

chromosomal instability was less than one in 54.0% of patients. Thus, individual somatic chromosome susceptibility to additional mutagenic load *in vitro* did not depend on sex and influence of mutagenic environmental factors and is genetically determined.

We determined the level of spontaneous and induced mutagenesis in blood lymphocytes of patients with depression *in vitro*, which was twice the spontaneous level of chromosome aberrations after mutagen introduction into the culture mixture that indicates pronounced individual and group latent chromosomal instability in adolescents with depression.

Key words: adolescents, depression, mutagen, aberrations, chromosomal instability.

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**KINETICS OF THE DEVELOPMENT OF THE MICROCIRCULATORY TRACT
OF THE MYOCARDIAL COMPLEX (LV + IVS) IN THE PROCESS OF EARLY POSTNATAL
ONTOGENESIS OF RATS WISTAR**

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Determination of the kinetics of the development of the microcirculatory bed (MCB) of the mammalian myocardium remains an urgent problem of ontogenesis. The work aimed to study the regularities of the volume ratios of the capillary (cap) and arteriolo-venular (a+v) components in the process of postnatal development of the myocardial MCB in the complex "left ventricle + interventricular membrane" (LV+LV) of the heart of Wistar rats. Electron-microscopic, optical and morphometric analysis of the ultrastructures of the MCB of the myocardium of rats from birth (d/b) to 45 days was carried out. The following morphometric parameters were determined: 1- relative volumes (%): V_{vmcb} , V_{vcap} , $V_{v(a+v)} = (V_{vmcb} - V_{vcap})$; 2 – absolute volumes (μm^3): V_{mcb} , V_{cap} , $V_{(a+v)} = (V_{mcb} - V_{cap})$; 3 – average daily growth rate ($\mu m^3/day$): $v_{cap/day}$; $v_{(a+v)/day}$. It was established that after the birth of rats, the morphological processes of intensive growth of the volumes of the components of the blood microcirculatory channel occur in the myocardium (LV+IVS). In newborns and 5-day-old rat pups, numerous blood microvessels were found, the endotheliocytes of which were in the process of proliferation and differentiation. The obtained results of the conducted morphometric analysis of myocardial negatives indicated that on the 10th day after the birth of the animals, the maximum average daily growth rate of the volume of the capillary component (v_{cap}) was determined in the MCB of the myocardium, and on the 25th day – the maximum average daily growth rate of the arteriolo-venular component- $v_{(a+v)}$. In the myocardium of newborn rats, the ratio of volumes $(a+v)/cap$ was equal to 1 : 44. At $t \rightarrow 45$ days, there was a significant increase in the ratio of volumes $v_{(a+v)}/v_{cap}$ to 1 : 3.1 as a result of absolute growth volume of microvessels ($a + v$). In the process of postnatal angiogenesis, the source of the formation of arterioles and venules in the blood-carrying MCB of the myocardium (LV+IVS) is the existing capillaries.

Key words: angiogenesis, morphometry, capillaries, arterioles, venules.

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Introduction. Over the past 20 years, numerous works by cardiologists, pathomorphologists, clinicians, and physiologists have been devoted to studying angiogenesis and biological functions of the MCB of the myo-

cardium of humans and laboratory animals [1-4]. This is because almost all heart diseases are associated with disorders of metabolic processes in cardiomyocytes (CMC) and components of the MCB of the myocardium [5-8]. Arterioles, capillaries, venules and arteriolo-venular anastomoses are distinguished as part of the blood microcirculatory channel of the myocardium [1, 2, 5]. Currently, the capillary link of the MCB, which performs the functions of transport and transmembrane move-

ment of various trophic substrates, regulatory molecules, and oxygen to the CMC of the myocardium of the ventricles, atria, and papillary muscles of the heart of humans and animals, is being actively studied [2, 5, 8]. Individual works in domestic and foreign publications are devoted to the postnatal morphogenesis of the blood-carrying MCB of the myocardium of mammals and humans. In most experimental and clinical studies, morphometric data relating to the dynamics of the age-standardized blood MCB are mainly used as a control [2, 6, 9]. There are practically no studies of the ratio of the volumes of the capillary and arteriolo-venular components of MCB in the myocardium of humans and mammals.

The work aimed to study the regularities of the capillary and arteriolo-venular components' volume ratios in the postnatal development of the blood MCB of the myocardium (LV + IVS) of the heart of Wistar rats.

