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SYNAPTIC MECHANISMS OF THE FACIAL NUCLEUS ACTIVITY

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Mixed facial nerve innervates facial muscles, those of head surface, helix and middle ear and also lacrimal and salivary (sublingual and submandibular) glands.It relays the gustatory sense from the anterior two thirds of the tongue. The facial nucleus (FN) is a purely motor unit - facial nerve's great motor root is formed by the axons of facial motoneurons.The most complete activation of mimic muscles is reflected in the motivation- emotional realization activity of the organism. In a large majority of higher mammals the mimics is developed so that it is possible by means of those facial reactions to follow the emotional state of animals. However, at the present time, systematic investigation on the descending control of facial motoneuron activity have not been carried out. According to morphological data in many animal species there are no direct cortico-motoneuronal connections in the brainstem, including those with FN. On the other hand, there are a lot of facts suggesting an important role of the subcortical structures in the organization of descending effects. This is revealed most distinctly during electrical stimulation of various parts of the hypothalamus, resulting in activation of structures responsible for the regulation of posture and facial mimics. Polysynaptic organization of descending influences on facial motoneurons implies the presence of an interneuronal apparatus for transmission and integration of the signals on various levels of the brainstem.The available data evidence about extensive connections of FN with many brainstem structures that requires its functional confirmation.

The present investigation is an attempt to consider and summarize the data on synaptic mechanisms of regulation FN activity in the light of general knowledge of structural and functional organization of FN.

Results

Analysis of reflex activation of mimic muscles evoked by peripheral impulses shows that there are three main afferent links in the general system of FN reflex arcs, which provide the contraction of facial muscles: 1) afferent fibers of trigeminal nerve; 2) afferent fibers of facial nerve; 3) afferent fibers of a neck branch of vagus nerve.

Trigeminal nerve system provides the main afferent input in FN. This nerve is the basic sensory nerve of head, relaying the information on tactile, pain and temperature sensitivity of skin and greater part of mucous membranes of mouth cavity and nose. Relay of signals from proprioreceptors,mechanoreceptors and other types of nerve endings as well as from specialized sensory hairsprings-vibrissae is implemented by trigeminal nerve. Efferent vegetative fibers are often joined to the trigeminal nerve branches on the periphery.

Excitatory Postsynaptic Potentials (EPSPs) have been registered in facial motoneurons in response to stimulation of afferent fibers of trigeminal and hypoglossal nerves [1].

At the same time excitation of the mentioned afferent fibers resulted in the appearance of inhibitory postsynaptic potentials (IPSPs) and EPSP-IPSP sequence in some motoneurons innervating ear muscles [2].Afferent fibers of hypoglossal nerve are included in a vagus nerve structures distal to ganglion nodosum.

Reflex activation of mimic muscles can be also evoked by impulsation from facial nerve afferent fibers. It was revealed that ipsilateral stimulation of a facial posterior auricularis branch together with antidromic activation of facial neurons results in EPSPs [3].

Analysis of synaptic influence of facial afferents on FN motoneuorons has revealed that ipsilateral stimulation of its three main branches (posterior auricularis, dorsalis,ventralis) evokes two types of reactions in motoneurons: constantly revealed antydromic action potentials following them.

Stimulation of posterior auricularis branch after intracranial section of a vagus nerve evoked only the first antidromic response in FN motoneurons [4]. Morphological investigation have revealed that posterior auricularis is connected with auricularis branch of vagus nerve at level of stylomastoid foramen. Vagus nerve fibers in the composition of afferent fibers of auricular facial branch transmit the information to FN motoneurons through the neurons set in the spinal trigeminal nucleus or around it [4].

SPINAL CORD. Some morphological investigations state the existence of a direct projection of spinal afferents to FN motoneurons. Electrophysiological confirmation of this fact has been obtained for cats [1] due to the registration of mono-and polysynaptic EPSPs in FN motoneurons in response to the electrostimulation of ipsilateral anterolateral fasciculus of a spinal cord [5]. It was revealed that stimulation of ipsi- and contralateral peripheral nerves of anterior limb doesn't lead to the activation of FN motoneurons. Therefore, spinal afferent fibers below the IV cervical segment of spinal cord don't contribute to the formation of spinofacial projections having exclusively excitative nature [5].

