THE SEQUENCE OF THE DISAPPEARANCE OF OCULOMOTOR REFLEXES IN TRAUMATIC SHOCK*

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We studied the general state and functional disturbances of the activity of the brain stem of animals during and immediately after prolonged pinching of the soft tissues of the limbs (the thigh muscles of rabbits were pinched for four hours in a vise). During the course of the experiments a record was kept of blood pressure, respiration, temperature, vasculomotor and oculomotor reflexes. In all, 44 experiments were conducted.

In the present report the question of the sequence of the disappearance of occulomotor reflexes is considered, a question which bears a direct relationship to the problem of the unequal resistance of different brain structures.

Oculomotor reflexes were produced by moving the bodies of the animals to the right and left of the median line while the head was held immobile. The eye muscles (external and internal rectus, the superior oblique and in some experiments even the muscle of the nictitating membrane) were connected with small rods which recorded the contractions of the muscles on a smoked kymographic sheet. The method of recording the oculomotor reflexes has been described in detail by P. A. Gultyaev [2].

In all of the experiments the extraordinary stability of the oculomotor reflexes was apparent. This fact was noted also in the work of N. G. Savvin [15]. Studying the influence of hypoxemia on the functional state of antagonistic eye muscles, he discovered that in many cases nystagmus persists up to the cessation of respiration. In a number of our experiments the amplitude of the oculomotor reflexes several minutes before the demise of the animals was not lower than the initial level (Fig. 1).

In virtue of the fact that the nuclei of the oculomotor nerves, which innervate the internal rectus muscles, and the nuclei of the trochlear nerves, which innervate the superior oblique eye muscles, are located in the mesencephalon, while the nuclei of the abducens nerves, which innervate the external rectus muscles, are located in the medulla oblongata, it was possible for us to control to a certain extent the functional state of these two divisions of the brain.

The notion of the many-storied construction of the nervous system and of centers of nervous activity corresponds to the study of I. P. Pavlov and to the work of V. M. Bekherev and A. A. Ukhtomsky. Observing the fading away of the functions of the central nervous system in the deep torpid phase of shock, we assumed that the reflexes of the internal rectus muscle disappeared earlier than the reflexes of its antagonist. In none of the experiments conducted, however, were we able to note such a sequence. On the contrary, the reflexes of the internal rectus muscle in a number of experiments disappeared last, directly before the cessation of respiration (Fig. 2).

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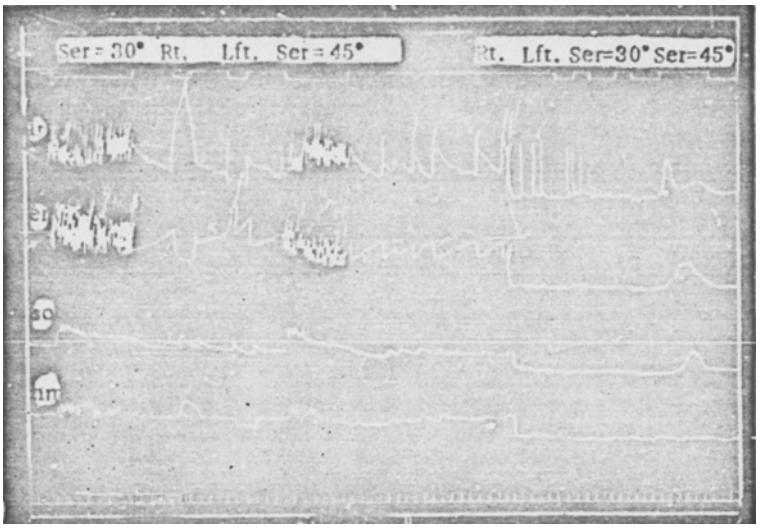

Fig. 1. Kymogram of oculomotor reflexes. Reflex stability. Five minutes before the death of the animal the amplitude of its reflexes is higher than the initial level. The independent contractions of the internal rectus muscle of the eye before the death of an animal are visible. The reflexes of the superior oblique and external rectus muscle as well as the muscle of the nictitating membrane, are absent at this time.
Significance of the curves (from the top down): the record of single (rt, lft) movements and serial (Ser. = 30°, Ser. = 45°) movements of the body of an animal to the right and left of the median line; ir) contraction of the internal rectus muscle; er) contraction of the external rectus muscle; so) contraction of the superior oblique muscle; nm) contraction of the nictitating membrane; unit of the time scale) 5 second.