Object and research methods. Male Wistar rats aged from birth (d/b) to 45 days were used in work. Animals from the nursery of the Faculty of Biology of KhNU (Kharkiv) were kept in standard vivarium conditions. All manipulations with rats were carried out in strict compliance with the «European Convention on the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes» (Directive 2010/63/EU) and the principles of bioethics outlined in the Law of Ukraine «On the Protection of Animals from Cruel Treatment» (No. 1759 from 15.12.2009). Pieces of the *intramural* zone (LV+IVS) were fixed, dehydrated, infiltrated, and embedded in a mixture of epoxy resins according to standard methods [10]. In each age group of animals, a morphometric analysis of 50 negatives measuring (6.5x9) cm² of ultrastructures of the myocardium and MCB components was performed at a magnification of 2000x. A point test system (650 points on the negative area) and an optical-mechanical device UMA-1 were used for morphometric analysis of MCB images of the myocardium. When determining the digital values of the relative volumes of the MCR and its components, the volume of the myocardium was taken as 100%. We determined: **1-** relative volumes (%): V_{mcb} , V_{vcap} , $V_{v(a+v)} = (V_{vmcb} - V_{vcap})$; **2 -** absolute volumes (μm³): V_{mcb} , V_{cap} , $V_{(a+v)} = (V_{mcb} - V_{cap})$; **3 -** average daily growth rate (μm³/day): v_{cap}/day ; $v_{(a+v)}/day$. Digital values of the *absolute* volumes of V_{mcb} , V_{cap} , and $V_{(a+v)}$ were determined by converting the *mass* of the myocardium of rats of various ages [11] into *volumes* (μm³), based on the values of the specific gravity of muscle tissue [12]. Digital data of morphometric measurements were processed by the graphic-analytical method and with the help of a standard package of programs for a personal computer IBM-SigmaPlotforWindows 9.0.

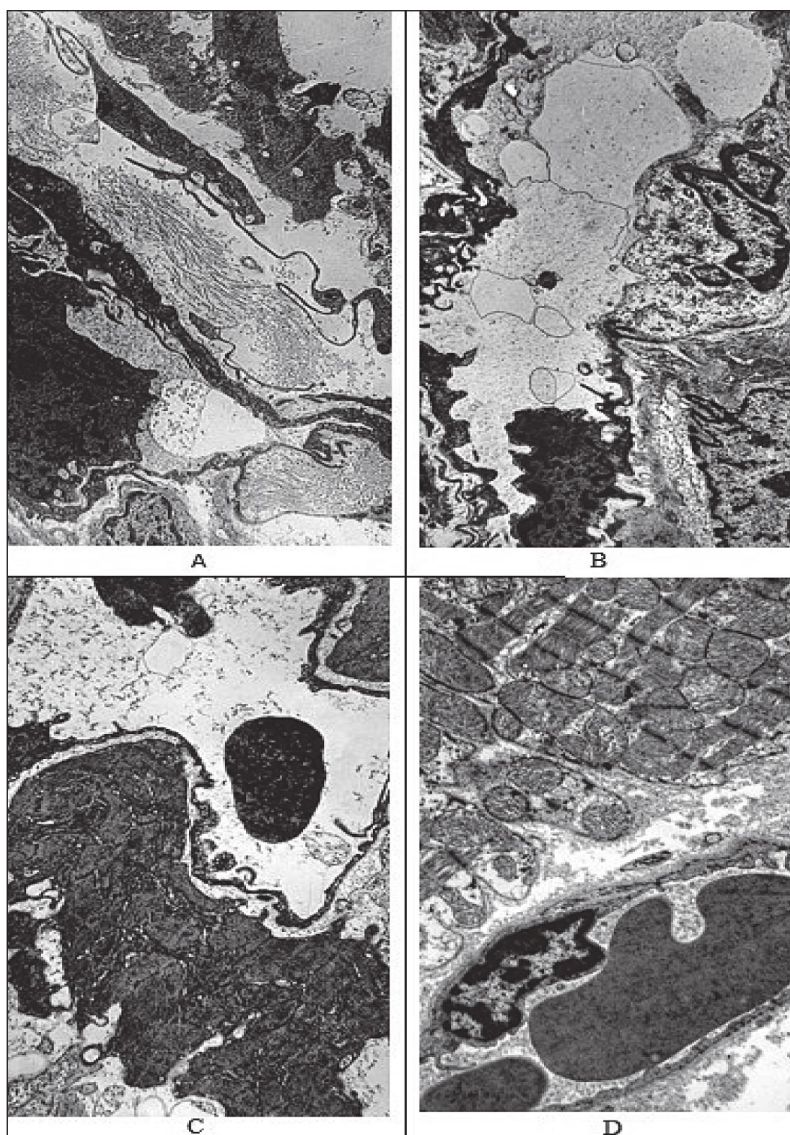


Figure 1 – Electronograms of the MCB of the myocardium. Magnification: 10000^x. A and B – microvessels of newborn rats, C – postcapillary venule in the myocardium on the 10th day after birth, D – capillary in the myocardium of rats on the 45th day.

