

Structural Features Of The Vascular Bed In The Liver's Left And Right Lobes Across Postnatal Ontogenesis

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ABSTRACT

In our scientific article, the vascular system of the left and right lobes of the liver in white outbred rats was studied on the 10th, 30th, and 60th days of postnatal ontogenesis. The liver fragments were fixed in neutral formalin, and the semi-thin sections were stained with hematoxylin and eosin. During the study, an age-related restructuring of blood vessels, sinusoidal capillaries, and central veins in the portal tracts was identified: in the early postnatal period, if the vessel walls are thin, the sinusoids are wider, and the hepatocyte systems are more irregular, a connective tissue sheath forms around the vessels in later periods, the sinusoids narrow, and the hepatocyte systems become radially oriented. The obtained data clarify the age morphology of the vascular system of the liver lobes and serve as a normative basis for comparison for experimental studies.

Keywords: *liver, left lobe, right lobe, blood vessels, microcirculatory bed, sinusoidal capillaries, postnatal ontogenesis, morphometry*

Introduction

The liver is the largest glandular organ in the body, performing many vital functions such as metabolism, neutralization, bile production, and blood storage. All these functions are closely linked to the specific structure of the hepatic vascular system: the organ receives blood from two sources: the portal vein and the hepatic artery, while blood flows through sinusoidal capillaries to the central veins and then to the hepatic veins [1, 2]. The portal vein at the hepatic portal divides into left and right branches, which supply blood to the corresponding lobes of the liver; therefore, a comparative study of the vascular structure of the left and right lobes is of not only theoretical but also practical importance [2, 3, 14].

The anatomical structure of the liver vessels plays a crucial role in surgical practice, particularly during liver resection and transplantation. The concept of segmental structure is based on the vascular and bile duct system of the liver [3, 4]. The understanding of the microscopic structure of liver tissue is expressed through the concepts of the classical hepatic lobule, portal lobule, and hepatic acinus [5, 6]. In each of these concepts, the vascular system is the main support of the structure.

Laboratory rats are a widely used experimental model for studying liver morphology. The rat

liver consists of several lobes, namely the middle, left lateral, right lateral, and caudal lobes, and the structure of its vessels and bile ducts has been described in detail [7]. Nevertheless, age-related changes in the microvascular system of the hepatic lobes at various stages of ontogenesis have not been sufficiently studied, especially in terms of comparing the left and right lobes. The state of the microcirculatory bed reflects the functional maturation of the organ; therefore, knowledge of its normal age dynamics provides the necessary comparative basis for assessing changes resulting from liver pathology and experimental effects. The development of the hepatic vascular system begins during the embryonic period and continues after birth. In the postnatal period, changes in nutritional habits, increased metabolism, and the formation of a hormonal background have a direct impact on the liver parenchyma and its vascular system. Therefore, describing the morphological changes during this period in specific timeframes allows for an understanding of the patterns of organ development and provides important information for age anatomy [1, 9, 10, 11].

Given the above, we set ourselves the task of studying the structural features of the vessels of the left and right lobes of the liver at different stages of postnatal ontogenesis.

Materials and methods

The research material was outbred white rats. The animals were divided into separate groups on the 10th, 30th, and 60th days of postnatal ontogenesis. All animals were kept under identical conditions and were not subjected to any experimental effects. The experiments were conducted in accordance with the norms of the Convention of the International Committee on Biological Ethics. At the end of the specified period, the animals were killed under ether anesthesia.

After opening the abdominal cavity, the liver was isolated, pieces were cut from its left and right lobes, and fixed in a 10% neutral formalin solution. After fixation, semi-thin sections were prepared using a microtome in accordance with the generally accepted methodology. The sections were stained with hematoxylin and eosin for general visualization, Weigert's method for determining elastic fibers, and van Gieson's method for identifying connective tissue fibers.

Morphometry was performed according to the method of G.G. Avtandilov [8]. Measurements and calculations were performed using a light microscope equipped with ocular meshes, linear scales of the object micrometer, and a screw-ocular micrometer MOB-1-15 LOMO. The following indicators were identified in the vascular structures: 1) the number of functioning hemocapillaries per 1 mm2 of area and their diameter; 2) total area of the microcirculatory channel (mkm2). The obtained numerical data were processed using methods of variational statistics.

Results and their discussion

On the 10th day of postnatal ontogenesis, the liver parenchyma was characterized by insufficient regulation of hepatocyte systems. The cytoplasm of hepatocytes is light-colored, slightly vacuolated, with large nuclei located in the center, and intercellular boundaries are not clearly visible. In the portal tracts, branches of the portal vein were found to be thin-walled, spacious, and blood-filled; a dense collection of small, dark-colored nucleated cells was observed around them. The connective tissue sheath was very thin, and the muscular layer of the vessel wall was poorly developed (Fig. 1).

