ROLE OF ARTIFICIAL VENTILATION OF THE LUNGS IN MECHANISMS OF DEVELOPMENT OF GENERALIZED ELECTRICAL ACTIVITY OF LIMBIC ORIGIN AFTER RESUSCITATION

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UDC 616-036.882-085.835.32-07:
616.831.314-073.97

KEY WORDS: post-resuscitation state; electrocorticogram; activity of the respiratory center.

Previous experimental investigations on dogs showed that in the early stages of recovery after clinical death (the first 20-40 min) in some cases a generalized form of spindle-like activity with waves with frequency usually of between 6-7 and 13-15 Hz appears on the electrocorticogram (ECoG). A more detailed study of this type of α-like activity [1] revealed that, first, it always has maximal amplitude (up to 1-2 mV) in the region of the amygdaloid nucleus, rather lower in the hippocampus, and minimal amplitude in the cortex, and second, as a rule this type of activity appears only after relatively long periods of clinical death.

Considering the generalized character of the activity, its high amplitude, and its connection with parts of the brain influencing homeostasis, many autonomic functions, and electrogenesis of the brain itself, as well as the known dependence of its appearance on the severity of hypoxic brain damage, it was decided to study the conditions and mechanisms of its appearance in the ECoG in the period after resuscitation. It was shown that an increase in the volume of artificial ventilation of the lungs (AVL) used during resuscitation leads to disappearance or a reduction in the amplitude of this activity on the ECoG [1]. It must be remembered that forced ventilation of the lungs by means of a respirator leads to hypocapnia, an increase in pH of the blood, and depression of spontaneous external respiration [2]. Carbon dioxide is known to excite the respiratory center and brain-stem reticular formation, to alter the membrane potential of nerve cells [3, 4] and intercentral relations between brain structures [5], and to effect the global electrical activity of the brain [6, 7]. Accordingly, the task of investigating the mechanisms of development of synchronized activity of limbic origin was tackled by conducting a series of experiments in which one of the factors depending on the conditions of AVL, such as pH, pCO_2 of arterial blood (p_aCO_2), and spontaneous activity of the respiratory center, was changed.

EXPERIMENTAL METHOD

Experiments were carried out on 25 dogs weighing 7-16 kg. The animals were anesthetized (pantopon 4-6 mg/kg, ether) and steel electrodes (diameter 1.5 mm) were inserted epidurally, to record the ECoG, into the motor, parietal, and occipital regions and also into bone of the frontal sinus. Resuscitation after circulatory arrest (ventricular fibrillation) for 12 min was carried out by intra-arterial injection of 30-50 ml physiological saline with adrenalin (0.1 mg/kg), indirect cariac massage, electrical defibrillation of the heart, and AVL with oxygen using the RO-2 apparatus at a rate of 30-35 ml/kg per inspiration, with a respiration rate of 14-15/min. Animals of group 1 (11 experiments) were resuscitated by the method indicated above, with AVL for the first hour of the resuscitation period. To study the effect of the pH of the blood in the initial period of resuscitation on this activity, in five experiments on animals of group 2 an 8% solution of sodium bicarbonate was injected intravenously at the rate of 0.1 ml/min/kg body weight during the first 20 min of the postresuscitation period in order to abolish the acidosis. To prevent the development of hypocapnia in the first 20-30 min of the resuscitation, these animals were made to breathe a mixture of 8% CO_2 and 92% O_2 for 10 min after 5 min of resuscitation, after which AVL with 100% oxygen continued

Research Laboratory of General Reanimatology, Academy of Medical Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR V. A. Negovskii.) Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny, Vol. 89, No. 5, pp. 529-331, May, 1980. Original article submitted July 10, 1979.

