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ABSTRACT

of the dissertation for the degree of Doctor of Science

NORMAL AND EXPERIMENTAL STUDY OF THE STRUCTURAL ORGANIZATION OF THE VEGETATIVE NERVOUS SUPPLY OF THE LARGE INTESTINE IN HUMANS

Speciality: 3241.01 «Human Anatomy»

Field of science: «Medical sciences»

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Baku – 2024

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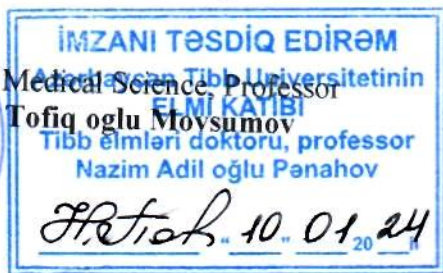Scientific Secretary of the One-time Dissertation Council:
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GENERAL REVIEW OF THE WORK

Topic relevance and degree of development. Despite over 150 years of research, the intestinal nervous system remains one of the least studied structures of the peripheral nervous system. Until recent times, the studies leading to the autonomic nervous system were devoted to the research of the neuronal composition and neurosecretory function of the star-shaped paravertebral ganglion, the cortical modulation of visceral reflexes, and the topography of sacral parasympathetic nuclei.[1]

However, the exact spatial localization and morphological characteristics of intraorgan ganglia neurons, which play an important role in neural regulation of large intestine functions, have been understudied.

Nowadays, increasing interest in the study of intestine nervous structures is associated with their important role in the pathogenesis of large intestine diseases. Clinical surveillance shows that after vagotomy, diarrhea[2], as well as after traumatic injuries to the sacral part of the spinal cord or surgical interventions, a significant slowing down of content transport in the large intestine is observed.[3]

The lack of clear information about the nervous mechanisms that ensure normal functioning of the large intestine greatly complicates the diagnosis and treatment of the noted pathologies in the large intestine.

Today discussion regarding neurons between scientists taking only synaptic connections and supporters of reticular theory is of

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[1] Шадлинский, В.Б., Коркмазов, Б.М., Мовсумов, Н.Т. (Shadlinskiy, V.B., Korkmazov, B.M., Movsumov, N.T.) Нейронный состав и нейросекреторная функция звездчатого паравертебрального ганглия человека в зрелом возрасте // – Баку: Здоровье, – 1996. №4, – с. 49-46

[2] Condon, J. The cause and treatment of postvagotomy diarrhea // J.Condon, V.Robinson, M Suleman [et al.] // British Journal of Surgery, – 2015. 62(4), – p.309-312

[3] Krogh, K. Colorectal transport during defecation in patients with lesions of the sacral spinal cord / K.Krogh, N.Olsen, P.Christensen [et al.] // Neurogastroenterol. Motil., – 2013. 15(1), – p. 25-31

fundamental importance.

The discovery of synapses by means of an electron microscope cannot serve as absolute proof for the victory of the neurons' doctrine.

Thus, the presence of synapses does not exclude the presence of inter-neural syncytial connections.[4] Currently, two- and multicellular syncytial connections have been discovered using computer methods which is direct evidence of reticular concept reality.

Due to the fact that it is a source of severe spontaneous bleeding, morphologists and clinicians have recently increased interest in studying the vessels of gastrointestinal system organs.[5] However, in the study of arteriolo-venular anastomoses, there are still many controversial and unsolved problems that require detailed and in-depth research.

In the modern scientific literature, information about extramural lymph flow in the intestine has been interpreted quite widely.[6] However, information on the lymphatic supply of the nerve plexus of the large intestine is rarely found in scientific literature.

Thus, the study of structural components of nerve the plexus of the large intestine is of great importance in clinical practice, in addition to understanding the principles of reflex regulation of its functions.

The study goal was to determine the structure of the nerve plexus components of the large intestine of a normal human and an

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[4.]Сотников О.С., Новаковская С. А., Соловьева И.А. (Sotnikov O.S., Novakovskaya S. A., Solov'eva I.A.) Синцитиальные перфорации нейрональных мембран эмбриона человека // Москва: Онтогенез, – 2012. № 1. – с. 31 – 36.

[5..]Xiao, Y. Clinical anatomy study of superior mesenteric vessels and its branches. Y.Xiao, Lu JY, Xu L [et al.] // Zhonghua Wai Ke Za Zhi. – 2019, Sep.;57(9), –p. 673-680.

[6..]Чумаков, В.Ю. (Chumakov, V.Yu.) Лимфатическое русло мышечной оболочки некоторых отделов кишечника домашних млекопитающих / В.Ю.Чумаков, Р.Э.Красовская, В.В.Чумаков // Известия Оренбургского государственного аграрного университета. – 2018. № 4, – с. 136-139.

experimental animal and the characteristics of their blood and lymph supply.

Research objectives:

1. The structural organization and regional characteristics of the nerve plexus of the large intestine (internal (Meissner), external (Shabadash), intramuscular (Auerbach) plexus located at the submucosal base-determination at a modern methodical level.
2. Characterization of the cellular structure of the nerve plexus ganglia of the large intestine.
3. Creating a 3D model of an isolated II type Dogel cell of the ganglion of the intramuscular plexus and measuring the morphometric indicators of this cell (volume of perikaryon and nucleus).
4. Obtaining information about synsitial connections between neurons and the presence of binuclear neurocytes in nerve ganglia of the large intestine.
5. Study of the blood supply and lymphatic vessels of the large intestine and its nerve plexus in the normal human and experimental animals.
6. Study of morphological changes occurring in the vascular sheath and ganglia during stenosis and occlusion of unpaired visceral branches of the abdominal aorta.

Research methods. During the study microscopic preparations were stained with hematoxylin-eosin, methylene blue, and Van Gieson methods to study the structure of nerve plexus as well as blood and lymph supply of large intestine.

Additionally, impregnation with silver salts (Ranvier-Goyer and Bilshovsky-Gross methods), universal impregnation for selective detection of argyrophilic structures, morphometric indicators of nerve cells in the 3D model of electron-microscopic and nerve cells, and blood and lymph flow in the large intestine wall were used in the experiment. In the preparations ganglions were calculated and diameters, lengths, densities of microvessels in 1 mm2 areas, cross-sectional areas, and volumes were measured as well as the amount of arteriolo-venular anastomoses was determined. The obtained

numerical indicators were calculated using the variation and dispersion methods in IBM Statistics SPSS-26 program.

The following provisions are presented for defense:

– Intramuscular and submucosal nerve plexus of the large intestine are normally characterized by complex histoarchitectonics. These nerve plexuses have ganglia and numerous sensory nerve protrusions. A significant part of them consists of Dogiel type II cell protrusions, and most of them are very long, extend beyond the ganglion, and form interganglionic reticulum. Nerve processes were identified in all membranes of the large intestine wall. Their number is much greater in the circular layer of the muscular membrane than in the submucosal layer.

– The intramuscular plexus of the large intestine resembles a network of cells of various shapes and consist of nerve ganglia composed by Dogiel type I and II cells. Dogiel type II cells predominate in these plexuses. A 3D model of Dogiel type II cell is cylindrical, thickened in the transverse direction, and elongated in the longitudinal direction.

– Syncytial connections between neurons were constantly detected in the ganglia of the large intestine. These are cytoplasmic anastomoses with several consecutive syncytia. Syncytial connections between the bodies of neurons and their peripheral projections form closed circular anastomoses. The syncytial connections between the protrusions of neurons create a narrow or wide ring network.

– The nerve trunk in the submucosal base of large intestine is accompanied by arterioles and one or two venules. Arterioles along the length of nerve trunk are located in its perineural bed. Regulation of blood flow in microvessels is ensured by smooth muscle sphincters or extracapillary blood flow pathways. Extracapillary blood flow paths are formed due to the direct passage of arterioles to venules or arteriolo-venular anastomoses without a capillary segment.

The scientific novelty. For the first time, the structure of the nerve plexus of the large intestine of normal people and experimental

animals was characterized by the complex use of morphological methods.

Regional features of the intramural nerve trunks of the large intestine have been elucidated and 3D model of Dogiel type II cell located in the intra-muscular ganglion created by means of "An5gs spaceclaim v. 19.2" program and the morphometric indicators (pericarion and nucleus volume) of this cell were measured. The presence of syncytial connections in the ganglia of the large intestine nerve plexus was investigated both at microscopic and ultramicroscopic levels. It was determined that such connections between bodies of two neurons and their processes are observed in most cases. The presence of binuclear neurocytes in ganglions has been proven. Such cells have been proven to be observed in different parts of the large intestine.

Regulation of blood flow in microvessels of the intramural nerve plexus of large the intestine is provided by sphincters of smooth muscles or extracapillary blood flow pathways. It has been confirmed that extracapillary blood flow paths are formed due to the direct transition of arterioles to venules or arteriolo-venular anastomoses without a capillary segment.

It was determined that lymphatic structures of the large intestinal wall include lymphatic vessels, closed and open lymphatic capillaries. Elongated sac-like, funnel-shaped and cystic expanded forms of closed lymphatic capillaries were found.

The theoretical and practical significance of the study.

The theoretical importance of the research is that the obtained scientific results have enriched the knowledge about the vegetative nerve supply of the large intestine, expanded the existing ideas about the mechanisms of transmission of nerve impulses in the intestinal ganglia, and made it possible to combine the synaptic and syncytial theories, which exist separately in science, into a single neuro-syncytial theory that created the conditions.

The evidence obtained as a result of the research was useful to pathophysiologists (to optimize the pathogenesis of numerous pathologies of the organs of the gastrointestinal system),

gastroenterologists (to improve the quality of treatment of various nosological forms of these organs).

Morphological data on the human large intestine plexus and their ganglions have ensured their use as standards (normatives) for comparison with biopsies and section materials taken during pathologies of this organ.

The results have been used in researches to be conducted in the direction of scientific justification and improvement of prevention and treatment schemes of various diseases of the gastrointestinal system organs encountered by clinicians in clinical practice.

The obtained scientific information is used in the teaching process (in classes held for students of morphological subjects, ordinators, and residents in the "gastroenterology" specialty), in the training of practicing therapists and surgeons, in the preparation of clinical protocols, recommendations, monographs and can also be used in the preparation of guidelines.

