INVESTIGATION OF THE PHYSIOLOGICAL CHANGES IN THE GRAY MATTER OF THE FROG'S SPINAL CORD DURING EXCLUSION OF THE AFFERENT IMPULSES FROM THE RECEPTORS OF THE AORTA

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The observations of B. D. Kravchinskii [1, 2, 3, 4, 5] on the depression of the spinal reflexes of the frog developing 6-9 min after the cessation of respiration when the receptors in the region of the bifurcation of the aorta were excluded were published in 1945. Kravchinskii found that this depression, which he obtained by Turck's method, arises as a result of the active inhibiting action developed by the respiratory center, arrested in consequence of the exclusion of the receptors of the bifurcation of the aorta. Transection between the medulla and spinal cord abolished this depression and the spinal reflexes were restored, the degree of restoration being the greater the sooner the transection was made. It is also generally known that in the spinal frog, when the shock has passed after separation of the brain, the spinal cord reflexes are restored, and if optimal conditions are provided, these may be preserved for several hours.

The object of our investigation was to analyze in greater detail the depression of the spinal reflexes.

EXPERIMENTAL METHOD

In the first series of experiments we recorded the reflex response of the semitendinosus muscle of the frog to stimulation of the tibial nerve (using the GZ-1 sound generator). After the initial optimal responses had been recorded, a swab soaked in 2% novocain solution was applied to the dorsal surface of the bifurcation of the aorta, after which the reflexes were recorded every 3 min until the responses disappeared. In the second series of experiments, in order to vary the physiological parameters, the stimulating test electrode (a nichrome wire, 3 μ in diameter, insulated at its sides with glass) was implanted into the premotor region or the motor region of the gray matter of the spinal cord. The indifferent electrode (a steel needle) was fixed to the skull bones. Stimuli were applied from a chronaximeter–accommodometer, fed by a direct current battery. The position of the point of the stimulating microelectrode was first determined from the local threshold contraction of the semitendinosus muscle, and confirmed histologically after the experiment.

EXPERIMENTAL RESULTS

It will be clear from Fig. 1, in which the first recordings of the reflex of the semitendinosus muscle were made before application of novocain to the aortic receptors, that the reflexes arising 2.5 sec after the beginning of stimulation were well marked and lasted throughout the period of stimulation (5 sec). After the application of novocain to the aorta, at the third minute the reflex became unstable and interrupted, although the height of the response was maintained. As the duration of action of the novocain increased, although the height of the reflex contraction and the initial length of the latent period were preserved, the reflex terminated sooner and sooner–before the stimulus had ceased to act. In the lower tracing (the pneumogram) it can be seen that respiration ceased on the 9th minute after application of novocain to the aorta, while at the 12th minute, i.e., 3 min after respiratory arrest, the amplitude and duration of the reflex respose were decreased. After the 18th minute of action of novocain, and 6 min after respiratory arrest, reflex responses were no longer present, notwithstanding the ever-increasing intensity of stimulation (from 10 divisions on the dial of the sound generator to 50). At the same time respiration was also completely absent. Another interesting fact was that stimulation of a spinal sensory nerve could still cause a reflex response of the respiratory center (which is only possible through ascending pathways), whereas the segmental spinal reflex was absent. Consequently, the ascending reflex arcs were excluded slightly later than the arcs of this particular segment of the spinal cord. It follows from this argument that after cessation of the automatism of the respiratory center, the constant

stream of afferent impulses from other sensory pathways not directly associated with the determination of automatism could still reproduce the automatic excitation of the respiratory center for a short time longer.

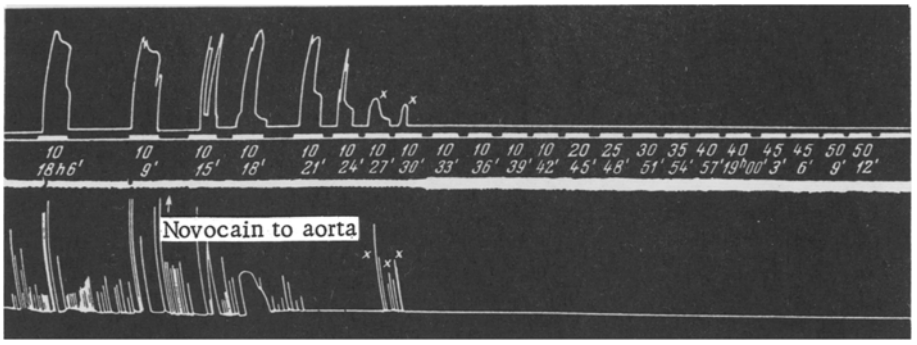

Fig. 1. Myogram of reflex contractions of the semitendinosus muscle of a frog in response to stimulation of the sensory tibial nerve (upper curve) and simultaneous recording of respiration (lower curve). The second tracing from the top is the stimulus marker (each mark represents 5 sec). Recordings were made after every 3 min of rest.

