# ELECTROPHYSIOLOGICAL ANALYSIS OF THE FUNCTIONAL STATE OF SOME STRUCTURES OF THE LIMBIC SYSTEM DURING EXPERIMENTAL TRAUMATIC SHOCK

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KEY WORDS: traumatic shock; hippocampus; amygdala; seizure reaction.

There is exceedingly little information [6, 9] in the literature on the character of response of the limbic structures of the brain to trauma. However, many workers [1-4, 8, 11, 12, 14] have demonstrated the very important role of the hippocampus and amygdala, key structures of the limbic system, in the afferent synthesis of polymodal discharges, the regulation of autonomic functions, and integrative activity of the brain as a whole. The diversity of both afferent and efferent connections of these structures with other brain formations [2-4, 7, 11, 15] suggests that they play a direct part in the mechanisms of formation of shock.

The object of this investigation was to study the functional state of the hippocampus and amygdala by electrophysiological analysis of their direct excitability in the course of traumatic shock.

## EXPERIMENTAL METHOD

Acute experiments were conducted on 29 adult rabbits weighing 2.5-4.0 kg. The animals were prepared for the experiments under superficial pentobarbital anesthesia (20-25 mg/kg). Tripolar constantan electrodes (diameter of tip 150 μ, interelectrode distance 0.3 mm) were implanted into the dorsal hippocampus and basolateral amygdala and single steel electrodes (diameter of tip 100 μ) were implanted into the sensomotor, parietal, and visual areas of the cortex in accordance with coordinates from an atlas for cats [13] in a type MV-4101 stereotaxic apparatus. The electrodes were fixed to the skull with acrylic glue. Derivation was unipolar, with the reference electrode located in the frontal bones. The EEG, the ECG in standard lead II, and respiratory movements were all recorded on a Medicor eight-channel encephalograph. Electroencephalographic thresholds of the seizure reaction (TSR) and the duration of the epidischarges (DE) evoked by direct electrical stimulation of the test structures by square pulses (frequency 60-100 Hz, amplitude 1-15 V, duration 0.1-0.5 msec) for 5-10 sec

TABLE 1. Changes in BP (in mm Hg), TSR (in V), and DE (in sec) in the Dorsal Hippocampus (Series I) and Basolateral Amygdala (Series II) during Traumatic Shock (M ± m)

| Stages of shock after trauma, min | Series I (n = 14) | | | Series II (n = 15) | | |
|---|---|---|---|---|---|---|
| | BP | TSR | DE | BP | TSR | DE |
| Initial state | 130,4±4,1 | 1,61±0,11 | 26,8±1,5 | 134,0±3,9 | 1,75±0,14 | 24,0±1,3 |
| 1 | 55,7±1,6* | 2,46±0,22* | 22,3±1,5* | 55,0±1,1* | 2,25±0,19* | 20,9±0,9* |
| 20 | 74,6±4,6† | 3,1±0,3† | 19,4±2,4* | 80,3±3,8* | 2,25±0,24* | 17,9±1,7* |
| 40 | 68,8±3,9* | 3,6±0,3* | 16,2±2,2* | 71,4±4,3* | 2,52±0,28* | 14,0±1,6† |
| 60 | 61,0±5,1* | 4,63±0,52† | 11,3±1,8† | 63,1±4,5 † | 3,05±0,33 † | 10,9±1,4† |
| 90 | 52,5±2,8† | 5,92±0,47† | 7,2±1,3† | 57,2±5,2* | 3,75±0,37 † | 7,1±0,5† |
| 120 | 40,0±4,0 † | 7,38±0,43† | 4,0±0,6 † | 45,0±4,2* | 6,5±0,43 † | 4,0±0,5† |
| 150 | 38,0±3,7* | 8,5±0,6 † | 2,7±0,3* | 37,5±2,8* | 8,25±0,32 † | 2,0±0,4* |
| Mean duration of survival, min | 128,1±22,9 | | | 142,0±18,7 | | |

*P < 0.05-0.001 compared with initial state.
†P < 0.05-0.001 compared with initial state and previous stage of investigation.

