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THE PHENOMENON OF NEUROPLASTICITY IN THE MECHANISMS OF REFLEXOTHERAPY

Abstract

Reflexotherapy (Chen-Chiu, acupuncture) is one of the most important and valuable part of mankind's heritage. Reflexotherapy has a long history and was formed as a practical healing method. Reflexotherapy methods include: acupuncture (Chen); Chiu-method (cauterization or warming of acupuncture points by means of wormwood or coal cigars); multi-needle stimuli by a special hammer; vacuum effect on acupuncture points; acupressure; tsubo-therapy; and hirudotherapy. Modern modifications of reflexotherapy are applied: electroacupuncture, electropuncture, laser reflexotherapy, craniopuncture, magnetopuncture, cryotherapy, color and light therapy, and others. There are many theories about the mechanism of action of this method. The focus of the Kazan school is on the role of sensory interaction at different levels of the nervous system in the implementation of the relexotherapy effects. The reflex mechanism for the development of therapeutic effect is considered in this connection as part of a universal method of information processing — sensorimotor interaction. The therapeutic effects of reflexotherapy are realized through the formation of local and background sensory flow, and their interaction at different levels of the nervous system. Afferent flow is processed at the peripheral, spinal-segmental, stem, subcortical levels, as well as at the level of the cortex. The realization of the positive effects of reflexotherapy occurs, including due to the phenomenon of neuroplasticity, which is implemented at the peripheral and central levels. Reflexotherapy methods can activate the phenomenon of brain neuroplasticity, leading to structural and functional changes that require further research in this direction.

Key words: *reflexotherapy, neuroplasticity*

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Reflexotherapy (Chen-Chiu, acupuncture) is an important and valuable legacy of both traditional oriental medicine and humanity as a whole. This is the only method of treatment that, having arisen thousands of years ago, has been preserved and is now used in a form very close to the original. Reflexotherapy has a long history and was formed as a practical therapeutic method. From ancient times it was noticed that injections in some points not only alleviated the course of several diseases, but sometimes even completely cured people. Therefore, it is recommended not to neglect ancient empiricism, it is often possible to derive something significant for modern science and practice [1]. The combined use of physical stimulation and mental stress has long been known in traditional medicine. Only now are scientists beginning to understand how to explain the effectiveness of these traditional practices in terms of Western medicine. Western medicine has ignored Eastern medicine for a long

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time, although millions of people have used the latter for thousands of years. [2]

Reflexotherapy is thought to have originated in Buddhist temples in Nepal or Tibet. The development of this method lasted for several centuries. Chen-Chiu (reflexotherapy) later became widespread not only in China but also in Korea, Japan, Burma, Mongolia, Vietnam, and India. In Europe, in particular in France, the method penetrated around the 13th century. Doctors described their observations of the good results of reflexotherapy in the treatment of multiple chronic diseases of internal organs, neuralgia, myositis, rheumatism, acupuncture anesthesia (analgesia). In Russia, Professor of Medical Surgery Academy P. Charukovsky, who noted a positive therapeutic effect for rheumatism and sciatica [3], applied the method of reflexotherapy in 1828. Interest in reflexotherapy in our country increased in the middle of the XX century. To date, the efficacy of this method is still studied by modern medicine, and it is obvious that the method of reflexotherapy has great success in the treatment of people with various diseases. Specialists in internal and general medicine mainly practice reflexotherapy.

The methods of reflexotherapy include: acupuncture (Chen); Chiu-method (burning or warming of acupuncture points using coal or wormwood cigars); multineedle exposure by a special hammer; vacuum exposure on the acupuncture points; acupressure; tsubo-therapy; and hirudotherapy. Modern modifications of reflexotherapy are also applied: electroacupuncture, electropuncture, laseromagnetotherapy, craniopuncture, magnetopuncture, cryotherapy, color and light therapy and others.

There are a lot of theories about the mechanisms of action of reflexotherapy. Eastern doctors, that had been using the method of Chen-Chiu since ancient times, sought to understand its essence, to explain the mechanisms of action. The theoretical concepts of the Ancient East thinkers have become fundamental for the interpretation of many natural phenomena and explanation of the reflexotherapy mechanism. Two fundamental philosophical concepts — the theory of Yin-Yang and the theory of the five elements (Wu-Hsing) — became the theoretical basis for all kinds of scientific activities of the peoples in the Ancient East, including medicine [4, 5]. For modern scientists, these concepts look archaic, but they are facts, concepts and hypotheses based on the spontaneous materialistic views of ancient doctors that have been proved over many centuries.