Hence the exclusion of the receptors of the aorta was revealed, firstly, by a decrease in the duration of the reflex contraction, later by a decrease in its amplitude and its disappearance from 6 to 9 min after the beginning of

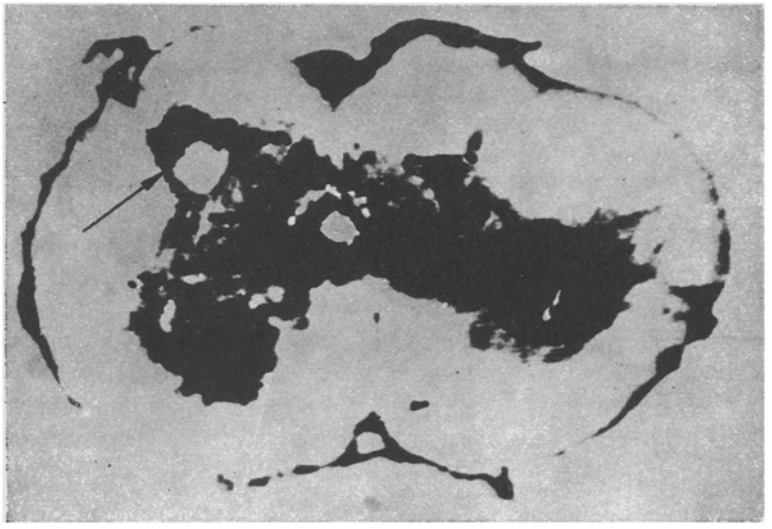

Fig. 2. Transverse section of the spinal cord of a frog at the level of emergence of the 8th spinal root. The arrow points to the position of the track of the point of the stimulating microelectrode in the premotor region (a hole in the section). Photomicrograph taken by means of 6 × 9 attachment. Objective, plane, chromatic, 9 × 0.20; eye-piece, SIM, 15×. Stained with hematoxylin-eosin.

the action of the novocain and from 3 to 6 min after respiratory arrest. Under these circumstances the reflex arcs of this particular segment were excluded in the first place, and only later the pathways ascending to the medulla.

Measurement of the physiological parameters, for example, in the experiment on October 11, 1960 when the point of the stimulating microelectrode was situated in the premotor region (Fig. 2), in normal conditions before application of novocain to the receptor region of the bifurcation of the aorta, gave a rheobase of 6 V. Five minutes after application of novocain the rheobase was 7.5 V, 10 minutes after–9 V, 15 min–10.5 V, 20 min–14 V, 30 min–17 V, and 35 min after application–21 V. Hence the rheobase of the nervous elements of the premotor region 15 min

after the beginning of the section of novocain on the receptors of the aorta was increased 1.75 times, and 30 min after—almost threefold.

At the beginning of the experiment the chronaxie was 0.155 millisec. Five minutes after application of novocain it was 0.37 millisec, 10 min after—0.629 millisec, 15 min after—0.814 millisec, 20 min—0.999 millisec, 25 min—1.073 millisec, 30 min—1.14 millisec, and 35 min after—1.184 millisec. Hence after novocain had acted for 15 min on the receptors of the bifurcation of the aorta, the chronaxie had increased in length 5.2 times, and for 30 min—7.3 times.

The normal value of the accommodation constant λ was 60 millisec. Five minutes after the beginning of the action of novocain on the receptor region of the aorta its value was 64.5 millisec, 10 min after—68.7 millisec, 15 min after—72.2 millisec, 20 min after—77.1 millisec, 25 min—87.2 millisec, 30 min—96.1 millisec, and 35 min after—107.2 millisec. Hence, after 15 min the accommodation constant λ had increased 1.2 times, and after 30 min—1.6 times.

Mean Results of the 21st Experiment of Measurement of the Physiological Parameters in the Premotor Region of the Spinal Cord of the Frog During Exclusion of the Receptors of the Bifurcation of the Aorta

Normal			30 min after beginning of action of novocain		
Rheobase (in V)	Chronaxie (in millisec)	Accommodation constant λ	Rheobase (in V)	Chronaxie (in millisec)	Accommodation constant λ
5.22	0.19	40	10.4	1.6	65.22

The changes in the physiological parameters in this experiment bore the same character as in the remaining 20 experiments (see table).

The results given in the table show quite clearly that the exclusion of the receptors of the bifurcation of the aorta, leading to respiratory arrest, in turn causes a marked lengthening of the chronaxie and then of the rheobase, followed by a slight change in the accommodation constant. Consequently, during stimulation of the premotor region of the spinal cord after exclusion of the receptors of the aortic bifurcation, we observe a lowering of excitability, a lengthening of the time taken for each excitation to arise, and a slight slowing of the process of accommodation.

Measurements of the physiological parameters in the region of the motor neurons and their axons showed practically no changes in their physiological state during the action of novocain on the receptors of the aortic bifurcation.

Consequently, in the frog, whose central nervous system is relatively insensitive to a deficient supply of oxygen during exclusion of pulmonary ventilation, and which evidently receives adequate oxygen through the skin, it is possible to detect the character of the intracentral reactions in the central nervous system during the exclusion of the constant afferent flow of impulses. This exclusion leads not only to cessation of the automatic function of the respiratory center of the medulla, but also to the development, according to our findings, of a state of inhibition in the region of the nervous elements of the inspiratory center [6, 7, 8]. The latter, in turn, as the results of our experiments have shown, has an inhibitory action on the nervous elements of the premotor region of the spinal cord.

SUMMARY

The functional state of various areas of the gray matter of the frog spinal cord was analyzed physiologically with the aid of myographic recording of the spinal cord reflexes and local measurement (by means of a microelectrode) of physiological parameters in normal conditions and in exclusion of receptors of aortic bifurcation. The experiments disclosed the nature of intracentral changes occurring in the CNS, manifested by reduction of the local functional level in the premotor spinal cord area in exclusion of constant afferent impulsation from the mentioned receptors.

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