TIMES OF RECOVERY OF FUNCTION OF THE RESPIRATORY CENTER IN DOGS AFTER SUDDEN CARDIAC ARREST DURING RESUSCITATION WITH A FULL ARTIFICIAL CIRCULATION

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To assess the effectiveness of the complete artificial circulation method as used for resuscitation, electrical activity of the respiratory muscles was investigated in dogs in which the heart was arrested for 10 min by electric shock. The investigation showed that a complete artificial circulation, both with whole blood and with blood diluted with polyglucin or rheopolyglucin, can rapidly (within 3-4 min) restore the activity of the respiratory center and secure a return to normal, stable external respiration without the use of artificial ventilation of the lungs.

One criterion of the method of resuscitation is the time of recovery of the bulbar centers, especially the respiratory center [5]. The object of this investigation was to study electrical activity of the respiratory muscles so as to assess the effectiveness of the method using a complete artificial circulation.

The use of a complete artificial circulation in cases of ventricular asystole or fibrillation does away the need to use artificial ventilation of the lungs, because the blood is oxygenated entirely in the extracorporeal circulation. In view of the promising nature of this method of resuscitation [1, 3, 4, 6, 9-11] and possible limits to the obtaining of large volumes of donors' blood for flowing the artificial circulation apparatus, in the present investigation the artificial circulation was maintained both with whole blood and with blood diluted by plasma expanders.

EXPERIMENTAL METHOD

Altogether 15 experiments were carried out on dogs weighing from 6 to 14 kg. Under superficial anesthesia with omnopon and nembutal (8 and 10 mg/kg respectively), the right femoral artery was cannulated for infusion of blood from the artificial circulation apparatus (ACA). A catheter for withdrawing blood into the ACA was introduced through the right jugular vein as far as the orifice of the venae cavae. Cardiac arrest was produced by electric shock, leading to ventricular fibrillation. Resuscitation was carried out by means of an artificial circulation apparatus with a working filling capacity of 900 ml, using venous and arterial roller pumps and a foam-film oxygenator. The apparatus was filled with heparinized donors' blood or plasma expanders (polyglucin, rheopolyglucin), so that 30% of the volume in the ACA–resuscitated animal system was occupied by plasma expanders. The artificial circulation was maintained at a rate of 80-100 ml/kg/min. Before restoration of cardiac activity, noradrenalin solution (1 : 10,000) was injected at the rate of 0.1 ml/kg/min. Cardiac defibrillation by Gurvich's method [2] was carried out 10-12 min after the beginning of perfusion, and supplementary artificial circulation was continued until the accessory muscles of respiration were excluded from the action of respiration, corresponding to restoration of the required

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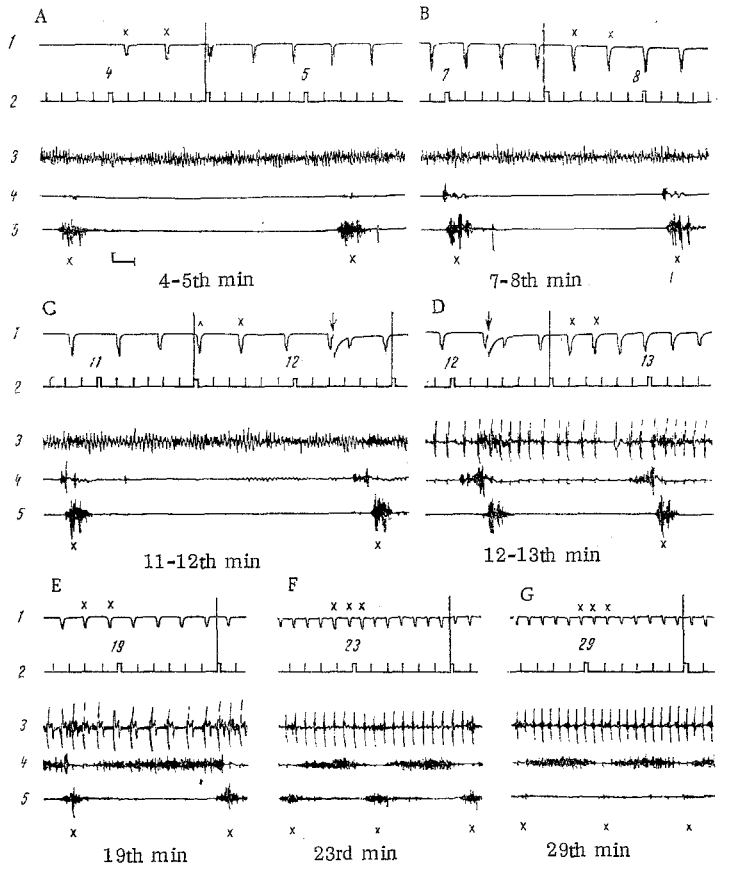