The transformation of the rhythm of the irritation into a more abrupt rhythm of contractions (Fig. 3) and the inhibitory phase of the reflexes (Fig. 4) were most often apparent in the superior oblique and external rectus muscles. Out of 8 experiments in which we attempted to apply a complex method of therapy in order to free the animals from the state of shock, the stepping up of the reflexes of the superior oblique muscle was noted in only one case, while the reflexes of the external rectus muscle were stepped up in 6 cases, and the reflexes of the internal rectus in 7 cases.

In addition, the reflexes of the superior oblique muscle almost always died out earlier than the other oculomotor reflexes. The nuclei of the trochlear nerves, located in the mesencephalon, were the first to be shut down, then the nuclei of the abducens nerves, located in the medulla oblongata, and the very last were the nuclei of the oculomotor nerves, located in the mesencephalon, i.e., certain nuclei of the mesencephalon. Upon further analysis of the experimental material, taking into account all the facts obtained, it turned out that not only the sequence of disappearance of the oculomotor reflexes, but also the dynamics of their changes in the course of the development of shock, attest to the considerable resistance of the nuclei of the oculomotor nerves in comparison with the nuclei of the abducens and trochlear nerves. Thus, the fluctuations in the magnitude of the reflexes of the internal rectus muscle in the basic series of experiments devoted to a study of the changes in oculomotor reflexes were significantly less than the fluctuations of an analagous character of the external rectus and, especially, the superior oblique muscle of the eye. The average value of the step-up of reflexes, which was as a rule, observed in the initial period of pinching, was also appreciably less for the internal rectus muscle. This is reflected in the Table.

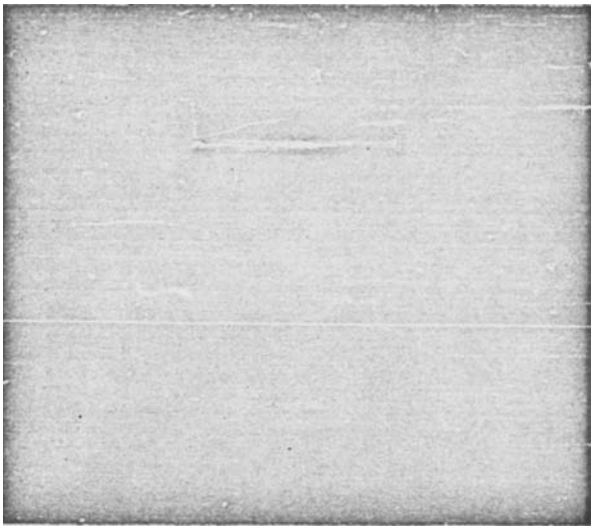

Fig. 2. Kymogram of oculomotor reflexes. The sequence of the shutdown of reflexes. The significance of the curves is the same as in Fig. 1.

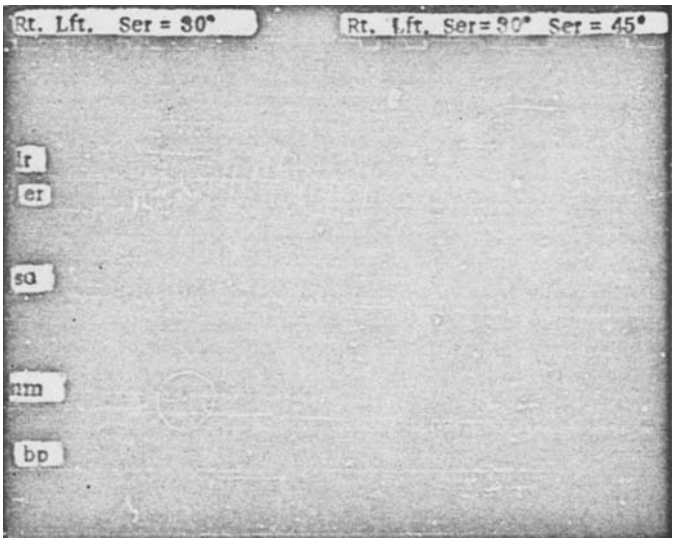

Fig. 3. Kymogram of oculomotor reflexes. The transformation of rhythm. The significance of the curves is the same as in Fig. 1. bp) blood pressure record (before the death of the animal the blood clotted in the cannula).

The question of the sequence of disappearance and restoration of the activity of the different divisions of the brain in grave traumas, loss of blood and other pathological processes has attracted the attention of researchers in connection with the study of the problem of the revival of an organism. Some authors, having observed the restoration of the functions of the medulla oblongata following a 10-15 minute disruption of blood circulation in the brain, maintained that after the indicated time, full restoration of the functions of the entire central nervous system was possible.