Research results and their discussion. Electron microscopic studies have revealed certain regularities in the age-related development of the components of the circulatory MCB. Thus, in the myocardium of the complex (LV+IVS) of *newborn* rats, numerous blood microvessels were found, the endotheliocytes of which were in the process of proliferation and differentiation. In the intercellular space, winding, long and unevenly thick processes of connective tissue cells, single poorly differentiated cells of smooth muscle tissue and fibroblasts were determined. Large bundles of collagen fibrils were located around many newly formed microvessels (fig. 1A). Endotheliocytes of blood capillaries are characterized by marked structural and functional *heteromorphism*. A significant number of endotheliocytes in blood vessels were in a state of physiological rest. Morphologically, this was manifested in moderately pronounced dehydration of the cytoplasm and nucleus (fig. 1B). Such endotheliocytes and their nuclei were optically *dark*, had tortuous contours. Marginal areas of the wall of *dark* endotheliocytes are thin and practically did not contain pinocytotic vesicles and organelles. Mi-

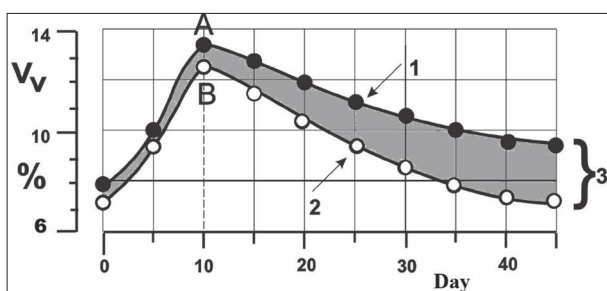


Figure 2 – The kinetics of “increase → decrease” of the relative volumes of MCB (graph 1) of capillaries (graph 2) and the monotonic increase of the relative volume of the complex “arterioles + venules” (3) in the myocardium (LV+IVS) in the course of early postnatal development of rats.

tochondria and other organelles are concentrated in the cytoplasm of *light*, moderately swollen endotheliocytes in the perinuclear zone (fig. 1B). Microvessels, the structure of which corresponded to arterioles or venules, were rarely found in the myocardium of *newborn* rats.

In the time interval (d/b – 10 days), a rapid increase in the volume of the capillary link was recognized in the MCR of the myocardium. Analysis of a series of images of MCB elements strongly suggested that postcapillary *venules* were formed from existing capillaries. Some endotheliocytes in microvessels were located mainly in a circle or spiral and limited to a wide lumen. Gradually, the postcapillary venules acquired a complex tortuous spatial shape and were located quite close to the lateral surface of the CMC for a considerable distance (fig. 1B). Single elongated poorly differentiated cells of smooth muscle tissue (SMT) and their processes were found around some microvessels. This indicated the beginning of the formation of precapillary *arterioles*. After the 10th day of postnatal development of rats, arterioles and venules containing only light endotheliocytes were clearly differentiated in the blood MCB of the myocardium. The number of blood arterioles and venules increased in the MCB of the myocardium. Capillaries acquired a typical ultrastructure. Individual large erythrocytes were identified in the middle of some capillaries (fig. 1D). Within 45 days after the birth of rats, the structural and functional elements of the MCB of the myocardium gradually reached their final development.

Figure 2 shows graph 1 of the “increase → decrease” kinetics of the digital values of the V_{vmcb} indicator in the myocardium of rats in the time interval (d/b – 45 days). Graph 1 is sharply convex upwards and consists of two consecutive sections demarcated by the extremum point “A” with a time coordinate ($t=10$ days). During the first 10 days, the values of the V_{vmcb} indicator increased rapidly from 7.60% to a *maximum* of $13.50 \pm 0.50\%$. After

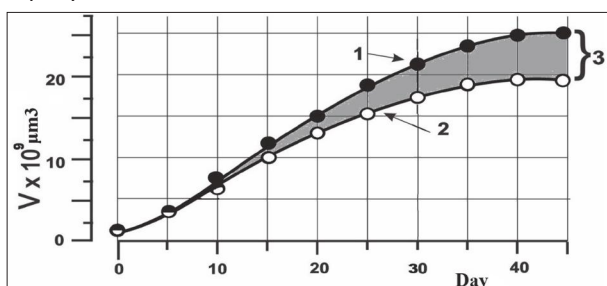


Figure 3 – Growth kinetics of the absolute volumes of MCB (graph 1) of capillaries (graph 2) of the complex “arterioles + venules” (3) in the myocardium (LV+IVS) in the course of early postnatal development of rats.

