INTEROCEPTIVE INFLUENCES ON TONIC LABYRINTHINE REFLEXES

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There are many facts in the literature which indicate the existence of marked interoceptive influences on somatic processes and, in particular, on the functions of the skeletal muscles [1, 2, 4, 5, 8-11, etc.].

However, the attention of these investigators cited was directed mainly towards the study of changes in the periodic activity of the skeletal muscles, and no schematic study has been made of the reflexes from the interoceptors on their tonic activity, which have usually been observed only incidentally. In particular, no data could be found showing the influence of interoceptive influences on the tonic reactions of the skeletal muscles arising as a result of stimulation of the labyrinthine apparatus [7]. The object of the present investigation was to shed light on this problem. It was considered that the changes in the labyrinthine reflexes during interoceptive stimulation would enable an assessment to be made of the functional state of the brain-stem centers "responsible" for the realization of these reflexes.

EXPERIMENTAL METHOD

Experiments were carried out on adult male rabbits. The tonic labyrinthine reflexes were investigated during rotation of the animal around the bitemporal axis (from 0 to 360°) with the aid of a special stand to which the rabbit was fixed. The animal's head was held in a halter, maintaining its position unchanged relative to the trunk, and eliminating the action of the neck reflexes. One complete revolution took place in 15-30 sec.

To detect the tonic reactions of the skeletal muscles, arising as reflexes in response to stimulation of the labyrinthine apparatus, an electromyographic method was used [14, 15, 18]. Action potentials were picked up by needle electrodes (distance between poles 1.0-1.5 cm) from the extensor muscles of both forelimbs and from the occiput (the dorsiflexors of the head). Preliminary amplification of the potentials was carried out by an ac amplifier with a symmetrical input and a transmission band from 0.2 to 8000 cps. A four-channel cathode-ray oscillograph with camera attachment was used for making the recordings. Along with the potentials of the muscles, a marker of the position of the animal's body (head) relative to the horizontal axis (the size of the angle in degrees) and the time marker were recorded (50 cps).

In some experiments the animals were decerebrated at the level of the anterior colliculi.

The mechanoceptors of the rectum were stimulated by inflating a rubber balloon inserted in it to a certain pressure. The muscle potentials during rotation of the animal were recorded before interoceptive stimulation, 3-5 min after the beginning of inflation of the balloon, and after the stimulation had been discontinued.

Altogether 32 experiments were performed.

RESULTS

The electromyogram (EMG) of the "resting" skeletal muscles (the triceps muscle) of the rabbit in most cases was characterized by fast (21-40 per sec) peak potentials of low amplitude (30-100 μV). In some experiments low-voltage potentials were recorded, with a well defined and slower (4-12 per sec) wave rhythm.

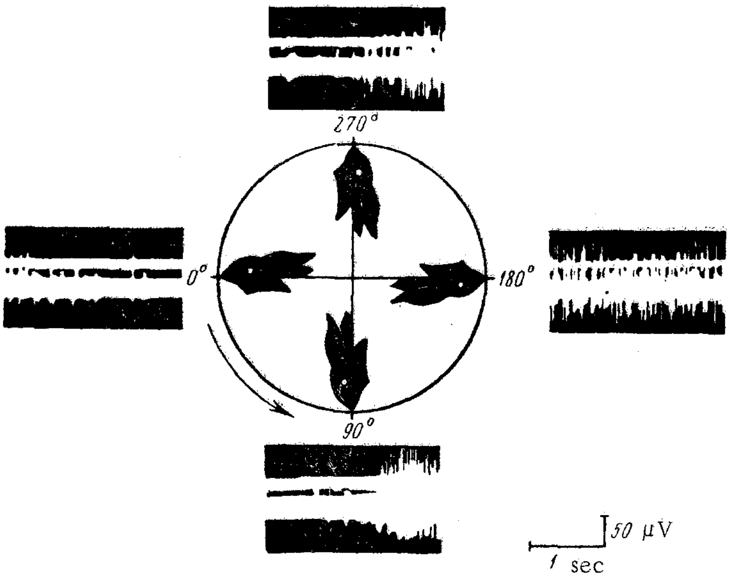

Fig. 1. Scheme of position of the rabbit's head in space during rotation of the animal about the bitemporal axis (from 0 to 360°), indicating the angle and the corresponding changes in the EMG of the triceps. The arrow shows the direction of rotation.

Changes in the position of the animal's body in space (rotation around the bitemporal axis) caused a gradual and distinct increase in the amplitude and the frequency of the initial potentials of the extensor muscles of the forelimbs and the dorsiflexors of the head, rising with a change in the angle between the axis of the head and the horizontal plane from 45 to 270°. In most animals a clear increase in the electrical activity of the muscles took place when the angle was changed from 45 to 90° (the head lowered vertically). The amplitude of the recorded potentials of the triceps muscle was maximal in the region from 135 to 220° (on its back, sinciput pointing downward), i.e., in the "maximal position." Thereafter the amplitude of the potentials returned to its initial level (Fig. 1). The time of the reaction was 6.0-10.5 sec.

