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Review Article

Brainstem Reflexes

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Abstract

Brainstem reflexes can be divided into intrinsic and systemic reflexes. Intrinsic reflexes arise from the activation of sensory fibers of cranial nerves, are closed at the level of the brainstem and manifest themselves in contractions of various muscle groups of the head or in autonomic reactions. Systemic reflexes also arise from the activation of cranial nerve receptors, but, unlike intrinsic reflexes, the nuclei of the long ascending and descending pathways are activated, eventually leading to a chain of motor and autonomic brainstem reflexes that significantly change the functional state of the entire organism.

Key Words: functional organization; brainstem reflexes; brain

Introduction

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Examples of intrinsic brainstem reflexes include masticatory reflexes, facial reflexes, tongue reflexes, accommodation reflex, pupillary reflex, salivary reflex. Examples of systemic reflexes include sneezing, coughing, nasopharyngeal aspiratory reflex, Aschner's oculocardial reflex, diving reflex, and others. These reflexes cause sequential activation of muscles of the tongue, larynx, pharynx, masticatory and mimic muscles, pilomotor and secretomotor reactions, as well as changes in respiratory rate and depth, heart rate, blood pressure.

The division of brainstem reflexes into intrinsic and systemic reflexes is to some extent conventional, since even the simplest reflex does not occur in isolation, but is accompanied by a group of associated reflexes.

In turn, both intrinsic and systemic brainstem reflexes can be divided into somatomotor and visceromotor depending on the predominance of somatic or visceral components. The organization of somatomotor reflexes in the brainstem is much more complex than in the spinal cord. This is due to the fact that the sensory fibers of mammalian cranial nerves are supplied with extremely abundant and diverse receptors, and the efferent fibers of these nerves innervate many compact, complexly oriented muscle groups; they differ considerably in the functions they perform, but are closely interconnected during reflex actions [1,2].

The basis of brainstem somatomotor reflexes is a group of simple reflexes with a certain degree of rigidity of their functional structure (reflexes of mouth opening and closing, reflexes of mimic muscles, reflexes of external eye muscles, reflexes of tongue protrusion and retraction). A common property of somatomotor reflexes, especially noticeable in the group of trigemino-motor reflexes, is their polyfunctionality. The predominance of individual modalities in the balance of sensory inputs and the involvement of the system of integrative control of the brainstem (reticular formation) and suprasegmental systems of the brain in reflex execution allows a highly organized organism to use simple somatomotor reflexes in various closely interrelated reflex acts aimed at performing complex behavioral reactions (food extraction, defense, attack, and expression of emotions).

The visceromotor reflexes of the brainstem encompass a group of sometimes very complex and not fully understood reflex reactions that ensure the normal functioning of various visceral systems. Many primary afferents of cranial nerves, terminating on neurons of the vagus and laryngeal nerves, as well as specialized structures of the reticular formation, influence the circulatory, respiratory, etc. systems.

Tongue Reflexes

Tongue reflexes are automatic reactions that are carried out with the help of certain centers in the brain stem. These reflexes can be triggered by a variety of stimuli, including mechanical, chemical, and temperature stimuli.

The basic reflexes of language:

1. Chewing reflex (mesencephalic reflex):

- Activated when food comes in contact with receptors on the tongue and teeth.

- Involved in the process of chewing and mixing food with saliva.

Mechanism of impulse transmission: the perception of food by the receptors of the tongue and teeth causes impulses that are transmitted via sensory nerve fibers (e.g., trigeminal nerve) to the appropriate centers in the brainstem. From the brainstem, signals are then sent to the masticatory muscles via motoneurons (also via the trigeminal nerve), triggering the chewing response [4].

2. Swallowing reflex:

- Triggered when food or liquid enters the back of the mouth and affects the pharyngeal receptors.

- A complex process that involves automatically closing the airway to prevent aspiration.

Mechanism of impulse transmission: activated when food touches the back of the tongue and pharynx. This causes impulses to travel along the palatine and pharyngeal nerves (IX and X pairs of cranial nerves) to the swallowing center located in the medulla oblongata. From the swallowing center, impulses are sent to the muscles involved in the swallowing process, activating successive contractions that close the airway and send food down the esophagus.

3. Vomiting reflex:

- Protecting the body from toxic substances or large amounts of food.

Mechanism of impulse transmission: irritation of receptors in the stomach, intestine or pharynx leads to activation of the vagus nerve (X pair of cranial nerves). The impulses travel to the vomiting center located in the medulla oblongata, from where commands are sent to contract the muscles necessary for vomiting [6,7]

4. Salivation reflex:

- Activated by the perception of food (e.g., smelling or tasting it).

- Always accompanies the feeding process, facilitating the digestion of food.

Mechanism of impulse transmission: the appearance of food (or its odor) activates the taste buds on the tongue. Sensory impulses travel through the lingual pharyngeal nerve (IX pair) to the brainstem, where they affect the salivary centers. Returning impulses travel through the facial nerve (VII pair) to the salivary glands, causing the secretion of saliva.

5. Sucking reflex:

- Is an innate reflex that is seen in newborns.

- Allows infants to receive nutrition from their mother's breast or from a pacifier.

Mechanism of impulse transmission: Newborns respond instinctively to contact with the nipple. Stimuli from the tongue and lips (via the trigeminal nerve) are transmitted to the suckling center in the brain stem. The response signals are regulated through the activity of the tongue and mouth muscles, allowing young infants to efficiently receive breast milk [8].

6. Disgust reflex (swallowing reflex):

- Manifests in response to an unpleasant taste or odor.

