AN ELECTROPHYSIOLOGICAL STUDY OF DIFFERENT PARTS OF THE NERVOUS SYSTEM IN SHOCK

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It has been shown both clinically and experimentally that there are many different causes of shock, and these may include operative measures, damage to the internal organs or limbs, injection of chemical substances, the action of ionizing radiation, or electrical nervous stimulation.

There are two phases – the excitatory and the depressive. They are shown by an initial increase in autonomic and somatic reactions which is followed by a period of decreased reactivity.

In the pathogenesis of shock, three factors of fundamental importance must be considered, and these are traumatic toxemia, loss of blood plasma, and pain.

Most Russian clinicians and physiologists [1-6, 8, 11-13, 15, 16] consider that shock is fundamentally a reflex mechanism resulting from a parabiotic condition of the central nervous system.

It is well known that extremely intense painful stimulation, such as occurs in damage to the limbs or internal organs, even when there is no great blood loss, may cause grave disorders in the central nervous system. Shock can also be caused by electrical stimulation of afferent nerves when there is no direct damage to the tissue and no production of toxic substances.

It was possible to follow the electrophysiological changes at different levels in the nervous system during the development of shock, and to form a concept of the primary cause of the resulting trophic disturbances.

METHOD

Shock was induced by painful stimulation applied to the intero- and exteroceptors, or by exposure to ionizing radiation.

The experiments were carried out on unanesthetized rabbits; unipolar and bipolar platinum electrodes were inserted into the cortex, hypothalamus, cerebellum, and preganglionic cervical sympathetic roots 1-2 weeks before inducing shock. In this way it was possible to make continuous observations before stimulation and to make continuous electrical recordings of the activity of these parts. In acute preparations, before applying the stimulation, electrodes were also placed in the superior cervical sympathetic ganglion and vagus.

Simultaneous recording of the potentials in the different parts of the nervous system was made using a six-channel oscillograph.

In one set of experiments, recordings of the electrical activity at the different levels in the nervous system were made during painful stimulation of the internal organs or limbs, done by pulling sharply on the mesentery of the small intestine, or by pressure applied to the limbs.

In another set of experiments, the changes were recorded during the exposure to ionizing radiation. Radiation was applied once to the surface of the belly (the head being screened), under the following conditions: voltage

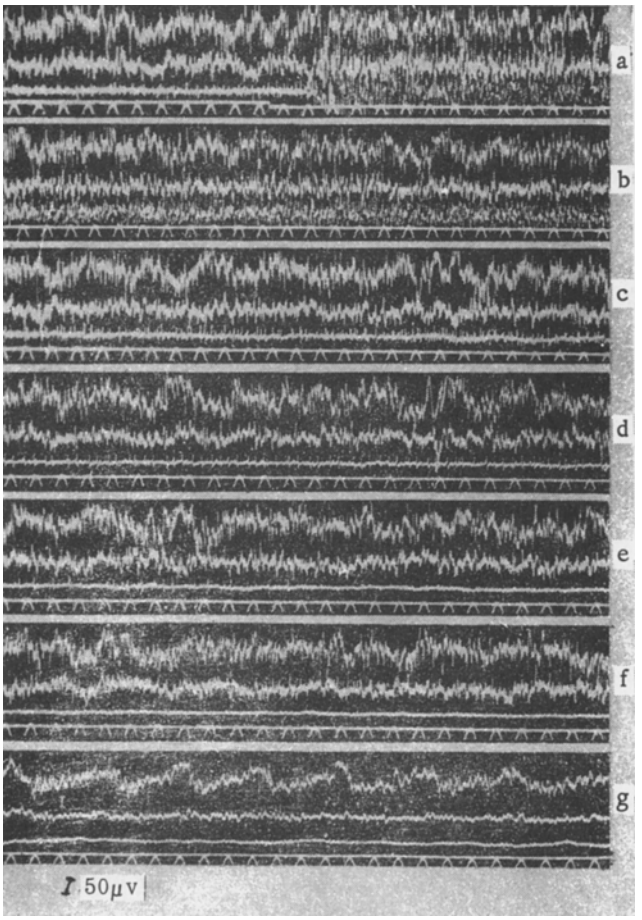

Fig. 1. Changes in electrical potentials recorded from different parts of the nervous system during continuous stimulation of the intestine. a) initial level of "spontaneous" activity, and beginning of stimulation; b, c, d, e, f, g, — ditto during stimulation. Curves, from above downwards: potentials from cortex, hypothalamus, superior cervical sympathetic ganglion; stimulus marker; time marker (0.1 second).

