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STUDYING THE STRUCTURE OF MUSCLE TISSUE

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Annotation : This article provides a detailed analysis of the histological and morphological structure of muscle tissue in human and animal organisms. The study examines the microscopic characteristics of smooth, striated (skeletal), and cardiac muscle tissues, their contraction mechanisms, and functional roles. Furthermore, the article highlights the regenerative capacities of muscle fibers and their cellular-level structural organization from a modern biomedical perspective.

Keywords : muscle tissue, myocytes, myofibrils, skeletal muscles, smooth muscles, cardiomyocytes, sarcomere, histology, morphology, regeneration.

ENTRANCE

Directions of modern biology and medicine is the study of systems that provide the locomotor function of living organisms, in particular, muscle tissue at the cellular and tissue level. Muscles are the basis not only of mechanical movement, but also of the processes of metabolism, blood circulation and thermoregulation in the body. Today, understanding the subtle structure of this tissue remains a primary task in world science in the treatment of muscle pathologies, the development of sports medicine and the improvement of regenerative histology. As our President Shavkat Mirziyoyev noted: “We have set ourselves the strategic task of building the foundations of the third Renaissance . For this, we need scientific personnel and a new generation of specialists with modern knowledge, capable of conducting deep fundamental research, like air and water.” Based on this idea , bringing research in the field of biology and medicine to a new level, in particular, analyzing the morphological structure of muscle tissue at the molecular level, is of great importance in preserving our national gene pool and scientifically substantiating a healthy lifestyle. The high attention paid by the head of our state to science, especially the task of strengthening the integration between fundamental sciences and applied medicine, makes the study of this topic even more relevant. General description of muscle tissue. Muscle tissue is one of the most complex specialized structures in the body, which has the properties of excitability and contractility. From a histological point of view, it is divided into three main types : striated (skeletal), smooth and cardiac muscles. Each

type differs in its specific anatomical location and physiological function. For example, skeletal muscles provide voluntary movements, smooth muscles control the activity of internal organs, and cardiac muscle, as the vital engine of the organism, works on the basis of automatism . This article presents the results of microscopic studies of each type of muscle tissue. It also discusses in detail the interaction of actin and myosin proteins in the sarcomere, the main functional unit of the muscle fiber , the role of calcium ions in the contraction process, and the trophic (nutrition) properties of the tissue. Our goal is to contribute to the science of modern histology by revealing the structural laws of this complex biomechanical system .

METHODOLOGY

This research work used a comprehensive approach to determine the morphological and functional properties of muscle tissue. The study subjects were different groups of muscles of mammals (laboratory mice and rats) - skeletal (thigh muscle), smooth (small intestine wall) and cardiac (myocardium) . At the initial stage of the study, special attention was paid to the process of obtaining tissue samples and fixing them. To prevent the tissues from losing their viability, they were fixed in a 10% neutral formalin solution for 24 hours. After that , the samples were passed through a series of alcohols of different concentrations, dehydrated and clarified using xylene. In order to bring the tissues into a convenient state for sectioning on a microtome, they were embedded in paraffin blocks. Several types of microscopy methods were used to study the fine structure of muscle tissue . Light microscopy: Prepared paraffin sections (5-7 μm thick) were stained with conventional hematoxylin-eosin and Van Gieson. This method allowed us to see the general architecture of muscle fibers, the location of the nucleus, and their connection with connective tissue. Electron microscopy: A transmission electron microscope was used to study the internal organelles of the muscle fiber - myofibrils, sarcoplasmic reticulum, and mitochondria . The sample was examined in the form of ultra-thin sections with a thickness of 50-70 nm . At this stage, the distances between the Z-lines and individual disks of the sarcomere were measured with nanometer accuracy. To ensure the reliability of the research results, the images obtained were subjected to morphometric analysis using the special “ImageJ” program . The following parameters were calculated: cross-sectional area and diameter of muscle fibers, nuclear-cytoplasmic ratio, capillary density per unit area. All obtained quantitative parameters were statistically processed using the Student t-test. In this case, the $p < 0.05$ indicator was set as the threshold confirming the statistical significance of the results. Histochemical methods were used to determine the processes of muscle energy metabolism. In particular, the ShIK reaction was performed to determine the amount of glycogen in skeletal muscles . Also, to study

oxidative processes , the activity of the succinate dehydrogenase enzyme was determined, which made it possible to distinguish between “fast” and “slow” contracting muscle fibers. This selected set of methodologies served to deeply analyze not only the external appearance of muscle tissue , but also its internal molecular-biological regularities.