The approbation of dissertation materials. The main results of the dissertation work were presented at the International Scientific-Practical Conference dedicated to the 100th anniversary of the Department of Human Anatomy and Medical Terminology of the Azerbaijan Medical University (Baku, 2019), and at the International Scientific-Practical Congress dedicated to the 90th anniversary of the Azerbaijan Medical University on the topic "Actual Problems of Medicine 2020" (Baku, 2020), at the XV Congress of the 15th International Association of Morphologists (Khanty-Mansiysk, 2020), at the 21st National Congress of Anatomy (Istanbul, 2020), at the 12th International Conference on Mathematics, Engineering, Natural and Medical Sciences (Paris, 2021), at the 27th International Symposium on Morphological Sciences (Almaty, 2021), at the 25th National Congress of the Bulgarian Anatomical Society (Pleven, 2021), the 4th International European Conference on Scientific Research (Warsaw, 2021), at the International Scientific-practical Congress (Baku, 2021) dedicated to the 100th anniversary of the birth of Honored Scientist, Professor Tamerlan Aziz oglu Aliyev on the topics "Current problems in medicine – 2021", at the All-Russian Scientific-Practical Conference dedicated to the 110th anniversary of

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the birth of Professor V.V. Kupriyanov, academician of the Russian Academy of Medical Sciences on the topic "Morphological schools today" (Moscow, 2022), at the International Practical Conference on "Actual Problems of Medicine – 2022" dedicated to the "Year of Shusha" in the Republic of Azerbaijan (Baku, 2022), at the Human Anatomy and Medical Terminology Department of Azerbaijan Medical University, joint meeting of Scientific Research Center's employees (Baku, 24.10.2022, Protocol No.1), as well as at a scientific seminar of Dissertation Council BED 2.08 of Supreme Attestation Commission under the President of the Republic of Azerbaijan acting at Azerbaijan Medical University (Baku, 2023, Protocol No. 1_).

Putting the results into practice. The results obtained in the study were applied to practice in the Department of Human Anatomy and Medical Terminology, Department of Histology, Embryology and Cytology, 3rd Department of Surgical Diseases, and Department of Normal Physiology of Azerbaijan Medical University.

The publications. Out of 38 works published on the subject of the dissertation, 17 are scientific articles, 20 are conference materials, and 1 is a thesis. Nine of the scientific articles were published in foreign journals: "American Journal of Anatomy and Physiology" – Houston (USA); "Archiv Euro Medica" – Hannover (Germany), "Journal of Morphology and Anatomy" – Brussels, (Belgium); "World of Medicine and Biology" – Poltava (Ukraine); "International Journal of Medicine Research" – Delhi (India); "Морфологические ведомости" – Samara (Russian Federation); "Известия высших учебных заведений. Поволжский регион. Медицинские науки" – Penza (Russian Federation). 3 of the articles were published in "WOS" and 2 in "SCOPUS" international summary and indexing journals.

Volume and structure of the dissertation. The dissertation is annotated on 286 pages (316079 characters) typed on a computer and is divided into "Introduction" (volume: 16091 characters), "The main content of the dissertation" (volume: 206171 characters), "Conclusion" (volume: 89266 characters), "Results" (volume: 3068

marks), "Practical recommendations" (volume: 1483 marks), "List of used literature" consists of structural sections.

The "Main content of the dissertation" section consists of 8 chapters: Chapter I. "Summary of literature" (volume: 124400 characters), Chapter II. "Materials and methods" (volume: 15747 characters), Chapter III. "Structural organization and regional characteristics of large intestine nerve plexus" (volume: 10310 characters), Chapter IV. "Characteristics of the cellular composition of the ganglia of large intestine plexus" (volume: 10946 characters), Chapter V. "Study results of syncytial connections between neurocytes in the ganglia of large intestine" (volume: 11926 characters). Chapter VI. "The results of the study of the blood vessels of the large intestine" (volume: 14275 characters), Chapter VII. "The results of the study of the blood and lymphatic microvessels of the normal large intestine" (volume: 11942 characters), Chapter VIII. "Morphological changes occurring in the vascular bed of the large intestine during stenosis and occlusion of abdominal aorta branches" (volume: 6625 characters).

The list of applied literature includes 309 sources, 5 of which are in Azerbaijani, 94 are in Russian, 204 are in English and 6 are in other languages.

78 photomicrographs, 4 tables, 3 diagrams taken from the preparations are given to illustrate the evidence obtained in this dissertation work.

MATERIAL AND RESEARCH METHODS

The material of this study was made up of various parts of large intestine taken from 61 cadavers of both genders at different ages of human extrauterine development, 64 pieces of resection and biopsy material obtained as a result of surgical interventions on that organ. In 2019-2022 corpse material was obtained from morgues of the public legal entity called "Union of Forensic Medical Expertise and Pathological Anatomy" of the Ministry of Health of the Republic of Azerbaijan and Department of Human Anatomy and Medical Terminology of Azerbaijan Medical University, and the resection

and biopsy materials obtained as a result of surgical interventions were collected from Academician M.A.Mirgasimov Republic Clinical Hospital.

Materials taken from human corpses that died from various traumas, asphyxiation, acute poisoning, myocardial infarction, and hemorrhagic stroke were studied. During selection of cadaver material, cases where diseases of digestive system were the cause of death were excluded.

The studies were held over the parts of large intestine resection and biopsy materials where pathological changes were not identified.

Along with the cadaver, resection and biopsy material, nerve derivatives of the large intestine were also studied on the experimental material.

As part of the experiments, the materials taken from 60 rats of unknown gender (30 in the main group, 30 in the control group) aging 3-4 months and weighing 180-320 g were taken under the Scientific Research Center of Azerbaijan Medical University.

The other part of the experiments was conducted on 12 dogs (9 in the main group and 3 in the control group) kept in the vivarium of Samara Veterinary Clinic "Drug", belonging to both breeds, weighing from 10.0 kg to 18.0 kg, in the research laboratory for morphological problems of Samara Medical University "REAVIZ" according to the agreement on scientific and technical cooperation between Samara Medical University and Azerbaijan Medical University dated January 17, 2019.

The keeping of animals and their euthanasia were carried out according to the Directive 2010/63/EU of the European Parliament and the Council of Europe "On the protection of animals used for scientific purposes".

In order to study nerve derivatives of the large intestine, pieces of this organ wall were cut after human cadavers were dissected by the macromicroscopic method. The obtained material is fixed in 10% neutral formalin, or Carnoy's fluid. The fixed pieces were processed in 96^0 alcohol and then embedded in paraffin. Sections of 5-7 μm thickness were made of the mentioned pieces. Prepared pieces were stained with hematoxylin-eosin, methylene blue, and Van Gieson

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methods.[7] Ranvier-Goyer and Bilshovsky-Gross methods and universal impregnation method of selective detection of argyrophile structures silvering reactions were performed with.[8]

In addition, the research laboratory for morphological problems of Samara Medical University "REAVIZ", analyzed the results of preparations study taken from cadavers of both sexes aged 20-70 years where vein occlusions and stenoses were detected.

Electron-microscopic examinations and construction of a nerve cell 3D model of large intestinal ganglia, study of blood and lymph flow in the wall of large intestine in the experiment were carried out in "REAVIZ" Scientific-Research Laboratory for Morphological Problems of Samara Medical University. For electron-microscopic examination, sections were prepared from the preparations obtained from different parts of intestine in "LKB-5" ultratome (Switzerland) and they were stained according to the Reingolds method.[9] The examination of the obtained material and taking of their photographs was carried out in the "FEI Tecnai G2 Spirit BioTWIN" electron microscope (Netherlands) at an 80kV voltage.

A 3D model of the nerve cell of the intramuscular ganglion in large intestine was prepared after fixing a piece of the large intestinal wall in 10% amethanol formalin for 5 days, then 30.0-40.0μm thick frontal and horizontal sections were prepared from it. Sections with an area of 3.0 x 5.0 cm were examined under a Lesa 1000DM microscope with a digital video system. For morphological analysis, two pieces of Dogiel type II cells visible to the eye in the frontal and horizontal sections of the intestinal wall were selected. Morphometric studies of cells were carried out in "Ymadei" software package, their 3D models were built in "An5gs spaceclaim v.19.2"

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[7.]Коржевский, Д.Э. (Korzhevskiy, D.E.) Основы гистологической техники / Д.Э.Коржевский – Санкт-Петербург: Спец.Лит, – 2010. – 95 с.

[8]Марков, И.И. Универсальный метод элективного выявления аргирофильных структур / И.И.Марков, Е.С.Петров, В.И.Маркова // Морфологические ведомости. – Самара: – 2016. № 1. – с. 114–117

[9.]Морозова, К.Н. (Morozova, K.N.) электронная микроскопия в цитологических исследованиях / К.Н.Морозова, – Новосибирск: Издательство Новосибирского государ-ственного университета, – 2013, – 85 с.

program. In the experiment, in order to study the blood and lymph flow in large intestine wall, the femoral arteries were opened, and catheters were placed in both lower extremitas of dogs. One of them was connected to a pressure sensor, and the other was used for bleeding. Abdominal cavity was opened by middle laparotomy. The loops of small intestine are pulled to the left. Primarily it is assigned to the first artery of the jejunum.A polyethylene catheter was inserted into it, and it reached the main part of upper mesenteric artery. A catheter was inserted into the portal vein through the first jejunal vein. Vascular resistance of superior mesenteric artery system was defined as the ratio of difference between arterial and portal pressure to volumetric blood flow in the superior mesenteric artery.

Bleeding in one of the femoral arteries was continued until the blood pressure in the other femoral artery fell to 60-70 mm Hg. Blood loss reached 30% of the total blood volume. A 70% solution of cardiotrast was used for angiography. Angiography of the superior mesenteric artery was performed before and after bleeding. The intra-organ blood vessels of the intestine were impregnated with a weak (0.1%) solution of silver nitrate, and the walls of microvessels were impregnated with a 4% solution of hydroquinone. The intestines were removed from abdominal cavity, then a 10% solution of amethanol formalin was injected into its opening.

Then the whole intestine was placed in a 10% solution of amethanol formalin. After 10 days of fixation, paraffin sections of the intestinal wall and layered preparations of muscular and submucosa layer muscular and submucosa membrane muscular and submucosa membrane were prepared. Paraffin sections 3.0 - 5.0 μm thick were stained with Van Gieson, Weigert's iron hematoxylin and hematoxylin-eosin. Preparations of the tela submucosal and muscluar membrane with a thickness of 35.0 - 50.0 μm and 6x8 cm were in size studied by the universal impregnation method.Photomicrographs of preparations of different parts of the large intestine were taken on a Leica-DM 1000 microscope (Germany) with a video system.

Quantitative and qualitative indicators obtained during the research were analyzed by modern biostatistical methods. Statistical

analysis was carried out in MS EXCEL-2019 and IBM Statistics SPSS-26 programs using variation and dispersion methods.[10]

In analysis of indicators mean (M±m, 95% EI) and average structure (median, quartiles, min, max) indicators were calculated for the description of variation series. For an initial comparison of ranks analysis of variance was applied. Difference between the indicators grouped depending on the factor was assessed by the F-Fisher test. The obtained results were specified by non-parametric H-Kruskal-Wallis test. When statistical integrity of the difference is $p<0.05$, hypothesis "0" is rejected. In cases where "0" hypothesis was rejected, the indicators of groups were compared in pairs using the Student-Bonferroni criterion and it was found out which groups had the difference.[11]

The final results obtained from the measurements were documented, and the results of the measured indicators were collected on specially prepared statistical cards.

Photomicrographs of the preparations were taken. The shooting was done at the limit of comparison magnification.

THE RESEARCH RESULTS AND THEIR DISCUSSION

The organs of digestive canal have external and internal innervation. Internal innervation is represented by the intestine part of autonomic nervous system which consists of a complex neural network controlling various cell populations, including smooth muscle cells, mucosal secretory cells, endocrine cells, microcirculatory cells, immune, and inflammatory cells.