- May cause spontaneous swallowing or vomiting, preventing the harmful substance from entering the body.

Mechanism of impulse transmission: unpleasant taste and smell sensations can activate the aversion reflex. Nerve impulses are triggered via the lingual pharyngeal nerve (IX pair) and travel to the brainstem, where the appropriate motor neurons are activated to remove the unpleasant substance from the mouth.

The afferent nerves of the tongue are the lingual nerve, the lingopharyngeal nerve and the tympanic string. Adequate stimulation of the tongue surface causes discharges in its efferent - hyoid nerve and contraction of the tongue musculature - lingual-hypoglossal reflex. The lingual-hypoglossal reflex is bilateral disynaptic, its interneurons are localized in or near the spinal nucleus of the trigeminal tract [9].

The nucleus of the hyoid nerve is formed by two groups of motoneurons, one innervating the protrusor muscles and the other innervating the tongue retractor muscles. Stimulation of the lingual nerve causes TPSP in the motoneurons of the protrusor muscles and TPSP or TPSP-TPSP in the motoneurons of the retractor muscles. With adequate stimulation, such differences occurred in response to stimulation of the ventral surface of the tongue, whereas stimulation of the dorsal surface of the tongue simultaneously excited motoneurons of both groups.

Afferent impulsation entering the brainstem via other cranial nerves causes postsynaptic responses in the motoneurons of the hyoid nerve and changes in the excitability of the lingual-hypoglossal reflex. In most cases, polysynaptic TPSPs occur in motoneurons of both groups, and sometimes only in motoneurons of the tongue retractor muscles, in response to irritation of the muscular branches of the trigeminal nerve or sensory branches of the lingual pharyngeal nerve. However, excitatory or mixed responses to irritation of the alveolar and masseter nerves are also observed. Stimulation of the masseter nerve could both depress and facilitate the lingual-hypoglossal reflex.

Motoneurons of the tongue muscles are under constant control of the cerebral cortex and reticular formation. The study of electromyograms of tongue muscles has shown that its protrusor muscles are in constant background activity, which increases in the inspiratory phase of breathing and during swallowing, but is inhibited during mastication.

Language reflexes, controlled by various brainstem structures, play a key role in feeding, defense, and communication. The mechanisms of impulse transmission involving various neurons and cranial nerves demonstrate the complexity and coherence of the central nervous system. Understanding these reflexes is essential for the development of treatments for swallowing disorders and other clinical practices involving functional disorders.

Reflexes Of Facial Muscles

A light blow to the facial skin causes a reflex contraction of facial muscles: blink reflex or contraction of the circular muscle of the eye when struck in the subbrow arch and contraction of the circular muscle of the mouth when struck in the oral region. The afferent fibers of the facial muscle reflexes are sensory fibers of the trigeminal nerve, which are polysynaptic through neurons of the nuclei of the spinal trigeminal tract and reticular formation to the motoneurons of the nucleus of the facial nerve. The blink reflex has two components, one transmitted via a disynaptic and the other via a multisynaptic reflex arc. The blink reflex of the circular muscles of the eye recorded electromyographically in response to electrical stimulation of the trigeminal nerve. An electrical rectangular impulse applied to the supraorbital nerve causes involuntary eyelid closure; this reflex response can be recorded by surface or needle electromyographic (EMG) electrodes from the circular muscles of the eye. The occurrence of 2 components of the EMG responses of the circular eye muscle during electrical stimulation of both supraorbital and suborbital nerves forming the blink reflex has been reliably established. The early reflex response, designated as the R1-component, occurs only ipsilateral to the stimulation side, has a latency of about 10 ms and the form of a 2-3 phase potential. The late reflex R2-component appears bilaterally to the side of stimulation in the form of a flash of EMG-activity with a latency of about 30 ms. A number of studies have noted the appearance of a third component in the pattern of EMG responses, denoted as R3, which occurs with a variable latency of about 70-80 ms. The nature of the R1- and R2-components was established by comparing the abnormalities of these responses in patients with local ischemic lesions in the brainstem visualized by magnetic resonance imaging. The ophthalmic nerve (n. ophtalmicus) and its branch supraorbital nerve (n. supraorbitalis) form a common afferent link in the reflex arc of these responses, whereas the efferent link is formed by motoneurons of the facial nucleus and their axons innervating the circular muscles of the eyes. In this reflex arc, the early (unilateral) R1-component is formed by activation of Aβ-afferents and is mediated by an oligosynaptic pathway through the area of the main trigeminal nucleus in the middle third of the pontine to the facial nucleus motoneuron of the same name. Late reflex R2-components are formed as a result of stimulation activation of afferent fibers of groups Aβ and Aδ, which was revealed in a comparative study of this component in response to electrical and laser stimulation of the supraorbital nerve. The central conduction pathways of the bilateral R2-components are more complex; their afferent fibers descend from the bridge formations along the spinal trigeminal tract into the medulla oblongata and terminate in the most caudal part of the spinal trigeminal nucleus. From this area, the R2 component is further carried ipsilaterally and contralaterally by polysynaptic pathways through the lateral tegmental field of the reticular formation, forming synaptic contacts with the facial nuclei.

Facial muscle reflexes can also be elicited by excitation of various afferent fibers of the tongue, masticatory muscles, dental pulp, trunk and limbs of the animal. Facial muscle reflexes can be significantly inhibited or facilitated by conditioning stimulation of the nerves of the masticatory muscles, hyoid nerve, sound stimulation and mechanical irritation of internal organs [10].

