CORTICAL RELATIONSHIPS WITH THE HYPOTHALAMUS AND RETICULAR FORMATION OF THE BRAIN STEM

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UDC 612.825:[612.826.4 + 612.823.5

Corticofugal influences on hypothalamo-reticular relationships in different functional states of the cerebral cortex were studied in acute experiments on 42 cats. The character of these influences during cooling of the sensorimotor cortex or application of strychnine and potassium chloride to it is analyzed. Both blocking and excitation of the cortical elements exert a definite and specific action on hypothalamo-reticular relationships.

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According to the views held in Anokhin's laboratory, descending cortical influences during responses of different biological character constitute a multicomponent dynamic system which, being specifically directed toward subcortical structures, thereby creates the integrated, adaptive actions of the organism. At the present time considerable importance is attached to the hypothalamus in the mechanisms of formation of adaptive behavior [1, 8, 10]. As investigations in Anokhin's laboratory have shown, the hypothalamus gives generalized influences acting on the cortex their "biological" attributes. At the same time, in the formation of adaptive responses the hypothalamus is known to work in close connection with the reticular formation of the brain stem [2-6].

The object of this investigation was to determine the character of corticofugal influences on hypothalamo-reticular relationships, depending on the functional state of the cortex.

EXPERIMENTAL METHOD

Experiments were carried out on 42 cats anesthetized with urethane (1.5-2 g/kg) and chloralose (20-25 mg/kg). The subcortical electrodes were made of Nichrome wire, 0.5 mm in diameter and insulated except at the tip. The electrodes were inserted into the subcortex in accordance with coordinates given by Jasper and Ajmone-Marsan in their Atlas of the Cat's Brain. Evoked potentials were recorded by both bipolar and unipolar methods. The hypothalamic nuclei were stimulated with single square pulses (3-8 V, 0.05-0.1 msec) from a "Physiovar" stimulator. The evoked activity was recorded on an Alvar Electronic 4-channel CRO. The experimental analysis of corticofugal influences on hypothalamo-reticular relationships was carried out with the cortex in different functional states: during cooling of the sensorimotor cortex, or application of 10% potassium chloride solution or 0.25-0.5% strychnine solution to it. The localization of the tip of the subcortical electrode was determined in sections by the projection method.

EXPERIMENTAL RESULTS AND DISCUSSION

The main purpose of the experiments in the first stage of the investigation was to study connections between the different hypothalamic nuclei and the reticular formation of the brain stem. Experiments accompanied by morphological controls revealed that mainly the posterior and posterolateral portions of the hypothalamus – the lateral hypothalamic, posterior hypothalamic, mamillary, and perifornical nuclei – are intimately connected with the reticular formation of the brain stem (Fig. 1). Evoked responses in the reticular formation during stimulation of these hypothalamic nuclei consisted as a rule of a three-phase complex (Fig. 2A).

Laboratory of General Physiology of the Central Nervous System, Institute of Normal and Pathological Physiology, Academy of Medical Sciences of the USSR, Moscow. (Presented by Academician P. K. Anokhin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 68, No. 8, pp. 3-6, August, 1969. Original article submitted September 21, 1967.