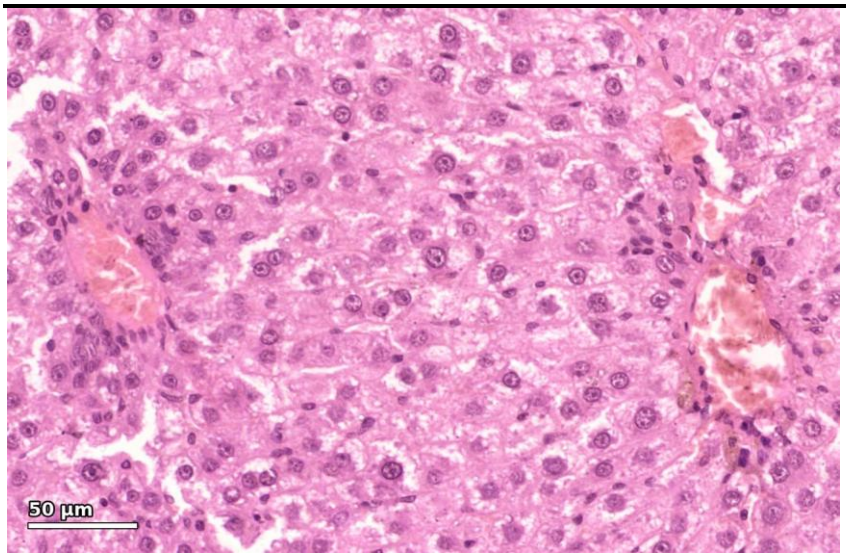


Figure 1. Rat liver, day 10. Thin-walled, blood-filled vessels in the portal tracts; irregular hepatocyte systems. Hematoxylin-eosin. Measurement line 50 µm.

During this period, the sinusoidal capillaries were relatively wide and uneven in shape, and their spaces did not have a clear direction between the hepatocyte systems. This indicates that the liver is still in the stage of functional maturation and the vascular system is actively forming. The radial orientation of hepatocyte systems around the central veins was only partially manifested.

By the 30th day, the structure of the liver tissue was significantly regulated. The hepatocytes are larger, the cytoplasm is denser and evenly stained, the nuclei have a clear outline, and the number of binucleated cells has increased. The hepatocyte systems were located radially between the portal tract and the central vein. Sinusoidal capillaries took on a narrow, fissure-like shape, and Kupffer cells and endothelial cell nuclei were clearly distinguished in their walls [12, 13, 15] (Fig. 2). Compared to the 10th day, the cavity of the portal vessels was orderly formed, and the connective tissue layer around them was thickened.

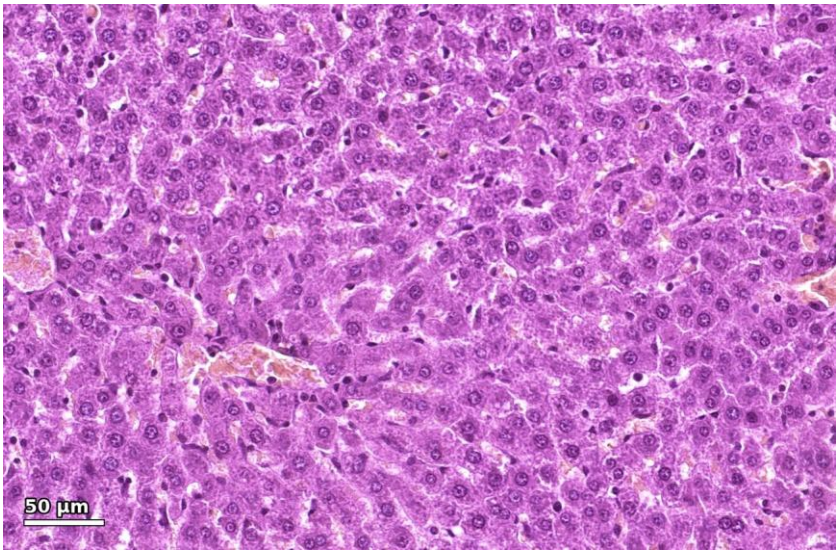


Figure 2. Rat liver, day 30. Radial arrangement of hepatocyte systems, narrow sinusoidal capillaries. Hematoxylin-eosin. Measurement line 50 µm.

On the 60th day, the liver structure resembled that of an adult animal. In the portal tract, the structures of the branch of the portal vein, the branch of the hepatic artery, and the bile duct were clearly distinguished; the wall of the portal vein was thin but well-formed, surrounded by a thin connective tissue sheath. The wall of the artery was relatively thick, the lumen was small, and the bile duct was covered with cuboid epithelium. The hepatocyte systems are ordered, the sinusoidal capillaries are narrow and evenly distributed, and dihydrocyte hepatocytes are more common (Fig. 3).