BRAINSTEM. Brainstem nuclei play great role in transmitting influences in FN. Projection of axons neurons located in a cat brainstem on motoneurons of facial, hypoglossal and trigeminal nuclei have been shown by the methods of anterograde degeneration and autoradiographic investigation using radioactive amino acids. These neurons are mainly localized in reticular formation of the inferior part of brainstem. Their axons, while grouping, form the lateral and medial propriobulbar systems of fibers [6].

It was shown that the stimulation of interstitial nucleus of Cajal, nucleus of Darkschewitsch,nucleus reticularis parvocellularis of medulla oblongata, oculomotor nucleus, substantia nigra, nucleus of Ediger-Westphal and periaqueductal gray evokes mainly monosynaptic EPSPs in FN motoneurons [7]. Monosynaptic EPSPs in response to the stimulation of solitar tract nucleus in FN motoneurons are described [8].

The presence of rubro-facial fibers has been revealed in many animal species. Electrophysiologically it was shown that the stimulation of contralateral red nucleus evokes monosynaptic EPSPs in facial motoneurons [9, 10].

Data on projections from pretectal area to FN were obtained. Termination of pretectofacial fibers in the region of representation of zigomatico-orbital branch of facial nerve is shown. Electrophysiological analysis of tactofacial pathways in cats has been carried out. Monosynaptic EPSPs in FN motoneurones to contralateral collicular [11] and pretectal area [7] stimulation are shown. Excitatory and inhibitory monosynaptic influences from ipsilateral locous coeruleus and inhibitory mono-and polysynaptic influences from contralateral locus cocruleus on cat facial motoneurons are revealed. Direct projections from vestibular nuclei to FN of cat and rat are shown. In vestibular nuclei the neurons projecting on FN overlap populations connected with oculomotor nucleus and neck motoneurons. The most probable role of vestibular projection to FN is to coordinate face movements with those of eyes and head. Antidromic activation of Daiter's nucleus neurons to FN stimulation was revealed [12]. Primary fibers forming the trigeminal nerve root and descending then in the structure of a spinal tract were shown to be distributed somatotopically in a spinal trigeminal tract.

Many investigators consider the caudal nucleus of spinal trigeminal tract to be a rostral extension of dorsal horns of spinal cord. Presynaptic processes in primary afferents of trigeminal nerve were determined [13]. Activation of facial neurons to stimulations of caudal trigeminal nucleus was revealed electrophysiologically. Intracellular investigation has made it possible to registrate the following four varieties of synaptic activation on FN motoneurons to single stimulation of spinal trigeminal nucleus: 1. ESPSs generating single action potentials; 2. Gradual shift of depolarization with evoked multiple action potentials; 3. Grouped action potentials arising at the low level of depolarization; 4. EPSPs and sequence EPSP-IPSP [14, 15].

CEREBELLUM. Trigeminal afferents were shown to activate cerebellar neurons via mossy and climbing fibers [16].

There are morphological data suggesting projection from motor nuclei of cranial nerves to cerebellum. In contrast to afferents from inferior olive, pons and lateral vestibular nucleus projecting to broad cerebellar zones fibers from motor nuclei of cranial nerves involve limited parts of cerebral cortex[17].Fibers from FN projecting on flocculus were stated to be not collaterals of FN motoneuron axons but represent axons of separate population of projecting neurons. Projection from cerebellar nuclei mainly from interposite ones to facial motoneurons belonging chiefly to dorsal branch of facial nerve has been shown by microelectrode investigation on cats [9].

SUBCORTICAL STRUCTURES. Complex of subcortical nuclei of limbic system and basal ganglia contributes largely to the formation of motivation- emotional activity of the organism. Stimulation or destruction of the mentioned structures decisively influence the mimic muscles.

Electrical stimulation of certain parts of the hypothalamus in cats calls forth the activation of structures responsible for posture regulation (animal gets ready for a jump, struggle) as well as face mimic is accompanied by vocal displays and vegetative reactions [18].

