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MORPHOFUNCTIONAL CHARACTERISTICS OF THE SPINAL CORD

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Abstract

The central nervous system of the rat includes the brain and spinal cord. The spinal cord undoubtedly provides many vital functions in the body. Thus, the data on the morphological organization of the rat spinal cord presented in the article will serve as a fundamental basis for further study of the nervous system in normal and pathological conditions and will create a fundamental basis for implementation in the practice of clinical medicine.

Key words: *rat, spinal cord, nervous system.*

INTRODUCTION

The central nervous system of the rat includes the brain and spinal cord. The spinal cord undoubtedly provides many vital functions in the body [1,2,7,10-12].

The spinal cord is located in the spinal canal in the form of a cylindrical cord, flattened dorsoventrally, stretches from the first cervical nerve to the end of the terminal thread. Cranially passes into the medulla oblongata, their border is considered to be the level of the large (occipital) foramen [1-3,7,8,10-12,24].

The spinal cord is subdivided into segments, or parts, corresponding to the outputs of certain spinal nerves. There are cervical, thoracic, lumbar, sacral and caudal parts - pars caudalis [1-3,7,8,10-13,20,24,25].

Throughout its length, the spinal cord forms two thickenings - cervical and lumbar; they correspond to the region of origin of the nerves of the thoracic and pelvic limbs. The cervical thickening, which is limited by the V-VIII cervical vertebrae and the I thoracic, the lumbar thickening is limited by the I-IV lumbar vertebrae [1-3,7,8,10-13,20].

As the spinal cord moves in the caudal direction, it decreases in diameter, forming a medullary cone - the final section of the spinal cord, located in the sacrum, containing the sacral and caudal segments and passing into the terminal thread. The filament is a thin continuation of the glial and ependymal cells of the cone of the spinal cord and its membranes, running into the tail behind the III caudal nerve [1-3,7,8,10-13,20].

On the ventral surface of the spinal cord, between the ventral cords, there is a deep longitudinal median (ventral) fissure, through which the ventral spinal artery passes. In addition, a paired ventral lateral groove is visible on the ventral surface, separating the ventral funiculus from the lateral one; the ventral motor roots of the spinal nerves emerge from the sulcus. The median (dorsal) groove runs along the middle of the dorsal surface. Parallel to it, there is a paired dorsal lateral groove separating the dorsal funiculus from the lateral; the dorsal sensory roots of the spinal nerves enter the groove [1-3,6-13,15,20-22,24].

The main functions of the spinal cord are reflex - conduction of motor impulses to the muscles of the body along descending pathways and conduction function - conduction of sensitive impulses from the skin, tendons, joints, pain and temperature receptors [1-3,7,8,10-13,20,24-26].

The structure of the rat spinal cord

On transverse sections of the spinal cord, the characteristic features of gray and white matter are clearly visible [1-3,7,8,10-13,20,24,25].

The gray matter on transverse sections at different levels of the spinal cord has an outline of symmetrical butterfly wings (or more or less similar to the letter H) and is located in the center of the section [1-3,7,8,10-13,20]. Both legs of the H-

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shaped gray matter are connected by a bridge - a gray commissure, consisting of numerous unmyelinated fibers passing through the gray matter, especially dorsal to the central canal. At the border of the spinal cord and the medulla oblongata, the central canal expands and communicates with the cavity of the IV ventricle of the brain. Two parts are distinguished in the canal: part of the medulla oblongata and the spinal part. At the rostral end of the central canal there is a special area - the most posterior field, which is part of the periventricular organs. At the level of the intersection of the pyramids, the first part passes into the second without any structural changes. In the region of the cerebral cone, the central canal expands and forms the terminal ventricle [1-3,7,8,10-13,20].

In each half of the spinal cord, the gray matter is subdivided into dorsal horn, ventral horn, and lateral horn, which form longitudinal protrusions along the entire length of the spinal cord - dorsal, ventral, and lateral columns. In the ventral part of the dorsal columns, there is a reticular formation on the side, represented by a combination of white and gray matter, reaching its greatest expression in the cervical part [1-3,7,8,10].

The cytoarchitectonic organization of the gray matter of the spinal cord includes 10 plates according to Rexed [1-3,7,8,10-13,20,26].

Plate I (marginal zone) forms a thin border along the dorsal and dorsolateral edges of the dorsal horn.

