FUNCTIONAL PECULIARITIES OF THE CENTRAL GRAY STRATUM OF THE MESENCEPHALON

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The central gray stratum (CGS) of the mesencephalon has been shown clinically and experimentally to be directly associated with the central autonomic regulation and to take part in the mechanism of development of sleep [2, 3, 4, 10, 13, 14]. As part of the reticular formation, the CGS in a zone for the despatch of processed impulses from the lateral areas of the reticular formation and other systems of the brain stem. The essential fact is that in the CGS, as in the reticular formation, the afferent signals lose their modality [8, 12, 17].

Meanwhile, as regards their morphological features, the neurons of the CGS have much in common with the cells of the hypothalamic region, indicating that they belong to the apparatuses of autonomic regulation. These neurons give off numerous collaterals inside the CGS and spread far beyond its limits, providing communication with the cerebral cortex, the diencephalon, and the more caudal structures of the brain stem [16, 19]. A wide variety of neuroreceptor and mediator zones is present in the CGS, some of them adrenergic. This is evidence of the important role of the biogenic amines in the mechanisms of its functional activity [6, 11, 20]. However no experimental investigation has been made of the character of the relationships between the CGS and the cerebral cortex.

The object of the present study was to examine the functional peculiarities of the CGS and its relationships with the sensorimotor region of the cerebral cortex.

METHOD

The method of monopolar recording of the primary responses and the transcallosal potentials of the primary projection zone of the somatosensory cortex to test stimulation of the cutaneous receptors and the specific relay nucleus of the thalamus was used. The primary responses to rhythmic test stimulation were recorded before and after sending single or serial rectangular conditioning impulses into the CGS. The initial responses were recorded by the superposition method. The local cortical motor reactions evoked by electrical stimulation of points of the cortex were also taken into account. Electrodes were implanted into the brain structures by means of a stereotaxic apparatus in accordance with the coordinates of Jasper and Ajmone-Marsan [15], and the position of their ends was subsequently verified histologically. Adrenalin solution was injected directly into the CGS by a microinjector. The experiments were conducted on 70 cats.

RESULTS

In the experiments of the first series, carried out on animals moderately anesthetized with sodium amytal, primary responses were evoked by stimulation of the cutaneous receptor fields with rectangular pulses of 3-5 V. The principal changes in the components of the primary responses after stimulation of the CSG consisted of an increase in the length of the latent period of the response, reduction of the positive component, and growth of the negative (Fig. 1, 1). In a series of experiments the latent period increased by 2-3 msec, while the positive component was reduced by 15-62% of its original amplitude. Meanwhile there was a large increase (up to 300%) in the negative wave, followed by persistent negativization. Reduction of the positive component of the primary response, it should be noted, was not the result of masking of positivity because of its curtailing by the negative wave, for the same reduction was observed in experiments on more deeply anesthetized animals, in which growth of the negative wave was not observed.

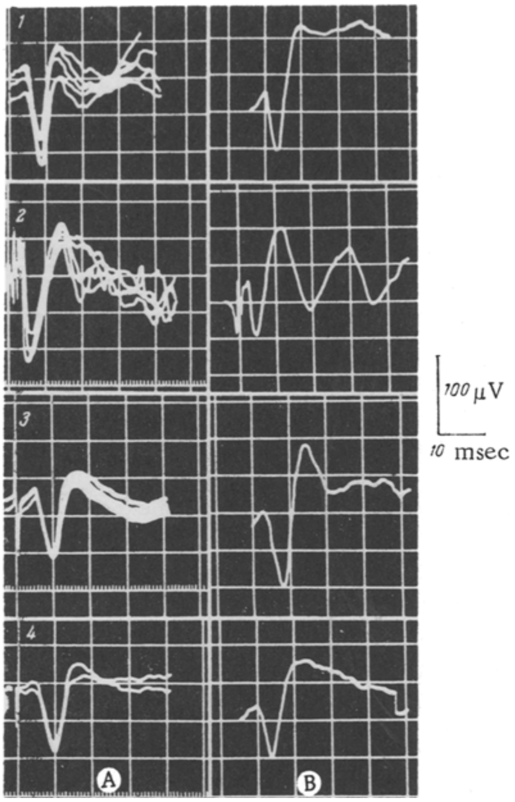

Fig. 1. Changes in primary responses of the first projection zone of general sensation. A) Initial primary responses; B) primary responses after stimulation of the CGS; 1) effect of stimulation of CGS in an anesthetized animal during test stimulation of the cutaneous receptor field; 2) effect of stimulation of CGS in a waking animal during test stimulation of the specific thalamic nucleus; 3) effect of stimulation of mesencephalic reticular formation; 4) effect of stimulation of CGS after bilateral coagulation of mesencephalic reticular formation.

