0,1	<0,001		
3rd	6	$M \pm m$	15,3±0,6	6,4±0,8	11,9±1,0	25,3±2,5	80,5±7,8	30,2±6,8
		P_2	<0,001	<0,1	<0,05	<0,002		

Legend. P_1) Level of significance of difference between results of first and second groups of experiments; P_2) level of significance of difference between results of first and third groups of experiments.

Passage of the current through the region of the heart caused ventricular fibrillation to develop, with a sharp fall of arterial pressure. The terminal process followed the same pattern in all animals (Fig. 1). By the end of the first minute after electric shock, the animals' corneal reflexes disappeared, followed by the pupillary reflexes at the end of the second minute, and respiration stopped on the average after 3.2±0.1 min.

Connection of the heart – lung apparatus restored the circulation in the resuscitated animals, and as a result the functions extinguished during the terminal process began to recover (Fig. 1). The appearance of respiratory movements in the animals was followed by restoration of the pupillary and corneal reflexes. It is clear from Table 1 that this order of recovery was preserved in all groups. However, with an increase in the duration of circulatory arrest, the rate of recovery of functions was slowed. Whereas in the animals of group 2, compared with those of group 1, there was only a tendency for recovery of the pupillary reflexes to be retarded, while the corneal reflexes were restored at significantly later periods, in the animals of group 3 the recovery of respiration showed merely a tendency to be delayed, while recovery of the pupillary and corneal reflexes took place at significantly later times.

The venous pressure was regulated during the artificial circulation by changing the output of the venous pump, and it was maintained between 50 and 90 mm water.

After 8-10 min of artificial circulation the amplitude of the fibrillatory waves on the ECG of all animals was increased to 1.5 mV and their frequency to 10-12/sec, after which a single discharge of the defibrillator was sufficient to restore cardiac activity, confirming the presence of an effective blood supply to the heart.

A special feature of the animals in the experiments of group 3 was the presence of marked disturbances of atrio-ventricular and intraventricular conduction, and of polytopic extrasystoles. In one experiment defibrillation had to be repeated to restore cardiac activity, and in four experiments the duration of assistance with the artificial circulation had to be prolonged because of a fall of arterial pressure and an increase in venous pressure on disconnecting the heart – lung apparatus on the animals after the same time intervals as for the animals in the experiments of groups 1 and 2.

The duration of circulatory arrest was also reflected in the outcome of resuscitation. Of the six animals in the experiments of group 1, permanent recovery of functions took place in 5, compared with four animals in group 2 and one animal in group 3. The outcome of resuscitation of the animals in group 1 differed significantly from that of the animals in group 3 ($P < 0.05$).

One factor which evidently exerted a positive influence on the outcome of resuscitation was the lowering of the body temperature during circulatory arrest and subsequent artificial circulation on the average to 32.9±0.5°.

These experiments thus showed that an artificial circulation with a volume velocity of 80-100 ml/kg/min, produced by a heart – lung apparatus, is an effective method of resuscitation and enables permanent recovery of the vital functions to be obtained, without the use of artificial respiration or cardiac massage, in dogs subjected to complete circulatory arrest as a result of lethal electric shock for a period of 10-12 min under superficial omnopon-nembutal anesthesia. With an increase in the duration of circulatory arrest on the average to 15.3±0.6 min the rate of recovery of the vital functions was retarded and the outcome of resuscitation considerably worsened.

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