The size of neurons is different: most of the cells are small (5–10 and 9–13 μm in diameter), but each section has several mediolaterally elongated large cells (30–50 μm) [1-3,6-8,10-13,16,17-19].

Fusiform neurons are found in the lamina; they are elongated rostrocaudally and are most numerous in the lateral part of the lamina. Multipolar neurons have characteristically radiant dendritic trees and predominate in the medial lamina. Pyramidal neurons have triangular cell bodies and are found throughout the mediolateral lamina, at the edge of the white matter. There are also flat neurons whose dendrites extend in the mediolateral and rostrocaudal axis. The mediators are substance P, met-enkephalin, leu-enkephalin [1-3,7,8,10-13,20,24,25].

Afferents come from pain receptors in muscles, skin, and joints. In addition, information comes to plate I from the axons of neurons in plate II [1-3,7,8,10-13].

Efferents are part of the spinothalamic tract, which carries information about pain and temperature sensitivity to the thalamus, the nuclei of the solitary tract, the parabrachial nuclei, and the periaqueductal gray nuclei [1-3,7,8,10-13].

Plate II is adjacent to plate I and is parallel to it. Compared to plate I, it is wider. Two zones are distinguished in the composition of the plate: the outer zone with densely packed cells and a less compact inner zone [1-3,7,8,10-13].

Lamina II was originally thought to be a closed system, receiving afferents but not projecting to any area of the brain. However, there is now evidence that a small number of neurons project to the brain, namely to the thalamus, lateral cervical region, and pons. In addition, a significant number of islet cells are projected into the region of the reticular formation [1-3,7,8,10-13].

The size of neurons, as a rule, is small - lamina II contains small cells about 10 μm in size. Among them, central and islet cells are distinguished, which are located along the entire width of the plate, stellate neurons - on the border of plates II and III, vertical neurons are localized in the lateral part of the plate [1-13,17-21].

The mediators are substance P and somatostatin [17,24,25].

Neurons receive nociceptive afferents from the spinothalamic tract, while efferents go to plate I [1-3,7,8,10-13].

Plate III runs ventrally and parallel to plate II. The boundary between lamina II and III is difficult to determine by cell morphology, but can often be distinguished by a distinct transition from the homogeneous neuropil characteristic of lamina II to the more heterogeneous neuropil in lamina III. If myelin staining is used, then the almost myelinated lamina II stands out clearly against the background of lamina III, which contains numerous thin myelinated fibers [1-13].

The neurons form connections with other regions within the same segment of the spinal cord, as well as with the nuclei of the dorsal column, the lateral cervical nucleus, and the thalamus [1-13].

Plate III has a cytoarchitecture similar to that of plate II, the mediator is substance P [10].

Afferents come from mechanoreceptors [1-13].

Plate IV forms the base of the head of the dorsal horn and curves ventrally along its medial border. A distinctive feature of plate IV is the branching of neuronal processes in all planes with a predominant distribution in the transverse direction. In the thoracic and upper lumbar regions, lamina IV is interrupted by elongated cells in Clark's column at the base of the dorsal horn [1-13,24,25,27].

The projection of the nuclei is carried out in the region of the cerebellum, within the spinal cord, the lateral cervical nucleus and the thalamus [1-12].

Neurons in this area are called "antenna-like" because their dendrites are oriented toward the surface plates [1-3].

Afferents come from plates II and III, axons close the reflex arcs of the spinal cord on motor neurons and participate in the spinothalamic tract [1-7].

Plate V forms the neck of the dorsal horn. The wide lateral part of this layer can be easily recognized by its reticulate appearance; the medial unreticulated portion narrows as it approaches the midline dorsally to the central canal [7].

The projection of the nuclei falls on the lateral cervical nucleus, the dorsal nuclei of the column, the brain stem, the reticular formation, the midbrain, and the cerebellum.

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The size of neurons varies from 12 to 45 μm [7].
The shape of the neurons is different [1,2,7]. Both stellate, round neurons and fusiform, triangular neurons are distinguished, which are determined in the medial part of the plate, while in the lateral part there are multipolar neurons.

Plate VI forms the base of the dorsal horn and corresponds to Clark's nucleus [3,7]. The boundaries of this plate are topographically difficult to determine due to the lack of clear differences between the neurons of plates V and VI.