Stimulation of amygdala also leads to those evoked by the hypothalamic stimulation. The latter are implement of hypothalamic mechanisms through the ventral amygdalofugal pathway [19].

Electrostimulation of different parts of mesencephalon,extending from mesodiencephalic connection up to the level of decussation of brachium conjunctivum called forth the behavior identical to the one evoked by hypothalamic stimulation [18]. Local destruction of ventral region of the mesencephalic tegmentum blocks the attacking behavior of animal in response to the region of mesencephalic tegmentum was revealed to be followed by degenerated descending fibers in structures of brainstem, FN in particular, as well as in main sensory and spinal trigeminal nuclei; whereas the ascending fibers terminate in hypothalamus and near the thalamic middle line, i. e. in the regions defined as the areas which evoke affective attack [17].

Stimulation effects of head of nucleus caudatus, globus pallidus, central nucleus of amygdala and lateral hyphothalamus on the facial motoneuron activity have been studied [14]. Reactions to stimulation of head of nucleus caudatus, nucleus entopeduncularis and globus pallidus have been represented by polysynaptic EPSPs of FN motoneurons. Lateral hypothalamic stimulation also evoked polysynaptic EPSPs of FN motoneurons [20]. Excitation of amygdalar central nucleus evoked EPSPs that could be divided into two groups according to their characteristics [20]: monosynaptic and polysynaptic EPSPs. The high degree convergence of influences from the investigated structures as well as from ventral part periaqueductal grey matter and pretectal area on facial motoneurons has been observed.The wide range of projection to FN from the structures, varying their functional peculiarities points out to the active participation of mimic musculature in motor and motivation emotional activity of organism.

CEREBRAL CORTEX. Cerebral cortex has a leading role in realization and regulation of numerous reactions including cranial reflexes. Motor cortex in human and in monkey is shown to have direct connection with FN [21]. While the morphological investigation on other animal species haven't revealed any direct connection of axons of cortical pyramidal cells with brainstem motoneurons [22]. Corticofugal influences in brainstem motoneurons are transmitted through the system of interneurons by the analogy with spinal motoneurons [21].

Lesion of facial zone of motor cortex in monkeys has been followed by bilateral degeneration of corticofugal fiber terminals in ventral and lateral FN regions, ventral region of motor trigeminal and hypoglossal nuclei.

Stimulation of sensorimotor cortex evoked polysynaptic EPSPs and IPSPs in cat FN motoneurons. Such reactions have been also recorded from interneurons localized near FN.

The stimulation of contralateral pyramidal tract also leads to di- and polysynaptic EPSPs and IPSPs in facial motoneurons. Synaptic influences on cat facial motoneurons in response to the stimulation of rostral part of ipsilatral orbital gyrus of cerebral cortex were studied. Recorded reactions include EPSPs, EPSP-IPSP sequence and isolated IPSPs [23].

Descending influences from motor cortex, gyrus proreus and pyramidal tract on cat facial neurons were studied [14, 20].Reactions recorded were represented by EPSPs, EPSP-IPSP sequence and isolated IPSPs.Relationship between the types of postsynaptic responses varied depending on the source of descending inputs. IPSPs recorded to proreal stimulation were twice as those recorded to the stimulation of motor cortex.

The descending flow of impulses substantially contributes to the large premotor system formed of interneurons and localized in the brainstem in the immediate vicinity of FN. Such neuronal organization determins greater sensitivity of FN neurons to afferent signals as well as variety of mechanisms of the afferent control of FN activity. All these factors are responsible for a large scale FN participation in various reflex reactions of the organism providing higher plasticity and mosaic character of motor reactions of the face muscles [17].

Conclusion

Presented facts characterize FN as a compound differentiated structure directly contributing to the activation of mimic muscles accompanying various motor and motivation- emotional reactions of the animal.

A number of brainstem structures are shown to have direct connections with FN. Many subcortical structures contribute to the regulation of FN activity. Highly developed convergence of cortical and hypothalamic signals of facial motoneurons is shown (71,4%) [20]. In this connection the fact should be mentioned that some investigators in neurology distinguish between two varieties of central or supernuclear paralysis of facial muscles: voluntary and emotional [13]. The first is caused by a disease of facial field of motor cortex or corticofugal pathway, while the emotional type of supernuclear paralysis is represented as a result of a disease deeply located in hypothalamus, mesencephalic tegmentum, indicating the important role the latter has in regulating FN activity.