This network is composed of several plexuses, and each of them provides completely independent control of gastrointestinal

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[10.]Боровиков, В.П. (Borovikov, V.P.) Популярное введение в современный анализ данных в системе STATISTICA / В.П.Боровиков. – Москва: Телеком. – 2015. – 288 c.

[11.]Qafarov İ.A. Biostatistika / – Bakı: Müəllim, – 2021. – 238 s.

functions (hence the term "second or intestinal brain").[12]

In the study morphological and topographical features of nerve structures innervating the large intestine were studied by both classical and modern methods. According to the received data, internal (Meissner), external (Shabadash) and intramuscular (Auerbach) plexuses located between longitudinal and circular layers of muscular membrane of this organ are observed on the wall of the large intestine. Ganglions and interganglionic laces formed from numerous nerve projections are observed both in the plexus located on the submucosal basis and in intramuscular plexus. The size of neurocytes in ganglia of Meissner's plexus is smaller than the size of neurocytes of ganglia of Auerbach's plexus (Figure 1).
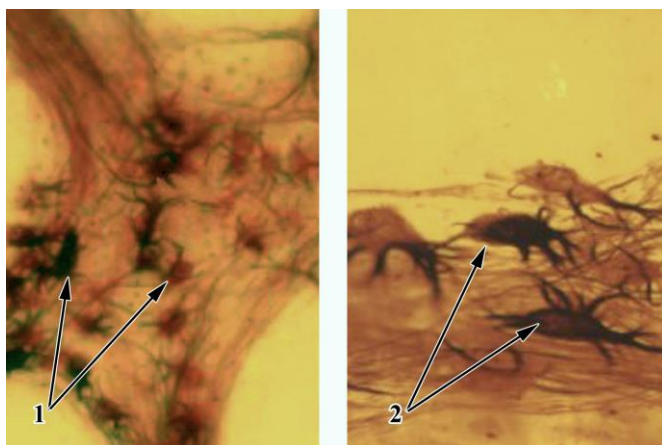

Figure 1. Ganglia of sheaths of large intestine.
Universal impregnation method. Magnification rate X600.
Note: 1. Neurocytes of the ganglion of Meissner's plexus;
2. Neurocytes of the ganglia of Auerbach's plexus.

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[12.]Natale, G. The nature of catecholamine-containing neurons in the enteric nervous system in relationship with organogenesis, normal human anatomy and neurodegeneration / G.Natale, L.Ryskalin, C.Busceti // Archives Italiennes de Biologie – 2017. Sep;155(3), – p. 118-130.

Intramuscular ganglia contained neurons, glial, and small amounts of unidentified cells with dark, small, round, or elongated nuclei.

During microscopic examination of the histological preparations stained with hematoxylin and eosin it is determined that the ganglions are located in the form of chain rows in the intramuscular cells.

Cells in the ganglia do not have clear borders; the space around them is filled with weak eosinophilic neuropil. In the neuropil, more clearly defined sparse foci are found in the peripheral zones of the ganglia, where they sometimes take the form of slit-like spaces that separate the ganglia from surrounding tissues. Neurons in the ganglia vary in size, and they lie in the same plane in the longitudinal ganglia.

Neurons have loose chromatin and one to two large round nuclei occupying about half of the cell area.

The cytoplasm of neurons is characterized by different degrees of basophilicity. Some neurons do not have a nucleus, or their nuclei are pyknotic. Glial cells that are smaller than neurons in size are located between them or at the border of ganglions, and their nucleus consists of more condensed chromatin.

Ganglions are surrounded by smooth muscle cells, individual fibroblasts and fibrocytes. When staining with hematoxylin and eosin in the intramuscular ganglion*s* structure of different parts of the large intestine no qualitative difference was detected.

The borders of the ganglia are clearly distinct and a weakly stained fibrous neuropil lies between the neurons. Neuron nuclei are pale purple in color with a clear border and loose chromatin.

In the cytoplasm Nissl substance collected in a reticular or rock-shaped tigroid was detected. In some neurons it is unevenly distributed and it is concentrated paranuclearly in the form of a vacuole-like sparse ring. The cytoplasm of neurons differed in intensity of staining that allowed to identify them as hypo-, normo- , and hyperchromic neurons. Nuclei were often eccentrically located, in which the nuclei were uniformly stained or light in the center. Some neurons (with pyknotic nuclei) have irregular contours, sharp

hyperchromic cytoplasm, and a deformed, more elongated small hyperchromic nucleus. In some neurons the cytoplasm is sharply hyperchromic. Many neurons are pyramidal in shape. Glial cells are characterized by a small, light blue nucleus. Their cytoplasm does not have clear borders with the neuropil.

Qualitatively, no differences were found in the cell composition in different parts of the intramuscular ganglions of large intestine. When examining the histological preparations, a thin connective tissue capsule with a red-orange color was seen around the ganglions. The capsule has a relatively uniform thickness and passes into the connective tissue stroma of the muscular membrane. Numerous interlayers of connective tissue extend from the capsule inward forming the stroma of nodule. Through these interlayers blood vessels feed the node and create a network inside it. Diffuse, cone-like, or encapsulated receptors are often found near blood vessels in the capsule and stroma of the nodule.

Microscopic examination of the histological preparations shows that the neurocytes of the ganglia in the intramuscular plexus of the large intestine have a circular, oval, and elongated shape and form chains.

Hematoxylin-eosin staining did not reveal differences in the structure of the different parts of intramuscular ganglions in the large intestine.

The ganglions are stained unevenly, clearly expressed sediment is recorded in the area of neuron nuclei. With the formation of a ring in some ganglions, the edges are stained, while in the other ganglions the central zone is stained more intensively. The neuropil in ganglia has a fibrous structure. Nerve fibers in the circular layer of the muscular membrane differ in diameter, have an oval, elongated or twisted shape, and are also characterized by a fibrous structure. Some of the nerve fibers leave the ganglia and pass through the muscular membrane. In preparations, most of the fibers are directed forward. Fibers mainly have clear contours and differ in the degree of staining; large-sized fibers, as a rule, are dyed more intensively. In the longitudinal layer of the muscular membrane, the number of nerve fibers is significantly less than in the circular layer, and their

diameter is smaller; they were not detected in the serous membrane. At the border of the muscular and the submucosa bases, numerous nerve fibers lie in the same plane but pass into the submucosa.

The ganglions of the intramuscular plexus form a network located in one plane and are connected by interganglionic cords consisting of numerous parallel nerve fibers. The large ganglia are located parallel to the circular layer of the muscular membrane and perpendicular to the nerve plexus. It has been established by us that normally the first ganglions are identified in the intramuscular plexus of the rectum at a distance of 0-40.0 mm cranial from the dentate line. Proximal to this, a zone is defined where individual ganglionic structures are found. The length of this zone is between 2.0 and 37.0 mm. From this zone, the nerve fibers connecting them cranially and densely located glial elements are easily identified.

Ganglia are connected by nerve pathways consisting of numerous nerve fibers oriented in the same plane, forming a network and located in parallel. Interganglionic spaces size and differ according to their forms. Thus, large ganglions are located parallel to the circular layer of the muscular membrane and perpendicular to the nerve paths. Larger ganglions are elongated and smaller ones are triangular in shape and contain neurons and nerve fibers.

Neurons have a round shape and a large nucleus that occupies most of the cytoplasm. Focal thinning of nerve fibers is observed in most of the neurons. This rarefaction is located in the center of the ganglia as well as at the border of the ganglia. In addition to neurons, glial cells were found in the ganglia and neural pathways; they are characterized by having a nucleus smaller than neurons and lacking well-defined cell boundaries.

Numerous nerve fibers exit the ganglia into the interganglionic spaces and, more rarely, into the longitudinal layer of the muscular membrane, and they vary in thickness. The thinnest fibers are formed by the branching of thicker fibers or arise directly from the ganglia. The fibers are located perpendicular to the circular layer of the muscular membrane and are bent and branched. Nerve fibers are larger and more numerous at the border between the circular layer of the muscular membrane and the submucosal base. In the longitudinal

layer of the muscular membrane, thin and small number of nerve fibers are visible, located perpendicular to the circular layer of the muscular membrane.

In the microscopic examination of histological preparations stained with hematoxylin-eosin, the submucous plexus is represented by ganglions compactly located on the submucosal basis of the connective tissue in all departments. Submucous ganglions are round, rarely oval, and consist of 1-3 neurons and glial cells. Compared to the proximal department, where they are located at the root of the folds formed by the mucous membrane and submucosal base, their quantity is reduced in the medial department, and they are single in the distal department. Neurons and glial cells of the submucosal ganglia did not differ from those of the intramuscular ganglia according to their morphological characteristics.

Submucosal ganglions are connected by numerous parallel nerve fibers directed in the same plane and forming a network. Neurons have a round shape and a large nucleus that occupies most of the cytoplasm. Most of the neurons are in the center of ganglia, where focal thinning of nerve fibers is noted; they are located on the surface of ganglia, and individual neurons are located in the projection of nerve pathways.

The results showed that the ganglion of submucosal and intramuscular nerve plexus of the large intestine has a formed connective capsule. The capsule has a relatively uniform thickness and passes into the connective tissue stroma of the muscular membrane. Numerous interlayers of connective tissue extend from the capsule inward, forming the stroma of the nodule. Through these interlayers, blood vessels feed the node and create a network inside it. In the capsule and stroma of the nodule, diffuse, bulbous or encapsular receptors are often found near blood vessels.

In the proximal part of the large intestine the number of ganglions of submucosal internal (Meissner) plexus per 1 mm of muscular membrane length is statistically significantly higher (1.16 times, $P > 0.001$) in the proximal part than in the distal part.

Submucosal ganglions of the outer (Shabadash) plexus were observed 1.18 times ($P > 0.001$) more in the proximal part than in the

distal part. The number of ganglions of intramuscular (Auerbach's) plexus in different parts of the large intestine was not significantly different.

It has been determined that the receptors on the wall of the large intestine have a number of different characteristics: 1) the presence of a wide distribution area of the receptors; 2) identification of receptors in various tissue structures; 3) afferent fibers ending with receptors on the wall of the large intestine are separated from Th1 - Th5 - S2 segments of the spinal cord.

Thus, the study results of structural organization and regional characteristics of the large intestine nerve plexus showed that internal (Meissner), external (Shabadash), and intramuscular (Auerbach) plexuses located between longitudinal and circular layers of the muscular membrane are observed in the wall of this organ. The size of Meissner's plexus ganglia is smaller than the size of Auerbach's plexus ganglia. In intramuscular plexus, ganglions are located in the form of chain rows. There are round, oval, or elongated forms of ganglia observed. In both Meissner's and Shabadash's plexus, the number of ganglions is significantly greater in the proximal part than in the distal part. The number of ganglions of the intramuscular (Auerbach) plexus in different parts of the large intestine does not differ much. The study results show that ganglia are compact structures clearly separated from surrounding tissue and composed of neuronal bodies, glial cell nuclei, and a dense neuropil. Ganglia consist of neuronal bodies surrounded by densely packed axons, dendrites, glial cells, and a small amount of intercellular substance.