The nuclei are projected onto the motor neurons of the ventral horns and the cerebellum.

Afferents come from muscles, tendons and ligaments, descending tracts from the brain, and efferents are two tracts: Flexig's tract - exits ipsilaterally into the lateral funiculus and Govers's tract - exits contralaterally into the lateral funiculus [26].

Plate VII corresponds to the intermediate zone of the gray matter and part of the ventral horn. It has a lighter and more uniform appearance on Nissl-stained sections than neighboring plates. The plate contains the intermediolateral nucleus in segments T1-L3 (preganglionic sympathetic neurons) and L6-S1 (preganglionic parasympathetic neurons) and the intermediolateral nucleus at all levels. The central cervical nucleus can be seen in segments C1-3[1-3,7,8,9,10].

The projection of the nuclei is carried out in the cerebellum, as well as to the vestibular nuclei [7].

The size of neurons in plate VII in rats is approximately the same, the cell diameter is 20–40 μm [3,7].

Their dendrites receive information from the muscles and tendons [7], and the axons go to the IX plate.

Plate VIII - located in the ventral or ventromedial part of the ventral horn, has a more heterogeneous appearance.

The projection of the nuclei falls into the region of the reticular formation, the brain stem and into the thalamus [7].

Afferents come from muscles and tendons, and efferents: axons go to plate IX.

Plate IX is represented by large motor neurons located near the lateral and ventromedial surfaces of the ventral horn.

Plate X surrounds the central channel. It borders the white matter ventrally and dorsally, with the exception of the lumbosacral region. The boundaries of plate X are difficult to determine due to the adjacent plates: ventrolaterally - VIII, laterally - VII, dorsolaterally – V [7].

The projection of the nuclei is carried out on the brain stem, amygdala, hypothalamus and thalamus [1-3,7,8,10,11-13,16].

The shape of the neurons is varied, there are oval, pyramidal, stellate and fusiform [1-3,7,8,10-13,20].

The white matter is located on the periphery of the spinal cord and is divided by gray columns into three pairs of separate sections - the cords of the spinal cord: dorsal, lateral and ventral. The ventral cords are connected to each other by a white adhesion - fibers passing between the median (ventral) fissure and gray matter[3,7,8].

The pathways are divided into 3 groups: proper pathways that connect different parts of the spinal cord to each other, ascending pathways that connect the spinal cord to the brain, and descending pathways that connect the brain to the spinal cord [6,7,13,14,24,26].

Dorsal funiculus - an area of white matter between the dorsal horn and the dorsal median sulcus; contains ascending paths [26]. The dorsal cords of both sides are separated by a dorsal median septum. The medial segment of the dorsal cord occupies a thin bundle, or Gaulle's bundle; refers to the pathways of proprioceptive and tactile sensitivity. In the lateral part of the dorsal funiculus, a wedge-shaped bundle, or Burdach's bundle, passes, which carries information from muscle receptors and mechanoreceptors of the skin. Both bundles described above are found in the cervical and thoracic segments, and only a thin bundle in the lumbar and sacral segments. In the dorsal funiculus, on the border with the dorsal horn, there are also proper bundles connecting adjacent segments [6,7,8,10-14,24].

Pyramidal (cortical-spinal) path - paired descending projection nerve path; is part of the pyramidal pathways, starting in the cerebral cortex and going to the nuclei of the cranial nerves and to the motor neurons of the spinal cord [1,2, 6-8,10-14,24,26].

Lateral funiculus - located between the dorsal and ventral horns and separated from the dorsal and ventral funiculus by the dorsal and ventral lateral grooves, respectively. The cord decreases in size from rostral to caudal areas; contains ascending and descending paths [26]. The ascending pathways are located in the outer, peripheral sections of the funiculus and include: the spinal reticular pathway, the dorsal spinal cerebellar pathway, or Flexig's bundle, the ventral spinal cerebellar pathway, or Govers's bundle, the dorsal tegmental, spinal ring and spinal thalamic pathways [1-3,6-8,10-13,14,20,24].

The descending tracts of the lateral cord are located in its internal parts and include: the red nuclear-spinal tract, or Monakov's bundle, the lateral tegmental spinal fibers and the lateral vestibulospinal tract (vestibulospinal), or Geld's bundle, or Leventhal's bundle - the descending bundle of the extrapyramidal system [1,2,26].