178 kv, current 10 ma, focusing distance 60 cm, filter 0.5 mm Cu and 1 mm Al, dose rate 12.2 r per minute, dose in air 9.5 r, and radiation dose 1200 r.

RESULTS

It has been shown experimentally that immediately after application of a painful stimulation, there is a burst of excitation which spreads reflexly to all parts of the nervous system (Fig. 1, a, b, c). However, owing to the different rates of propagation of the nervous impulses at the different levels and in the different parts of the nervous system, the period of abnormally high excitation is immediately followed by one of inhibition [17].

The inhibition develops first in the ganglia of the sympathetic system where the least labile synaptic connections in the descending reflex pathway are found. This effect is shown by a disturbance in the transmission of impulses through the superior cervical sympathetic ganglion occurring in the first 10-15 minutes (Fig. 1, d, e).

After the activity of the peripheral part of the sympathetic system has been reduced, as the painful stimulation continues there is a reduction also in the activity of the hypothalamic autonomic centers. This is shown

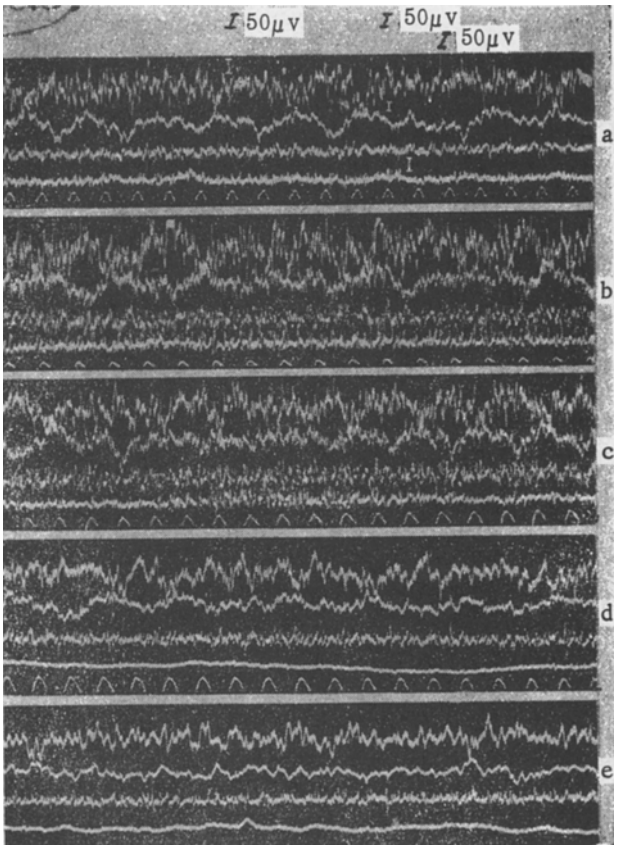

Fig. 2. Change in potentials recorded from different parts of the nervous system during exposure to ionizing radiation. a) background level; b, c) after exposure to dose of 400 r; d, e) after a dose of 1200 r. Curves, from above downwards: potentials from cortex, hypothalamus, cerebellum, superior cervical sympathetic ganglion; time marker – (0.1 second).

by a greater reduction in the electrical potentials of the hypothalamic area in comparsion with those of the cortex, where the potentials are still increased under the influence of impulses arriving from the periphery (Fig. 1, f). However, as the potentials in the hypothalamic area continue to fall, those in the cortex become reduced as well (Fig. 1, g). This last change is no doubt due to disturbance of the blood supply to the brain and changes in the oxidation-reduction processes associated with sympathetic failure. Simultaneous recording of the blood pressure in the common carotid artery and respiration showed that immediately after failure of synaptic transmission in the sympathetic ganglia, there is a fall in blood pressure and a sharp change in respiration rate.

The sequence of changes established for the different levels of the nervous system in traumatic shock also holds for shock caused by other kinds of stimuli, including large doses of ionizing radiation.

With large radiation doses, it was also found that when the animal was irradiated with a dose of 800-1200 r, immediately after the first increase in the potentials recorded (with dose of 100-200 r), marked changes in excitability occurred in the different parts of the nervous system. First there was an inhibition in the sympathetic ganglia, i.e., in the peripheral portion of the sympathetic nervous system (Fig. 2, c, d). Inhibition then occurred in the hypothalamus and cerebellum. During this period there was a gradual reduction in the potentials recorded from the cortex (Fig. 2, d, e).

