STRUCTURAL ASPECTS OF CEREBRAL CORTICAL SYNAPTIC FUNCTION IN THE EARLY POSTRESUSCITATION PERIOD

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The integrative function of the brain under normal and pathological conditions is determined by the functional maturity and activity of synapses responsible for specific interneuronal exchange [1-3]. Functional maturity of the synapse is characterized by the degree of differentiation of a specialized part of the cytoskeleton of the synapse – the system of subsynaptic units (SSU), including dense projections (DP), the substance of the synaptic cleft, and the postsynaptic condensation, whereas functional activity is characterized by the intensity of secretion of quanta of neurotransmitter. The most reliable structural criterion of functional maturity of synapses is the formation of discrete DP of the presynaptic network and the asymmetrical organization of SSU, whereas for functional activity it is the positive curvature of the plane of contact in the region of SSU. Close direct correlation exists between functional maturity and activity of synapses [5, 6].

Despite many investigations of the morphology of interneuronal connections under normal conditions and during various procedures [5, 9], structural aspects of synaptic functional activity during restoration of interneuronal relations in the cerebral cortex in the early postresuscitation periods have received little study.

The aim of this investigation was to study the morphology and function of interneuronal contacts in layer I of the cerebral cortex in the early postresuscitation period.

EXPERIMENTAL METHOD

Experiments were carried out on 18 male albino rats weighing 190-210 g. The systemic circulation was arrested by lethal mechanical asphyxia (6 min) under ether anesthesia. The animals were resuscitated by indirect cardiac massage and artificial ventilation of the lungs. Material (sensomotor cortex) was taken at the end of clinical death and 5, 30, and 90 min and 6 h after resuscitation. The method of processing the tissue was published previously [4]. The density of synapses with a distinct cleft line was counted on electron micrographs under a magnification of 30,000. Depending on their shape, all junctions were divided into flat, concave (positive curvature), and convex (negative curvature) [5], and on the basis of the organization of their SSU, into asymmetrical (functionally mature) and symmetrical (functionally immature) [6].

EXPERIMENTAL RESULTS

All functionally immature synapses of the molecular layer of the neocortex of the control and experimental animals were flat, whereas functionally mature synapses were flat, concave, and convex (Table 1).

Flat functionally mature contacts predominated in the neuropil of the control animals (Table 1; Fig. 1), closely followed by the number of flat immature and concave mature synapses; the lowest density was characteristic of convex synapses. Thus in layer I of the neocortex of the control animals only 27.6% of all synapses were in an active functional state. The remaining synapses were either a reserve (immature flat contacts) or they were in the state of preparation for function, namely secretion of transmitter (flat and convex mature contacts).

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TABLE 1. Density of Synapses with Different Organization of the System of Subsynaptic Units in the Molecular Layer of the Cerebral Cortex in the Postresuscitation Period (M ± m)

Experiment	Number of synapses in 100 μm² of neuropil						
	asymmetrical			symmetrical			total content
	concave	flat	convex	concave	flat	convex	
Control	6,8±0,2	8,4±0,6	3,7±0,1	0	5,7±0,7	0	24,6±1,0
Clinical death	2,8±0,2*	7,2±0,7	7,2±0,5*	0	5,8±1,0	0	23,0±1,9
Recovery period							
5 min	4,1±0,2*	8,9±0,5	5,0±0,4*	0	5,1±0,8	0	23,1±2,4
30 min	4,0±0,3*	9,1±0,6	3,5±0,1	0	5,7±0,7	0	22,3±2,1
90 min	3,9±0,1*	4,5±0,3*	2,5±0,2*	0	2,9±1,3*	0	13,8±0,5*
6 h	6,4±0,4	3,0±0,1*	2,4±0,2*	0	2,7±0,4*	0	14,5±0,6*

Legend. *p < 0.

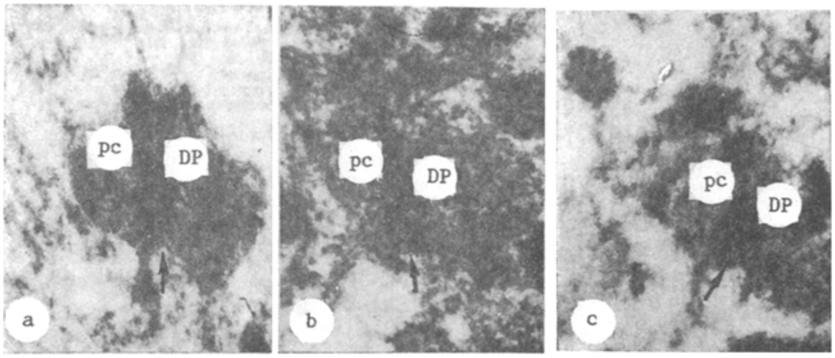

Fig. 1. Organization of system of subsynaptic units of interneuronal synapses differing in curvature of the plane of contact in molecular layer of cerebral cortex in postresuscitation periods. a) Flat (control), b) convex (30 min), c) concave (6 h) synapses; DP dense projections. arrows indicate substance of synaptic cleft. pc) Postsynaptic condensation. ×35,000. Stained with PTA.