The border of ganglia is formed by numerous protrusions of gliocytes. Most part of axons surface is covered by projections of glial cells but in some areas the axons are separated from the surrounding tissue only by a basal plate consisting of collagen fibers. Neurons of intestinal plexus ganglions mainly belong to two morphological types: I and II type Dogiel cells. This indicates that enteric plexus ganglia are distinct from all other enteric neurons.[13]

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[13.]Brehmer, A. Classification of human enteric neurons // Histochemistry and Cell Biology, – 2021. 156, – p. 95-108

According to the results obtained in our study, many protrusions from the bodies of I-type Dogiel cells were observed. These are the dendrites and one long projection; the axon that branches into sphincter muscles gives I-type Dogiel cells their stellate and elongated appearance. II-type Dogel cells are round, oval, or fan-shaped, have a smoother appearance than I-type Dogiel cells, and have 3–10 long and short projections branching at some distance from neuronal bodies (Fig. 2).
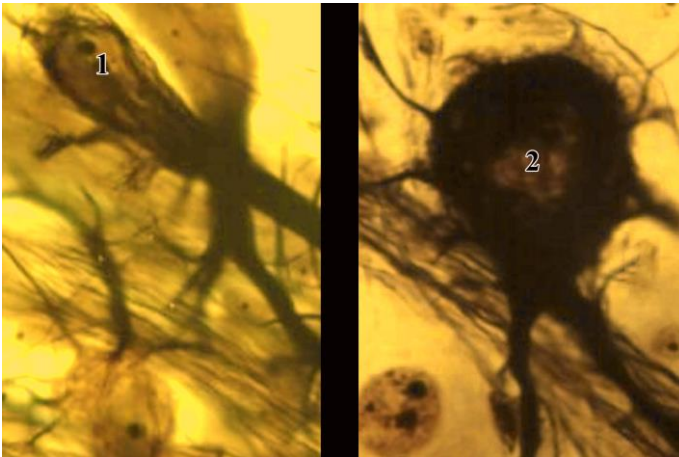

Figure 2. I and II type Dogiel cells in ganglion of large intestine. Universal impregnation method. Magnification rate X900
Note: 1) I type Dogiel cell; 2) II type Dogiel cell

In some cases, two protruding II-type Dogiel cells are observed. One of them repeatedly branches dichotomously. Very small and huge neurons are also found in intramuscular plexus ganglions.

As a result of this research it can be concluded that the universal impregnation method allows revealing all the details of structural organization of neurocytes located in intestinal ganglions, as well as their connection with microvessels. So from our side very

short and unbranched fringes of II-type Dogiel cells involved in the innervation of microvessels were also identified.

According to the obtained results, neurocytes located at the periphery of ganglions are surrounded by moderately impregnated gliocytes, and their short, unbranched protrusions form local contacts with the wall of microvessels.

These contacts are well-formed structures in the form of preterminal or terminal plates. The protrusions are surrounded by a glial foot and have an uneven thickness. Other II-type Dogiel cells are located directly in the walls of microvessels. They have several short, but, wide and unbranched dendrites ending in terminal receptor plates.

Individual neurocytes and mostly unipolar II-type Dogiel cells are located in an extensive glial bed.

When studying physiological and pathological processes in biological systems, it is necessary to take into account the main ideas and concepts of cybernetics. In this regard, currently the most promising method for studying histological material is CAE (Computer-aided engineering) technologies.[14]

We calculated the morphometric parameters (volume of perikaryon and nucleus) of an II-type Dogiel cell isolated in the intramuscular plexus. A 3D model of an oval-shaped II-type Dogiel cell of intramuscular plexus ganglion was constructed and studied. II-type Dogiel cell cell was determined by the impregnation method in the frontal and horizontal sections of large intestine wall.

Color photographs were taken to evaluate the volume of the perikaryon and nucleus of the isolated II-type Dogiel cell located in the frontal and horizontal planes. The obtained images were first connected in the Cartesian coordinate system, then, after connection of planes and conversion to a Stl file, their solid model was constructed in the Autodesk^R software environment.

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[14.]Берендеев, Н.Н. (Berendeev, N.N.) Методы решения задач усталости в пакете ANS WORKBENCH / Н.Н.Берендеев – Нижний Новгород: Нижний Новгородский Университет. – 2020. – 73с

In the virtual mode of II-type Dogiel cell, the number of network elements is 156595. The resulting 3D model of the cell was scaled 900 times to obtain a three-dimensional cell and nucleus with absolute 1:1 dimensions to their actual dimensions.

A number of corrections were made in the calculations: 1) the cross-section of the cell in the horizontal plane was approximated as a regular figure; 2) the distance between the cuts is 0.1% of the cell volume; and 3) the material of the studied volume is isotropic.

The object of study—the body of the cell H, whose volume properties are to be calculated—is located between two arbitrary planes.

The coordinate system is set up so that the Ox axis is perpendicular to the a and b planes. The abscissas of points of axis intersection with these planes are marked with the letters a and b planes (a<b). We will assume that the body of cell H is such that its section F(x) is a plane passing through the abscissa point (x) and perpendicular to the (Ox) axis. So they are ellipses.

The method used to calculate the volume of a cell consists of dividing its cross-section into separate areas, calculating the area of each of them, and then summing up the obtained results. A number of formulas have been applied to determine the size of Dogiel cell area:

$$A^{(i)} = \frac{(x_{i+1} + x_i)}{2}(y_{i+1} - y_i);$$

$$S_x^{(i)} = A^{(i)}\frac{(y_{i+1} + y_i)}{2} = \frac{(x_{i+1} + x_i)}{4}(y_{i+1}^2 - y_i^2);$$

$$J_x^{(i)} = A^{(i)}\frac{(y_{i+1} + y_i)^2}{4} = \frac{(x_{i+1} + x_i)}{8}(y_{i+1} - y_i)(y_{i+1} + y_i)^2;$$

$$J_{xy}^{(i)} = A^{(i)}\frac{(x_{i+1} + x_i)}{4}\frac{(y_{i+1} + y_i)}{2} = \frac{(x_{i+1} + x_i)^2}{16}(y_{i+1}^2 - y_i^2).$$

The following results were obtained: the volume of II type Dogiel cell is 2785.11 mcm^3, the volume of the nucleus is 647.7 mcm^3.

It has been determined by us that, in addition to neurons, glial cells are the cellular component of the ganglia, which is no less important. Morphologically, glial cells have a much smaller cell body and nucleus than neurons, which occupy most of the cell body.

Depending on their morphological characteristics, we detected two types of glial cells: intraganglionic glial cells and interganglionic glial cells. Intraganglionic glia are morphologically similar to plasma astrocytes of the central nervous system and are located at the boundaries of the intramuscular and submucosal ganglia. Its protrusions are in close contact with neurons and participate in the formation of neuropil. Interganglionic glia are similar to fibrous astrocytes of the central nervous system and are localized in neural tracts. The number of glial cells is higher in the intramuscular ganglia and lower in the ciliated cells.

The cytoplasm of glial cells was not clearly visible. In ganglions unknown cells with a small amount of dark color, small size, round or elongated nucleus were identified.

Intra-ganglionic and inter-ganglionic glial cells, glial cells in the space between the ganglia and in the circular layer of the muscle membrane, were identified in the intramuscular ganglia.

Glial cells in ganglia form a dense fibrous neuropil that surrounds the bodies of neurons. Glial cells were also seen at the border between the circular and submucosal layer of the muscular membrane. Glial cells have a small, radiating light, mostly oval, triangular, or polygonal body, and protrusions that form a fibrous-rock-like neuropil and surround neurons with a dense network. Glial cells are mainly located in one plane, forming a continuous network due to their projections.

Intramuscular glia was localized in the spaces between the ganglia and along the nerve fibers in the circular layer of the muscle membrane. Its cells were characterized by a round body and two large protrusions running parallel to the circular layer of the muscle membrane. Glial cells are located at the border of muscle membrane with the submucous base. They are relatively large; they were distinguished by their bodies and several protrusions separated in different directions.

Thus, in the ganglions of the plexus of the large intestine, neurons of two morphological types were identified in most cases. I-type Dogiel cells have many short and long protrusions extending from their body. The bodies of these cells have elongated stellate contours. II-type Dogiel cells have a round, oval or fan-shaped, smoother contours than I-type Dogiel cells, and 3-10 long and short protrusions. In some cases, II-type Dogiel cells with two protrusions are observed. One of these protrusions is repeatedly dichotomously branched. Along with neurons, we found that glial cells are an equally important cellular component of the ganglia. Morphologically, glial cells are smaller than neurocytes and have a nucleus that occupies most of the cell body.

In the study, the fragments of different departments of the large intestine were examined by electron-microscopic and light-optical methods.

While interpreting images obtained from the preparations, it becomes clear that countless neurite branches hide the complexity of the structural organization of neurons. In our opinion, this situation leads to the masking of neural structures and causes debate between neuronists and supporters of the reticular theory.

Therefore, it is necessary to simplify the picture of their impregnation to reveal the confusion of fibers and neurons, making most of the thin "spider webs" that hide the main neural column invisible. To do this, it is necessary to dramatically increase the contrast of the image by means of a computer, first of all. Next, use the Focus Dodge tool to dim the image of neurites that are not in contact with each other. In this case, only large, contrasting argentophilic structures are left that are in contact with each other. These are mainly neural crests and syncytial contacts.

As a result of the examination of the preparations, several variants of typical intermembrane cytoplasmic syncytia were revealed. These are usually in the form of perforations bounded by pairs of adherent dice in transverse sections. (Fig. 3).

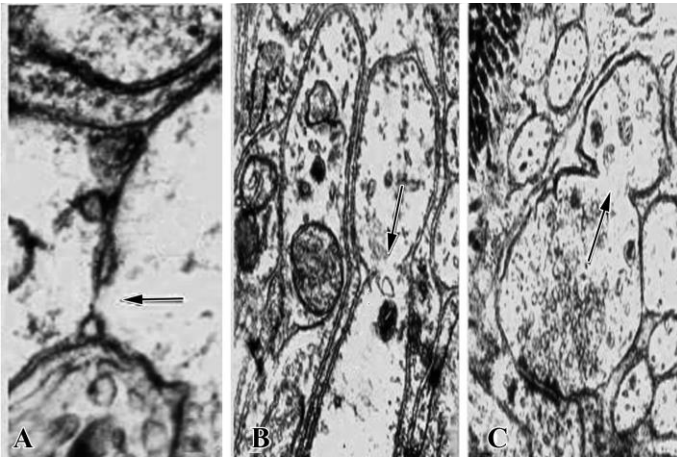This indicates that the syncytial connections are of loose and tight contact origin.

Figure 3. The stage of syncytial perforations formation in the lining of large intestine.
A) Destruction of membrane contacts before perforation occurs;
B) Signs of developing syncytial perforation;
C) Large interfibrous syncytium.
Electron microscope images. Zoom rate:
X45000 in picture A, X35000 in pictures B and C

Sweeney Y., Clopath C. (2017) proved that some neurotransmitters can freely diffuse between cell membranes, affecting neighboring neurons regardless of synaptic connection. The effects of this diffuse plasticity are found in some neuronal networks and lead to spatial structure in synaptic connections.[15]

As a result of transformation of double-layered axolemms in contact into syncytium, it is observed that transformation into "joined" thin membranes (gap and tight contacts) occurs before syncytial perforations. Distant in all departments of the large intestine connecting thick interneuronal bridges called paired syncytial junctions are found. They are often obvious because they

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[15]Sweeney, Y., Clopath C. Emergent spatial synaptic structure from diffusive plasticity // European Journal of Neuroscience, – 2017, Apr;45(8), – p. 1057-1067.

are wide, short and thin-long.