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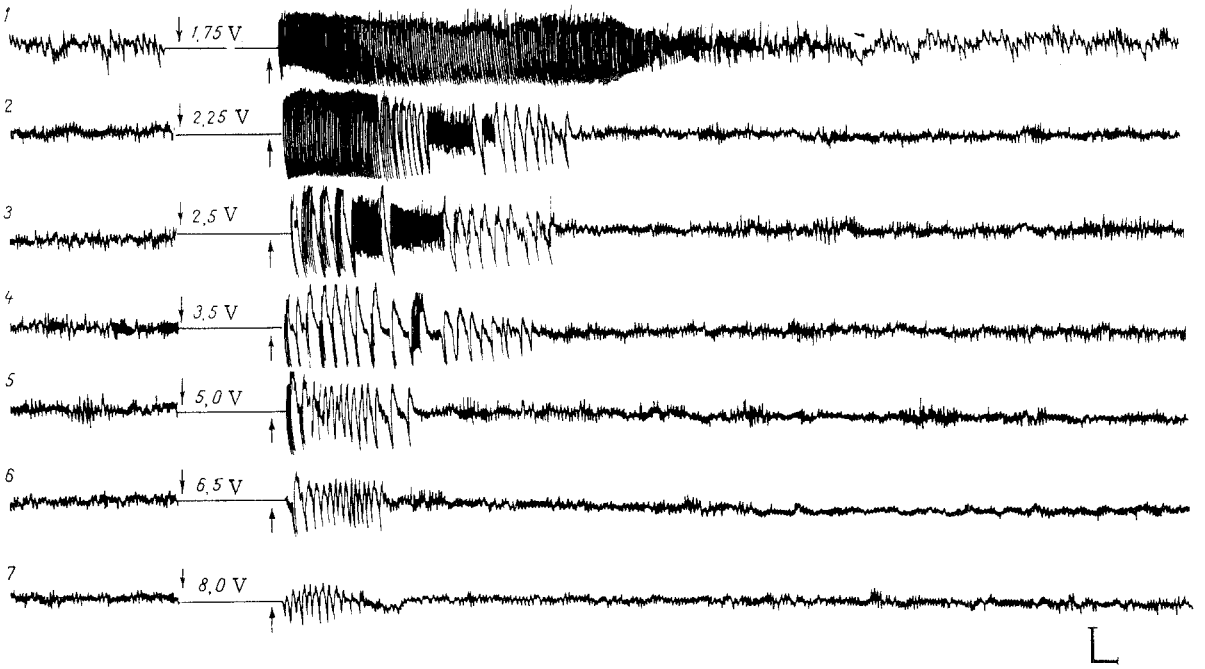


Fig. 1. Changes in TSR and DE in dorsal hippocampus during traumatic shock. 1) Initial state (BP 115 mm Hg); 2-7) 1, 20, 40, 60, 90, and 120 min after trauma (BP 60, 85, 75, 70, 55, and 45 mm Hg). Arrows indicate beginning and end of stimulation; numbers between arrows give TSR (in V). Parameters of electrical stimulation: 60 Hz, 0.1 msec, duration 5 sec. Calibration: 200 μV, 1 sec. The animal died at the 235th minute.

were used as criterion of the functional state of the hippocampus and amygdala. For these purposes a two-channel ESU-2 electronic stimulator with radiofrequency attachments was used. Shock was induced by Cannon's method with monitoring of the blood pressure (BP) by means of a mercury manometer in one of the common carotid arteries. (The animals had practically recovered from anesthesia when trauma was inflicted.) The numerical results were subjected to statistical analysis by the nonparametric Wilcoxon–Mann–Whitney test on an Odra computer.

## EXPERIMENTAL RESULTS

Electrophysiological analysis of evoked seizure activity in the hippocampus and amygdala in the original state showed no significant quantitative differences in its parameters. Both structures were characterized by a relatively low (1-2 V) TSR, and DE was between 10 and 50 sec. The character of the seizure discharges did not remain strictly stereotyped but depended primarily on the parameters of the stimulating current. However, paroxysmal activity during stimulation of the basolateral amygdala consisted as a rule of a continuous hypersynchronous discharge, terminating with depression of electrical activity. At the end of the epidischarge evoked by stimulation of the dorsal hippocampus, however, periods of high-amplitude (300-400 μV). The frequency of the seizure discharges in the structures tested varied from 5-12 to 15-30 Hz. Substantial changes in the parameters of evoked seizure activity in the central formations of the limbic system were discovered during the course of shock. The length of survival of the animals after trauma varied from 35 to 300 min, but in most experiments the course of the shock was prolonged (2.5-4 h) and phasic. The averaged results of the two series of experiments are given in Table 1.