The emergence of reflexes of facial muscles from receptor zones of organs and tissues of the head, as well as from the trunk, limbs and internal organs, is a reflection of the participation of mimic muscles both in reflex movements involving the muscles of the lower jaw, tongue and lips (chewing, swallowing) and in generalized reflex reactions.

The nucleus of the facial nerve is under constant control from the structures of the brain and spinal cord. It has been shown that its motoneurons generate EPSPs and TPSPs in response to stimulation of the sensorimotor zone of the cortex, and are also monosynaptically excited by stimulation of the red nucleus and the anterolateral canal of the cervical spinal cord.

Oculomotor Reflexes

The oculomotor reflexes have centers that functionally unite the sensory nuclei of the trigeminal and anterior cochlear nerves, the tuberosities of the quadratochalmia, and the motor nuclei of the oculomotor, block, and withdrawal nerves. Their activity is coordinated by the reticular formation of the brainstem, as well as the cerebellum and the cortex of the large hemispheres. As a result of these reflexes, the eyes move together in different directions.

Oculomotor reflexes are formed by a large group of complex reflex arcs closing at different levels. The afferent part of oculomotor reflexes is formed by sensory fibers of the optic nerve, nerves of the external muscles of the eyes, cochlear and vestibular subdivisions of the auditory nerve, trigeminal nerve, accessory nerve and nerves of the cervical segments of the spinal cord, and the efferent part is formed by somatic and visceral nuclei of the oculomotor nerves. The most common features of all oculomotor reflexes are clear reciprocal innervation of eye muscles and maintenance of constant tone in them. This ensures the fulfillment of one of the most important tasks of the oculomotor reflexes - ensuring the accuracy of coincidence of the eye axes in a certain point of space [11].

The functional interrelationships of the neural systems of the brain that provide different types of eye movements (cooperative and dissociated, saccadic and tracking) are currently not fully defined. An exception is the vestibulo-ocular reflex, in which activation of the sensory organs of the labyrinth (semicircular canals and otolith organs) through the disynaptic circuits of the vestibular nuclei causes a strong contraction of a single muscle of each eye with simultaneous postsynaptic inhibition of paired antagonist muscles. The role of separate subsystems in various eye movements is also known, involving the superior tubercles of the quadratochalmia, the nuclei of the optic tract, and the flocculus lobe of the cerebellum. However, the information about them does not allow us to determine the general scheme of interaction between the structures of the oculomotor system. A detailed description of the principles of neural organization of oculomotor reflexes is given in special literature.

Sensory fibers providing proprioreceptive innervation of the oculomotor muscles belong to the ophthalmic division of the trigeminal nerve. In different animals the bodies of sensory neurons are localized either in the gasserian ganglion or in the trigeminal mesencephalic nucleus, and their central terminations are apparently distributed in the same neural structures, where other primary afferents of the trigeminal nerve terminate - the oral nucleus of the spinal trigeminal tract, the main trigeminal sensory nucleus, the supratrigeminal nucleus, the nuclei of the medial reticular formation, and in the region of the oculomotor nucleus. Stretching of any of the external muscles of the eye resulted in excitation or inhibition of motoneurons of other oculomotor muscles after a significant latency period.

Sensory fibers of the ophthalmic subdivision also form exteroreceptive reflexes that are protective in nature. Thus, touching the cornea causes the cat to retract the eyeball into the orbit and extend the blinking membrane. This reflex is closed by a short reflex arc - discharge in the motor nerve to the retractor muscle of the eye occurs 6-7 ms after irritation of the suborbital nerve. In humans, in response to periorbital cutaneous stimulation, bilateral inhibition occurs in the muscle that raises the upper eyelid.

Vertical oculomotor reactions, as well as horizontal ones, are complex oculomotor reactions in the formation of which visual afferentation plays an important role. The main purpose of the oculomotor system is to provide optimal conditions for normal visual functions, in particular, to keep the image in the area of the central fossa of the retina. This is possible only if the pathways along which afferent signals from the retina pass are intact and if all parts of the oculomotor system function adequately and coherently, ensuring the common movement of the eyes and the merging of static and dynamic objects into a single whole. The system of eye movement regulation has a hierarchical plan of structure similar to other systems of movement organization. Its organization can be conditionally represented by the following levels and their neural pathways: neuromuscular, nuclear, internuclear and supranuclear. A lesion of a certain level of the oculomotor system has its own characteristic features, knowledge of which will help to avoid diagnostic errors.

In order to better understand the variety of clinical manifestations of vertical gaze disorders, it should be noted that from the functional point of view, oculomotor mechanisms are usually divided into those that are used to maintain a stable gaze and those that shift the gaze. These mechanisms are realized through the following complex reflexes: 1) gaze fixation, 2) tracking, 3) optokinetic nystagmus (OKN), 4) vestibulo-ocular reflex (VOR), 5) vergence (convergence-divergence), 6) saccades. More often, when performing certain tasks, these functions are involved in various combinations and their conjugation results in clear binocular vision. If they are not coordinated, double vision, blurring or oscillopsia (a feeling of unsteadiness of the environment) may develop.

The following paresis is distinguished:

I. By type of synchronization of eyeball movements

1. Conjoint gaze paresis involves both eyes to the same extent. In this case, eye movements are symmetrical, performed with the same speed and amplitude.

2. Unfriendly gaze paresis is manifested by asymmetry in the speed and amplitude of left and right eye movements (various types of internuclear ophthalmoplegia, semitemporal syndrome, etc.).