10 days, V_{vmcr} values decreased and slowly approached $9.50 \pm 0.30\%$ on the 45th day. Figure 2 shows graph 2 of the “increase → decrease” kinetics of digital values of the V_{vcap} indicator in the myocardium of the complex (LV + IVS).

The form of the graph is similar to graph 1 and consisted of two consecutive sections demarcated by the extreme point “B” with a time coordinate ($t=10$ days). Within 10 days, the values of the V_{vcap} index rapidly increased from 7.20% (d/b) to a maximum of $12.50 \pm 0.50\%$. At $t \geq 10$ days, V_{vcap} values decreased monotonically and approached $7.20 \pm 0.30\%$ by day 45. The given data indicated that within 45 days after the birth of rats, the heart muscle’s dominant component in the blood MCB is the **capillary link**. If we take the volume of the blood MCB of the myocardium as 100%, then the relative volume of the capillary link in **newborn** rats was equal to $\approx 95\%$. In 45-day-old rats, the relative volume of the capillary link in the blood MCB was $\approx 76\%$. The obtained morphometric data allow us to state that all blood vessels of the MCB myocardium have the exact origin from the *same type of capillaries*. Therefore, the migration, localization and accumulation of poorly differentiated SMT around individual capillaries contributed to the formation and formation of *arterioles*, and the circular and spiral arrangement of endotheliocytes in microvessels contributed to the formation of *postcapillary venules*.

In fig. 2, the sign “3” indicates the *area* of the “gray” figure, bounded above by graph 1, below by graph 2, on the left and right by time coordinates of 0 and 45 days, respectively. Figure “3” is formed by a series of gradually increasing digital values of the indicator $V_v(a+v) = V_{vmcb} - V_{vcap}$. From the given data it follows that after the birth of rats, the relative volume of the arteriole-venular component in the MCB of the myocardium monotonically increased by ≈ 6 times, from 0.40% (d/b) to 2.30% on the 45th day (according to 100% accepted myocardial volume). Indicators ($V_v, \%; IU$) have limited informativeness and are *insufficient* for an unambiguous interpretation of the results of biometric studies. This is because the V_v indicators do not consider the actual changes in absolute volumes ($V, \mu m^3$) of biological objects in the process of ontogenesis and in the conducted studies [13]. To obtain an *unambiguous* morphometric characteristic of the studied bioobjects, it is necessary to determine the value (V_v) and the changes in their absolute volumes ($V, \mu m^3$), which occur in the process of ontogenesis and in the conditions of experiments.

Figure 3 shows graph 1 of the growth kinetics of digital values of the V_{mcb} indicator in the myocardium (LV + IVS) after the birth of rats. Graph 1 has an “S” – similar shape. Within 45 days, the digital values of the V_{mcb} indicator increased ≈ 31 times, from $0.80 \times 10^9 \mu m^3$ (d/b) to $25.60 \times 10^9 \mu m^3$. The shape of the graph indicates that the intensive growth of the volume of MCB is observed in the time interval (5 – 30) days.

At $t \geq 30$ days, there is a significant slowdown in the growth of the MCB volume in the myocardium (LV + IVS). The *minimum* increase in the volume of MCB was determined in the time interval of 40-45 days. One of the methods of researching the processes of postnatal ontogenesis of biological structures is to establish the *doubling* time of their absolute volumes and determine the number of such doublings. We established that dur-