The changes in the electrical activity of the muscles continued while the animal's head was in the corresponding position in space. Consequently, these were pure "position reflexes" [17], objectively recorded by electromyographic investigation. The changes described above appeared most clearly in the reflex tonic reactions from the labyrinths on the dorsiflexors of the head and in decerebrate rabbits, in which the extensor muscles of the limbs were in a state of rigidity.

Stimulation of the mechanoceptors of the rectum (pressure 60-100 mm Hg) was accompanied in all the experiments (without rotation of the animal) by an appreciable depression of the background electrical activity of the "resting" muscles, usually developing immediately after the beginning of interoceptive stimulation. The initial EMG was restored 10-15 min after stimulation ceased. A change in the position of the animal's body in space, against the background of stimulation of the rectal mechanoceptors, led to an appreciable increase in the initial muscle potentials on the EMG sooner (in a position from 15 to 45°) than in the control experiments (Fig. 2A, B). The maximum of the increase in amplitude in these circumstances often showed a shift of 90-135° (in two experiments by 45-90°), i.e., it took place in response to weaker stimulation of the labyrinths. The time of the reflex reaction was slightly lengthened (by 1-2 sec) or remained unchanged. The changes in the reflex reactions from the labyrinths on the skeletal muscles observed on the EMG persisted 3-5 min after the beginning of stimulation of the interoceptors, but they were less well defined.

In some experiments, especially associated with strong stretching of the rectum (pressure 100-120 mm Hg), instead of the maximal increase in the amplitude of the muscle potentials observed in the position 135-220°, they fell to minimal values. Meanwhile, during weaker stimulation of the labyrinths, the electrical activity of the skeletal muscles increased appreciably (Fig. 2C and D).

Changes of a similar character were found in the labyrinthine reflexes during prolonged stimulation of the rectal interoceptors caused by painting its mucous membrane with a 5% silver nitrate solution.

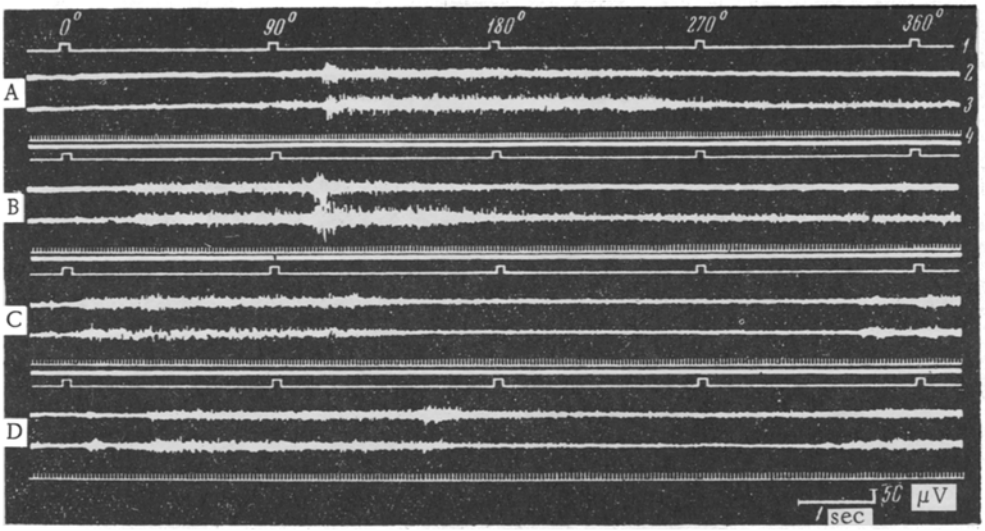

Fig. 2. Changes in labyrinthine tonic reflexes in a rabbit under the influence of interoceptive stimulation: A) before; B) 30 sec after stretching rectum (pressure 60 mm Hg); C and D) 30 sec and 3 min after stretching rectum (pressure 120 mm Hg). Here and in Fig. 3: 1) marker of stimulation of labyrinths by rotating rabbit about the biotemporal axis; 2 and 3) EMG of right and left triceps muscles; 4) time marker (50 cps).

In these conditions a paradoxical reaction developed, evidently as a result of the parabiotic state arising in the central portions of the investigated reflex arc under the influence of intensive or sustained visceral stimulation incorporationg a nociceptive component. Meanwhile the amplitude of the muscle potentials fell slightly in these circumstances, evidently on account of the inhibitory effect of the interoceptive afferent impulses on the motor neurons of the spinal cord [2, 4, 9, etc.]. The influence of interoceptive stimulation on the labyrinthine tonic reflexes also depends on the initial state of these reflexes in rabbits: when they were at a high level stretching of the intestine rarely produced clear activation of the tonic reflexes – the action potentials on the EMG showed only insignificant changes when the animal was rotated.