During the very first minutes of shock, when BP had fallen to 50-60 mm Hg, a significant increase in TSR by 0.25-2.0 V and shortening of DE by 2-10 sec were observed in both test structures. Later, despite relative stabilization of BP at the level of 75-85 mm Hg (20th-40th minutes of shock) inhibition of evoked paroxysmal activity continued in most experiments, especially in the hippocampus (Fig. 1). In some experiments (when the course of shock was prolonged) stabilization of TSR or even a tendency for their recovery were observed in this period (more often in the amygdala), but the duration of the after-discharges under these circumstances was significantly reduced (Fig. 2). Starting from the 60th minute of

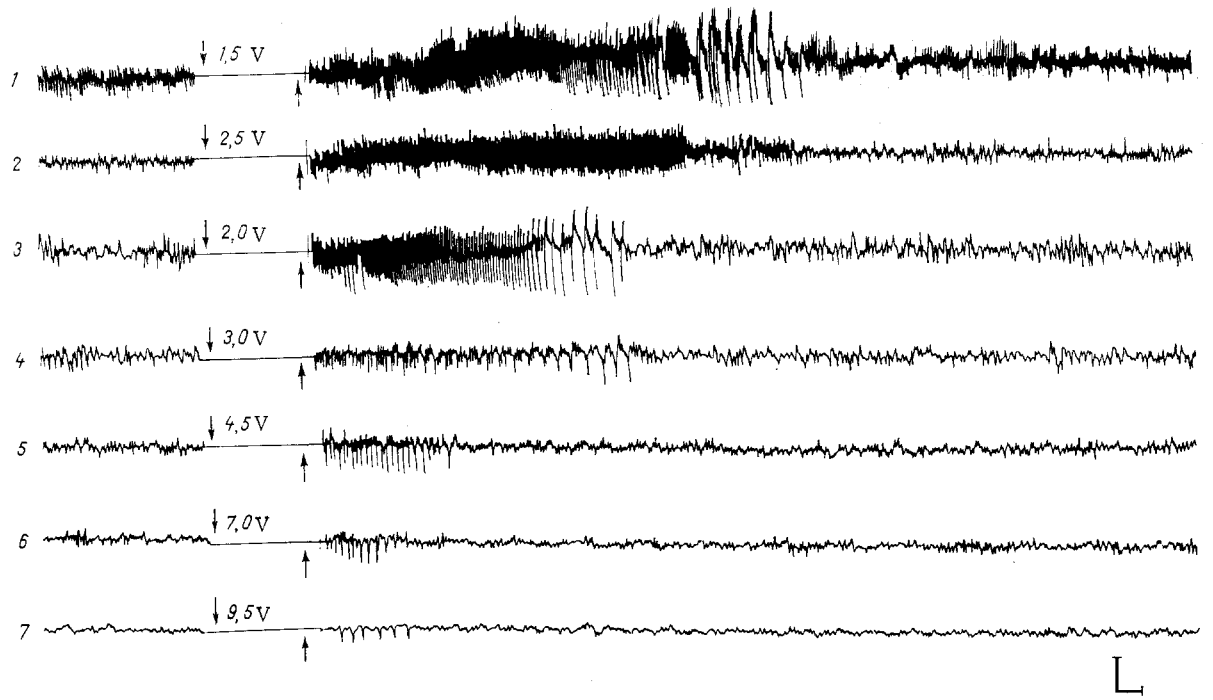


Fig. 2. Changes in TSR and DE in basolateral amygdala during traumatic shock. 1) Initial state (BP 135 mm Hg); 2-7) 1, 20, 40, 60, 90, and 120 min, respectively after trauma (BP 55, 85, 75, 65, 50, and 40 mm Hg). Remainder of legend as to Fig. 1. The animal died at the 195th minute.