Most studies conducted by Western European scientists are mainly aimed at studying the mechanism of certain aspects of acupuncture effect on the human body. Therefore, there is a significant number of theories explaining the mechanisms of reflexotherapy. Most theories are based on defined, concrete facts: capillary theory, tissue theory, histamine theory, flocculation theory, electrical theory, thermoelectric theory, ion theory. Attention is paid to organ neurocutaneous relationships and reverse skin neuro-organic relations. Most authors suggest that the therapeutic effect of reflexotherapy is based on the effect on the central nervous system, through which the regulating and trophic effect on the impaired functions of the body is carried out [6].

Numerous studies of domestic reflexotherapy schools also offered a sufficient number of theories. The focus of the Kazan School is on the role of sensory interaction at different levels of the nervous system as the way for the implementation of reflexotherapy effects. The reflex mechanism of the development of the medical effect is considered in this connection as part of the universal method of information processing — sensorimotor interaction [7]. The principle of sensory interaction was articulated for the first time by R.A. Durinyan to explain the mechanisms of auricular reflexotherapy [8].

The practical basis of acupuncture is controlled sensory flow. Of the existing five sensory analyzers — extractive proprioceptive, visual, auditory, gustatory and olfactory — the extractive proprioceptive one is used in the practice of acupuncture. Exposure of the acupuncture point by various methods leads to the excitation of sensory afferent flow. Therapeutic effects of reflexotherapy are realized through the formation of local and background sensory flow, and their interaction at different levels of the nervous system. According to G. A. Ivanichev [7], the following main levels of sensory systems are distinguished:

- Peripheral level,
- Spinal segmental level,
- Stem level,
- Subcortical level,
- Cortical level.

The **peripheral level** of sensory systems is represented by receptors. In the receptors of the acupuncture point, irritation is registered and coded for transmission to other parts of the nervous system. In the receptors, the energy of the stimulus is transformed into a nerve impulse of the sensory fiber. Irritation of acupuncture points causes local reactions in the form of color changes of the skin, its blood supply, temperature, moisture, sensitivity. Anatomically and histologically, an acupuncture point is the most concentrated cluster of nerve elements located at different depths and different tissues. A limited number of receptors located at different depths in the skin, fascia, periosteum, muscles, vessels and nerves, available to irritation from the body surface, take part in the implementation of acupuncture therapeutic effects. In the receptors of the acupuncture point, irritation (the action potential of the sensory fiber), the coding of this irritation and its transfer to the segmental apparatus of the spinal cord are recorded.

The second reaction is a segmental response to stimulation of the exposure point. Thus, the nerve impulse (the potential of the sensory fiber) that has arisen in the receptors reaches the first relay station for processing the afferent (sensitive) flow in the central nervous system — the spinal cord with peripheral sensory nerves — **the spinal segmental level.** The bodies of neurons, which are the structural, functional and genetic unit of the nervous system, represent the gray matter of the spinal cord. Neuronal processes provide a nerve impulse from receptors or other neurons to the following neurons, as well as to the periphery to efferent performers. The spinal cord with peripheral sensory nerves is the first relay station for processing afferent flow. The reception, gate control, and further processing of the primary product to the next part of the nervous system are carried out here [7].