To exclude the influence of the CGS on the internuncial afferent links at the spinal level, a series of experiments was carried out in which primary responses were evoked by stimulation of the ipsilateral specific relay nucleus of the thalamus. In these experiments, as in the preceding series, it was found that after stimulation of the CGS an increase took place in the latent period, accompanied by reduction of the positive component of the primary response and growth of the negative. Experiments on waking cats, immobilized with the curariform agent diplacin, revealed similar changes in the components of the primary responses during stimulation of the CGS (Fig. 1, 2). These facts indicate that the CGS has its effect mainly on the conduction of specific afferent impulses through the thalamocortical link of the sensory system.

The lengthening of the latent period of the primary response and the reduction of its positive component, observed after stimulation of the CGS, reflecting the arrival of the signal in layers 3 and 4 of the projection cortex, suggest that this particular bioelectrical effect reflects a process of blocking of the transmission of the specific sensory signal through the thalamocortical system by the central gray stratum. This does not rule out the possibility that the increase in the negative component in these conditions is to some extent associated with a lowering of the level of excitability of the cortical field [1].

Bearing in mind that the CGS in the neighborhood of the aqueduct of Sylvius lies close to the nuclei of the mesencephalic reticular formation, the suggestion may be made that the observed effect of stimulation of the CGS is not due to influences arising from this formation in the brain stem, but is the result of secondary excitation of the recticular formation. This suggestion was made more probable by the fact that in several cases a reduction in the positive component of the primary response of the optic and acoustic cortical fields was observed during stimulation of the mesencephalic reticular formation. To confirm or refute this hypothesis, it was necessary to compare the observed effects of stimulation of the CGS with the effects of stimulation of the reticular formation, and also to investigate these effects after coagulation of the reticular formation. For this purpose an additional series of experiments was carried out in which electrodes were implanted in the CGS and the reticular formation of animals at the same level in the frontal plane, at a distance of 1.0-1.5 mm apart. Under these circumstances it was found that single or serial stimulation of the reticular formation, preceding by a short time interval test stimulation of the specific thalamic nucleus, has a facilitating effect on the primary responses of the first cortical projection zone of general sensation (Fig. 1, 3). In these experiments an increase could be observed in both the positive and the negative components of the primary response, in agreement with data in the recent literature [5, 7, 8]. Stimulation of the CGS after unilateral or bilateral coagulation of the reticular formation, on the other hand, led as before to a reduction in the positive wave of the primary response (Fig. 1, 4), indicating the relative independence of the observed effect from the mesencephalic reticular formation.

After local poisoning of the cerebral cortex with 6% sodium amytal solution, stimulation of the CGS was ineffective in relation to the components of the primary response (Fig. 2, 1). It may be concluded from this finding that the influences of the CGS are most probably brought to bear on the postsynaptic level of the thalamocortical link.

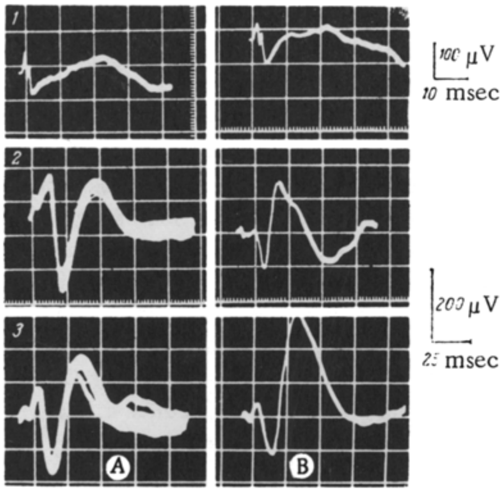

Fig. 2. Changes in primary responses and transcallosal potentials during stimulation of the CGS. A) Initial evoked potentials; B) after stimulation of CGS; 1) effect of electrical stimulation of CGS on primary responses of the cortex after application of 6% sodium amytal solution to its surface; 2) effect of stimulation of the CGS on transcallosal potentials; 3) effect of microinjection of adrenalin into the CGS on the transcallosal potentials.