Fig. 1. Dynamics of electrical activity in inspiratory, expiratory, and accessory respiratory muscles in dog during resuscitation after sudden cardiac arrest for 10 min. From top to bottom, in all sections of curves (A-G): 1) pneumogram (arrow indicates time of defibrillation of heart); 2) time marker 5 sec, numbers denote time (in min) from beginning of resuscitation; 3) EMG of external intercostal muscle (ECG superposed on record: fibrillary waves before cardiac defibrillation, ECG of working heart thereafter); 4) EMG of external oblique abdominal muscle; 5) EMG of sterno-cephalic muscle. In all sections of curves, letter x denotes inspirations on pneumogram to which record on EMG corresponds. Scale of amplification 50 μV, time scales 1 sec. Minutes from beginning of resuscitation marked below segments of curves. Remainder of explanation in text.

values of pulmonary ventilation. The pneumogram, arterial pressure in the femoral artery, and venous pressure in the inferior vena cava were recorded on the drum of a kymograph; the EMG of the inspiratory (external intercostal), expiratory (external oblique abdominal muscles), and accessory respiratory muscles (sterno-cephalic) was recorded on an Alvar-15 electroencephalograph, with time constant 0.03-0.04 sec.

EXPERIMENTAL RESULTS

All the animals were divided into three groups (5 animals in each group): in group 1 whole blood was used for the artificial circulation, in group 2 blood diluted with polyglucin was used, and in group 3 blood diluted with rheopolyglucin.

In the animals of group 1, activity of the inspiratory muscles was restored on the average 3.0 ± 0.3 min from the beginning of resuscitation. Volleys were recorded on the EMG in the phase of inspiration in the inspiratory and accessory respiratory muscles (Fig. 1A). The original electrical activity in the ex-

piratory muscles, in the form of short volleys (0.2-0.3 sec) at the very beinning of inspiration, was restored 6.6 ± 2.8 min after the beginning of perfusion (Fig. 1B). As normal respiration was restored, activity appeared in the expiratory muscles at the end of the respiratory pause, which gradually became "shifted" toward the preceding inspiration, occupying the whole period of expiration and of the respiratory pause (Fig. 1C, E), and active expiration was restored after 17.2 ± 1.0 min. Normal respiration on the pneumogram was restored at this same time. The amplitude of fluctuations of electrical activity in the accessory respiratory muscles gradually diminished, and after an average of 22.2 ± 2.1 min, potentials in these muscles disappeared (Fig. 1E-G); the structure of the respiratory act, i.e., the relationships between activity of the various groups of respiratory muscles, returned to its original state.

In animals resuscitated with blood diluted with polyglucin (group 2), the times for recovery of activity in the inspiratory muscles, of initial activity in the expiratory muscles, and of active expiration (3.5 ± 0.3, 8.2 ± 0.8, and 19.2 ± 0.4 min, respectively) were indistinguishable from the recovery times of these indices in the animals of group 1. However, respiration as reflected by the pneumogram was restored to normal rather later in these animals, and after the accessory respiratory muscles had been excluded from participation in respiration (after 28.6 ± 4.5 min).

In the animals of group 3, resuscitated with blood diluted with rheopolyglucin, the times of recovery of the investigated indices of activity of the respiratory center were not appreciably different from those in the animals of group 2.

Hence, complete artificial circulation, both with whole blood and with blood diluted with plasma expanders, rapidly (within the first 3-4 min after the beginning of perfusion) restores the activity of the respiratory center after sudden circulatory arrest lasting 10 min, and without the use of artificial respiration. The subsequent use of a supplementary artificial circulation after cardiac defibrillation helped to restore the normal structure of the respiratory act still further during the first 30 min after the beginning of resuscitation.

Previous investigations [7, 8] showed that in vagotomized animals surviving clinical death from acute blood loss for 5 min and resuscitated by a combined method (intra-arterial infusion of the lost blood combined with artificial respiration, during which air was pumped into the lungs), respiration was restored at the same times as in dogs with intact vagus nerves. It was postulated on the basis of these results that the Hering–Breuer reflexes do not play a decisive role in the appearance of the first inspiration, and that the leading role in restoration of activity of the respiratory center after clinical death is played by the resumption of an adequate circulation of blood to the medulla. The results of the present investigation confirmed this hypothesis, for with the use of the complete artificial circulation as a method of resuscitation, activity of the respiratory center of the experimental animals was restored during the first 3-4 min from the beginning of perfusion, despite the fact that no artificial respiration was used during resuscitation.

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