At the end of clinical death the density of concave synapses was reduced by 2.4 times, as a result of which their relative number in the synaptic pool of the cortex was reduced to 12.2% (Table 1; Fig. 2). The number of convex synapses, meanwhile, was increased whereas the density of mature and immature flat synapses was unchanged.

After 5 and 30 min of recirculation the density of concave synapses was increased compared with the previous period, whereas that of convex (Fig. 1b) synapses gradually fell to the control value. The density of all flat synapses remained at the control level (Table 1).

The density of flat (mature and immature) and convex synapses decreased toward the 90th minute whereas the density of concave synapses was unchanged. The relative number of concave synapses returned to the control level, whereas that of flat and convex synapses was unchanged compared with the previous period (Fig. 2).

The density of concave synapses 6 h after resuscitation (Fig. 1c) was restored to the control value, and their relative number increased to 44.1%, which exceed the control value. The density of mature flat synapses fell considerably (Table 1; Fig. 2).

Thus a regular time course of change in the number of synapses with different functional activity was discovered in the molecular layer of the sensomotor cortex during clinical death and the early postresuscitation period. At the time of asphyxia, as a result of transformation of concave synapses into convex, there was already a sharp decline in the number of functioning synapses. Intensive transformation of concave synapses into convex was probably due to reversible disturbance of processes of regulation of the conformational

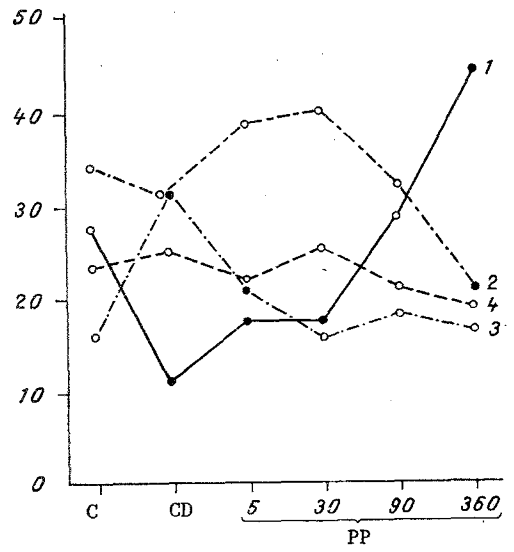

Fig. 2. Relative numbers of concave and flat interneuronal junctions in layer I of the cerebral cortex in the postresuscitation period. Abscissa, time of investigation (in min), C) control, CD) clinical death, PP) postresuscitation period; ordinate, number (in %) of concave (1), flat (2), convex (3), and asymmetrical and flat symmetrical (4) synapses. Filled circles $p < 0.05$, empty circles $p > 0.05$.

state of the microfilaments of SSU as a result of developing autointoxication of the brain tissues during the period of systemic circulatory arrest [4]. Correlation between the conformational state of microfilaments and the character of curvature of the plane of contact has been demonstrated in a number of studies [7, 8].

Partial restoration of the relative number of concave and convex synapses after 5 and 30 min of recirculation was evidently due to the reverse transformation of a fraction of the convex synapses into concave, while the number of flat synapses remained stable, and was evidently the result of restoration of mechanisms of regulation of the conformational state of the microfilaments of SSU of some synapses at this period. After 90 min the relative number of actively functioning synapses increased to the control value, and after 6 h it exceeded it. In the early postresuscitation period, the formation of new synapses was not found [4]. Evidence in support of this also is given by data on the stable relative number of flat, functionally immature synapses in the molecular layer of the cortex throughout the period of recirculation studied. Consequently, in the early postresuscitation period, intensive utilization of residual synapses takes place in order to maintain the integrative function of the cerebral cortex. This allows partial compensation of the marked deficit of the density of interneuronal synapses developing in the neocortex toward the 90th minute after resuscitation.

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