ing 45 days of postnatal maturation of the myocardium (LV + IVS), five complete doublings of the absolute volume of the MCB occur. The **first** increase in the volume of the MCB of the myocardium by 2 times from $(0.80 \text{ to } 1.60) \times 10^9 \mu\text{m}^3$ occurred within ≈ 2.5 days after the birth of rats. The **second** increase in MCB volume by 2 times from $(1.60 \text{ to } 3.20) \times 10^9 \mu\text{m}^3$ occurred in the time interval $\approx (2.5\text{--}5.0)$ days. The **third** increase in the volume of MCB by 2 times from $(3.20 \text{ to } 6.40) \times 10^9 \mu\text{m}^3$ occurred in the time interval $\approx (5.0\text{--}9.0)$ days. The **fourth** increase in the volume of MCB by 2 times from $(6.40 \text{ to } 12.80) \times 10^9 \mu\text{m}^3$ occurred in the time interval $\approx (9\text{--}17)$ days and the fifth increase in the volume of MCB by 2 times (from $12.80 \text{ to } 25.60) \times 10^9 \mu\text{m}^3$ occurred in the time interval $\approx (17\text{--}45)$ days. Therefore, the **first** and **second** doubling of the absolute volume of the blood MCB of the myocardium occurred within ≈ 2.5 days. It took **4, 8, and 28** days for the **third, fourth, and fifth** doubling of the myocardial MCB volume, respectively. In fig. 3 shows graph 2 of the growth kinetics of the digital values of the **Vcap** indicator in the myocardium (LV + IVS) after the birth of rats. The form of graph 2 is similar to graph 1. During **45** days, the digital values of the **Vcap** indicator increased ≈ 26 times, (from $0.76 \text{ (d/b) to } 19.46) \times 10^9 \mu\text{m}^3$. The form of graph 2 indicates that the intensive growth of the volume of the *capillary link* of the MCB was observed in the time interval (5-20) days. At $t \geq 20$ days, there was a significant slowdown in the growth of the absolute volume of capillaries. The **first** increase in the volume of the capillary link in the MCB of the myocardium by 2 times (from $0.76 \text{ to } 1.52) \times 10^9 \mu\text{m}^3$ occurred within ≈ 2.5 days after the birth of rats. The **second** increase in Vcap values by 2 times (from $1.52 \text{ to } 3.04) \times 10^9 \mu\text{m}^3$ occurred in the time interval (2.5–5.0) days. The **third** increase in the volume of the capillary link in the MCB of the myocardium by 2 times (from $3.04 \text{ to } 6.08) \times 10^9 \mu\text{m}^3$ occurred in the time interval (5.0-10.0) days. The **fourth** increase in Vcap values by 2 times (from $6.08 \text{ to } 12.16) \times 10^9 \mu\text{m}^3$ occurred in the time interval (10-17) days. During the next 28 days (17–45 days), the increase in the volume of the capillary link in the MCB of the myocardium occurred only **1.6** times (from $12.16 \text{ to } 19.46) \times 10^9 \mu\text{m}^3$. Therefore, the **first** and **second** doubling of the absolute volume of capillaries in the blood MCB of the myocardium occurred within 2.5 days. For the **third** and **fourth** doubling of Vcap in the blood MCB, it took **5** and **7** days, respectively. The **fifth** increase of Vcap in the MCB of the myocardium by only **1.6** times occurred in **28** days. In figure 3, the sign “}3” marks the area of the “gray-colored” figure, bounded from above by graph 1, from below by graph 2, to the left and right by time coordinates of 0 and 45 days, respectively. The figure “}3” is formed by a series of gradually increasing digital values of the indicator $V(a+v) = V_{mcb} - V_{cap}$. From the given data it follows that after the birth of rats, the *absolute* volume of the arteriolo-venular component in the MCB of the myocardium monotonically increased by ≈ 102 times!, from $0.060 \times 10^9 \mu\text{m}^3 \text{ (d/b) to } 6.14 \times 10^9 \mu\text{m}^3$ at 45 days after birth of rats. The given graphs of *relative* volumes of MCB and capillaries (fig. 2) differ from the graphs of *absolute* volumes of MCB and capillaries (fig. 3). These graphs describe different patterns of postnatal changes in MCB and its components in the myocardium. Thus, it follows from the results of the research that the relative volumes of blood capillaries in the MCB of new-

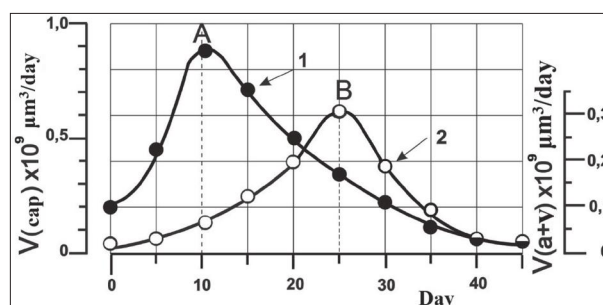


Figure 4 – “increase → decrease” kinetics of the average daily growth rate of the absolute volume of capillaries (graph 1) and the complex of microvessels (a+v) in the MCB of the myocardium (graph 2). The abscissa is the period of postnatal development of rats.

borns and 45-day-old rats are the same and amount to **7.20%**. At the same time, the digital values of their absolute volumes differ by **26 times!**