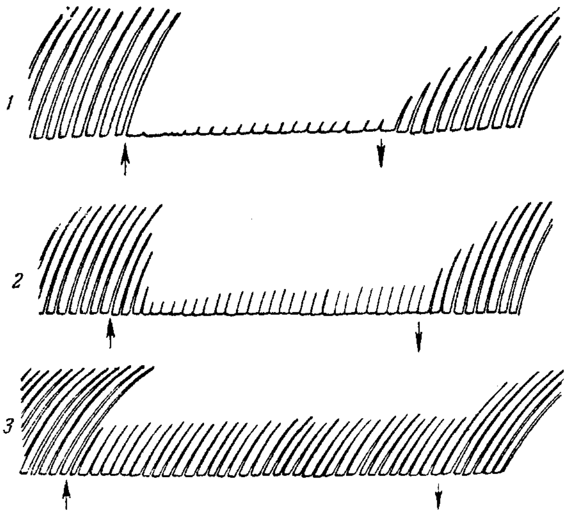

Fig. 3. Changes in the cortical motor reactions during electrical stimulation of the CGS. 1) In an intact cat; 2) after a circular incision around the motor area of the cortex; 3) after additional division of the corpus callosum. The arrows denote the beginning and end of stimulation of the CGS with an electric current, rectangular in shape, with a voltage of 4.5 V and a frequency of 200 pulses/sec. Stimulation of the motor cortex was applied every 7 sec.

The question naturally arises of the role of the CGS in the mechanism of interaction between the primary sensory fields of the cerebral cortex. This interaction between the fields of opposite hemispheres, and their mutual dynamic control, are known to be effected through the exchange of sensory information along the callosal pathway. The effect of stimulation of the CGS on the transcallosal transmission of excitation was therefore studied. Experiments showed that stimulation of the CGS leads to reduction of the positive wave of transcallosal potential and to growth of the negative. Besides this, in some experiments a shortening of the duration of the positive wave and a lengthening of the negative were observed (Fig. 2, 2). These effects were frequently observed also after the cessation of stimulation of the CGS. For example, in a series of experiments the after-effect persisted for 50-60 sec. A similar after-effect was also observed in experiments in which the primary responses to the arrival of specific afferent impulses were recorded. A more prolonged after effect of a fluctuating character (up to 25 min) was observed after microinjection of 0.25-1.0 μg adrenalin into the CGS (Fig. 2, 3). The comparatively long duration of the after-effect indicates that the CGS is capable of accumulating excitation, which tonically limits the conduction of specific afferent impulses to the projection areas of the cortex along the ascending and transcallosal tracts. The fact that the CGS is capable of sharply modifying its functional state for a long period of time under the influence of microdoses of adrenalin is an argument in favor of the hypothesis of the essential role of the adrenergic mechanisms of the CGS in the regional accumulation of the process of excitation.

Another interesting problem requiring solution is the effect of the CGS on the efferent cortical mechanisms which, with sensory correction, take part in the motor reflex act. Our investigations showed that stimulation of the CGS against a background of evoked motor responses leads as a rule to partial or total inhibition of motor reactions of cortical origin. The distinctive feature of these influences of the CGS is that inhibition of motor activity most frequently develops after a short latent period (1-4 sec), accompanies the whole period of stimulation of the CGS, and may be recorded during the after-period (Fig. 3, 1). The presence of a period of after-effect following cessation of stimulation of the CGS, manifested by inhibition of the cortical motor reactions, is a further indication of the static, tonic character of the influences arising from the CGS.

Since the CGS has an inhibitory action on the cortical afferent and efferent mechanisms, it seemed important to discover how the effects of stimulation of the CGS are mediated in respect of the motor act after isolation of the motor area of the cortex from the sensory. For this purpose, after the preliminary determination of the magnitude of the inhibitory effect of stimulation of the CGS, vertical incisions were made in the cortex at the borders of these areas. It was found that isolation of the sensory and motor areas only partially depressed the effect of stimulation of the CGS, as manifested by the slightly increasing amplitude of the motor reactions (Fig. 3, 2).

Incisions around the whole circumference of the motor cortex, leaving the vertical pyramidal tracts intact, likewise did not completely abolish the effect of stimulation of the CGS. Only by a combination of the circumferential and callosal incisions could the effect of stimulation of the CGS be obviously reduced by comparison with that observed after unilateral section (Fig. 3, 3). After incisions of this type stimulation of the CGS no longer led to so marked a reduction of the motor responses.

Hence, the influence of the CGS on the cortical motor reactions is considerably weakened after isolation of the cortical motor area from the other cortical areas. The fact that division of the corpus callosum leads to considerable weakening of the influence of the CGS on motor reactions demonstrates that other, independent mechanisms of the opposite hemisphere are concerned in the operation of this influence. Nevertheless, it must be mentioned that not even by a combination of circumferential and callosal sections can the influence of the CGS on the cortex be abolished completely. This suggests that other systems of the brain are concerned in the realization of the influence of the CGS on the cortical motor reactions. The residual effect after these sections of stimulation of the CGS evidently is largely dependent upon descending influences.

The results of these experiments demonstrate that the CGS of the mesencephalon exerts a tonic, inhibitory influence on conduction of specific afferent impulses to the sensorimotor cortex, blocks the spread of impulses into the opposite hemisphere, and also blocks the outflow of excitation along the motor pathways.

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