Segmental reaction is expressed by the direct reaction of the segment with the inclusion of the fibers of the autonomous nervous system to various formations (internal organs, vessels, muscles, etc.). To obtain a stable segmental reaction, a certain exposure time is necessary, since short-term stimulation can result in rapid attenuation of the reflex. In classical acupuncture, such cases pertain to inhibitory techniques. Apparently, in some cases, this response is the main one in reflexotherapy, especially if it is local segmental influence of points. It is also possible that the therapeutic effect of exposure on messenger points of Zakharyin-Ged zones, simply pain points is based on such communication. In the process of human evolution, the principle of segmental innervation has changed significantly (it is observed only in the early stages of embryonic development). The appearance of the brain has significantly complicated segmental relationships, although the basic principle of segmental innervation has been preserved. Moreover, in the process of evolution, nature „re-insured itself", each metamer began to innervate not at the expense of one segment, but it was overlapped by neighboring ones (upper and lower). Such phenomena are extremely important in clinical practice. Relationships at the level of the segmental apparatus are extremely complex; many issues in their detailed functioning are not fully understood. For example, the role of the so-called transition segments is poorly understood. It is known that vegetative centers are located in the lateral horns of the spinal cord and are located at the level of C_8 — L_2 (sympathetic) and S_2 — S_5 (parasympathetic). [9, 10] According to W. Schneidt, 1952; G. Bachmann, 1961, through these segments (C_8 and S_2) communication can be carried out between motor fibers of the vagus nerve at the top tractus parependimalis in lower parts. At the same time G. Bachmann notes that the main points of acupuncture (toning, inhibitory, points-sources, lo-points, etc.) are located in the areas of innervation of these segments or near them. This interpretation of the role of transitional segments deserves attention. If we consider that the vagus nerve evolutionarily had a significant somatic part, partially preserved, as well as a close connection with the trigeminal nerve (their common core — nucleus ambiguus), then, indeed, mutual influences and information transfer are possible, bypassing the classical pathways of the brain and spinal cord.

From segmental formations, nerve impulses along specific and nonspecific pathways of the spinal cord are directed to the subcortical stem structures (reticular formation, thalamus and hypothalamus, pituitary, limbic system and other formations) and, finally, to the cerebral cortex. There is also feedback between all these formations. The perception of irritation by different structures of the brain depends on the specificity of the structures themselves and the area where the irritation is applied. Typically, the more functionally important is an organ or an area of the body, the more widely it is represented. This applies, for example, to the face, tongue, mouth, arms, especially the hands, and partly to the feet. Probably, it should be expected that the application of irritation to the areas of the body functionally more differentiated, with a higher density of nerve endings (limbs, face) will be perceived much more fully than, for example, in less differentiated areas (back).

In the practice of acupuncture, this assumption is fully confirmed. The known main acupuncture points (toning, inhibitory, lock, etc.) are located mainly in the distal extremities. The same applies to the points of „first aid", located in the mouth and at the fingertips. It is naturally, that the functionally differentiated massive representation of the marked body areas will have a stronger impact than the irritation of poorly differentiated areas. Hence, the distal points are the main points and have a general regulatory action (according to traditional concepts, the regulation of „energy" in general). They act stronger than, for example, the points on the back (in the classical version — the points of sympathy), which have a local segmental nature of the impact [11].

The stem level of sensory systems is structurally represented by the posterior, which includes the medulla and cerebellum, middle and intermediate brain. The emergence of the medulla oblongata is associated with the development of statics, acoustics and gill apparatus involved in the formation of the respiratory and circulatory systems. Many vital autonomic reflexes involving reticular formation, the nucleus of four pairs of lower cranial nerves (IX, X, XI, XII) and other structures are mediated through the medulla oblongata. The substance of the reticular formation contains vital respiratory and vasomotor centers, functionally closely related to the vagus nerve. The sensory input system of the medulla oblongata is represented by the afferent pathways of the vagus, pharyngeal and vestibular-cochlear nerves [7, 8, 10]. From the point of view of acupuncture, IX, X pairs are important, because we can influence their afferent channels. The receptive field of the vagus and pharyngeal nerves, available to acupuncture, is located on the ear in the area of the external auditory canal, bowl (cimbala conchae) and the cavity of conchea (cavum conchae). These areas include the points of the following areas: XIV — adjacent to crus of helix, XV — the bowl of conchea, XVI — the cavity of conchea [6, 8]. An important sensory area is a three-sided fossa (X area) — on reflex effects on a number of visceral reactions is not much inferior to conchea, due to its origin, formation and innervation (V, VII, IX, X pairs of cranial nerves). Reflex reactions, caused by this area of the auricle, should be by nature close to those, which are caused by the area of the conchea, and differ only in the topography of its implementation. If the conchea is the area of reflex reactions to the functions of the thoracic and abdominal cavities, the trilateral fossa is the area of reflex reactions to the functions of the pelvic organs, in particular to the terminal functions of the genital and excretory organs, the regulation of which is associated not only with the autonomic nervous system, but also with the somatic one. The presence of somatic afferent innervation of the trilateral fossa region with branches of the trigeminal nerve (in contrast to the conchea region, where this is practically absent) is necessary because the function of the pelvic organs is sufficiently strongly corticalized and well amenable to arbitrary (conscious) control. To influence these functions, it is necessary to involve thalamocortical projections in the activity, which is easily achieved when the trigeminal system is activated, thanks to its powerful thalamocortical projections [8].