LITERATURE ANALYSIS

Muscle tissue has been a fundamental direction since the formation of the science of histology. An analysis of the literature shows that research in this area has gone through an evolutionary path from simple microscopic observations to complex molecular-genetic analyses. In the classical literature, the main attention is paid to the origin and morphological classification of muscle tissue . These sources describe in detail the embryonic development of muscles - their differentiation from the mesoderm. However, modern studies, in particular, in the works of internationally recognized scientists such as Junqueria and Carneiro, are reinterpreting not only the structure of muscle tissue , but also its interaction with the extracellular matrix. Studies confirm that the endomysium and perimysium layers are not only a support, but also a complex metabolic environment that provides nutrition and innervation of muscle fibers. In modern literature, the “sliding fiber” theory of muscle contraction is dominant. This theory was first proposed by H. Huxley, and today it has been further enriched with the help of electron microscopy and X-ray structural analysis. It is emphasized in the literature that the change in the distance between the Z-disks and M-lines in the structure of the sarcomere is directly related to the interaction of actin and myosin proteins. In recent scientific articles (for example, in Pollack's studies), it has been proven that not only ATP, but also the elastic properties of calcium channels and titin protein play a decisive role in muscle contraction. The ability of muscle tissue to regenerate is one of the most discussed topics in the literature. The doctrine of satellite cells discovered by Mauro is today the basis of regenerative medicine. In the scientific works of domestic and foreign scientists, the proliferation of these cells in the reparative regeneration of skeletal muscles and the process of their transformation into myocytes have been analyzed in various pathological conditions. Researchers say that the decrease in the activity of satellite cells with age is associated with general involutional processes in the body. In the study of the heart muscle, the literature mainly focuses on the structure of the intercalating discs and nexuses between cardiomyocytes. These structures ensure the functioning of the heart as a single syncyst. Modern literature on smooth muscles, on the other hand, has extensively covered the high sensitivity of this tissue to autonomic

nervous system and hormonal factors, and the control of its contraction mechanism by the protein "calmodulin".

RESULTS AND DISCUSSION

Of histological and morphometric studies, specific microscopic and functional data were obtained on the three main types of muscle tissue - striated (skeletal), cardiac and smooth muscles. These results made it possible to deeply analyze the relationship between the degree of specialization of tissues and their role in the body. When examined under a light microscope, skeletal muscles appeared in the form of multinucleated symplasts (muscle fibers) reaching several centimeters in length. In preparations stained with hematoxylin-eosin , a specific morphological feature was revealed - the location of the nuclei in the peripheral part, directly under the sarcolemma. This indicates that the central part of the muscle fiber is completely occupied by the contractile apparatus - myofibrils. Morphometric measurements showed that the diameter of muscle fibers is on average 60-80 \mu m, and the accuracy of transverse propagation in them is the result of a highly ordered alternation of anisotropic (A) and isotropic (I) disks. Electron microscopy analyses confirmed that the sarcomere length in a resting state is 2.2-2.5 \mu m, which is the optimal distance for maximum mutual binding of actin and myosin proteins. Unlike skeletal muscle , cardiac muscle consists of separate specialized cells - cardiomyocytes, which form anastomoses (junctions) with each other, creating a single network-like system. The study analyzed the intercalating disks between cardiomyocytes separately. During the discussion, it was found that these disks are a complex of nexuses (slotted contacts) that provide not only mechanical connections , but also the passage of electrical signals from cell to cell with minimal resistance. The location of 1-2 large nuclei in the center of cardiomyocytes and the extremely high density of mitochondria in the cytoplasm (30-35% of the cell volume) indicate that the heart is an energy apparatus adapted to continuous, rhythmic functioning. Compared with skeletal muscle, the almost complete absence of regeneration processes in the myocardium , its replacement by connective tissue after injury, is explained by its postmitotic nature. Analysis of smooth muscles showed that they consist of spherical-shaped cells . Their length is on average in the range of 20-200 \mu m, and in the center there is a single rod-shaped nucleus. The lack of transverse striation in this tissue is associated with the irregular arrangement of myofibrils. Histochemical analyses confirmed the presence of a special caveolae system for the deposition of calcium ions in smooth muscles. In the discussion, it should be noted that the ability of smooth muscles to contract slowly and for a long time is associated with their energy efficiency . They are not voluntarily controlled and

work mainly under the influence of the autonomic nervous system and hormones, which is crucial for maintaining a constant tone of internal organs and blood vessels. A comparative study of all three muscle tissues also revealed significant differences in their regenerative potential. While skeletal muscles have a high regenerative capacity due to satellite cells , smooth muscles regenerate through direct mitosis of cells. Cardiac muscle remains the weakest link in this regard . In general, it has been scientifically proven that each type of muscle tissue has its own unique and perfect microscopic architectonics to perform the physiological task assigned to it - be it dynamic movement or vital rhythmic contraction.

CONCLUSION

In conclusion, this study, conducted on the histological, morphological and functional study of the structure of muscle tissue , allows us to draw the following important conclusions: First, each type of muscle tissue - skeletal, cardiac and smooth muscles - has a highly specialized microscopic structure in accordance with its physiological function. The multinucleated symplastic structure of skeletal muscles and the fact that they are composed of orderly sarcomeres ensure their rapid and powerful voluntary movements. Cardiac muscle, on the other hand, performs tireless, rhythmic and automatic activity due to the intercalated discs between cardiomyocytes and a high density of mitochondria. Smooth muscle striated cells and their molecular control mechanism are adapted to perform long-term tonic contractions with low energy expenditure. Deep analysis of muscle tissue serves as an important scientific basis not only for fundamental biology, but also for the treatment of various myopathies, cardiovascular diseases, and the development of sports physiology in applied medicine. As the head of our state noted, the development of such fundamental areas of science will be the foundation for bringing the fields of medicine and biology in our country to world standards.

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