 0007-4888/80/8905-0572$07.50

TABLE 1. pH, p_aCO_2, and BE of Arterial Blood and Unaided RMV (in ml/kg) of Dogs at Different Times of Resuscitation (M ± m)

Group of animals	20th minute of resuscitation				30th minute of resuscitation				40th minute of resuscitation	Frequency of appearance of α-like activity on ECoG, %
	pH	p_aCO_2, mm Hg	BE	RMV	pH	p_aCO_2, mm Hg	BE	RMV	RMV	
1	7,0±0,02	31,8±2,50	≈—22	115±31,2 †	7,08±0,03	25,5±2,20	≈—22	87±47,1*	56±29,8*	18
	n=5	*n*=5	*n*=5	*n*=5	*n*=4	*n*=4	*n*=4	*n*=4	*n*=4	*n*=11
2	7,29±0,08†	52,4±4,62 †	—4,5±5,58	857±108,0	7,29±0,06*	52,2±9,04 ‡	—5,0±4,6	807±147,3	585±63,6	80
	n=5	*n*=5	*n*=5	*n*=3	*n*=5	*n*=5	*n*=5	*n*=3	*n*=3	*n*=5
3	6,97±0,04	29,8±2,66	≈—22	387±38,9	7,08±0,05	34,0±3,76	≈—22	877±305,6	649±238,8	100
	n=4	*n*=4	*n*=4	*n*=6	*n*=4	*n*=4	*n*=4	*n*=3	*n*=4	*n*=9

* P < 0.05 for comparison with corresponding index for other two groups.
† P < 0.01 for comparison with corresponding index for other two groups.
‡ P < 0.05 for comparison with corresponding index of group 1.

until the 60th minute of the resuscitation period. In the animals of group 3 (9 experiments) hypocapnia combined with high activity of the respiratory center was created by early (12th-15th minute of resuscitation) discontinuation of AVL and changing the animals over to unaided breathing. In five experiments of each group the pH, pCO_2, and BE of the arterial blood were determined by Astrup's method.

EXPERIMENTAL RESULTS

In the animals of all three groups pH, pCO_2, and BE of the arterial blood did not differ significantly in the initial state and the time taken for spontaneous breathing and the corneal reflex to be restored also was identical. In the animals of group 1 a state of moderate hypocapnia (30 ± 2.28 mm Hg) developed by the 5th minute of the recovery period, as a result of the use of large volumes of AVL. The work of the respiratory center, assessed from the respiratory minute volume (RMV), in excess of the value established for the respirator, was weak at the 20th-40th minute of resuscitation (Table 1). In group 2, injection of 8% sodium bicarbonate solution into the animals raised their pH to 7.29 ± 0.08 at the 20th minute of the recovery period, against the background of moderate hypercapnia (Table 1). However, because of the hypercapnia, activity of external respiration was considerable, as was manifested by an increase in the values of the unaided RMV (Table 1). α-Like activity was recorded on the ECoG of 4 of 5 animals of this group. In dogs of group 3, despite the early discontinuation of AVL, hypocapnia took place on account of strengthening of spontaneous respiration (Table 1), and in all the experiments of this group bursts of regular waves of limbic origin were recorded on the ECoG in the recovery period.

The results of this investigation show that a significant decrease in acidosis (group 2) and the appearance of hypocapnia (group 3) do not themselves exclude the appearance of generalized α-like activity on the ECoG, if under these circumstances increased activity of the respiratory center occurs, due in the dogs of group 2 to hypercapnia and in those in group 3 to early discontinuation of AVL. In the dogs of group 1, in which spontaneous respiratory activity was weak, the frequency of appearance of regular waves of limbic origin on the ECoG, evaluated by the χ^2 criterion, was significantly lower than in the animals of groups 2 ($P < 0.05$) and 3 ($P < 0.01$). It can therefore be postulated that increased activity of the respiratory center was a factor leading to the appearance of this type of wave activity and its spread over the brain. The results are also evidence that carbon dioxide or pH affect this limbic activity through excitation of the respiratory center and the brain-stem reticular formation.

During restoration of the functions of the CNS after relatively severe hypoxic injury, a state of readiness for generation and spread of rhythmic electrical activity of limbic origin over the brain is evidently created in the brain structures. However, its appearance and intensity depend on certain additional conditions in the form of neurogenic activation of brain structures in the early postresuscitation state [5]. Increased activity of the respiratory center through irradiation of excitation into higher levels of the brain facilitates the appearance of generalized rhythmic waves of the ECoG.

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