Administration of chlorpromazine to the rabbits (2 mg/kg intravenously) was accompanied by depression of the background electrical activity of the skeletal muscles, in some cases down to the noise level of the amplifier. During rotation of the animal around the bitemporal axis from 45 to 170° the potentials of the extensor muscles of the forelimbs and neck increased in amplitude, but much less than in the experiments without chlorpromazine. The duration of the reflex reaction diminished (to 3-4 sec). In these conditions stimulation of the mechanoceptors of the rectum caused no appreciable changes in the character of the electrical reactions of the skeletal muscles to labyrinthine stimulation (Fig. 3C and D).

The results described above show that under the influence of interoceptive impulses a distinct fall takes place in the threshold of stimulation of the labyrinthine apparatus, together with a certain "distortion" of the tonic labyrinthine reflexes, associated evidently with an increase in the reflex excitability of the medullary centers (the vestibular nuclei) "responsible" for the realization of these reflexes. This suggestion is confirmed by the results of experiments conducted by the author on decerebrate animals, in which the changes in the reflex from the labyrinths on the skeletal muscles during interoceptive stimulation were more marked than in the animals with an intact nervous system. Since, by decerebration, influences from the higher levels of the brain are abolished, it may be assumed that the observed "exacerbation" of the Magnus reflexes was mainly dependent on the action of interoceptive impulses on the subcortical centers in the brain stem. This is shown by the results of the experiments with the neuroplegic drug chlorpromazine, which, by blocking the adrenergic systems of the reticular formation of the brain, caused a sharp depression both of the labyrinthine reflexes themselves and of the interoceptive influences on them.

At the same time, during the analysis of these results it must be remembered that moderately strong simulation of the receptors of the internal organs leads to depression of the functional state of the cerebral cortex [1, 2, 5, 7], as a result of which the "de-inhibition" of the tonic brain-stem reflexes may also arise [3, 6, 12, 16, etc.].

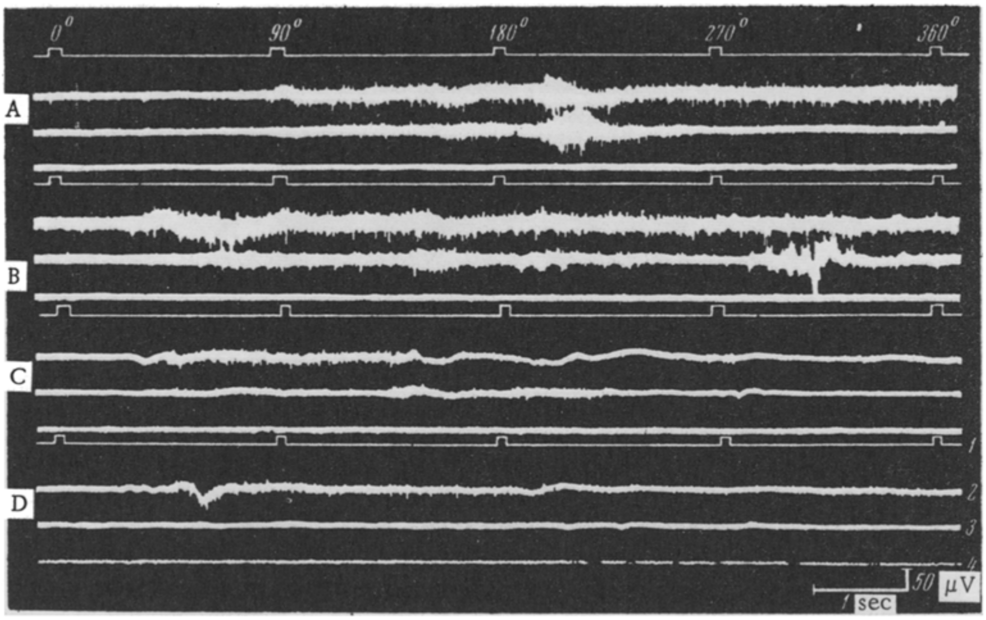

Fig. 3. Changes in labyrinthine tonic reflexes in a rabbit under the influence of interoceptive stimulation: A) before; B) 30 sec after stretching the rectum (pressure 80 mm Hg); C) against the background of the action of chlorpromazine (2 mg/kg); D) the same, during stimulation of the mechanoceptors of the rectum.

The changes in the vestibulo-somatic postural reflexes described above, arising under the influence of interoceptive impulses, may be one of the possible causes of the motor disturbances frequently taking place in man and animals with certain diseases of the internal organs.

SUMMARY

Chronic experiments on cats with the aid of electromyographic methods were used to study the influence of the interoceptive impulse emission on the tonic reaction of the muscles – extensors of the anterior extremities and the neck – occurring as a result of stimulation of the labyrinthine apparatus (rotation of the animal about the bitemporal axis). It was established that the influence of stimulating the interoceptors of the rectum produced a certain activation or inversion of tonic labyrinthine reflexes, which was associated with an increase in the stimulability of the stem centers of these reflexes. In decerebrated animals, the above-mentioned changes in reflexes from the labyrinths to the skeletal muscles in case of interoceptive stimulation were more pronounced. The administration of aminazine caused a sharp reduction both in the labyrinthine reflexes and in the interoceptive influences on them.

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