Figure 4 presents graph 1 of the “increase → decrease” kinetics of digital values of the *average daily* growth rate of the absolute volume of capillaries (**vcap/day**) in the MCB of the myocardium within 45 days after the birth of rats. The graph is significantly shifted to the *left* along the time axis and is located *asymmetrically* with respect to the vertical dashed line that passes through the *extreme point* “A” with a time coordinate of **10 days**. Point A is the border of two successive periods of change in the digital values of the vcap/day indicator. In the *first period*, for 10 days, there is an intensive increase in vcap/day values by **4.5** times (from **0.20** to a maximum of **0.915**) $\times 10^9 \mu\text{m}^3/\text{day}$. The *second period* is limited to coordinates (10–45) days. At this time, there is a significant decrease in the digital values of the vcap/day indicator by ≈ 18 times from **0.915** $\times 10^9 \mu\text{m}^3/\text{day}$ (10 days) to a minimum of **0.035** $\times 10^9 \mu\text{m}^3/\text{day}$ (45 days).

Figure 4 presents graph 2 of the “increase → decrease” kinetics of the digital values of the average daily rate of growth of the absolute volume of the microvessel complex **v(a+v)/day** in the blood MCB of the myocardium within 45 days after the birth of rats. Graph 2 is significantly shifted to the *right* along the time axis and is located *asymmetrically* to the vertical dashed line that passes through the *extreme point* “B” with a time coordinate of **25 days**. Point B is the limit of two successive periods of change in the digital values of the indicator **v(a+v)/day**. In the *first period*, within 25 days, there is a *gradual* increase in the values of **v(a+v)/day** by ≈ 52 times (from **0.006** to a *maximum* of **0.310**) $\times 10^9 \mu\text{m}^3/\text{day}$. The *second period* is limited to coordinates (25–45) days. During this period, there is a significant *decrease* in the digital values of the indicator **v(a+v)/day** by ≈ 16 times from **0.310** $\times 10^9 \mu\text{m}^3/\text{day}$ (25 days) to a *minimum* of **0.020** $\times 10^9 \mu\text{m}^3/\text{day}$ (45 days).

Conclusions. In the time interval (d/b – 45 days) of postnatal development of Wistar rats, the structural and functional elements of the blood-carrying MCB of the myocardium in the complex (LV+IVS) gradually reach their final development.

1. Within 45 days after the birth of rats, the dominant component in the blood MCB of the myocardial complex (LV+IVS) is the *capillary link*.

2. In the process of postnatal angiogenesis, the source of formation of arterioles and venules in the blood MCB of the myocardium (LV+IVS) is the existing capillaries.

3. Intensive development of the capillary link in the MCB of the myocardium occurs during the first 10 days after the birth of rats. During this period, the average daily growth rate of the absolute volume of capillaries in the MCB of the myocardium increases by ≈ 4.5 times (from 0.20 to a maximum of 0.915) $\times 10^9 \mu\text{m}^3/\text{day}$. At $t > 10$ days, there is a significant decrease in the digital values of the $v_{\text{cap/day}}$ indicator by ≈ 18 times from 0.915 $\times 10^9 \mu\text{m}^3/\text{day}$ (10 days) to a minimum of 0.035 $\times 10^9 \mu\text{m}^3/\text{day}$ (45 days).

4. The gradual development of the complex of microvessels (arterioles + venules) and the increase of their absolute volume in the blood MCB of the myocardium occurs during the first 25 days after the birth of rats. During this period, the average daily growth rate of the absolute volume of the microvessel complex

($a + v$) increases ≈ 52 times (from 0.006 to a maximum of 0.310) $\times 10^9 \mu\text{m}^3/\text{day}$. At $t > 25$ days, there is a significant decrease in the digital values of the indicator $v(a+v)/\text{day}$ by ≈ 16 times from 0.310 $\times 10^9 \mu\text{m}^3/\text{day}$ (25 days) to a minimum of 0.020 $\times 10^9 \mu\text{m}^3/\text{day}$ (45 days).

5. In the MCB of the myocardium of newborn rats, the ratio of the volumes of microvessels ($a+v$)/cap was equal to 1 : 44. Within 45 days after the birth of rats, there was a significant increase in the ratio of the volumes of microvessels ($a+v$)/cap in the MCB to 1 : 3.1 as a result of an increase in the absolute volume of microvessels ($a + b$).

Prospects for further research. Morphometry of postnatal proliferation kinetics of rat myocardial MCB endotheliocytes will be performed.