The trigeminal nerve system, through which a functional multilateral connection with various afferent systems of the brain stem is carried out, has a great importance in the implementation of the effects of reflexotherapy. The sensory input system of the afterbrain includes a large diverse receptive field of the trigeminal nerve (head and neck part), bounded by extractives of the facial nerve (bowl of the ear). The main afferent system of the head is a powerfully organized anatomical and functional structure of the trigeminal nerve. The ascending afferent flow from the trunk is controlled by the trigeminal nerve, so the acupuncture points in the trigeminal nerve system have greater activity in comparison with the points located on the trunk [7, 8].

The midbrain is an entity that has brought together all the afferent pathways and is of great importance in controlling sensory flow. The reticular formation plays a special role in the activation and inhibition of brain activity. The generalized background activity of the reticular formation is supported by a converged afferent flow formed by all types of analyzers. In this case, the reticular formation can selectively activate or inhibit the motor, sensory, visceral, behavioral systems of the brain. The reticular formation controls the transmission of sensory information through the nucleus of the thalamus. It should be emphasized that in the implementation of reflexotherapy effects, especially general reactions, the functions of the middle brain have an important place [7, 9, 10].

The structure of the intermediate brain, which ensures the integration of homeostatic reactions of the body and the design of behavioral and emotional reactions, is the hypothalamus. Powerful afferent connections of the hypothalamus with the olfactory brain, basal ganglia, thalamus, hippocampus, orbital, temporal and parietal cortex determine its awareness of the state of almost all brain structures. The hypothalamus itself provides information to the thalamus, reticular formation, vegetative centers of the trunk and spinal cord. Due to the large number of input and output connections, polyfunctionality of structures, the hypothalamus performs the integrating function of vegetative, endocrine and somatic activity [9, 10]. In the practice of acupuncture points of the cervical area and auricular points of tragus area, intertragic notch, posterior auricular grooves and antitragus are used to influence the functional state of the hypothalamus. The points of general action that increase the activity of non-specific brain systems determine the stability of numerous processes implemented by the hypothalamus [7].

The structure in which the processing and integration of almost all signals going into the cerebral cortex from the neurons of the spinal cord, mid and medulla oblongata, cerebellum, pale ball, from the visual, auditory, gustatory, skin, proprioceptive analyzers, from the nuclei of cranial nerves take place, is the thalamus. The ability to obtain information about the state of many body systems is provided by about 120 multifunctional nuclear groups of the thalamus. Nonspecific and associative nuclei make up the bulk of the neural substance of the thalamus. The main flow of information is processed by nuclear formations and the most significant part is delivered to the cerebral cortex. The activity of specific thalamus nuclei has a special place in the realization of many effects of reflexotherapy. The corporeal sensory flow is collected in the posterior ventrolateral nuclear complex and from the face through the trigeminal nerve system — to the posterior ventromedial nuclear complex. Thus, two afferent flows have relatively independent existence for subsequent transformations [5, 7, 12]. Thus, the thalamus is the highest center of sensory information control.

The subcortical level, the afferent organization of basal ganglia functions, mainly focuses on supporting functions of extrapyramidal motility organization. The limbic system is the oldest part of the cerebral cortex, located on the inner side of the cerebral hemispheres. It includes hippocampus, cingulate gyrus, amygdala, bulb-shaped gyrus. Limbic formations belong to the higher integrative centers of regulation for vegetative functions of the body. The neurons of the limbic system receive impulses from the cortex, subcortical nuclei, thalamus, hypothalamus, reticular formation and all internal organs. The limbic system is involved in afferent synthesis, in the control of electrical activity of the brain; it regulates metabolism and provides a number of vegetative reactions. A characteristic feature of the limbic system is the presence of well-defined ring neural connections that unite its various structures. Thus, the structures of the limbic system are involved in the implementation of such complex brain functions as behavior, emotions, learning, and memory. The limbic system is involved in the implementation of therapeutic effects of acupuncture in combination with thalamus, hypothalamus, reticular formation [5, 7]. Among the structures responsible for memory and learning, the hippocampus and the associated posterior zones of the frontal cortex play a major role. Their activity is important for the transition of short-term memory to long-term memory. The hippocampal complex is highly sensitive to hypoxia and at the same time is characterized by a unique plasticity, which explains the important role of this structure in the genesis of epileptic seizures, as well as in learning and memory. In addition, it is the main center of neurogenesis of the mature brain.