shock, in the period of a second fall of BP, TSR increased sharply both in the hippocampus and in the amygdala, and in the late stages of shock (120th-150th minutes, BP 50-40 mm Hg) they were 6-8 times higher than initially. Moreover, in animals with a rapid course of shock (30-90 min after trauma) ability to generate an electroconvulsive response disappeared after the 20th-40th minutes, against the background of sharp depression of global bioelectrical activity of the limbic structures tested, possible evidence of marked inhibition of their functional state. If the course of shock was prolonged, as the hypotension deepened, high-amplitude (300-400 μV) and high-frequency (15-30 Hz) hypersynchronized waves were replaced by low-amplitude (150-100 μV) and low-frequency (3-5 Hz) paroxysmal discharges up to 1-2 sec in duration (Figs. 1 and 2). In addition, whereas in the initial state threshold stimulation of the limbic structures was often accompanied by generalization of seizure discharges in other parts of the brain (more especially the parietal cortex of the ipsilateral hemisphere and symmetrical zones of contralateral structures of the limbic system) and was manifested as a general behavioral seizure reaction, during the immediate post-traumatic period generalization of seizure activity was severely restricted and, later, these electrophysiological and viscerosomatic manifestations disappeared completely and the focal electroconvulsive responses were reduced (Fig. 3).

The experimental results thus indicate not only marked inhibition of neuron function in the hippocampus and amygdala, but also a sharp disturbance of the intra- and intercentral connections of these structures with other parts of the brain.

Considering data in the literature [1-4, 7, 8, 12, 14, 15] on the broad participation of the hippocampus and amygdaloid complex in the modulation of multisensory information in the afferent synthesis stage and in the regulation of vitally important autonomic functions, it seems evident that inhibition of their functional activity as early as from the first few minutes after severe mechanical trauma, must make an important contribution to the disintegration of nervous activity during the formation of traumatic shock.

Meanwhile, on the basis of existing views regarding the predominantly inhibitory influences of these formations (together with the cerebral cortex) on the diencephalic activating structures of the brain [2, 7, 8, 11, 12], it can be suggested that early inhibition of func-