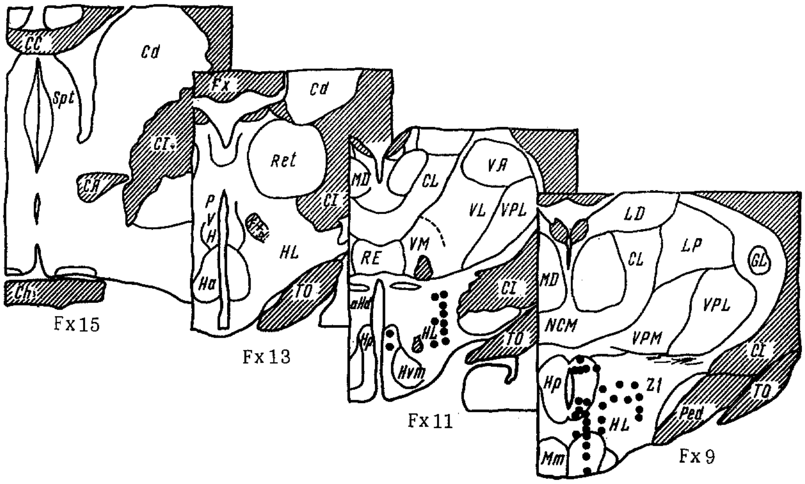

Fig. 1. Frontal sections through hypothalamus. Areas of hypothalamus during stimulation of which statistically significant evoked potentials were obtained in the mesencephalic reticular formation are shown by dots. These areas can be seen to be concentrated mainly in the zone of the posterolateral and posterior group of hypothalmic nuclei. Mm: Corpus mamillare; HL: Hypothalamus lateralis; Hp: Hypothalamus posterior; Hvm: Hypothalamus ventromedialis; aHd: Area hypothalamica dorsalis; Ha: Hypothalamus anterior; PVH: Hypothalamus paraventricularis; LD: N. lateralis dorsalis; CL: N. centralis lateralis; LP: N. lateralis posterior; MD: N. medialis dorsalis; NCM: N. centralis medialis; VPM: N. ventralis posteromedialis; VPL: N. ventralis posterolateralis; VM: N. ventralis medialis; VL: N. ventralis lateralis; VA: N. ventralis anterior; RE: N. reuniens; Ret: N. reticularis; Spt: septum; Cd: N. caudatus; CA: comissura anterior; CI: capsula interna; Ch: chiasma opticum; TO: tractus opticus; Fx: fornix; Ped: pedunculus cerebri; GL: corpus geniculatum laterale; ZI: zona incerta.

The first component of the hypothalamo-reticular responses was a stable primary negative wave with short latent period (2-4 msec) comparatively low amplitude (60-80 μV), and duration of the order of 10-25 msec. The second component was a positive wave with very variable amplitude (3-80 μV and a duration of 15-40 msec). The third component, a secondary negative wave, had the highest amplitude (80-130 μV) and a durationof 40-100 msec. During stimulation of nuclei of the anterior hypothalamus (supraoptic, preoptic, suprachiasmatic, and paraventricular) and the medial hypothalamus (paraventricular, ventro- and dorso-medial nuclei) no stable, statistically significant evoked responses were observed in the reticular formation of the brain stem.

The question of the pathways of conduction of hypothalamic excitation responsible for the formation of the primary and secondary negative waves of the evoked reticular responses to stimulation of the posterior hypothalamic nuclei naturally arose. The short latent period of the primary negative wave, its relative resistance to a high frequency of stimulation (50-70 Hz), to deep anesthesia, and to asphyxia suggest that this component is transmitted by direct or, at least, by oligosynaptic hypothalamo-reticular pathways. Meanwhile, the long latency and duration of the secondary negative wave, its extreme lability, and its sensitivity to the depth of anesthesia and asphyxia, and the considerable decrease in amplitude of the secondary negative wave after extirpation of the anterior regions of the cortex (sensorimotor, premotor, orbital, and proreal areas) indicate that the secondary negative wave is due to polysynaptic conduction of hypothalamic excitation, probably transmitted through the cortex.

To test this hypothesis, a series of experiments was carried out to study the character of corticofugal influences on hypothalamo-reticular relationships in various functional states of the cortex: after application of substances inhibiting or intensifying the functions activity of cortical neurons, or during local cooling of the cortex.

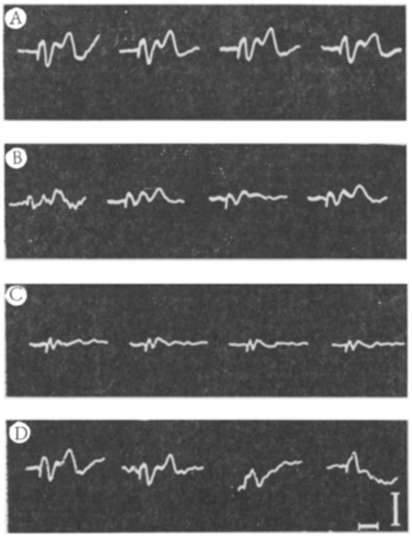

Fig. 2. Dynamics of changes in hypothalamo-reticular evoked responses during cooling of ipsilateral sensorimotor cortex. A) Background; B) 2 min after cooling cortex; C) 4 min; D) recovery of responses after warming cortex with warm physiological saline. Frequency of stimulation 1/sec. Amplitude calibration 100 μV. Time marker 20 msec. Urethane-chloralose anesthesia.