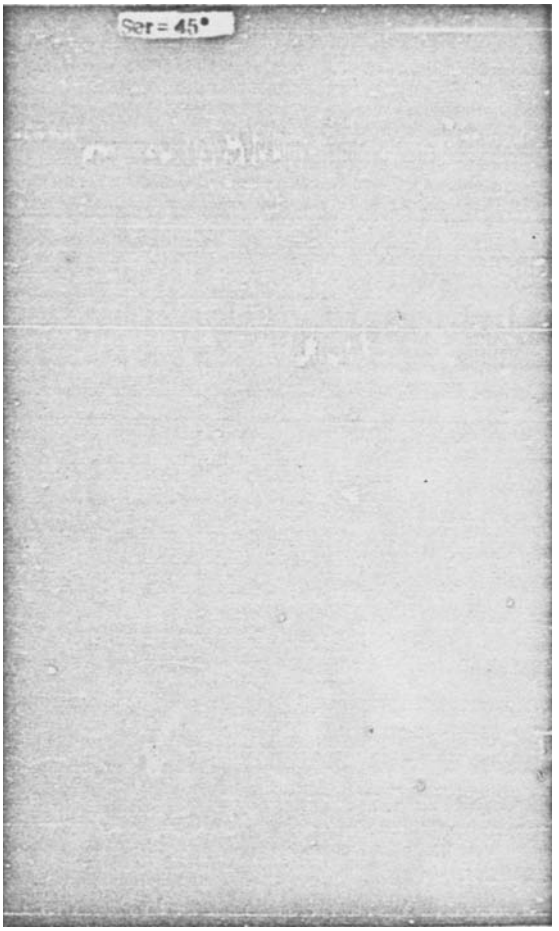

Fig. 4. Kymogram of oculomotor reflexes. The inhibitory phase. The significance of the curves is the same as in Fig. 1.

The fallacy of this sort of notion was shown by the work of I. R. Petrov [14], V. A. Negovsky [7], Heyman and Boukaert [17] and others. In experiments on animals, as well as by clinical observations of humans, it was established that the order of the exclusion or restoration of this or that division of the brain is determined by its phylogenetic age; the younger structures are eliminated earlier and are reinstated later. There appeared the idea of the fading and restoration of the divisions of the brain "by floors."

However, even in the early works of I. R. Petrov [12, 13] he mentions exceptions to this general rule. It turned out that certain functions intrinsic to the higher divisions are restored earlier than those of lower divisions of the brain. The author connects this with the nidal quality of afflictions of the central nervous system. In addition to this, it was discovered that the revival of the formations of the same level also does not occur simultaneously. In the research of V. A. Negovsky [7, 8, 9, 10] it is noted that, long before full restoration of the function of the entire diencephalon, signs are observed of the restoration of the functions of the extrapyramidal system.

The amazing stability of the ocular reflexes is attracting attention. According to the data of A. A. Narychev [6], who studied the pupillary reflexes of humans under narcosis during operations, the reaction of the pupil to light disappears only after paralysis of the respiratory center. In the experiments of E. I. Garber [1] on frogs, in the process of dying, the corneal reflex disappeared also only after breathing stopped.

Comparing our data with the observations of other authors, we came to the conclusion that the hypotheses advanced to explain the deviations from the rule of revival "by floors" of the different divisions of the brain do not enable us to explain the results of our experiments conducted. The premature falling off of certain reflexes could be linked with the nidal quality of affliction, but their increased resistance could not, since in the latter case one would have to admit the presence of continuous "nidi" of infection around an undamaged area. At the same time, the later disappearance of a number of reflexes (oculomotor reflexes of the internal rectus muscle of the eye, reflexes of the pupil to light) which are affected via the mesencephalon, in comparison with reflexes effected via the medulla oblongata, is evidence of increased resistance of certain centers of the mesencephalon. The reference of V. A. Negovsky to the greater stability of the parasympathetic nervous system in contrast to the cerebrospinal system has no relation to the facts adduced, inasmuch as only somatic motor reflexes were recorded by us. There are indications [17] that the innervation of the external rectus muscle of the eye appeared earlier in the process of evolution than the innervation of the internal rectus muscle. Thus, even the age criterion does not clear up the situation.

What is the reason for the increased resistance of a number of reflexes connected with the mesencephalon?

The greater stability of certain reflexes effected with the participation of higher centers, in comparison with reflexes connected with lower centers, is apparently explained by the greater biological significance of the

former. This resistance was consolidated in the course of evolution since, to a considerable extent, it guaranteed the survival of an animal in various difficult situations, and thereby favored preservation of the species. Thus, between the resistance of a system and its biological significance there exists a direct connection, which determines the sequence of the shutdown of the different divisions of the brain during the expiration of an organism and of their restoration during its revival. The rule of a shutdown "by floors" is an objective expression of the fact that the lower divisions of the brain have a greater biological significance for a dying organism than the higher divisions.