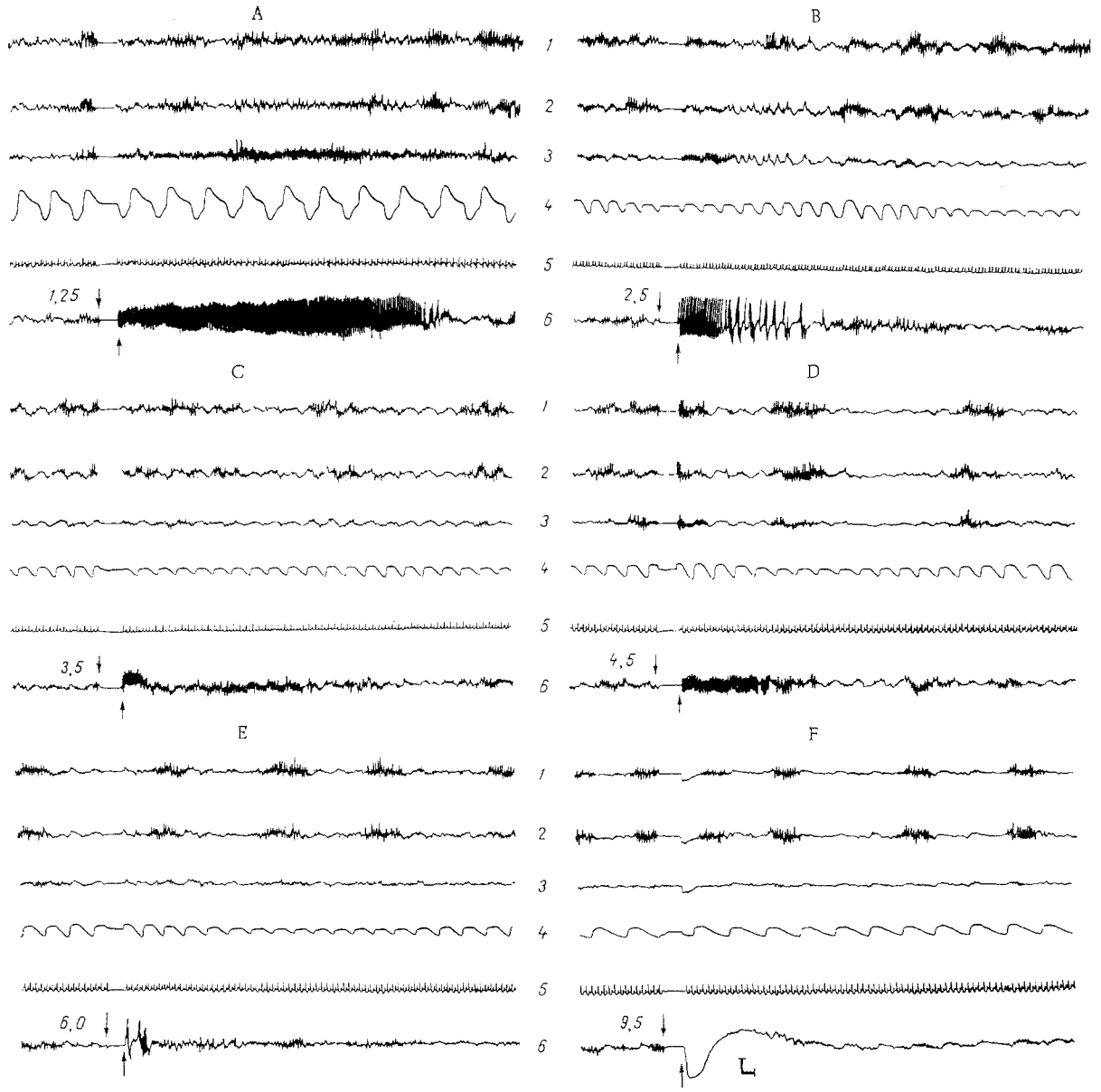


Fig. 3. Changes in character of evoked seizure activity in some brain structures during electrical stimulation of the amygdala. 1-3) Sensomotor, visual, and parietal areas of cortex respectively; 4) respiratory movements; 5) ECG; 6) basolateral amygdala. A) Initial state (BP 140 mm Hg); B-F) 1, 20, 40, 60, and 90 min, respectively, after trauma (BP 60, 85, 75, 65, and 50 mm Hg). Calibration: 100 μV, 1 sec. The animal died at the 165th minute. Remainder of legend as to Fig. 1.

tional activity of the key limbic structures during the development of traumatic shock liberates the activating systems of the brain from their inhibitory control. This readjustment of intra- and intercentral relationships can be regarded as an important pathogenetic component of the compensatory and adaptive reactions of the body to shock-inducing trauma [10], leading essentially to the formation of the typical phasic course of shock. Such a response of the body may have a biologically useful role in exposure to all kinds of extremal factors [5], and it may ultimately make possible the emergency regulation of vitally important functions of the body under critical conditions.

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# POSTURAL CHANGES IN HEALTHY RATS AFTER INTRACRANIAL INJECTION OF BRAIN EXTRACTS FROM ANIMALS WITH EXPERIMENTAL VESTIBULOPATHY

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It has been suggested that brain activity under normal and pathological conditions is accompanied by the production of substances capable of inducing similar states in animals not exposed to that particular experimental situation [2-4, 9]. After injury to the cerebellum, substances acting on the spinal cord of healthy animals in the same way as suprasegmental structures in this form of pathology have been discovered in brain extracts [2, 3, 7]. In the present investigation the possibility of reproducing a pathological state in healthy recipients by means of extracts of injured brain was studied on a model of experimental vestibulopathy [5]. A special feature of the investigations was that unilateral injury to the vestibular system was confined to Deiters' nucleus, and in some cases hyperactivation was induced, whereas in others the nucleus was destroyed, and these procedures were reflected in clinically different types of vestibulopathy. An evident advantage of this experimental model, and one that is very important for evaluation of the effects, is that the vestibular rotation syndrome is readily observable.*

## EXPERIMENTAL METHOD

Albino rats weighing 150-200 g were used. Prolonged hyperactivity of the lateral vestibular nucleus (LVN) was induced with the aid of tetanus toxin (microinjection of 2 MLD in a volume of 0.04 µl). LVN was destroyed by electrocoagulation (current 10 mA, duration 15 sec). On the side of destruction of LVN the rats' neck and trunk were flexed and the limbs were flexed and abducted. On the other side the two limbs were extended. In rats with hyperactivity in LVN no changes of posture were present at rest. All animals developed rotation relative to the long axis of the body toward the nucleus with lower activity, i.e., to-

*The preliminary results of this investigation were published previously [4, 6].

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