In large binucleate cells, the diameter of the syncytial connection is small, and additional branches are formed in them. Sharply expanded short-syncytial connections and even neuron bodies in nerve sheaths can communicate with each other. In some cases, three or more syncytial connections are formed between neurons. One receptor from a sensory neuron can share not 1 but 2 dendrites, forming a flagellum.

Large intestine plexus is characterized by numerous fibrous, long, closed loops, and annular connections.

In type II Dogiel cells, the neurites are bushy and have widely distributed receptors, which further confirms the sensory nature of these cells. The shape and diameter of protrusions in annular connections are variable, and they have fragments of myelin membrane. We were able to detect networks of interneuronal and intersomatic connections of 7-8 neurons connected by cytoplasmic connections with unpaired, consecutive syncytia connecting 3 cylindrical protrusions.

This is a rare type of syncytial fusion. The presence of such a rare, virtually asynaptic, that is, cytoplasmic neuron connection in the nerve plexus requires new physiological approaches to explain.

In the study, it was proven that the thin, unbranched protrusions of type II Dogiel cells are separated not only from the body itself but also from its cytoplasmic protrusions. From our side, it is possible to detect syncytial connections between these protrusions and the bodies of neighboring neurocytes.

In the studied ultramicroscopic preparations, a relatively thin layer of neuroplasm surrounding the nucleus of nerve cells and poorly developed glial protrusions separating the bodies of neurons are observed. The absence of glia causes neurons to be located close to each other and often form membrane contacts. In a number of cases, in united cells, smooth intercellular gap contacts and multiple consecutive local constrictions are identified.

Dense connections with long and punctate glioneurites, narrowing the intercellular gap and forming its varicose deformations, were found. A peculiar picture of varicose

deformations of the cleft appears. Perforations are often formed in the area of contractions, reminiscent of punctate gaps or tight contacts communicating with cell neuroplasm in contact.

These are faintly visible pores, gradually expanding and forming large cytoplasmic perforations between fused neurons. It is noteworthy that the edges of perforations are not simple fragments of cubes but a rounded shape of neighboring cell cubes. The formation of several perforations arranged in one row is possible.

Vesicular residual bodies are formed between fragments of perforated membranes. They can be single or multiple.

The detection of such a picture actually proves that the neurons are fully connected. The vesicular remnant bodies apparently disintegrate over time, and preparations reveal binucleate cells without boundary membranes between them.

Rupture of the contact membranes leads to the formation of a glioneuritic pore that expands and forms large syncytial perforations. At the edge of the perforation, either the remnants of tight contacts are revealed in the form of thin rod-shaped structures or the damaged membranes are united and rounded. In the cavity of the perforation, there are always residual membrane bodies in the form of several vesicles. Their departure from the middle line may be an indicator of the mutual translocation of glio- and neuroplasmic substances.

In semi-thin sections along the contact edges of neurons, it is possible to detect the formation of numerous protrusions (cytoplasmic stalks) firmly attached to adjacent cell stalks. Paired pedicels are separated by large vacuole-like vacuolated outgrowths that are locally sharply enlarged fragments of the intercellular space.

Alternating feet and vacuole-like outgrowths are located along the precise boundaries of cells and can be reliable landmarks of these boundaries. These are cytoplasmic bonds that connect neighboring cells.

By means of electron microscopy, this is indeed confirmed. However, in some electronic images, the stalks of two neurons in contact may be separated by their outer membranes, with most of the membranes that bound the cytoplasm of neighboring cells disintegrating in the stalk region. Instead of outer cell membranes

separating the cytoplasm of neurons, in some places only a short remnant of their intercellular spaces—about 20 nm-wide fragments—are detected. In other places, the neuroplasms of adjacent cells pass directly into each other.

In semi-thin sections, it is possible to detect numerous bulges (cytoplasmic junctions) common to neighboring cells along the contact edges of neurons. Connecting bridges are separated from each other by large vacuole-like derivatives with locally sharply expanded fragments of the intercellular space. Alternating connecting bridges and vacuole-like outgrowths are located at the border and are considered a definite sign of neuronal fusion.

Instead of the outer cell membranes separating the cytoplasm of neurocytes, only short residual fragments of their combined membranes with rounded ends are detected, in some places maintaining intercellular spaces about 20 nm wide. In other places, the neuroplasms of adjacent cells pass directly into each other. In fact, the cytoplasm of two neighboring cells is completely united in the junctional bridge part. Over time, the number of vacuole-like expansions of the intercellular space decreases, and the cells completely fuse to form a binucleate neuron.

The fact that neurons are connected to each other, not just in contact, shows that there are two absolute proofs that neurons get connected. First, the angles between neurocyte bodies are greater than 1250, which is a sign of cell fusion. Second, as we have shown by means of an electron microscope, the spaces between the vacuole-like structures are junctional bridges, where the boundary membranes of neighboring cells break down and their cytoplasms merge.

In order to prove the completeness of the fusion feature of a neuron neurolemma, it is necessary and sufficient to prove the possibility of fusion of a neuron with isolated fragments of another nerve cell separated by special methods, as previously happened in many non-neuronal cells. For this, it is necessary to separate the nucleus from the whole cell and then obtain information about the syncytial connection of the isolated cytoplasm (cytoplast) with another neuron or the connection of the karyonlast with the body of another neurocyte. Studies have shown that other

neuromorphological phenomena observed in normal material, such as bulging of the nucleus of neurons, "rewiring" of nerve cells, and "neuronal division," are not true division of neurons but a process of natural nuclear ectopy ending with enucleation of neurocytes. In this case, the matrix of combined cytoplasts has a relative density. At the periphery of anucleate fragments, vacuoles and lysosome-like granules were found, as is usually the case at the junction of cytoplasts with other types of cells. Small lysosomes and unchanged nuclei are located in the cytoplasmic thin layer of karyoplasts. Some of the small cytoplasms fused with the cell bodies, forming fusion bridges and a vacuole-like expansion of the intercellular space similar to neuron body fusion. These structures are a clear indicator of the fusion process of cytoplasts. When cytoplasts are fully integrated with the cytoplasm of the neuron body, the border vacuole-like structures are reduced, and the cytoplasm begins to resemble a neuron bulge.

Our results regarding the study of large intestinal ganglions confirm the high adhesion properties of neurolemma and demonstrate the possibility of the formation of syncytial cytoplasmic connections in neurites.

In the conducted studies, it is possible to detect binuclear and multinuclear neurons, proving their fusion under an electron microscope, and thus to confirm the fundamental similarity of neurons with other cells in the matter of intercellular communication.

Electron-microscopic studies made it possible to determine the absolute sign of the neuronal connection. It consists of the formation of vacuole-like expansion of the intercellular space at the border of the confluent cells and the formation of numerous junctional bridges that concentrate the remnants of destroyed boundary membranes.

Neurons in sections have a narrow layer of cytoplasm around the nucleus, attenuated by organelles. In some cases, around the neurons, there are enlarged intercellular spaces, parts of the neuronal bodies, and their projections glial membranes present. If not, it is in direct contact with its outer cell membranes. It is quite in these regions that, in our opinion, it is possible to detect imperceptible, specific changes that can significantly affect the electrical properties

of neurons. In some places, the paired membranes of two adjacent neurons are perforated. These are morphologically distinct perforations of paired membranes rather than the random, shapeless artificial membrane defects often seen on electron micrographs. They are not found in single membranes. First of all, rather long parts of adjacent membranes are detected, and they are connected by contact and form a structure reminiscent of a tight connection. Here necklace-like varicose structures whose walls are formed from adjacent membranes and whose cavity consists of the remnants of intercellular space can also be formed. In fact, the beads are separated by very short, pointy, tight contacts.

When relatively long contacts are perforated, the thin ends of the cut contacts remain along the edges of the perforations. One of the important signs of intermembrane (intercellular) perforations is the rupture of one or two varicose beads that become residual vesicular bodies inside perforations. In some cases, the edge remnants of tight contacts are poorly defined. In this case, the morphological feature of naturally formed perforations consists of clearly rounded edges of adjacent membranes. Occasionally, residual bodies appear as faint oval structures interspersed within perforations between neurites.

Variants of changes observed in the paired membrane are schematically summarized. They can be represented as stages of the same process of syncytial perforations of embryonic membranes.

Based on the research, it is possible to formulate the following main morphological regularities of syncytial connections: 1) Pores and perforations between syncytial neurons are formed only on the basis of point or extended membrane contacts; 2) Syncytial perforations are formed as a result of size expansion of syncytial pores; 3) bladders in the cavity of perforations in the form of residual membrane bodies are observed; 4) edges of perforations take on the thermodynamically more favorable oval shape of combined membranes.

Thus, several variants of typical intermembranous cytoplasmic syncytia were revealed as a result of the study of the preparations of large intestinal ganglia. They are usually found in cross-sections as

perforations, limited to conjoined pairs of cells. This proves that they are formed on the basis of loose and dense connections. In all parts of the large intestine, thick connective interneuronal hulls called syncytial connections to remote addition are widespread. Multiple closed loops and annular connections are characteristic of the plexus of the large intestine. The study also showed that conditions for the formation of syncytial connections between neurons of large intestinal ganglions are the absence of glial layers, the formation of syncytium based on membrane contacts, local expansion of the intercellular gap in the form of varicose deformations, and the formation of membrane fragments that disintegrate in the form of residual membrane bodies (vesicles).

In order to study the characteristics of blood supply and lymphatic vessels in large intestine nerve sheaths in accordance with the goals and tasks of the study, we first studied the vessels that supply this organ in general.

It was determined by us that the arteries feeding the large intestine, which are branches of the upper and lower esophageal arteries, form a common arterial system from the cecum to the upper edge of the rectum. This system is characterized by:

1) the presence of parallel arteries along the length of the intestine;

2) the presence of vascular "doors" surrounded by paravasal connective tissue into which vessels enter and open to the submucosal base;

3) intramural blood flow of the intestine is common and consists of a serous, muscular, mucous, and submucous microvascular plexus.

The extra-organ arteries (coeliac trunk, superior mesenteric, and inferior mesenteric arteries) that provide blood flow to the large intestine are muscle-elastic type vessels. Their wall has 20 to 40 layers of myocytes. External and internal elastic membranes are clearly defined. The adventitia is wide; it consists of a large number of blood and lymphatic microvessels and nerve elements. This, in turn, is associated with fascial-cellular vaginas located in connective tissue derivatives of the surrounding organs. The angle of separation

of the superior mesenteric artery is 32º, and the angle of separation of the inferior mesenteric artery is 24 °.