Normally, central nervous trophic control is mediated via a complex sequence of nervous and endocrine mechanisms. The flow of impulses from the exteroceptors passes to the central nervous system and reaches the cells of the cortex where the impulses become added to those from the interoceptors. In response to stimulation of

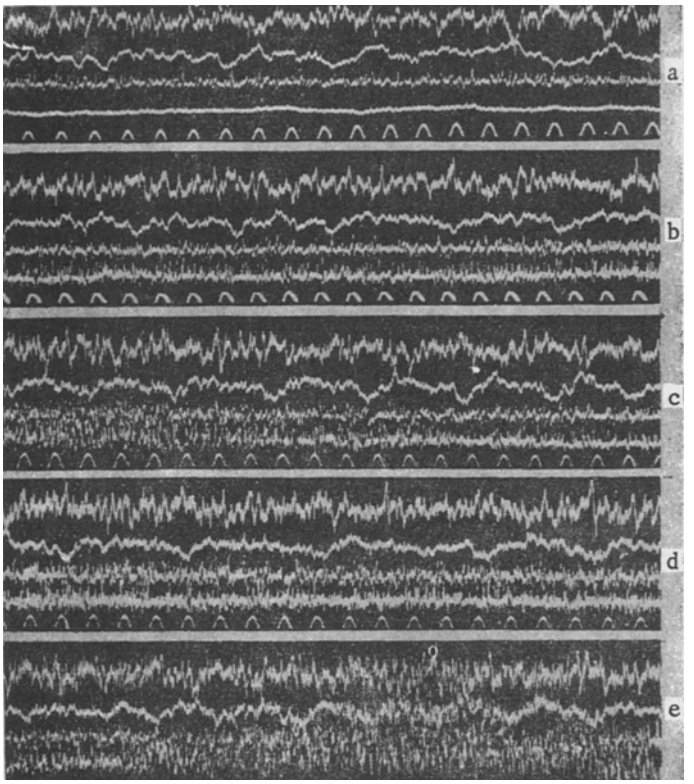

Fig. 3. Restoration of electrical activity in different parts of the nervous system by the mixture of drugs described in the text and ephedrine which remove the effect of the previously administered 1200 r dose of ionizing radiation. a) electrical activity before injecting the drugs, b) after injection; c, d, e) after an additional injection of ephedrine. Curves, from above downwards: potentials from cerebral cortex, hypothalamus, cerebellum, and superior cervical sympathetic ganglion; time marker (0.1 second).

cortical cells, impulses leave the cortex and pass peripherally to the effector organs. Nervous structures at lower levels now become reflexly excited. Impulses forming part of the reflex are transmitted along sympathetic neurones, and are concerned in the regulation of vital processes, including mobilization of liver glycogen, increasing the working capacity of muscles, redistribution of blood, maintenance of blood pressure, in thermoregulation, and in hormonal control [9, 10, 14]. When extremely strong stimuli are applied, the excessive excitation which is followed by parabiotic inhibition in the sympathetic nervous system stops the transmission of impulses from the center to the periphery.

The cessation of flow of impulses through the sympathetic system brings to an end the trophic control exerted by the central nervous system which normally brings about the mobilization of carbohydrate reserves and so maintains the energy balance, particularly when it is disturbed by extraneous stimuli. Failure of sympathetic transmission represents the onset of shock, which is followed by the characteristic autonomic and somatic reactions.

Further evidence that the shock is initiated by sympathetic disturbance is afforded by the fact that trophic changes due to shock, either in the excitatory or depressive phases, has been shown by many special investigations [3, 15] to be directly comparable with the changes which have frequently been encountered in physiological experiments on sympathectomy.