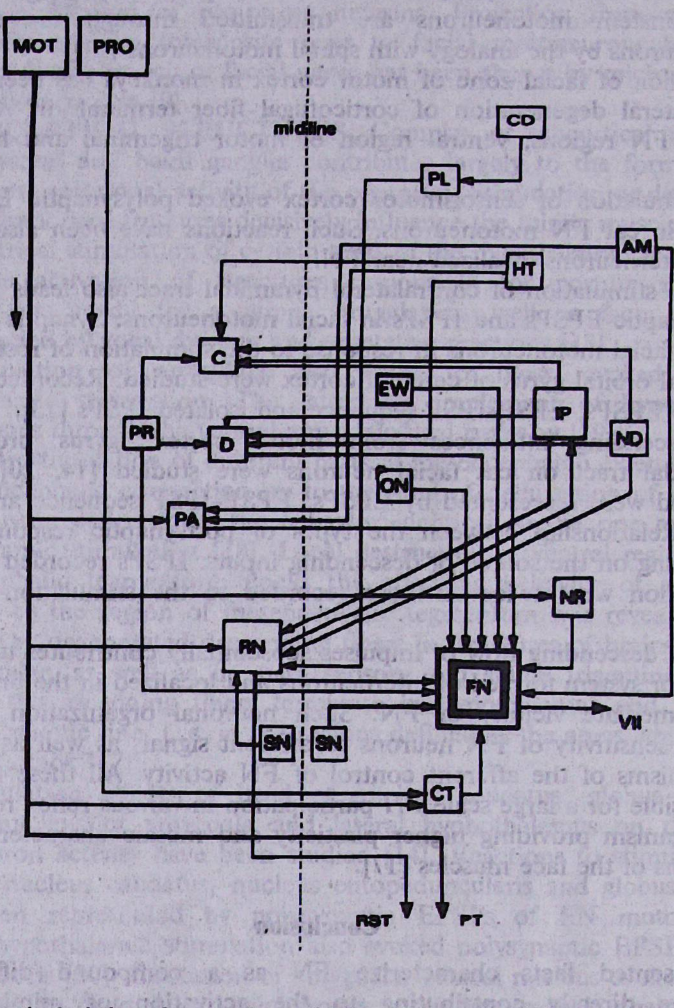

Fig. 1. Schematic depiction of neuronal organization of descending influences onto the facial nucleus. Arrows indicate the synapses and the direction of information transmission. Abbreviations: MOT-motor cortex; PRO-gyrus proteus; CD-caudate nucleus; PL-globus pallidus; AM-amygdala; HT-hypothalamus; C-interstitial nucleus of Cajal; EW-Edinger-Westphal nucleus; PR-protectal area; D-nucleus of Darkschewitsch; IP-nucleus interpositus; ND-nucleus dentatus; ON-oculomotor nucleus; PA-periaqueductal gray; NR-nucleus reticularis parvocellularis of the medulla; RN-red nucleus; FN-facial nucleus; SN-substantia nigra; CT-caudal trigeminal nucleus; RST-rubrospinal tract; PT-PY-pyramidal tract.

Results obtained in the investigation have formed the basis for a diagram of neuronal organization of descending pathways to FN (Fig.). Several projections can be distinguished. The basic pathways of corticofugal influences include the caudal trigeminal nucleus as well as nucleus reticularis parvocellularis of the medulla oblongata, periaqueductal grey and the red nucleus. Single and group action potentials as well as a excitatory and inhibitory reactions are evoked through the caudal trigeminal nucleus. Hypothalamic influences are transmitted through ventral part of midbrain tegmentum: interstitial nucleus of Cajal, nucleus of Darkschewitsch and periaqueductal gray. These influences are exclusively excitatory by their nature. Amygdala has direct connection with FN, although its influences can also be realized through periaqueductal gray. There is the evidence that cerebellar structures can use interstitial nucleus of Cajal and nucleus of Darkschewitsch in sending their influences to FN motoneurons, as well as the red nucleus is considered to be one of the main structures of this kind. It also serves as a relay for signals from globus pallidus. Influences from caudate nucleus to facial motoneurons can be realized through a number of brainstem structures including pons and medulla.