II. By type of dissociation (dissociation) of the functions of oculomotor reflexes

1. Dissociated gaze paresis is observed when all rapid eye movements (saccades, rapid phase of nystagmus) are depressed in one direction, but the ability to hold the gaze, tracking, PRA, slow phase of nystagmus is preserved in the same direction.

2. Undissociated gaze paresis is manifested by impairment of saccades, OKNs, tracking, PRA only in one and the same direction, e.g., upward, while they are preserved in other directions.

3. Selective (selective) saccadic gaze paresis is manifested by impaired saccades and absence of the fast phase of vestibular and optokinetic nystagmus in the horizontal and vertical directions, while tracking, VOR, the ability to hold an eccentric gaze, and vergence eye movements remain intact.

The described types of oculomotor disorders can be detected at any level of damage to the vertical gaze system. When the fibers of the oculomotor nerve and, in particular, its nucleus are affected, the classic symptom-complex including ptosis, restriction of eyeball mobility inward, upward and downward, and pupil dilation is not always detected, and selective paresis of individual eye muscles is more often noted. This is due to the fact that motoneurons of the nucleus of the oculomotor nerve are organized in subgroups or subnuclei for each innervated eye muscle. Therefore, the direction of gaze restriction, including vertical gaze restriction, can be isolated and determined by the peculiarities of damage localization. The clinical peculiarity of unilateral lesion of the subnucleus of the superior rectus muscle is impaired elevation of both eyeballs, often combined with bilateral ptosis [12].

Swallowing Reflex

When food is formed as a result of chewing and salivation the lump, then comes the next stage - swallowing proper, which has been studied in great detail by Miller and Sherrington on decerebrated cats. The receptive field of the swallowing reflex is the mucous membranes of the root of the tongue, palate, larynx, and epiglottis, innervated by the sensory branches of the trigeminal and laryngeal nerves, as well as the superior laryngeal branch of the vagus nerve. It is interesting to note that in the decerebrated preparation, the swallowing reflex is readily elicited by water or aqueous solutions over a wide range of temperatures, but is not elicited by oil. Apparently the most effective swallowing stimulus is an alcohol solution, which elicits repeated swallowing movements. A food lump placed even in the optimal reflexogenic zone of swallowing either does not elicit this reflex at all, or the reflex occurs with great delay and irregularly. Apparently, the swallowing response to a food ball is possible only when centers at a higher level are irritated, or a preceding chewing reflex is necessary to facilitate it. Under normal conditions, the swallowing reflex is elicited by liquid and mucous substances, but not by dry substances [4-6].

This explains why we don't swallow chewing gum and why we have such a hard time swallowing pill, even if they are smaller than a normal food ball. We usually swallow a pill with water; the dry object does not make contact with the receptors. Dry, rough or sharp-angled objects, having reached the reflexogenic zone, generate the opposite reflex - the gag reflex. The lowest center of the act of swallowing lies in the medulla oblongata. Some researchers consider the swallowing reflex also as a protective reflex of the respiratory tract. The swallowing reflex requires for its realization a complex bilateral and symmetrical succession of excitation and inhibition processes in a complex interneuron apparatus in about two dozen motor nuclei of the brainstem and spinal cord, as well as a sequential contraction of the external and internal muscles of the tongue, chewing muscles, muscles of the larynx and pharynx, and mimic muscles. This complex process has three components and lasts for several seconds.

- oral (arbitrary),
- pharyngeal (involuntary, rapid).
- esophageal (involuntary, slow).

The food lump (volume 5-15 cm3) is moved to its root (behind the anterior cords of the pharyngeal ring) by coordinated movements of the muscles of the cheeks and tongue. This completes the first phase of swallowing and begins the second. From this moment the act of swallowing becomes involuntary. Irritation of the food clump receptors of the mucous membrane of the soft palate and pharynx is transmitted along the laryngeal nerves to the swallowing center in the medulla oblongata. Efferent impulses from it go to the muscles of the oral cavity, pharynx, larynx and esophagus along the fibers of the hyoid, trigeminal, lingual and vagus nerves. This center provides coordinated contractions of the muscles of the tongue and the muscles that lift the soft palate. Due to this, the entrance to the nasal cavity on the pharyngeal side is closed by the soft palate, and the tongue moves the food lump into the pharynx. At the same time there is a contraction of the muscles that lift the lower jaw. This causes the teeth to close and stops chewing, and contraction of the hyoid muscle causes the larynx to rise.

This results in the closure of the entrance to the larynx by the epiglottis. This prevents food from entering the respiratory tract. At the same time, the upper esophageal sphincter, formed by circular fibers in the upper half of the cervical part of the esophagus, opens, and the food lump enters the esophagus. Thus begins the third phase. The upper esophageal sphincter contracts after the food ball passes into the esophagus, preventing esophagogastric reflux (i.e., backflow of food into the pharynx). The passage of food through the esophagus and into the stomach is then accomplished. The esophagus is a powerful reflexogenic zone. The receptor apparatus is represented here mainly by mechanoreceptors. Due to irritation of the latter by a food clod, there is a reflex contraction of the esophageal musculature. In this case, the ring muscles are successively contracted (with simultaneous relaxation of the underlying muscles). Waves of peristaltic contractions spread towards the stomach, moving the food ball. The speed of their propagation is 2-5 cm / s. Contraction of the esophageal musculature is associated with the arrival of efferent impulsation from the medulla oblongata along the fibers of the recurrent and vagus nerves. Movement of food through the esophagus is caused by a number of factors, firstly, the pressure difference between the pharyngeal cavity and the beginning of the esophagus - from 45 mm Hg. in the pharyngeal cavity (at the beginning of swallowing) to 30 mm Hg. (In the esophagus); secondly, the presence of peristaltic contractions of the esophageal muscles; thirdly, the tone of the esophageal muscles, which in the thoracic section is almost three times lower than in the cervical section; and fourthly, the force of gravity of the food clump. The speed of passage of food through the esophagus depends on the consistency of food: dense food passes for 3-9 s, liquid - for 1 - 2 s.