Unpaired visceral branches of the abdominal aorta all have dilated beds (diffusers), increasing the diameter of these vessels. They have significantly larger diameters and form an arch of 7.5 ±2.4 cm along the superior mesenteric artery. Intestinal arteries are separated from the lower edge of the arch, and arteries of the colon are separated from the upper edge. This structure of the superior mesenteric artery makes it possible for all intestinal arteries to branch at an angle of 36–40º; the inferior mesenteric artery forms an arc with a smaller radius (4,0-5,0 cm). Except for the middle colic artery, the superior colic artery is fixed at the colon root, and the right and left colic arteries are fixed in the ascending and descending parts of the colon, which are located mesoperitoneally.

Short and long, straight branches from the artery enter the wall of the large intestine. Their number varies significantly in different parts of the intestine. Thus, the number of straight arteries is almost two times higher in the left half of the transverse colon, in the descending and sigmoid colon, than in the right half of the transverse colon, ascending colon, and cecum. Angioarchitectonics is complex due to increased arterial anastomoses in the right and left curvatures of the colon. Extracorporeal arteries are closely connected with the serous membrane of the intestinal wall and enter the submucosal base along the edges of the muscle bands. At this time, the short arteries are directed towards the fat strips, and the long veins are directed towards the free and fat strips. The length of the large intestine is free, and no straight arteries between pistils are observed.

It was determined by us that after removing the serous membrane of the intestine, an entrance gate for straight arteries appears between the superficial bundles of the muscle membrane. These are oval holes formed by bundles of myocytes that surround each neurovascular bundle entering the intestinal wall. Deeper than this is the perivasal loose connective tissue, and deeper is the submucosal base. In the submucosal base, the common vascular plexus is located in three layers. Arteries enter the muscular membrane of the large intestine from two sides: 1) from the outside,

straight arteries entering through the portal vein; and 2) from the inside, arteries leaving the submucosal arterial plexus. Larger arteries with a diameter of 250.0–430.0 μm were found in the area of muscle bands. The blood supply of both the circular and longitudinal layers of the muscular membrane of the colon wall is carried out by straight arteries. Their branches form polygonal microvascular networks located along the layers of the muscle membrane. However, there is no strict orientation of blood microvessels in the annular layer of the muscle membrane relative to the muscle bundles. Here, various components of the microvascular bed are located either parallel, oblique, or perpendicular to them. Blood capillaries are located in different planes and form cells of different shapes that do not have a specific orientation. The veins of the rectum are located in the mucous membrane of its wall. Then they perforate the muscle membrane and open into the submucosal venous plexus.

The longitudinal layer of the rectum consists of myocytes that form longitudinal plates that are 500.0 or more micrometers wide. They are located in the form of overlapping plates along the entire perimeter of the intestinal wall. In turn, all plates are united in a single functional structure by means of a very thin layer of connective tissue. Such a structure of the muscular membrane of the wall of the rectum is observed up to the line of transition to the anal hole.

The structure of the longitudinal layer of the muscularis mucosa changes significantly in the transitional area, where the intestinal opening is sharply narrowed. Here, the muscle plates are at the level of the internal sphincter, and outside of it, they come into contact with the myocyte layers of the sphincter. These are thick, short, whitish flexible folds and are located between the internal and external sphincters in the anal canal. Their number is from 7 to 14, and their height is from 20.0 to 30.0 mm.

The distribution density of straight arteries varies significantly in different departments of the intestine.

Arteries located between the walls of the intestine are devoid of fascial cell beds but are surrounded by loose connective tissue and connected to both layers of the peritoneum by collagen fibers. In

transverse sections, the outlet of arterial arcades and intestinal arteries is elliptical. The distribution density of arteries in different departments of the intestine varies significantly. The length of the arteries in the large intestine's proximal part is 7.3 ± 1.2 mm on average, and in the distal part it is 10.1 ± 1.5 mm. Often, the continuity of the arch vessels is broken, and there are no direct arteries in this part of the stomach and intestinal wall. Violation of continuity of arterial arches was observed in 40.3% of cases along the large intestine.

The outer layer of the muscular membrane has a longitudinal direction, and the inner layer has a circular direction in areas of the arteries entrance and exit of the straight veins. Muscle "gates" are formed here, and often they are separate for arteries and veins.

The muscular membrane of arteries consists of 8–12 myocyte layers.

New information on the histostructure in the longitudinal layer of the muscle membrane has been obtained. It was found that this membrane is not whole along the intestine circumference but consists of separate segments. The number of segments has changed from 8 to 16, the distance between individual segments is from 25 to 525 µm, and the length of segments is from 300 to 1200 µm. The location of intersegmental spaces around the intestine circumference in a clockwise direction was recorded, indicating that the longitudinal layer of the muscular shell moves in a spiral pattern.

The intersegmental space of the longitudinal layer at the top of the mesentery margin is constant and always coincides with parts of the circular muscle layer. Muscle "doors," or rather, muscle "tunnels," are formed in this way, and through them, arteries enter the submucosal base, and veins leave it and go to the mesentery of the intestine.

The longitudinal layer of the muscle membrane has a thickness of no more than 170-250 µm and is ¼-1/6 of the circular layer thickness. The longitudinal layer is more evenly distributed along the perimeter than the circular layer. A muscle circle with a varying number of cavities filled with longitudinal layers of vessels and loose connective tissue is considered a non-closed muscle ring.

Under physiological conditions, the area of intersegmental spaces along the perimeter of the intestine ranges from 1.98% to 4.77% of the ring area. This means that the permeability of the vascular bed can increase or decrease by 2.5 times during intestinal peristalsis. Passing through the muscular "gates," the arteries divide into two arteries of equal diameter and form the main submucosal sheath of the gastrointestinal tract. In transverse sections, the interaction of the muscular membrane's longitudinal layer with the arteries and arterioles, veins, venules, lymphatic vessels, and capillaries passing through it is revealed quite clearly.

A significant range of functional states of these vessels, from their complete compression between muscle segments to their significant expansion, indicates the effect of shortening activity in the stomach, longitudinal muscle layer, and intestines on the vascular cavity. There is no loose connective tissue between the walls of lymphatic vessels, capillaries, and muscle segments.

During the experiment, the results of the blood supply and lymphatic vessels of the large intestine nerve plexus after bleeding from the femoral arteries of animals showed that the diameter of the main trunk of the superior thoracic artery decreased to 2.5–3.0 mm in the angiograms after blood collection (the diameter of the superior thoracic artery before bleeding was 4.0–5.0 mm). Portal pressure decreased from 6.4 ± 0.5 mm Hg to 3.8 ± 0.7 mm Hg. Volume bleeding into the superior musculature decreased from 294 ± 29 ml/min to 90 ± 12 ml/min.

When studying the preparations and vascular permeability in the microvascular bed of the mucous membrane, loss of blood plasma was accompanied by changes in hemoconcentration. However, the formation of blood clots in the venules was not observed. A large number of arterioles have a sharp decrease in their diameter along their entire length that indicates bleeding stoppage in them. The diameter of the venules was reduced in a fragmentary manner, accompanied by an even alternation of contraction areas similar to a peristaltic wave. Extravasation is less pronounced in microvessels in the muscle membrane, and bleeding in them is weak throughout the experiment.

With a violation of the perfusion of the intestinal wall's microcirculatory bed, the rate of bleeding in the superior mesenteric artery decreases, and the internal diameter of its main trunk decreases. The diameter of arterioles is 15.8 ± 0.8 μm, capillaries are 6.9 ± 0.5 μm, and venules are 17.6 ± 1.3 μm. Capillaries are excessively twisted; their deformation coefficient is equal to $182 \pm 24\%$.

Data characterizing the microcirculatory bed of free duplicators of omentum majus indicate that a significant volume of blood plasma is released beyond its limits into the peritoneal cavity. This makes it possible to consider the omentum majus as a donor of peritoneal fluid or the third kidney of mammals.

A high concentration of microvessels is observed in plaque-like duplications of omentum majus.

The main part of the intestinal wall's microcirculatory bed and lymph collectors are located in the submucosal base. This layer can be considered a functionally independent membrane that provides a close morphofunctional connection with the microvessels of muscular and mucous membranes.

On a submucosal basis, lymphoid nodes, nerve plexus ganglions, and closed and open lymphatic capillaries are observed. Lymphatic capillaries of the cecum have elongated, sac-like, sheath-like, and dilated forms.

A microcirculatory bed is an open zone of the circulatory system for two-way exchange. Arterioles are defined by a single layer of myocytes in the end walls of the extra-organ arteries of the intestine. They are elongated cells with sharp ends that are extremely unevenly arranged in the wall of arterioles.

In impregnated preparations, myocytes differ significantly from each other both in terms of shape and size. In separate parts of the arterioles, direct contacts of myocytes arranged in a spiral form are observed.

It should be noted that there are numerous microcirculatory structures belonging to specific tissue derivatives, along with large arterial and venous vessels that perform the distribution function on a submucosal basis. These are ganglions of the submucosal nerve

plexus, nerve trunks of the vagus nerve, loose connective tissue, and individual lymph nodes.

According to our data, nerve trunks in the submucosal base are always accompanied by arterioles and one or two venules. There are always numerous arteriolo-venular half-shunts between them. Arterioles along the length of the nerve trunk are located in its perineural bed.

Extracapillary blood flow pathways in the gastrointestinal tract wall are an integral part of its intra-organ vascular bed.

However, their role in the regulation of blood flow in the nerve plexus remains unclear. It was determined by us that typical arteriolo-venular anastomoses with constant blood flow are located in the submucous base of the large intestine.

Arteriolo-venular anastomoses are formed due to the direct transition of arterioles to venules or various forms of connections without a capillary segment.

Constant blood flow is carried out through the first group of connections. This is evidenced by the interconnection of arterioles and venules and the absence of a sphincter in the transition zone of the connection, as well as their ability to be constantly detected during intravascular impregnation, according to Ranvier. The second group of arteriolo-venular anastomoses is periodically active. Blood flow to them is regulated by a local endothelial sphincter located at the source of the arteriole.

The most convenient form of structural arrangement of the microcirculatory bed is the parallel and sequential insertion of its capillary network into the circulation. In this case, there are opportunities to adapt to the changing conditions of blood flow. The vasculature in the intramuscular nerve plexus of the intestine was interpreted by our vasculature as a system consisting of two separate compartments: a parallel connected capillary network and arteriolo-venular anastomoses (Fig. 4).