The ventral cord is located between the ventral median fissure and the ventral horn; contains descending pathways. The main part of the funiculus is occupied by the medial longitudinal bundle [1,26].

Distinguish between the reticular-spinal path and the medial vestibular-spinal (vestibulospinal) path. In addition, there is also an ascending spinal-olive path [26].

From the spinal cord in each of its segments, with twelve or more radicular filaments, the dorsal root (sensory) and the ventral root (motor) begin, which then combine into one mixed metameric (segmental) spinal nerve that exits the spinal

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cord through the corresponding intervertebral foramen of the spinal column. In the dorsal root, at the place of its confluence with the ventral root in the spinal canal, there is a spinal ganglion (sensitive). After confluence, the spinal nerve gives off a large ventral and a smaller dorsal branch. In addition, the connecting branches between the spinal nerve and the sympathetic trunk depart, and the meningeal branch, which again goes into the spinal canal. In the cervical and thoracic segments, the spinal nerves depart almost at the level of the intervertebral foramen. In the lumbar segments, the exit point of the roots from the spinal cord is cranial to the corresponding spinal canal. In the sacral and caudal segments, the nerves run in a caudal direction[7,15,18,22,26].

Blood supply to the spinal cord

Arterial blood supply to the spinal cord is carried out through three spinal arteries proper - the anterior spinal artery, two posterior spinal arteries, as well as through the segmental branches of the cervical, intercostal, lumbar and sacral veins [7,9,15,18,22,24].

The anterior spinal artery is formed as a result of the fusion of the branches of the right and left vertebral arteries, extending from them at the level of the medulla oblongata. It descends down the anterior surface of the spinal cord, located along the anterior fissure of the spinal cord. Throughout its length, this artery gives off central branches that go through the anterior fissure of the spinal cord to its center and breaks up into small arteries that feed the anterior and lateral horns from the inside, the base of the posterior horns of the gray matter, as well as the anterior and lateral cords of the spinal cord [7-9,15].

The right and left posterior spinal arteries arise independently from the right and left vertebral arteries, respectively; they are much thinner in diameter than the anterior spinal artery. They go down, located in the right and left posterior lateral grooves of the spinal cord. Along their course, these arteries give branches deep into the spinal cord, which supply blood to the posterior cords of the spinal cord, as well as the peripheral parts of the posterior horns of the gray matter [9,15].

The posterior spinal arteries form a large number of branches communicating them with each other, as well as with the anterior spinal artery. These branches are called coronary arteries, they encircle the spinal cord and give off small branches involved in the formation of the coronary arterial plexus in the pia mater of the spinal cord. From this plexus, as well as from the coronary arteries, arteries enter the spinal cord from the outside, providing nutrition mainly to the white matter of the spinal cord [9,15].

It should be noted that the blood from the vertebral arteries flows through the spinal arteries only to the cervical segments of the spinal cord. Further, as their diameter decreases, the resistance to blood flow increases and the pulse pressure of the blood decreases, the movement of blood from the vertebral arteries becomes more difficult. Therefore, starting from the cervical segments, the contribution of segmental arteries to the blood supply to the spinal cord, which form anastomoses with the spinal arteries, increases more and more. The segmental arteries are branches of the cervical, intercostal, lumbar, and sacral arteries that originate from the aorta [9,15,22].

Venous blood flows from the spinal cord into the intracerebral veins. From them, blood enters the venous canals of the spinal cord (anterior, posterior, anterior-lateral and postero-lateral) or into the vessels of the coronary venous plexus of the spinal cord, formed by branches of the venous canals [9]. The venous plexus of the spinal cord forms a large number of anastomoses with the epidural venous plexus located between the dura mater of the spinal cord and the periosteum of the vertebrae that form the spinal canal [15]. From the venous canals of the spinal cord, as well as from the epidural venous plexus, blood flows either into the superior vena cava through the anterior and posterior medial veins of the medulla oblongata and the vertebral vein, or into the inferior vena cava through the intercostal, lumbar and sacral veins accompanying the arteries of the same name [7,9,15,22].

Thus, the data on the morphological organization of the rat spinal cord presented in the article will serve as a fundamental basis for further study of the nervous system in normal and pathological conditions and will create a fundamental basis for implementation in the practice of clinical medicine.

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