Neurogenesis in the adult brain is a phenomenon relatively recently recognized by the scientific community, which has disproved the long-standing scientific theory about the static nature of the nervous system and its inability to regenerate cells. It is now generally accepted that neurogenesis is constantly occurring in two limited areas of the brain — the hippocampal subgranular area (HSA) and the subventricular area (SVA) of the lateral ventricles. New neurons formed in the HSA migrate to the layer of granular cells of the hippocampal dentate gyrus [13]. Neurons generated in SVA enter a new associative cortex, entorhinal cortex, and olfactory bulb [14, 15]. Recent studies have shown that newly formed neurons in the adult brain are embedded in existing neural networks and receive functional inputs [16]. Neurogenesis in the adult brain is regulated by physiological and pathological factors at all levels, and new neurons may be necessary for certain brain functions, such as learning and memory. Recent work demonstrates neurogenesis in a number of other brain structures: in the caudate nucleus, frontal cortex, primary and secondary motor and somatosensory cortex [17, 18]. It was recently shown that in primates, newly formed neurons from the subventricular area can migrate to the striatum, which is responsible for complex motor reactions and the formation of conditioned reflexes [19]. Thus, two afferent systems pass through the brain stem into the cerebral cortex: one — specific — all specific sensitive pathways, carrying impulses from all receptors (extra, inter-and proprioceptors) and ending on the bodies of cells mainly of the 4th layer of the cortex; another — nonspecific, formed by reticular formation and ending on dendrites of all layers of the cortex. The interaction of both these systems determines the final reaction of cortical neurons.

The cortical level of sensory systems includes somatosensory and associative areas of the cerebral cortex. At this level, there is a conscious processing of the sensory flow, including nociceptive. Sensory areas of the cortex are areas in which sensory stimuli are projected. They are located mainly in the parietal, temporal and occipital lobes. Afferent pathways to the sensory cortex come mainly from specific sensory nuclei of the thalamus (central, posterior lateral and medial). The sensory cortex has well defined 2 and 4 layers (granular). Areas of the sensory cortex, irritation or destruction of which cause clear and constant changes in the sensitivity of the body, are referred to as primary sensory areas (nuclear parts of the analyzers, as believed I.P. Pavlov.) They consist mainly of monomodal neurons and form sensations of the same quality. In primary sensory zones, there is usually a clear spatial (topographic) representation of body parts, their receptor fields. Around the primary sensory areas, there are less localized secondary sensory areas, polymodal neurons, which respond to several stimuli. The most important sensory area is the parietal cortex of the postcentral gyrus and the corresponding part of the postcentral lobule on the medial surface of the hemispheres (fields 1–3), which is designated as the somatosensory area. There is a projection of the skin sensitivity of the opposite body side from the tactile, pain, temperature receptors, interoceptive sensitivity and sensitivity of the musculoskeletal system, from muscle, joint, tendon receptors. The projection of the body areas in this area is characterized by the fact that the projection of the head and upper trunk is located in the lower lateral areas of the postcentral gyrus, the projection of the lower half of the trunk and legs is located in the upper medial areas of the gyrus, and the projection of the lower leg and feet — in the cortex of the postcentral lobule on the medial surface of the hemispheres. The projection of the most sensitive areas (tongue, larynx, fingers, etc.) has relatively large areas compared to other parts of the body. Most of the information about the outside world and the internal environment of the body, received in the sensory cortex, is transmitted for further processing in the associative cortex.