They are part of the myenteric nerve plexus, which is the strongest of all autonomic nerve plexuses in the intestine. The main principle of sigmoid microcirculatory bed formation of the colon from the arteriole is arteriolo-venular anastomoses with diverging

precapillaries and postcapillaries flowing into the venule. These arteriolo-venular anastomoses are arcuate or arcade-shaped and of considerable length. Microphotographs of impregnated microvessels often show an aperistaltic wave going from the arteriole to the venule. In addition to classic arteriolo-venular anastomoses, numerous extracapillary blood flow pathways belonging to the category of pre- and postcapillary half-shunts have been found in the submucosal base. As a rule, they are constituent elements of microcirculatory constructions of lymphoid nodes and intramural nerve stumps.
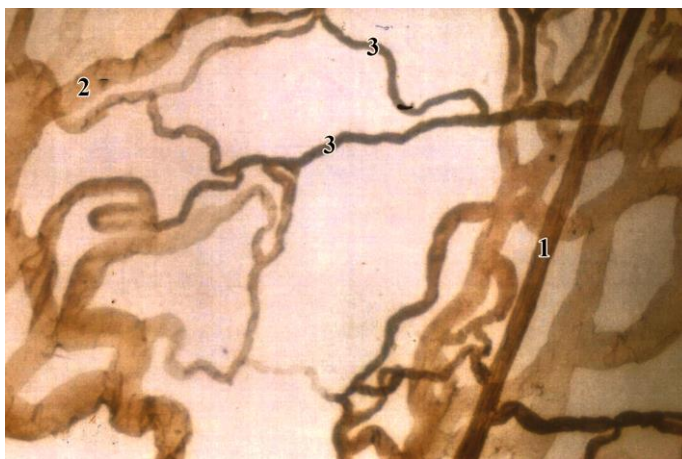

Figure 4. Arteriolo-venular anastomoses observed in the intramuscular nerve plexus of the large intestine. Intravenous impregnation by the Ranvier method. Magnification rate X400
Note: 1) Arteriole; 2) Venula; 3) Arteriolo-venular anastomoses

Analysis of literature data shows that extracapillary blood flow paths perform a hemodynamic function. Thus, they intensify blood flow in the active structures of the body and provide transorganic blood flow regardless of functional or pathological disorders.

Extracapillary blood flow pathways lead to the hemocirculation of neutrophil granulocytes. However, the role of extracapillary blood flow in blood distribution in the microvascular bed is not so significant.[16]

The results of the study allow us to suggest that the modular principle is the basis of the structural organization of the microcirculatory bed of the nerve plexus of the large intestine. Three vascular modules have been identified: intraganglionic, interganglionic, and trunk. In the ganglia of the large intestine, a network-type microcirculatory bed with short but wide arterioles and venules of the intraganglionic module was formed. The diameter of the arterioles that make up the intraganglionic module is 14.0–17.0 μm, the diameter of the precapillaries is 7.0–10.0 μm, the diameter of the capillaries is 5.5–6.1 μm, the diameter of the postcapillaries is 15.0–18.0 μm, and the diameter of the venules is 20.0–24.0 μm.

These indicators show that vascular resistance is weak compared to the microvessels of other organs.[17]

This feature of the module allows it to maintain an effective blood supply during the various phases of digestion in the large intestine.

Each neurocyte in the ganglia is either in direct contact with exchanged microvessels or is separated from them by a distance of no more than 15.0–20.0 μm.

According to the obtained results, the microcirculatory module of internodal nerve projections was built according to magistral type. In this case, arterioles, venules, and capillaries are located longitudinally in parallel, and transverse connections are a minority.

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[16.]Марков, И.И. (Markov, I.I.) Роль артериоло-венулярных анастомозов в циркуляции нейтрофильных гранулоцитов / И.И.Марков, В.И.Маркова Т.В.Малыхина, [и др.] // Морфологические ведомости, – Самара: 2017. № 1, – с. 10-14.

[17.]Lovering, A., Duke, J., Elliott, J. Intrapulmonary arteriovenous anastomoses in humans-response to exercise and the environment // Journal of Physiology, – 2015. Feb;593(3), – p. 507-520.

Extra - and intra-ganglionic microvessels are interconnected in the module. Intraneural capillaries pass through the internodal neural processes, which are between 30.0 and 150.0 µm in diameter.

The space between them is filled with erythrocytes, which indicates a high capillary hematocrit. The small microcirculator is formed from an arteriole with a diameter of 25.0–35.0 µm that enters the perineural space at the modular corners. The arteriole is equipped with a smooth muscular sphincter of the arteriolar septum, which is able to coordinate the work of the entire vascular module. At its entrance, a shunting device is always defined in the form of an arteriolo-venular connection. This allows for hemoseparation before the trunk and directs blood with a low hematocrit to endoneural capillaries, creating conditions for ultrafiltration of blood plasma and the formation of perineural liquor.

In the study, the number of arteriolo-venular anastomoses located on the submucosal basis of the walls of different parts of the large intestine was calculated, and their diameters were measured. The results showed that 2–8 (on average 4.0 ± 0.5) connections are determined in a 1 cm^2 area of the cecal wall. Compared to the cecum, this indicator is 1.25 times ($P_H<0,001$) in the ascending colon, 1.67 times ($PH<0,001$) in the transverse colon, 2.45 times ($P_H<0,001$) in the descending colon, 2.55 times ($P_H<0,001$) in the intestine, and 3.10 times (P) in the rectum.

Measurement of arteriolo-venular anastomose diameters located on the submucosal basis of the walls of different parts of the large intestine shows that this indicator is maximal in the rectum (on average 24.2 ± 0.4 µm) and minimal in the transverse colon. (14.2 ± 0.4 µm on average).

Thus, both the amount and diameter of arteriolo-venular anastomoses are maximal in the submucosal base of the rectal wall (diagram).

We calculated the number of arteriolo-venular anastomoses located in the muscular membrane of the wall of different parts of the large intestine in a 1 cm² area and measured their diameters.

The results of the morphometric study prove that 5–13 (on average, 7.7 ± 0.9) connections are determined in a 1 cm^2 area of the

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cecal wall. This indicator is 1.14 times ($P_H<0,001$) in the ascending colon compared to the cecum, 1.71 times ($P_H<0,001$) in the transverse colon, and 1.84 times ($P_H<0,001$) in the descending colon. The S-like circle increased 2.10 times ($P<0.05$) in the intestine and 2.36 times ($P_H<0,001$) in the rectum.

Measurement of arteriolo-venular anastomose diameters located in the muscular membrane of the wall of different parts of the large intestine shows that this indicator is maximal in the rectum (21.0 ± 1.4 µm on average) and minimal in the transverse colon (16.0 ± 1.4 µm on average).
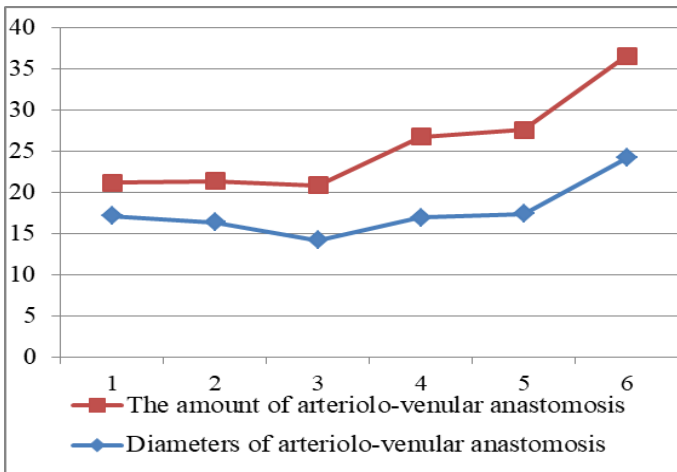

Diagram.
The number and diameters of arteriolo-venular anastomoses located on the submucosal basis of the wall of different parts of large intestine.
Note: 1. Cecum; 2. Ascending colon; 3. Transverse colon ; 4. Descending colon; 5. Sigmoid colon; 6. Rectum.

Thus, both the number and diameter of arteriolo-venular anastomoses located in the muscular membrane of the large intestine wall increase from the cecum to the rectum.

In addition to extracapillary blood flow pathways, the vascular structures of autonomic large intestine nerve plexus reflex gas exchangers are also identified. Their function is performed by intermuscular arterioles and venules, precapillaries and postcapillaries, which are located in parallel and are located at a distance of 12.0–18.0 microns as part of interganglionic veins.

We discovered two variants of hematolymphatic connections in the intestinal wall. The first option is tight hematolymphatic connections between blood and lymph vessels without any intermediary (loose connective tissue). In the second variant, blood microvessels are located in the openings of lymphatic vessels. (Figure 5).
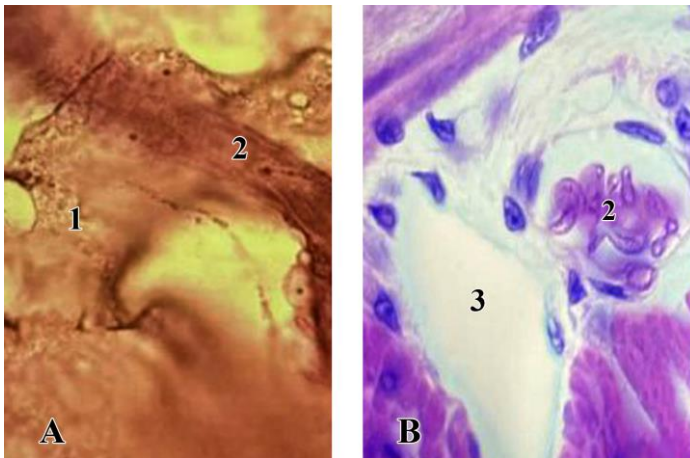

Figure 5. A) Dense hematolymphatic connection between blood and lymphatic vessels at the submucosal base of the large intestine. Universal impregnation method. Magnification rate X600.
B) Location of the blood microvessel in the muscular membrane of the large intestine in the opening of the lymphatic vessel. Hematoxylin-eosin staining. Magnification rate X600
Note: 1) Lymph vessel; 2); Venula; 3) Drainage of lymphatic vessels.

Thus, the results of the study showed that the main blood collectors of the microvascular bed of the intestinal wall are located in its submucosa. Along with relatively large arteries and veins, numerous microvascular structures of specific anatomical origins are observed in the submucous base. These include the submucous nerve plexus ganglia, branches of the vagus nerve, and loose connective tissue. The modular principle is the basis of the myxovascular bed's structural organization of intestinal nerve plexus ganglions. Three distinct modules have been identified: ganglionic, interganglionic, and trunk. Regulation of blood flow in microvessels is provided by muscle sphincters or extracapillary blood flow pathways. Extracapillary blood flow paths are formed due to the direct passage of arterioles to venules or arteriolo-venular anastomoses without a capillary segment. Lymphatic structures of the large intestinal wall include lymphatic vessels and closed and open lymphatic capillaries. Elongated, sac-like, sheath-like, and cystic expanded forms of closed lymphatic capillaries were found.

In order to get comprehensive information about the morphology of the structures of the wall of the large intestine in the study, not only in the norm but also during some pathologies, the task was to investigate morphological changes of the wall.

The study results of autopsy material taken from corpses of both genders aged 20–70 years whose veins were found to have occlusions and stenoses were analyzed in the Scientific-Research Laboratory for Morphological Problems of Samara Medical University, "Reaviz." Signs of atherosclerosis were determined by a visual examination of the intestinal intima membrane. Two criteria for atherosclerosis were used: 1) prevalence (total number of plaques along the length of the artery regardless of occlusion); 2) degree of occlusion (percentage of arterial space narrowing): a) up to 25%; b) from 26% to 50%; c) from 51% to 75%; d) from 76% to 100%.