References

1. Dyumin MS, Pronin VV. *Angiologia*. Ivanovo: FGBOU; 2020. 103 s.
2. Livanova AA, Deev RV. *Sovremennyye metody issledovaniya angiogeneza v eksperimente*. Genu & Cellis. 2015;X(1):195-221.
3. Ribatti D, Nico B, Crivellato E. Morphological and molecular aspects of physiological vascular morphogenesis. *Angiogenesis*. 2009;12(2):101-111.
4. Ribatti D, Nico B, Crivellato E. The role of pericytes in angiogenesis. *The International Journal of Developmental Biology*. 2011;55(3):261-268.
5. Kozlov VI. *Sistema mikrotsirkulyatsii krovi: kliniko-morfologicheskiye aspekty*. Region. krovoobr. i mikrotsirkul. 2006;1(17):84-101.
6. Sapin MR, Melyukov VE, Dolgov EN. *Koronarnyye sosudy i gemomikrotsirkulyatornoye ruslo miokarda v norme i pri ishemicheskoy bolezni serdtsa*. Region. krovoobr. i mikrotsirkul. 2013;1(45):5-10.
7. Swed NV. *Patologicheskaya anatomiya remodelirovaniya miokarda pri pochechnoy nedostatochnosti [avtoreferat]*. St. Petersburg; 2020. 24 s.
8. Gorustovich OA Okolokulak ES. *Mikrotsirkulyatornoye ruslo sosochkovykh myshts serdtsa cheloveka*. Sb. trudov nauchno-prakt. konf. 2016; Grodno; 2016. s. 47-52.
9. Panysheva IA, Smirnov VP. *Dinamika morfometricheskikh pokazateley izmeneniya funktsionalnogo elementa ishemizirovannogo miokarda*. *Molodoy uchenyy*. 2017;5(139):88-92.
10. Morozova KN. *Elektronnaya mikroskopiya v citologicheskikh issledovaniyah: metodicheskoe posobie*. Novosibirsk: NNIGU; 2013. 85 s.
11. Zagoruiko YuV, Shmulich AV, Zagoruiko GE. *Zakonomernosti kinetiki rosta massy serdtsa, kompleksa (LZH+MZH) i parenkhimy miokarda v prenatalnom i postnatalnom ontogeneze krysa*. *Visnik problem biologiyi i medycini*. 2018;2(144):87-90. [in Ukrainian].
12. Amirov DR, Tamimdarov BF. *Klinicheskaya gematologiya zhivotnykh*. Kazan: Information Technology Centre KGAVM; 2020. 134 s.
13. Zagoruiko GE, Skidan IG. *Problemy i perspektivy razvitiya metodov kolichestvennogo analiza fraktalnykh biologicheskikh struktur*. *Visnik problem biologiyi i medycini*. 2007;2:102-107. [in Ukrainian].

КІНЕТИКА РОЗВИТКУ МІКРОЦИРКУЛЯТОРНОГО РУСЛА МІОКАРДА КОМПЛЕКСУ (ЛШ + МШП) У ПРОЦЕСІ РАНЬОГО ПОСТНАТАЛЬНОГО ОНТОГЕНЕЗУ ЩУРІВ ВІСТАР

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Резюме. Проведено електронно-мікроскопічне, оптичне та морфометричне дослідження серії негативів мікросудин кровоносного мікроциркуляторного русла (МЦР) міокарда комплексу «лівий шлуночок + міжшлуночкова перетинка» (ЛШ+МШП) щурів Вістар у віці від народження до 45 діб. У серії електронно-мікроскопічних зображень (по 50 негативів розміром 6,5 x 9 см отриманих при збільшенні електронного мікроскопу 2000 \times) компонентів МЦР міокарда визначали відносні об'єми (%), абсолютні об'єми (мкм³) та середньодобову швидкість росту (мкм³/доба) МЦР, капілярів, комплексу мікросудин (венули + артеріоли). Отримані цифрові дані морфометрії дозволили визначити закономірності кінетики розвитку компонентів МЦР у міокарді щурів на протязі їх раннього постнатального розвитку. *Встановлено*, що в інтервалі часу (н/р – 45 діб) постнатального розвитку щурів Вістар структурно-функціональні елементи кровоносного МЦР міокарда поступово досягають свого остаточного розвитку. Протягом 45 діб після народження щурів, домінуючим компонентом у кровоносному МЦР міокарда комплексу (ЛШ+МШП), є *капілярна ланка*. У процесі постнатального *ангіогенезу*, джерелом утворення артеріол і венул у кровоносному МЦР міокарда (ЛШ+МШП) є існуючі *капіляри*. Інтенсивний розвиток *капілярної* ланки у МЦР міокарда відбувається протягом перших 10 діб після народження щурів. За цей період часу *середньодобова* швидкість росту абсолютного об'єму капілярів у МЦР міокарда збільшується (від 0,20 до максимуму 0,915) $\times 10^9$ мкм³/доба. Поступовий розвиток комплексу мікросудин (артеріоли + венули) та збільшення їх абсолютного об'єму у МЦР міокарда відбувається протягом перших 25 діб після народження щурів. За цей період часу *середньодобова* швидкість росту абсолютного об'єму комплексу мікросудин ($a + v$) збільшується у ≈ 52 рази (від 0,006 до максимуму 0,310) $\times 10^9$ мкм³/доба. У МЦР міокарда *новонароджених* щурів співвідношення об'ємів мікросудин ($a+v$)/кап дорівнювало 1 : 44. Протягом 45 діб після народження щурів відбувається суттєве *збільшення* співвідношення об'ємів мікросудин ($a+v$)/кап у МЦР до 1 : 3,1 у результаті росту абсолютного об'єму мікросудин ($a + b$).