The swallowing center through the reticular formation is connected with other centers of the medulla oblongata and spinal cord. Its excitation at the moment of swallowing causes inhibition of the respiratory center and a decrease in the tone of the vagus nerve. The latter causes respiratory arrest and increased heart rate. Delayed breathing prevents food from entering the respiratory tract. In the absence of swallowing contractions, the entrance from the esophagus to the stomach is closed because the cardiac muscles of the stomach are in a state of tonic contraction. When the peristaltic wave and a lump of food reaches the terminal part of the esophagus, the tone of the muscles of the cardiac part of the stomach reflexively decreases, and the lump of food enters the stomach. When the stomach is filled with food, the muscle tone of the cardiac part of the stomach increases and prevents the backflow of gastric contents from the stomach into the esophagus (gastroesophageal reflux) [6].

The neurons of the reticular formation, lying near the midline at the level between the nucleus of the facial nerve and the inferior olive, form the swallowing center. It has been shown that the swallowing center, being included in the action, has considerable automatism, is almost unaffected by sensory streams, but is easily modulated by a number of central structures, such as frontal cortex and brainstem reticular formation.

Chewing Reflexes

The afferent link of masticatory reflexes is provided mainly by the sensory system of the trigeminal nerve, and the efferent link is formed by neurons of the motor nucleus of the trigeminal nerve. Chewing reflexes unite a group of reflex movements that carry out opening and closing of the mouth, as well as lateral displacements of the mandible. These reflexes are performed by two groups of muscles, one of which raises and the other lowers the lower jaw. There are two basic reflexes, the closing reflex and the mouth opening reflex. In each of them, several unidirectional reflex lines can be distinguished, differing in the quality of sensory modality and, possibly, in the functional design of the afferent link, but having a common efferent part. Thus, the mouth-closing reflex may be low-threshold myotactic or tactile. The mouth opening reflex includes four reflex lines: mechanoreceptive reflex, high-threshold myotatic reflex, tendon reflex, and pain reflex [13].

The receptive field of the low-threshold mouth closure reflex is the muscle spindles of the masseter and temporalis muscles. When activation of the annulospinal endings of muscle spindles caused by stretching of these muscles, monosynaptic excitation of trigeminal motoneurons occurs through afferent fibers of group 1a belonging to the primary sensory neurons of the trigeminal mesencephalic nucleus. This leads to contraction of the muscles that raise the lower jaw. The presence of electrical synapses between the bodies of trigeminal mesencephalic nucleus neurons, as well as monosynaptic connections of their axons with trigeminal motoneurons of the ipsi- and contralateral side provides synchronous bilateral contraction of the muscles that lift the lower jaw.

The receptive field of the tactile reflex of mouth closure is the tactile receptors of the mucous membrane of the tongue, hard palate, gums, and skin around the mouth. Stimulation of these areas causes, after a very short latent period (5-6 ms), brief contractions of the muscles that raise the lower jaw. The tactile reflex is based on the activation of the thickest Aa-fibers of the sensory branches of the trigeminal nerve belonging to the vibrissae, leading to monosynaptic excitation of a significant part of motoneurons innervating the muscles lifting the lower jaw. The tactile reflex is easily produced by the spatial and temporal summation of several stimuli following with high frequency. It is believed that such monosynaptic connections of thick cutaneous fibers of the suborbital nerve are realized through synapses localized on distal dendrites of motoneurons innervating the mandibular muscles.

The mechanoreceptive reflex of mouth opening occurs when pressure is exerted on the hard palate, teeth or gums, as well as when activation of higher threshold Aa afferents of cutaneous branches of the trigeminal nerve occurs. In this case, against the background of the pause observed in electromyograms of muscles lifting the lower jaw, the bicuspid muscle is activated, which leads to mouth opening. Characteristic features of the mechanoreceptive reflex are: the need for spatial and temporal summation of afferent signals, as well as its short duration and dependence on the position of the lower jaw. Our studies have shown that when the thinner Aa-fibers of the suborbital nerve are excited, the motoneurons of the bicuspid muscle produce VPSP and PD, but simultaneously with them the motoneurons of the masseter muscle develop complex reactions of the VPSP-TPSP type [14].

The high threshold myotatic reflex of mouth opening can be caused by strong pressure on the masseter and temporal muscles, or by their significant stretching. This excites the rod-like endings of muscle spindles (group II), as well as Pacini's corpuscles and free endings of muscle tissue. This reflex is based on bilateral polysynaptic excitation of motoneurons of the biceps muscle accompanied by the appearance of TPSP in motoneurons of the masseter muscle. Rapid and significant stretching of the masseter and temporalis muscles also causes activation of the tendon Golgi organs, which are located at the interface between muscle and tendon tissue and serve as sensors of muscle tension approaching dangerous levels. The result is the tendon reflex of mouth opening - inhibition of muscle tension. In this case, pauses in activity lasting 15-17 ms are observed on electromyograms of the masseter and temporalis muscles in humans. Unfortunately, the synaptic mechanisms of the masticatory muscle reflex caused by excitation of Golgi tendon organs or muscle afferents of group 1b belonging to them are poorly studied. Some authors who have studied this reflex note that the organization of this reflex for the masseter muscle is fundamentally similar to the organization of tendon reflexes of extensor muscles of the limbs.