The diagram presented is only a fragment of multiple network serving as a structural basis of descending influences, which regulate the activity of FN motor cells. However, this fragment well demonstrates the basic canals of descending control, relay structures of these canals, presenting the premotor system of FN, as well as structural basis for converging influences from various nuclei which affect the FN neuronal system. These peculiarities would certainly provide large participation of FN, as well as grater sensitivity and responsibility of mimic muscles in the realization of diverse reactions of the organism.

The wide range of facial nucleus links with different brain structures is conditioned by its responsibility to various synaptic signals. Clarification of peculiarities of facial nucleus afferent inputs organization is the key for understanding complex integrative processes, taking place in the nucleus itself and determining the selective action of its motor output. This is confirmed in neurological clinic when the lesion of brain with various localization results in voluntary and emotional type of paralysis.

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ԴԻՄԱՅԻՆ ՆՅԱՐԴԻ ԿՈՐԻԶԻ ԳՈՐԾՈՒՆԵՈՒԹՅԱՆ ՍԻՆԱՊՍԱՅԻՆ ՄԵԽԱՆԻԶՄՆԵՐԸ

Վ. Բ. Ֆանարջյան

Ներկայացվում են դիմային նյարդի կորիզի կառուցվածքային եւ ֆունկցիոնալ կազմավորման ժամանակակից կոնցեպցիաները:

Վեր են լուծվում դիմային նյարդի կորիզի ռեֆլեկտոր աղեղները: Բացահայտվել են տրիգեմինո-ֆացիալ փոխհարաբերությունները: Դիտարկվում են դիմային նյարդի կորիզի աֆերենտ համակարգի նյարդային սինապսային կազմավորման մեխանիզմները՝ նկատի ունենալով նաեւ ողնուղեղից, ուղեղաբնից, ուղեղիկից, ենթակեղեւային կորիզներից եւ ուղեղի կեղեւից դուրս եկող մուտքերը:

Դիմային նյարդի կորիզի ուղեղի տարբեր բաժինների հետ լայնամասշտաբ կապերը պայմանավորում են նրա բարձր պատասխանատվությունը տարբեր

սինապսային ազդակների նկատմամբ: Դիմային նյարդի կորիզի աֆերենտ մուտքի կազմավորման առանձնահատկությունների բացահայտումը հանդիսանում է այն բարդ բացասական պրոցեսների հասկանալու բանալին, որոնք տեղի են ունենում իր իսկ կորիզում եւ բնորոշում են նրա շարժիչ մուտքի ընտրողականությունը: Այդ իր հաստատումն է գտնում նաեւ նյարդաբանական կլինիկայում, երբ ուղեղի տարբեր տեղակայում ունեցող ախտահարումները վերածվում են կամային կամ էմոցիոնալ տիպի պարալիչի:

СИНАПТИЧЕСКИЕ МЕХАНИЗМЫ ДЕЯТЕЛЬНОСТИ ЯДРА ЛИЦЕВОГО НЕРВА

В.В.Фанарджян

В статье представлены современные концепции по структурной и функциональной организации ядра лицевого нерва. Анализируются рефлекторные дуги ядра лицевого нерва. Показаны механизмы тригемино- фациальных взаимоотношений. Рассматриваются нейроны и синаптические механизмы организации афферентной системы ядра лицевого нерва, включая входы из спинного мозга, ствола мозга, мозжечка, подкорковых структур и коры мозга.

Широкие связи ядра лицевого нерва с различными отделами мозга обуславливают его высокую ответоспособность на различные синаптические посылки. Выяснение особенностей организации афферентных входов ядра лицевого нерва является ключом к пониманию сложных интегративных процессов, разыгрывающихся в самом ядре и определяющих избирательность его моторного выхода. Это находит подтверждение в неврологической клинике, когда поражения мозга с различной локализацией результируются в произвольный или эмоциональный тип паралича.

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