In shock, a kind of functional sympathectomy occurs through the complete cessation of impulses in the peripheral or ganglionic portion of the sympathetic system and a gradual reduction in the number of impulses in

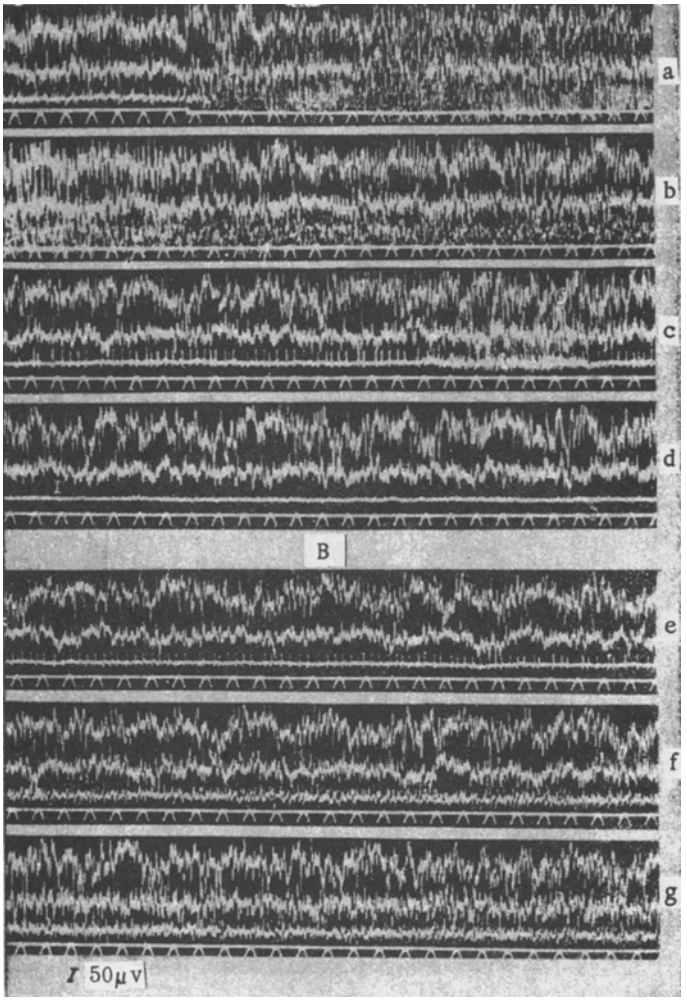

Fig. 4. Electrical activity of different parts of the nervous system during stimulation of intestinal receptors. A) before giving drugs: a) background level of electrical activity and beginning of stimulation (shown by drop in bottom line); b, c, d) continuous stimulation; B) after administering mixture of drugs (1 ml/kg); e, f, g) during continuous stimulation. Curves, from above downwards: potentials from cerebral cortex, hypothalamus, and superior cervical sympathetic ganglion. Time marker (0.1 second).

in the central parts of the system, i.e. , in the hypothalamus and cerebellum. Besides the metabolic disturbances, there is also an inhibition of the cells of the cerebral cortex which are under the direct influence of afferent impulses and which require energy to expend, which must be made good by the supply of appropriate material, in order to carry out reflex transmission to other parts of the nervous system. When the sympathetic system fails, this process is no longer possible and the excitatory condition of the cells of the central nervous system is replaced by one of inhibition.

Because the fundamental phenomenon underlying the condition of shock is the cessation of sympathetic synaptic transmission, we thought it advantageous to combat shock by using a complex preparation prepared by us for intravenous injection and consisting of a number of substances which stimulate the oxidation-reduction processes in nerve cells; these substances are thiamine, riboflavin, nicotinic acid, ascorbic acid, calcium chloride, alcohol, and glucose.

In this way we hoped to increase the lability of nerve cells in the lower levels of the nervous system and so to equalize the rate of transmission of impulses in the different parts of the nervous system. For this purpose, besides administering the mixture of drugs just described in order to stimulate the autonomic centers we also used ephedrine, given either intramuscularly or intravenously.

It was found that injection of 1-2 ml per kg weight of our preparation into rabbits in the inhibitory condition caused a restoration of the transmission of impulses. This took place independently of whether the parabiotic inhibition was induced by the action of extreme painful stimulation or by ionizing radiation. Figure 3 represents the direct continuation of Fig. 2, and it can be seen that after irradiation with 1200 r there was a complete blockage of impulses in the sympathetic ganglia and a marked reduction in hypothalamic and cerebellar potentials; intravenous injection of our preparation caused a rapid return of synaptic sympathetic transmission (Fig. 3, b). When an intramuscular injection of 0.5 ml of 5% ephedrine was also given, there was a further increase in the amplitude of the potentials recorded from the sympathetic ganglion, and from the hypothalamus and cerebellum (Fig. 3, c, d). At the same time there was a gradual increase in the amplitude and frequency of the impulses in the cerebral cortex (Fig. 3, d, e).