The pain reflex of mouth opening occurs under the influence of mechanical or temperature effects on various structures of the face and oral cavity reaching the nociceptive level, as well as as as a result of electrical stimulation of thin myelinated AV fibers, unmyelinated C fibers, group III and IV muscle afferents of the trigeminal nerve. This reflex is stable - it lasts for the duration of the pain stimulus. It is characterized by the appearance of high activity in the myogram of the biceps muscle with simultaneous suppression of activity in the myograms of the masseter and temporal muscles. The study of synaptic processes has shown that the pain reflex caused by stimulation of the cat tooth pulp arises as a result of polysynaptic excitation of motoneurons of the bicuspid muscle, which is preceded by TPSP in motoneurons of the masseter muscle. The above-described reflex lines providing mouth opening are developed in a polysynaptic manner involving interneurons of the supratrigeminal nucleus, nuclei of the spinal trigeminal tract and reticular formation.

Numerous studies of masticatory reflexes have not, however, given a clear answer to the question of the role of individual structures of the central nervous system in the mechanism of mastication, as well as the ways of origin and control of rhythmic masticatory movements. Currently, there are two main hypotheses. The first, which was proposed by Sherrington and became widespread, states that chewing movements arise as a result of reciprocal interaction between the two main chewing reflexes, the mouth opening reflex and the myotatic mouth closing reflex. Sherrington, studying the chewing reflex in decerebrated cats, showed that it proceeds as follows. In the decerebrated preparation the mouth is tonically closed as usual in the awake animal. Under the influence of tactile stimuli - touching or pressing on certain parts of the mouth area - the mouth opens due to contraction of the muscles opening the jaws and reciprocal relaxation of the muscles closing the jaws. The optimal reflexogenic zone for this reflex is the gingiva on the upper or lower jaw and the anterior part of the hard palate. The cessation of irritation of these areas immediately causes the phenomenon of recoil: the muscles that open the jaws, relax, and the muscles that close the jaws, contract, with the mouth forcefully closed. When the jaws are closed, the hard unchewed food again presses on the palate and the walls of the mouth - the mouth opens again and then closes. These chewing movements are repeated until the food is completely chewed. Although the chewing reflex is indeed based on such a mechanism. it is apparently too crude and unplastic to be quite effective. The higher levels of the nervous axis (in particular, the sensorimotor "oral" zone of the cortex) make this primitive mechanism more flexible, ensure that it corresponds to the specific size, shape and consistency of food portions throughout the act of chewing. In this respect, observations on dogs in which the sensorimotor oral zone (located in the coronary gyrus) was bilaterally removed are very revealing. Chewing is impaired in these dogs. Food often falls out of their mouths, and jaw movements, although stronger than in normal dogs, lose subtlety and precision. Chewing takes much longer and becomes less efficient because the animal has lost the appropriate feedback about the location and consistency of food in the mouth and has lost the ability to make coordinated fine movements of the tongue and jaws. There is clear evidence that the primary stimuli controlling chewing are somatic stimuli: touch, pressure, and possibly proprioception. Taste plays no role in the act of chewing, except in deciding whether a given piece should be chewed or spit out. With a decrease in gustatory sensitivity or its complete disappearance after the removal of gustatory innate activity of the organism 19 zone, the animal thoroughly chews everything that enters his mouth, even inedible, say a rag or paper. The widespread use of chewing gum once again clearly demonstrates that the sensation of taste is not a necessary component of the chewing reflex. Since chewing gum does not turn into a food lump because it has water-repellent properties, the reflex continues indefinitely as long as the gum is in the mouth and irritates the corresponding reflexogenic zones.

The second hypothesis, which has recently emerged, proves the existence in the brainstem of a central generator of the neural mechanism controlling the rhythm of chewing. The reflex interaction hypothesis suggests that the opening and closing of the mouth follow one after the other automatically, due to stimulation of receptors that first activate the muscles that lower the lower jaw and then the muscles that raise it. The closing phase of the mouth is thought to be caused by stimulation of stretch receptors - muscle spindles - in the muscles that lift the jaw. This causes these muscles to contract. Closure occurs until the force of pressure on the teeth is sufficient to activate the mechanoreceptors of the periodontal ligaments. The appearance of these discharges reflexively inhibits the mouth closure reflex, and the mouth opening reflex occurs. When this reflex develops, the muscle spindles in the muscles that lift the mandible are stretched in turn, and the cycle repeats from the beginning.

The hypothesis of reflex interaction, for all its attractiveness, has a number of significant drawbacks. It cannot be used to explain the mechanism of central control of mastication, the variability of mastication types depending on the mechanical properties of food. The hypothesis of a central oscillator, or "chewing center," was proposed by Delow and Lund, who found that stimulation of the pontine reticular formation could induce cyclic movements of the rabbit mandible similar to those observed during changes in impulsation in the sensory nerves of the masticatory muscles. In these experiments, prolonged stimulation of the shell and cortico-bulbar pathways of the rabbit brain caused rhythmic opening and closing of the mouth, the frequency of which coincided with the frequency of natural mastication and was independent of the frequency of brain stimulation. Further experiments showed that rhythmic movements of the jaw caused by brain stimulation persisted after partial and even complete disconnection of afferent flow from the structures of the oral cavity, which allows us to assert the presence of a central origin of rhythmic masticatory movements. The central generator of rhythmic mastication is very sensitive and is actually dependent on both peripheral sensory flow and influences from central structures. Sensory impulses coming from various branches of trigeminal, facial, laryngeal, vagus and hyoid nerves, as well as impulses from the cortex, basal ganglia, hypothalamus, red nucleus, reticular formation and cerebellum can significantly modulate both the basic chewing reflexes and the parameters of the rhythmic mechanism of mastication (rhythm frequency, amplitude, degree of compression), thus forming the necessary "pattern" of mastication.