Atherosclerotic changes were found isolated or in different combinations in the single visceral branches of the abdominal aorta in the analyzed biopsy material. Moderate narrowing of the arterial space was found more often than clearly expressed occlusion. Moderate narrowing of the arterial space was more common than a

clearly defined occlusion. Most of the intestinal arteries had 1-2 plaques located in the arterial beds. One was enough for their complete occlusion. The majority of occlusions in the coeliac trunk system were found in the splenic, gastroepiploic, and pancreatic-duodenal arteries. The splenic artery was curved in most of the adults. In 28% of cases (ages 50–72), the artery was spirally twisted. There is no clear correlation between damage to the splenic artery by atherosclerosis and its curvature. The main trunks of unpaired visceral branches of the abdominal aorta were damaged by atherosclerosis in 52.9% of cases. From 32 to 42 years of age, local and diffuse fat spots and bands were determined in the intima of the back and lower wall of the coeliac trunk at the place where it exits from the aorta or at 1.0–2.5 cm of the distal orifice. Atherosclerotic plaques were found in these areas at later ages (44–72 years). Isolated arteries for coeliac trunk system lesions are characteristic, and they are found at a later age than in the superior mesenteric artery system. Up to 50 years of age, the distribution of coeliac trunk injuries in the entire studied group is the same according to gender. After the age of 50, an increase in the number of cases of coeliac trunk occlusion was observed among women (in a ratio of 3:2). After the age of 60, this ratio changed toward men.

Stenosis of the coeliac trunk occurs as a result of atherosclerotic damage to the vessel, congenital compression of the arch ligaments of the diaphragm, inflammatory diseases, aneurysms of the aorta, and compression of the abdominal cavity by tumors. Currently, two main causes of stenoses observed in the branches of the abdominal aorta have been determined: 1) atherosclerotic stenosis of the coeliac trunk; 2) stenosis caused by compression of the coeliac trunk.[18] Two types of coeliac trunk occlusion have been noted: concentric and eccentric. During concentric occlusion, the arterial cavity is narrowed circularly; in eccentric occlusion, the upper and lower walls thicken.

[18.]Tracci, M. Median arcuate ligament compression of the mesenteric vasculature // Techniques in Vascular and Interventional Radiology, – 2015. Mar;18(1), – p. 43-50.

The transition dynamics of coeliac trunk eccentric occlusions to concentric ones were not revealed in either men or women. Concentric occlusions have also been observed in cases of joint damage to the coeliac trunk, superior mesenteric artery, and inferior mesenteric artery. Most likely, this is due to general atheromatosis of the abdominal aorta.

Lipid spots in the intima of the superior mesenteric artery were first detected during the autopsy of a 28-year-old man. Spots are located at the opening of the superior mesenteric artery, on its lower wall, and extend to the opening of the middle colic artery. In the same case, thickening of the intima was found at the outfall of the intestinal arteries. In older people (35–40 years old), already-formed fibrotic plaques were found to a large extent. At the branch openings of the superior mesenteric artery—in the intestinal arteries, in the middle and right colic arteries—plaque is larger than at the openings of the superior mesenteric artery.

Unpaired plaques were often identified at the openings of the superior mesenteric artery, whereas at the openings of its branches, groups of fused plaques were located over a small lesion. Atherosclerotic plaques in the inferior mesenteric artery were detected during autopsies of 40–46-year-old women and men. They are small in size and clearly outlined. At younger ages, plaques have been found in the flat arteries that enter the descending colon. Atherosclerotic plaques are limited from the outside by the internal elastic membrane. The muscle membrane under the plaques is normally thinner than the intimate areas. Its atrophy can reach a significant degree; therefore, in some cases, plaques are located in the immediate vicinity of the adventitia. During occlusive damage to single visceral branches of the abdominal aorta, the adventitia of the arteries is weakened by cellular elements and becomes dense and fibrous. The integrity of the endothelial cover is broken, the inter-endothelial spaces widen, the relief of arteries becomes uneven, the intima breaks from the internal elastic membrane, and its fragmentation is observed.

During the autopsies, attention was paid to the interaction of the coeliac trunk with the surrounding tissues—the median arch-

shaped connection of the diaphragm, sympathetic ganglia, and retroperitoneal connective tissue. The average link has considerable variation in size, shape, and position. Its width is 1-3 mm. When the ventral parts of the aortic slit of the diaphragm are formed, the edges of the ligament are compressed. The beginning of the coeliac trunk was detected at the level of the middle arcuate junction in 42% of cases. While dividing by age groups, it is known that the position of the coeliac trunk and middle ligament changes in distal direction relative to the spine in older people. Moon-shaped abdominal ganglia were found to the right and left of the coeliac trunk. The right ganglion is larger than the left ganglion in 66% of cases. The superior mesenteric ganglions are located in a ring around the superior mesenteric artery.

The abdominal and superior mesenteric ganglia are interconnected by numerous ligaments located around the coeliac trunk and the superior mesenteric artery. During autopsy, infiltration of the abdominal ganglia and interwoven nerve fibers with fatty and fibrous tissues was found in 38% of cases. This tissue conglomerate is located on the ventral wall of the abdominal aorta around the abdominal. Radiologically and histologically, in 100 autopsies, coeliac trunk stenosis was identified in 29 cases. Moreover, clearly expressed stenosis was observed in 16 cases. In only 2 cases, the cause of coeliac trunk compression is fibrotic changes in the tissues surrounding it, and in the remaining cases, it is the pressure of the middle arcuate ligament of the diaphragm. In the abdominal examination of unpaired visceral branches of the abdominal aorta, attention was paid to the branching options of the trunk and upper mesenteric artery. In two cases (at autopsy of 62- and 68-year-old men), a common abdominal-mesenteric trunk was found. In both cases, the cause of death is an extensive myocardial infarction.

Gastric ulcers, chronic pancreatitis, and chronic colitis were found during the examination of the gastrointestinal tract of corpses. Retrospective analysis of ambulatory records confirmed that the deceased had had gastrointestinal diseases for a long time and that these diseases had been treated repeatedly in the hospital. In all

cases, the occlusion of the abdominal-mesenteric trunk did not exceed 50% of its diameter.

The inferior mesenteric artery and the arch of Riolan are dilated. The diameter of the unpaired visceral branches of the abdominal aorta is 3.2–3.8 mm. Intestinal arteries, middle colic artery, superior mesenteric artery, splenic artery, coeliac trunk, and inferior mesenteric artery were the most frequent and most noticeable injuries. Common hepatic, left gastric, and gastroduodenal arteries are often involved in the process. Despite the different distribution of age indicators, a correlation was observed between the average age of the patient and the prevalence of atherosclerotic changes. Thus, in the first group, it is 52 for both men and women, and in the fifth group, it is 67 for men and 66 for women.

The degree of damage to unpaired visceral branches of the abdominal aorta directly depends on the severity of changes occurring in the abdominal aorta. Atherosclerotic plaques are localized at the opening of unpaired visceral branches of the abdominal aorta, spreading only to the initial part of their trunk.

Thus, studies show that the degree of damage to unpaired visceral branches of the abdominal aorta directly depends on the degree of changes occurring in the abdominal aorta. Atherosclerotic plaques are observed only in the openings of the initial parts of the unpaired visceral branches of the abdominal aorta.

INFERENCES

1. The size of neurocytes in the ganglia of Meissner's plexus, located at the submucosal base of the large intestine wall, is 1.2–15 times smaller than the size of neurocytes in the ganglia of Auerbach's plexus. Ganglions are located in the form of chain rows in intramuscular sheaths. Round, oval, or elongated forms of ganglia are observed. The number of ganglia located in the submucosal base is significantly greater in the proximal part of the organ than in the distal part. There is not much difference in the number of ganglions of the intramuscular (Auerbach) plexus.

2. Ganglions of the large intestinal plexus are clearly separated from the surrounding tissue and are compact structures consisting of bodies of neurons and glial cells. In most cases, two morphological types of neurons (I-type and II-type Dogiel cells) were identified. I-type Dogiel cells have an elongated, star-shaped body. The contours of II-type Dogiel cells are smooth, and their bodies are round, oval, or fan-shaped. In addition to neurons, intra-ganglionic and inter-ganglionic glial cells were also observed.

3. Using the "An5gs spaceclaim v.19.2" program, we built a 3D model of the isolated II-type Dogiel cell of the intramuscular plexus ganglion and measured the morphometric indicators of this cell (the volume of the perikaryon and nucleus) using the "Ymadei" software package. The 3D model of the II-type Dogiel cell is gyre-shaped, flattened in the transverse direction, and elongated in the longitudinal direction. The volume of an II-type Dogiel cell was 2785.11 mcm3, and the volume of its nucleus was 647.7 mcm3.

4. As a result of the study, typical interneuronal cytoplasmic syncyts were found in large intestinal ganglia. We observed three or more syncytial connections between neurons. In the study, the fact of the formation of one large binuclear cell as a result of the fusion of two neurons was proven. Such cells have been observed in different parts of the large intestine.

5. In the majority of observations (62%), a microcirculatory bed corresponding to the network type of the vascular module is observed in the nerve plexus of the large intestine. Regulation of blood flow in microvessels is provided by muscle sphincters and extracapillary blood flow pathways. Extracapillary blood flow paths are formed due to the direct passage of arterioles to venules or arteriolo-venular anastomoses without a capillary segment. Blood flow is constantly carried out through the direct passage of arterioles to venules. Arteriolo-venular anastomoses operate periodically. The lymphatic structures of the colon wall include lymphatic vessels and closed and open lymphatic capillaries. Expanded forms of closed lymphatic capillaries in the form of

elongated sac-like, sheath-like, and cyst-like structures were found.

6. The analysis of the data obtained as a result of the examination of the autopsy material taken from the corpses in which occlusions and stenoses were found showed that the diameter of the coeliac trunk decreases by two times during the indicated pathologies, the inferior mesenteric artery and the arch of Riolan expand, and the crescent ganglia are both on the right and on the right side of the coeliac trunk. On the left side, upper cervical ganglions are located in a ring around the upper mesenteric artery, and infiltration of the abdominal ganglia and nerve fibers is detected.

PRACTICAL RECOMMENDATIONS

1. Evidence of the structure of the nerve plexus components of the large intestine and their blood and lymph supply can be useful to pathophysiologists (to optimize the pathogenesis of numerous pathologies of the gastrointestinal system) and to gastroenterologists (to improve the quality of treatment of various nosological forms of this organ). Morphological information about the plexus and ganglions of different parts of the large intestine of a normal person with biopsy and section materials taken during pathologies of this organ is recommended to be used as standards (normatives) for comparison.

2. The research results can be used in future research to improve prevention and treatment schemes for various diseases of the gastrointestinal system organs encountered by clinicians, especially disorders of transport of contents in the large intestine after traumatic injuries or surgical interventions and their scientific justification.

3. The study results of the blood supply of the large intestine nerve plexus of animals in the experiment can help surgeons accurately determine the cause of spontaneous bleeding observed in this organ.

4. The obtained scientific information can be used in the teaching process (in classes held for students of morphological subjects,

attending physicians, and residents in the specialty "gastroenterology"), in the training of practicing therapists and surgeons, in monographs and information on diseases of the gastrointestinal system, as well as in neurogastroenterology.

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The defense will be held on 12th february 2024 at 14:00 at the meeting of the One - time Dissertation Council BED 2.08 of Supreme Attestation Commission Under the President of the Republic of Azerbaijan operating at Azerbaijan Medical University

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Abstract was sent to the required addresses on 10 january 2024