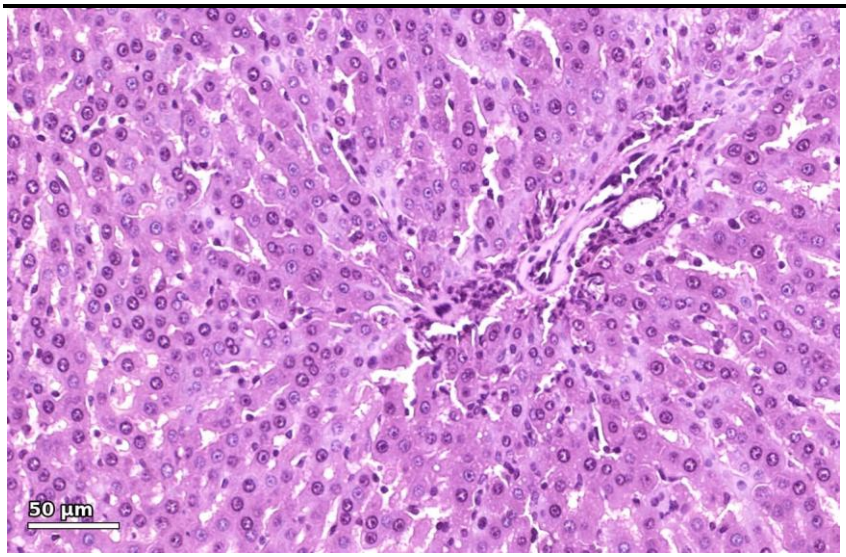


Figure 3. Rat liver, day 60. Structures of veins, arteries, and bile ducts in the portal tract; radially oriented hepatocyte systems. Hematoxylin-eosin. Measurement line 50 µm.

Overall, across the periods examined, the hepatic vascular system was reorganized following a common pattern: thin-walled, wide vessels gradually gave way to vessel structures with a specialized wall enclosed by a connective tissue sheath, accompanied by narrowing and ordering of the sinusoids. This process accompanies the functional maturation of the parenchyma, suggesting that microvascular development proceeds in parallel with hepatocyte differentiation [9].

To compare the left and right lobes of the liver, the aforementioned morphometric parameters (number of functioning hemocapillaries, their diameter, and the area of the microcirculatory bed) were determined separately for each period. A summary of these indicators is presented in the form of a diagram in Figure 4. The differences between the lobes are primarily explained by the volume of blood supply to the left and right branches of the portal vein and the size of the lobes [2, 7, 14]. The reliability of inter-segment differences is evaluated based on statistical data processing. When discussing the obtained data, it should be noted that age-related changes in the hepatic vascular system occur as a result of the combined influence of several factors. First, the volume of blood flowing through the portal vein increases as the organ grows, leading to a restructuring of the vessel cavity and its wall structure. Secondly, the differentiation of hepatocytes is interconnected with the formation of sinusoidal capillaries: as cellular systems become more ordered, the sinusoids also take on a narrow and directional shape. Thirdly, the formation of a connective tissue sheath around the portal vessels mechanically strengthens the vessel wall and ensures the integrity of the vascular system [5, 6, 9, 10, 12].

These findings reinforce the view that the vascular supply of both liver lobes develops along a shared sequence, with each lobe's vascular system reaching maturity at stages corresponding to specific phases of ontogenesis [10, 11]. Establishing the normal structural pattern of liver tissue across age groups also provides a necessary foundation for accurately interpreting changes induced by endocrine disturbances, such as thyroid hypofunction, or by exogenous intoxication.

Morphometric indicators of the microvasculature of the left and right lobes of the liver