Nasopharyngeal Reflexes

Nasopharyngeal reflexes are groups of reflexes, the occurrence of which is associated with the irritation of receptors in the nasopharyngeal region (nasopharyngeal area). These reflexes play an important role in the protective and adaptive mechanisms of the body, ensuring the proper functioning of the respiratory and digestive systems, as well as participating in the regulation of various reflex responses. They occur when the mucous membranes of the nose and pharynx are stimulated and the branches of the trigeminal, laryngeal or vagus nerves innervating these areas are irritated. The occurrence of each of them is determined by the quality of the sensory stimulus, its localization, area and intensity.

The basic components of the nasopharyngeal reflex:

1. Receptors:

- Mechanoreceptors that respond to pressure or stretch.

- Chemoreceptors that perceive chemical stimuli (including allergens or infections).

- Thermoreceptors that respond to changes in temperature.

2. Conductive pathways:

- Sensory neurons that transmit information from receptors to the CNS.

3. Information Processing Centers:

- Reflex centers in the brain, mainly in the brainstem, that analyze incoming signals and form responses.

4. effectors:

- Muscles responsible for motor responses and exocrine glands that secrete secretions (e.g. saliva or mucus).

Examples of nasopharyngeal reflexes are:

1.Sneezing reflex: sharp irritation of the nasal mucosa leads to activation of the sneezing reflex. Sneezing is a powerful release of air, which helps to remove irritating elements from the nose - dust, pollen, germs. The sneezing reflex, like the swallowing reflex, is a complex motor act in which the sequence of actions is rigidly programmed and controlled by a central generator, the basis of which is the respiratory center. The sneezing reflex, once initiated, continues to its predetermined end and does not require further sensory signals or feedback from the periphery.

The sneezing reflex occurs with mechanical irritation of the nasal mucosa or electrical irritation of the ethmoidal branch of the trigeminal nerve. In this case, there is a premature cessation of the inspiratory phase, accompanied by inhibition of rhythmic activity of neurons of the medulla oblongata. Simultaneously, after a short latency period, the activity of most expiratory neurons sharply increases and previously silent expiratory neurons are activated. However, despite this, active exhalation does not occur immediately, but occurs only after the first deep (preparatory) breath. The phase of active exhalation is preceded by high-frequency group discharges of expiratory neurons, and the phase of active exhalation itself occurs after a significant filling of the lungs with air, i.e., activation of lung stretches receptors belonging to the vagus nerve.

2.Sniffing (aspiration) reflex: occurs when mechanical stimulation of deep regions of the nasal cavity or contact with the epiglottis mucosa leads to a superficial inhalation caused by a rapid and brief contraction of the diaphragm. Reciprocally organized circuits of respiratory neurons of the medulla oblongata take part in the implementation of this reflex act: the earliest and lowest threshold reactions to stimulation of the nasal mucosa occur in inspiratory neurons lying ventrolateral to the solitary tract. Their discharges appear 25-40 ms earlier than electromyographic signs of diaphragm muscle contraction. Simultaneously with the excitation of inspiratory neurons, the activity of expiratory neurons near the reciprocal nucleus is inhibited, and the degree of this inhibition is proportional to the degree of intensity of nasal mucosa stimulation.

The neural organization of other nasopharyngeal reflexes is poorly understood. Protective polysynaptic nasopharyngeal reflexes have been described, when in response to stimulation of tactile receptors of the subglabellar branch of the trigeminal nerve in a cat there is a contraction of the laryngeal muscle leading to closure of the vocal cleft, as well as the laryngo-laryngeal reflex. In the latter case, in addition to activation of motoneurons of the laryngeal muscles, a decrease in the depth and frequency of inspiration was observed. Numerous studies have shown that mechanical, electrical and chemical stimulation of nasal receptors, as well as immersion of the face in water, causes a complex cardiorespiratory nasopharyngeal reflex resulting in respiratory arrest in the exhalation phase, bradycardia, an increase in blood pressure and marked vasoconstriction of peripheral vessels. There are a number of morphological and physiological data indicating that this reflex is carried out through the brainstem reticular formation and, above all, through its specialized centers. There are at least two possible functions of this reflex: the first is protective, preventing the entry of liquid and harmful gases into the lungs, and the second is adaptive, leading to cardiovascular restructuring in animals and humans during immersion in water. Nasopharyngeal reflexes are important for maintaining health and keeping the body functioning properly. They: Provide protection of the respiratory tract from foreign bodies, infections and allergens; participate in the regulation of the respiratory process, which is especially important in conditions of physical activity or stress; help maintain homeostasis by responding to changes in the environment. Disruption of these reflexes can lead to various diseases such as chronic pharyngitis, allergies at the level of the upper respiratory tract, as well as affect the ability to eat properly [15].

Visceromotor Reflexes

Visceromotor reflexes are reflexes that elicit responses from the smooth muscles of organs in response to appropriate stimuli. They are controlled by the autonomic nervous system and can be triggered by various internal and external factors such as mechanical stretching, chemical changes, temperature fluctuations and others.