Associative areas of the cortex include areas of the new cerebral cortex, which are located near the sensory and motor areas, but do not perform directly sensitive or motor functions. The associative cortex is the phylogenetically youngest region of the new cortex, most developed in primates and humans. In humans, it makes up about 50 % of the entire cortex or 70 % of the neocortex. The main physiological feature of neurons in associative cortex that distinguish them from neurons in the primary areas is polysensority (polymodality). They respond with almost the same threshold not to one, but to several stimuli — visual, auditory, skin and others. The polysensority of neurons in the associative cortex is created both by its corticocortical connections with different projection areas, and its main afferent input from the associative nuclei of the thalamus, in which there has already been complex processing of information from various sensitive pathways. As a result, the associative cortex is a powerful device for the convergence of various sensory excitations, allowing performing complex processing of information about the external and internal environment of the body and using it for the implementation of higher mental functions. Thus, sensory support of the central mechanisms in nervous regulation is crucial for the integration of numerous functional physiological systems of the body. Brain functions are organized so that the more complex is the function, the more branched neural networks are involved in its organization.

Perhaps the implementation of reflexotherapy effects on the cortical level is due to the phenomenon of neuroplasticity (modulation of neurogenesis). The use of acupuncture, Chiu-method, multineedle irritation, craniopuncture, as well as other methods of influence on the distal, local, facial, auricular points, as well as systems of wonderful meridians, causes a controlled afferent flow, with which it is possible to affect various areas of the cerebral cortex. Afferent flow is treated at the peripheral, spinal-segmental, stem, subcortical levels, and sensory interaction occurs at the level of the cortex. Due to the properties of neuroplasticity, the human body includes its own self-healing resource. We assume that reflexotherapy due to sensory interaction at different levels of the nervous system leads to the activation and inclusion of previously inactive neuronal connections to the process of functioning; perhaps, that positive effect of reflexotherapy leads to the formation of new synapses by the sprouting of fibers in preserved cells, new nerve cells (neurogenesis); migration of glial elements; re-organization of neuronal circuits with the formation of new sequence relationships, providing performance of lost functions (neoneurogenesis).

The processes of neuroplasticity are largely determined by the afferent component, which also affects the provision, modification and implementation of motor control and determines its flexibility/dynamics depending on the current need [20-23]. This leads to the fact that the cortical representation areas can vary depending on the incoming sensory information [22, 24]. The afferent system has significant potential for compensation, which is largely due to the considerable length and abundance of sensory fibers even at the cerebral level [25].

The basis of this biological phenomenon is the ability of various parts of the central nervous system to reorganize both due to structural changes in the brain substance, including qualitative and quantitative neuronal rearrangements, and due to the functional systems of the central nervous system, changes in neuronal connections and glial elements [21, 23, 26], as well as the development of new sensorimotor pathways and integrations in the central nervous system during recovery [27].

Neuroplasticity processes in the central nervous system occur at different levels (molecular, cellular, synaptic and anatomical) involving large groups of neurons in cortical and subcortical structures [23]. Studies have shown that the brain changes with each action we perform, transforming its circuits so that they suited better to the task at hand. If some brain structures fail, others take over. The brain is not a mechanism consisting of rigidly linked parts. The brain is able to change its own structure and functioning [2].

The most common definition is [28] the one according to which neuroplasticity is considered as the ability of the nervous system to adapt in response to endogenous and exogenous stimuli through optimal structural and functional rearrangement. This ensures the adaptation of the body and its effective activity in a changing external and internal environment [29, 30].

For many decades, medicine and neurobiological sciences were dominated by the idea of the immutability of morphological and functional structure of the adult formed brain and inability of nerve cells for self-recovery [31, 32]. The ability of nervous tissue for structural and functional changes in neuronal networks and elements throughout life was discovered several decades ago and further demonstrated in numerous experimental, neurophysiological and neuroimaging studies Many experiments conducted on animals have shown that the functional organization of neuronal structures of the cerebral cortex can be subject to modulation in the learning process, as well as in the damage to the peripheral or central nervous systems [32-36].

Knowledge of pathophysiological mechanisms at macro- and microscopic levels, underlying neuroplasticity, can improve therapeutic approaches to the restoration of lost functions and improve the quality of life of patients with various diseases. To achieve the maximum possible effect, a rehabilitation strategy should be followed, based on the results of the study of the role of neuroplasticity in the restoration of impaired functions. It is necessary to take into account the important role of social and hygienic lifestyle factors that influence the processes of neuroplasticity, and, accordingly, have an undoubted impact on the efficacy of rehabilitation measures [37]. Neuroplasticity is of great importance for physiological development and training, for development of adaptive abilities and restoration of lost neural connections in case of their damage [23, 35, 38–40].