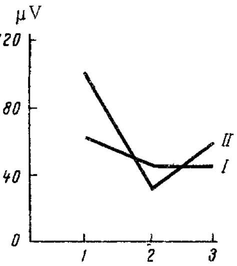

Fig. 3. Graph showing changes in amplitude parameters of primary (I) and secondary (II) negative components of hypothalamo-reticular evoked responses following application of 10% KCl solution to ipsilateral sensorimotor cortex. 1) Background; 2) 8 min after application of KCl to cortex; 3) rinsing of cortex. Curves plotted from mean values.

These experiments showed that 5-8 min after application of 10% KCl solution to the sensorimotor cortex the amplitude of evoked potentials in the mesencephalic reticular formation was lowered (Fig. 3). The decrease in amplitude of the hypothalamo-reticular responses took place predominantly on account of the secondary negative wave. It should be noted that the focus of potassium depression created in the visual projection area did not cause suppression of responses in the mesencephalic reticular formation. This was evidently due to the fact that most cortico-reticular fibers depart from the anterior cortical areas [9].

During cooling of the sensorimotor cortex the evoked hypothalamo-reticular responses aldo diminished considerably in amplitude, this being observed to the greatest degree after cooling of the ipsilateral sensorimotor cortex (Fig. 2). Usually 2-3 min after cooling a gradual decrease in the amplitude of the secondary negative phase of the evoked responses began in the mesencephalic reticular formation. After 4-5 min, the depression of the evoked hypothalamo-reticular responses reached its maximum. After rinsing of the cortex with warm physiological saline, evoked activity in the reticular formation was restored.

The study of the mechanisms of inhibition of hypothalamo-reticular responses during reversible functional blocking of the cortex raised the question whether the decrease in amplitude of the secondary negative wave of the evoked hypothalamo-reticular responses is the result of blocking of functional activity of the reticular formations or whether it reflects blocking at the cortical level of the polysynaptic dispatch of hypothalamic excitation, which is regarded as responsible for the formation of the secondary negative phase of evoked hypothalamo-reticular responses.

To answer this question a special series of experiments was carried out in which the spontaneous activity of the mesencephalic reticular formation was recorded together with its evoked potentials. Blocking of function of the sensorimotor cortex (by cooling or by application of 10% KCl solution was shown to have no effect on the spontaneous activity of the mesencephalic reticular formation. Since the character of the spontaneous activity of the reticular formation of the brain stem remained virtually unchanged during reversible blocking of cortical function, the decrease in amplitude of the secondary negative phase of the evoked hypothalamo-reticular responses at this moment was most probably due to blocking at the cortical level of the polysynaptic pathways of conduction of hypothalamic excitation participating in the formation of this phase. It is interesting to note that application of a 0.25-0.5% strychnine solution to the sensorimotor cortex was accompanied by a marked increase in amplitude of the hypothalamo-reticular responses, usually observed 2-4 min after application. If the excitability of the sensorimotor cortex is increased within certain limits, cortico-reticular pathways are evidently activated, as a result of which evoked activity is facilitated in the reticular formation [7]. There is good evidence in favor of this hypothesis because after application of 0.5% strychnine solution to the cortex, marked facilitation predominantly of the secondary negative phase of the evoked hypothalamo-reticular responses took place, due to the spread of hypothalamic excitation through the cortex.

The results described above thus show that both excitation and blocking of cortical neutrons has a definite and specific action on hypothalamo-reticular relationships because of the presence of specialized corticofugal influences.

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