The basic components of the visceromotor reflex:

1. Receptors are specialized structures (mechanoreceptors, chemoreceptors) that perceive changes in internal organs.

2. Conduction pathways are sensory neurons that transmit signals from receptors to the spinal cord or brain.

3.Information processing centers - areas of the CNS that analyze incoming signals and make decisions about necessary responses.

4.Effector - nerve endings that act on the smooth muscles of organs, thereby providing responses.

Examples of visceromotor reflexes are:

1. Gastric distension reflex: when the walls of the stomach are distended as a result of ingestion of food, mechanoreceptors are activated and send signals to the brain. In response, there is a reflexive increase in the secretion of gastric juice and relaxation of the stomach muscles, which aids digestion.

2. Coriander reflex (colic): when painful sensations occur in the intestines, spasms may occur. Nerve impulses from pain receptors cause reciprocal contractions of smooth muscles, which promotes the movement of contents through the intestine.

3. Cardiovascular reflexes: for example, changes in oxygen or carbon dioxide levels in the blood activate chemoreceptors that regulate heart rate and vascular tone.

Visceromotor reflexes play a key role in maintaining the health of the body. They provide automatic regulation of the functions of internal organs, which, in turn, helps to cope with physiological and pathological conditions. For example, under stress there is an activation of the sympathetic nervous system, which contributes to an increase in heart rate and blood pressure, which prepares the body for a response (the so-called "fight or flight reflex").

A large group of intrinsic and systemic brainstem reflexes is a component of general adaptive reactions, which are aimed at maintaining the "internal environment" of the organism. The afferent part of such visceromotor reflexes belongs to sensory fibers of cranial nerves (optic, trigeminal, facial, vestibular, auditory and vagus nerves), while the efferent part is formed either by motoneurons of cranial nerves or neurons of the spinal cord and autonomic ganglia. Visceromotor reflexes have clear afferent inputs, but, unlike somatomotor reflexes, easily arise in the process of development of various complex protective, adaptive, nutritional and other reflex reactions. This is well illustrated by the example of the lacrimal reflex.

The lacrimal reflex, the internal organization of which is still insufficiently studied, occurs upon stimulation of sensory fibers of the lacrimal branch of the trigeminal nerve distributed in the cornea. Polysynaptic pathway with the participation of neurons of the oral nucleus of the spinal trigeminal tract, lateral and parvicellular reticular formation forms an output to preganglionary parasympathetic neurons of the upper salivary and lacrimal nuclei, which in turn end on postganglionary neurons of the wing ganglion, which together with sympathetic neurons regulate the activity of the lacrimal gland. Reflex lacrimation caused by drying of the cornea or getting on its foreign particles can also occur when sneezing, yawning, chewing, coughing, vomiting and even in bright light. Pupillary reflexes, the prototype of which is the constriction or dilation of the pupil depending on the intensity of illumination, have a similar "polymodality". At the same time, different sensory influences (acoustic, tactile, vestibular, olfactory and, especially, pain stimulation), as well as changes in heart rate, blood pressure and respiration caused by different emotional states or work, change pupillary reflexes in different ways.

A large group of visceromotor reflexes is formed by reflexes realized through the system of laryngeal and vagus nerves. Depending on the properties of receptors (mechanoreceptors, baroreceptors, chemoreceptors) and their localization, the vast majority of enteroceptive reflexes are formed with their participation. Powerful modulating effects on blood circulation and respiration are exerted by receptors of arteries and veins, the largest clusters of which belong to the carotid nerve (carotid body), aortic nerve, precordial and great veins of the heart. It is known that through the chemo- and baroreceptors of these nerves, the content of C02 and 02 in the blood is controlled, as well as fluctuations in arterial and venous pressure; changes in impulsation from these receptors activate the well-known chemo- and baroreflexes of the heart and lungs. Recently, the carotid body has been found to contain chemoreceptors sensitive to fluctuations in blood temperature and changes in osmotic pressure, phenomena that can be induced by fever, excessive muscular exertion, and water restriction. This suggests an important role of the laryngeal and vagus nerve systems in complex homeostatic reactions, in which, along with brainstem structures, the higher autonomic center - hypothalamus - also takes part.

Various mechano- and chemoreceptors of the laryngeal and mainly vagus nerves control the functions of respiratory and digestive systems, their participation allows to maintain optimal conditions for the activity of internal organs and to form a number of compensatory and protective reflexes. The main receptors that regulate the frequency and pattern of breathing are, in addition to the arterial chemoreceptors already mentioned, the mechano- and chemoreceptors of the lungs. There are at least three types of receptors in the lungs: tension receptors, receptors for chemical or mechanical irritation ("irritant" receptors), and "jay" receptors that respond to excessive blood flow in the lungs. Increased activity in tension receptors causes reflex inhibition of inspiration and bronchial dilation. Decrease of impulsation from these receptors causes exhalation reflex, and in conditions of partial violation of conduction along vagus nerves - paradoxical reflex of Hed (inflating lungs in a rabbit leads not to reflex inhibition of inhalation, but to prolonged and strong contraction of diaphragm). When "irritant" receptors are activated, hyperventilation and bronchial constriction develop, and when "jay" receptors are excited, respiratory rate increases, bronchial constriction and cough [16].

Vomiting is a protective reflex arising in response to irritation of mechano- and chemoreceptors of the root of the tongue, gastric mucosa, as well as impulses coming from various parts of the small intestine, uterus, gallbladder and other internal organs. This is a very complex and coordinated reflex that develops against the background of increased secretion of saliva and mucus and successive contractions of extensive groups of skeletal and smooth muscles.

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