Even in cases where there are no spontaneous movements in the limb, physical rehabilitation can have a beneficial effect on the restoration of the brain. Long-term proprioceptive stimulation by performing passive paretic limb movements, according to functional magnetic resonance imaging, leads to increased activity of the sensorimotor and additional motor cortex [41].

Rehabilitation, in its essence, is the repeated performance of certain tasks, the purpose of which is to stimulate neuroplasticity that ultimately leads to the consolidation of the stereotype of one movement and inhibition of another one. With the help of functional neuroimaging methods, it was shown that activation of sensorimotor areas of the cerebral cortex could be caused by observation of any motor act, its mental image or passive training [42]. At the same time, the early start of more complex rehabilitation, including such elements as kinesiotherapy, therapy with induced restriction (constraint-induced movement therapy), electromyostimulation, transcranial magnetic stimulation, various logopedic methods, is of interest [43]. Also of interest are the rapidly developing methods of physical rehabilitation associated with the use of mechanotherapy, virtual reality technology, optimization of therapeutic exercises using isometric physical exercises, use of therapeutic suits, methods of biological feedback, as well as more widespread use of orthotic devices [44].

For natural stimulation of neurogenesis in the elderly, natural positive stimuli should be considered as „training“ and „supporting“ neurogenesis factors: favorable environment, mental activity, physical activity, low-calorie balanced diet [45-47]. A small group of studies comprises papers on neuroplastic mechanisms of reflexotherapy. The papers present data on the effects of acupuncture [48-50], electroacupuncture [51], Chinese medicinal plants [52, 53], craniopuncture [54] on neuroplasticity.

In recent years, the use of craniopuncture in practical reflexotherapy has been of great interest. When conducting craniopuncture, exposure is not isolated at one point, but embraces the whole area. There are more than 20 areas of the scalp, the stimulation of which has a therapeutic effect. It is believed that affecting the scalp area cause irritation of the receptors, afferent impulses (mainly nociceptive and protopathic) involving the structures of the medulla oblongata, subcortical nuclei, cerebral cortex and subsequent influence on various systems of the body. It should be emphasized that the localization of the reflex areas to a certain extent, coincides with the projection of the anatomical brain structures. For example, the sensory and motor areas correspond to the sensory and motor cortical regions, which are localized in the precentral and postcentral gyrus. The scalp areas are innervated by the structures of the trigeminal nerve and upper cervical spinal segments C2-C3, therefore their irritation causes a targeted effect on the segmental and suprasegmental structures of the brain, with particular importance of selective activation of various parts in the limbic-reticular complex, which provide adaptive functions by integrating emotional-motivational, vegetative and somatic reactions [8, 55]. Many leading reflexologists believe that cranial therapy has a direct impact on the cortical brain structures.

Despite the active study of the neuroplasticity problem, at the present stage of research, the question remains about what mechanisms can be used to influence the formation of new neurons in the brain, as well as what stages of neurogenesis these effects extend to. A sufficient level of adequate afferentation from the periphery is a condition and basis for normal reactions of the whole brain in the implementation of long-term processes of nervous regulation, providing a functional reserve of reliability. Keeping it in mind, we can count on the possibility of exposure to these mechanisms by methods of reflexotherapy.

The study of neuroplastic reflexotherapy mechanisms has not yet received proper development in clinical randomized trials. At the same time, these methods need to be confirmed not only by catamnestic results, but also by high-tech control methods, such as positron emission tomography and functional magnetic resonance imaging. The use of neuroimaging and neurophysiological methods allows to observe the processes of reorganization and plastic changes in the central nervous system [56].

The high clinical efficacy of reflexotherapy in the treatment and rehabilitation of patients opens up wide boundaries for further research. For the effective use, development and creation of new methods of reflexotherapy comprehensive scientific development of its foundations is needed. And such thorough scientific research will open up new opportunities for reflexotherapy. We intend to conduct research and study of neuroplastic reflexotherapy mechanisms, as the prospects of neuroplasticity theory are extremely great for both healthy people and people suffering from serious diseases. Perhaps, with the help of reflexotherapy methods, it is possible to influence the neuroplasticity mechanisms, which requires further research in this direction

Conflict of interests

The authors declare no conflict of interests.

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