The Change in Reflexes of the Eye Muscles After Pinching of a Limb

Muscle	Limits of the fluctuations in the magnitude of the reflexes (in % as compared with the initial value)	Mean value of the step-up of reflexes (in % as compared with the initial value)	The number of experiments in which the development of an inhibitory phase was observed.
Internal Rectus	138	21	4
External Rectus	180	36	6
Superior Oblique	215	56	8

* Note: The numbers express the mean values of the fluctuations. Total number of experiments, 23.

According to the data of E. K. Senn [16], the development of the mesencephalon is closely connected with the development of the visual analyzer, that most important sense organ. Particular significance in guaranteeing the full-scale work of the visual organ was acquired by the system of oculomotor nerves, which has a complex structure and which guarantees the accomplishment of a number of important visceral and somatic functions. The physiological significance of the functional performance of this system apparently also led to securing its increased resistance in the course of evolution. The reflexes which are effected with the participation of the trochlear nerves and the nerves of the nictitating membrane (the motor nuclei of which, according to the data of G. L. Komendantov [4], are also located in the mesencephalon) are less important with respect to physiological role than the reflexes realized with the participation of the oculomotor nerves. This clearly also explains the fact that the times of the shutdown of the indicated reflexes keep within the rules of a shutdown "by floors" of the divisions of the brain.

SUMMARY

In a study of the deep torpid shock phase on rabbits it was brought out that oculomotor reflexes of the internal and external rectus muscles, superior oblique muscle and muscle of the nictitating membrane are characterized by a high stability: they disappear just before the cessation of respiration, maintaining significant amplitude till their very disappearance. Reflexes of the superior oblique muscle, realized through the mesencephalon are the first to disappear, they are followed by those of the external rectus realized through the medulla oblongata; the reflexes of internal rectus, realized through the mesencepalon are the last to disappear.

Not only visceral, but also somatic centers of the mesencephalon, particularly the centers of oculomotor nerves, possess higher stability in comparison with certain centers of the medulla. This characteristic is apparently connected with their great physiological importance.

LITERATURE CITED

[1] E. I. Garber, Arkh Patol., No. 2, 59-69 (1949).

[2] P. A. Gultyaev, "The comparative characteristics of the influence of ether, chloral hydrate, hexobarbital, urethane and morphine on the reflex activity of an animal," a Thesis, Leningrad (1952).

[3] I. V. Davidovsky, Problems of Localization and Organopathology in Light of the Teaching of Sechenov, Pavlov and Vvedensky,* Moscow (1954).

[4] G. L. Komendantov, Fiziol. Zhur. SSSR, Vol. XXXIV, No. 4, 449-456 (1948).

[5] V. P. Kurkovsky and I. R. Petrov, in the book: Oxygen Hunger and the Struggle Against It,* Leningrad, 3-48 (1940).

[6] A. A. Narychev, Arkh. Patol., Vol. XV, No. 6, 77-81 (1953).

[7] V. A. Negovsky, The Restoration of the Vital Functions of an Organism in the State of Agony or during Clinical Death,* Moscow (1943).

[8] V. A. Negovsky, Experimental Therapy on the States of Agony and Clinical Death in a Military District,* Moscow (1945).

[9] V. A. Negovsky, Arkh. Patol., Vol. XV, No. 4, 3-14.

[10] V. A. Negovsky, The Pathophysiology and Therapy of Agony and Clinical Death,* Moscow (1954).

[11] I. R. Petrov, Fiziol. Zhur. SSSR, Vol. XXIV, No. 1, 34-48 (1936).

[12] I. R. Petrov, Arkhiv Patologicheskoi Anatomy i Patologicheskoi Fiziology, Vol. III, No. 3, 12-36 (1937).

[13] I. R. Petrov, in the book: A Collection of Memory Difficulties from the I. P. Pavlov Academy,* 63-73, Leningrad (1938).

[14] I. R. Pavlov, Klin. Med., Vol. XVII, No. 11, 6-24 (1939).

[15] N. G. Savvin, in the book: Transactions of the Military Medical Academy,* Moscow, Vol. 1, 214-224 (1946).

[16] E. K. Sepp, A History of the Development of the Nervous System of Vertebrates from the Acraniates to the Human,* Moscow (1949).

[17] C. Heymans and J. J. Boukaert, Fiziol. Zhur. SSSR, Vol. XXI, No. 5-6, p. 770 (1936).

* In Russian.