Ключові слова: ангіогенез, морфометрія, капіляри, артеріоли, венули.

KINETICS OF THE DEVELOPMENT OF THE MICROCIRCULATORY TRACT OF THE MYOCARDIAL COMPLEX (LV + IVS) IN THE PROCESS OF EARLY POSTNATAL ONTOGENESIS OF RATS WISTAR

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Abstract. An electron-microscopic, optical and morphometric study of a series of negatives of the microvessels of the blood microcirculatory tract (MCT) of the myocardium of the complex «left ventricle + interventricular septum» (LV + IVS) of Wistar rats aged from birth to 45 days was carried out. In a series of electron microscopic images (50 negatives of (6.5 x 9) cm² in size, obtained at a magnification of an electron microscope of 2000^x), the relative volumes (%), absolute volumes (μm³) and average daily growth rate (μm³/ day) of MCT, capillaries, complex of microvessels (venules + arterioles). The obtained digital morphometry data made it possible to determine the regularities of the development kinetics of MCT components in the myocardium of rats during their early postnatal development. It was established that in the time interval (birth to 45 days) of the postnatal development of Wistar rats, the structural and functional elements of the blood-flowing MCR of the myocardium gradually reach their final development. For 45 days after the birth of rats, the dominant component in the blood MCT of the myocardial complex (LV + IVS) is the capillary link. In the process of postnatal angiogenesis, the source of the formation of arterioles and venules in the blood MCT of the myocardium (LV + IVS) are the existing capillaries. Intensive development of the capillary link in the MCT of the myocardium occurs during the first 10 days after birth of rats. During this period of time, the average daily growth rate of the absolute volume of capillaries in the MCT of the myocardium increases (from 0.20 to a maximum of 0.915) x10⁹ μm³ / day. Gradual development of the microvascular complex (arterioles + venules) and increase in their absolute volume in the MCT of the myocardium occurs during the first 25 days after birth of rats. During this period of time, the average daily growth rate of the absolute volume of the microvascular complex (a + v) increases ≈ 52 times (from 0.006 to a maximum of 0.310) x 10⁹ μm³ / day. In the MCT of the myocardium of newborn rats, the ratio of microvascular volume (a + v) / cap was 1:44.1. Within 45 days after the birth of rats, there is a significant increase of microvascular volume (a + v) / cap in the MCT to 1: 3.1.

Key words: angiogenesis, morphometry, capillaries, arterioles, venules.

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Актуальною проблемою онтогенезу залишається визначення закономірностей кінетики розвитку мікроциркуляторного русла (МЦР) міокарда ссавців. Метою роботи було дослідження закономірностей об'ємних співвідношень капілярного (кап) та артеріоло-венулярного (а+в) компонентів у процесі постнатального розвитку МЦР міокарда в комплексі «лівий шлуночок + міжшлуночкова перетинка» (ЛШ+МШП) серця щурів Вістар. Проведено електронно-мікроскопічний, оптичний та морфометричний аналіз ультраструктур МЦР міокарда щурів від народження (н/р) до 45 діб. Визначали такі морфометричні показники: 1- відносні об'єми (%): V_{мцр}, V_{кап}, V_{в(а+в)}} = (V_{мцр}–V_{кап}); 2 – абсолютні об'єми (мкм³): V_{мцр}, V_{кап}, V_{(а+в)}} = (V_{мцр}–V_{кап}); 3 – середньодобову швидкість росту (мкм³/доба): v_{кап/доба}; v_{(а+в)/доба}. Встановлено, що після народження щурів у міокарді (ЛШ+МШП) відбуваються морфологічні процеси інтенсивного росту об'ємів компонентів кровоносного мікроциркуляторного русла. У новонароджених і