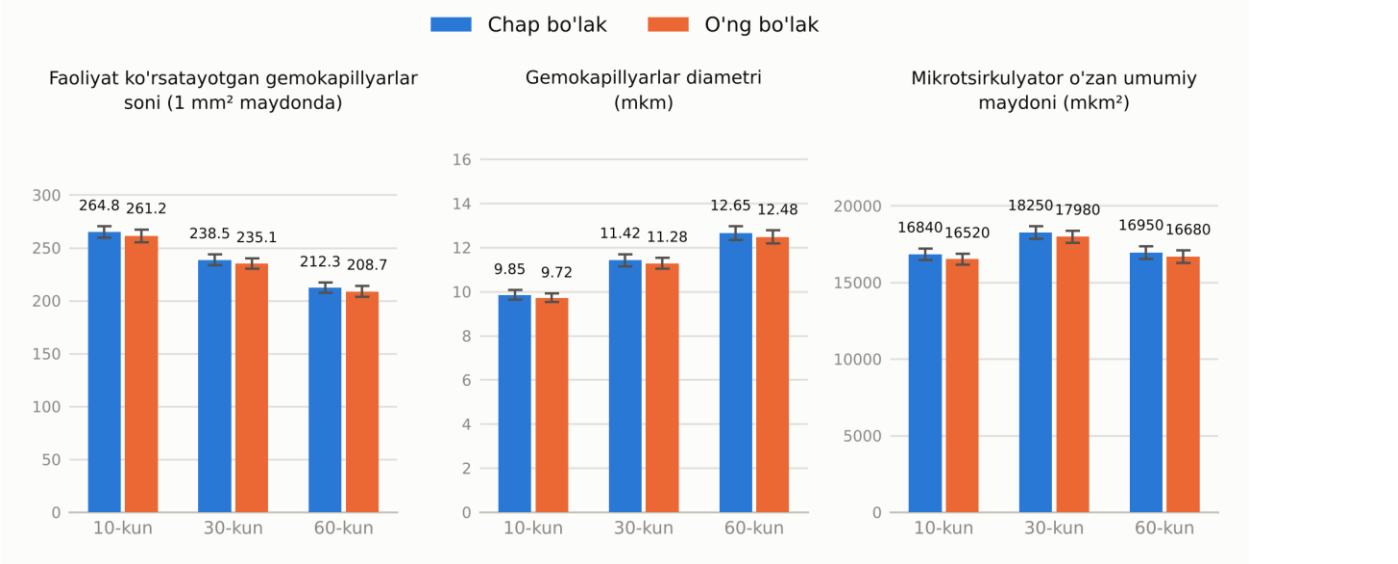


Figure 4. Indicators of the microcirculatory bed of the left and right lobes of the liver on the 10th, 30th, and 60th days of postnatal ontogenesis (M±m).

Note: M±m is the mean value and the mean error (error lines on the diagram). The indicators of the left and right segments were measured separately in each time group; their statistical significance was evaluated using methods of variational statistics, as indicated in the text.

These results confirm that the hepatic microvascular bed undergoes clear age-dependent dynamics, meaning that any evaluation of changes arising from experimental interventions—such as endocrine disorders or intoxication—cannot be considered accurate without accounting for this baseline dynamic. For this reason, the normative age-related indicators established here provide the reference framework for comparison in future studies.

Conclusion

1. Across the 10th, 30th, and 60th days of postnatal life, the hepatic vascular system of the rat undergoes a gradual, stage-by-stage reorganization: at the earliest stage (day 10), vessel walls remain thin and the lumens wide, the surrounding connective tissue sheath is only loosely formed, hepatocyte systems lack clear orientation, and sinusoidal capillaries are broad and irregularly shaped—findings that point to an organ still undergoing functional and structural maturation [1, 9].

2. By day 30, hepatocyte systems become radially arranged between the portal tract and the central vein, sinusoidal capillaries narrow into a slit-like form, and the nuclei of endothelial cells and Kupffer cells can be clearly distinguished within their walls; this stage closely parallels the heightened activity of the sinusoidal wall's cellular components—endothelial cells, Kupffer cells, and Ito cells—together with ongoing hepatocyte differentiation [9, 12, 13, 15]. By day 60, the portal vein, hepatic artery, and bile duct within the portal tract are already distinctly organized, resembling the adult pattern, with a stable connective tissue sheath enclosing the vessels.

3. This age-dependent reorganization of the hepatic vascular bed results from several interrelated processes acting together: growing blood volume through the portal vein reshapes both the vessel lumen and wall, hepatocyte differentiation proceeds alongside the narrowing and directional ordering of sinusoidal capillaries, and the connective tissue sheath forming around the portal vessels provides mechanical stability and structural integrity to the vascular network [10, 11, 12].

4. While the left and right hepatic lobes follow the same overall sequence and direction of vascular reconstruction, the quantitative differences observed between them stem from differing blood volumes delivered through the left and right portal vein branches and from the distinct anatomical dimensions and shape of each lobe; this points to a physiological asymmetry in lobar development and

underscores the lobes' independent clinical and anatomical relevance [2, 3, 14].

5. Har bir postnatal muddat uchun olingan me'yoriy morfometrik ko'rsatkichlar — faoliyatdagi gemokapillyarlar soni, ularning diametri va mikrotsirkulyator o'zan maydoni — jigar tomir tizimining yoshga bog'liq o'zgarish dinamikasini miqdoriy tarzda ifodalaydi hamda endokrin buzilishlar (jumladan, gipotireoz) yoki ekzogen zaharlanish ta'sirida yuzaga keladigan patologik holatlarni baholashda ishonchli qiyoslash mezoni (etalon) vazifasini bajaradi [8].

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