The stimulating effect of the mixture of drugs and of ephedrine on the electrical activity of the nervous system was observed during the application of painful stimuli to the intestine. This can be seen from Fig. 4, which shows simultaneous records from the cortex, hypothalamus, and a sympathetic ganglion. By injecting the mixture of drugs intravenously during the inhibition of the sympathetic system (Fig. 4, d), so increasing the lability of the cells of the sympathetic ganglia, it was possible to restore the transmission of excitation in the sympathetic system so that the parabiotic condition of the central nervous system failed to develop despite a continuation of the painful stimulation (Fig. 3, d). As the synaptic transmission in the sympathetic system returned, under the influence of the drugs, the blood pressure returned to its initial value, and the respiratory rhythm was re-established.

The increased sympathetic activity, by restoring the blood pressure, improved the circulation, and so made possible the mobilization of energy reserves. This in turn favored the return of synaptic transmission in all parts of the nervous system and increased the lability of all nervous cells, including those of the cerebral cortex, which in turn responded reflexly to impulses derived from external stimuli to send further trains of nervous impulses to cells of the autonomic centers, thus raising the level of their activity. This latter effect in turn resulted in the mobilization of sufficient energy and hormonal reserves to counteract the trophic disturbances induced by the excessive stimulation, so bringing about conditions which enabled the animal to emerge from the condition of shock, and the central nervous system once more to react to external stimuli.

This study of electrical activity in different parts of the nervous system during the action of extreme levels of stimulation has shown that the descending portion of the inhibitory reflex develops primarily in the peripheral sympathetic nervous system. By blocking the transmission of impulses in the sympathetic ganglia, central trophic control of tissue is eliminated, and conditions develop in which the shock syndrome appears.

SUMMARY

Electrical recordings were made of changes occurring at different levels of the nervous system during the development of shock.

In response to the action of the extremely strong stimuli, inhibition developed primarily in the peripheral portion of the sympathetic nervous system.

As a result of the blockage of impulses in the sympathetic ganglia, central nervous trophic control over the tissues was eliminated, and conditions created which led to the development of shock.

LITERATURE CITED

[1] E. A. Asratyan, Outlines of the Etiology, Pathology, and Therapy of Traumatic Shock*. Moscow, 1945.

[2] V. V. Babuk, Traumatic Shock and Gross Hemorrhage*, Minsk, 1953.

[3] S. I. Banaitis, Traumatic Shock in Laboratory Experiments, Clinical Practice, and Field Surgery*. Kaunas, 1948.

[4] A. A. Bogomolets, Transactions of the Conference on Problems of Shock*. Kiev, 1937, p. 5.

* In Russian.

[5] N. I. Burdenko, Klin. med., volume 16, issue 2, p. 135 (1936).

[6] L. L. Vasil'ev and D. A. Lapitskii, Research Reports of Leningrad State University*, Biological Series, Leningrad, 1944, issue 12, p. 114.

[7] N. E. Wedensky, Excitation, Inhibition and Anesthesia*. Leningrad, 1953.

[8] A. V. Visnevskii, Collected Works*, Moscow, 1950, volume 3.

[9] L. A. Orbeli, Izv. Nauchn., issled. in-ta im. Lesgafta, 1923, volume 6, p. 197.

[10] L. A. Orbeli, Lectures on the Physiology of the Nervous System*, Moscow—Leningrad, 1938.

[11] L. A. Orbeli, in book: Military Medicine, Collection*, Moscow—Leningrad, 1944, p. 5.

[12] L. A. Orbeli, in book: Military Medicine, Collection*, Moscow—Leningrad, 1945, issue 2, p. 3.

[13] L. A. Orbeli, in book: Military Medicine, Collection*, Moscow—Leningrad, 1946, issue 3, p. 3.

[14] L. A. Orbeli, Problems of Higher Nervous Activity*, Moscow—Leningrad, 1949.

[15] I. R. Petrov, Shock and Collapse*, Leningrad, 1947.

[16] I. R. Petrov, in book: Problems of the Physiology of the Central Nervous System*, Moscow—Leningrad, 1957, p. 447.

[17] V. S. Sheveleva, Fiziol. zhurn. SSSR, volume 44, No. 9, p. 882 (1958).

* In Russian.