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Morphological Features of Human and Rat Liver and Biliary Tract Comparisons (Literary Review)

Kiyamov Bakhtiyar Ergashovich, Kamalova Malika Ilhomovna
Department of Human Anatomy, Samarkand State Medical Institute

Abstract: The rat liver and biliary tract morphogenesis during prenatal development shows the stages of the organ formation similar to humans, which are continuous passing from one to another. In spite of the relatively large mass of the liver, greater number of liver lobes and absence of the gallbladder in the rat, the microscopic organization of the liver and cytophysiological features of rat and human hepatocytes are not fundamentally different. The review presents data proving homology of the liver and biliary tracts of humans and rats, which is the basis for extrapolation to humans of the results of experimental studies on laboratory rats.

Key words: liver, biliary tract, gallbladder, rat

INTRODUCTION

Liver and biliary tract diseases are widespread in modern society and are an important problem of practical medicine [1, 2]. Gallstone disease makes a significant contribution to this pathology: 10 to 15% of people in industrialized countries, 20% of Europeans and about 50% of American Indians suffer from this disease [3, 4]. The liver is a vital organ that performs many important functions, in particular, together with the biliary tract, it ensures the excretion of the physiologically important hepatocyte secretion, bile, into the intestine [5]. In animal models of human liver and biliary tract pathology, laboratory rats are often used [6 - 10]. To extrapolate obtained experimental data to humans, it is necessary to deeply understand morphofunctional features of the liver and biliary tract in rat, peculiarities of their histo- and organogenesis from embryonic period of development to adult animal and human. Stages of liver development The human liver and biliary tract bud appears at the end of the 3rd week of embryogenesis as a thickening of the entoderm of the primary intestine, called the "liver field".

Further, the hepatic diverticulum is formed, which is divided into 2 unequal parts: the larger is the cranial section and the smaller is the caudal section, from which the liver with the hepatic duct and the gallbladder with its duct develop later, respectively [10,13]. In rat embryos, at the end of the 10th day a thickening is formed in the endoderm of the intestinal tube, the cells of which mitotically divide and on the 14th day of embryogenesis plunge into the ventral mesentery towards the heart, forming the hepatic diverticulum [9, 14]. According to the degree of differentiation, hepato- and cholangioblastic cells can be distinguished among the epithelial elements of the human and rat embryo. Cholangioblasts and cholangiocytes contact mesenchymal and fibroblast-like cells of developing connective tissue interlayers and large blood vessels. In early postnatal development in rats (first 14 days of age), cell proliferation and hypertrophy make the greatest contribution compared to other periods, which is due to an increase in the number and size of organelles due to the intensification of liver function. Polyploidization and proliferation of hepatocytes make a marked contribution to the increase in liver mass from 15 to 60 days after birth. The hematopoietic function of the liver is characteristic of the early period of its development, and by the time of birth the transition is made mainly to the medullary pathway of hematopoiesis. A characteristic feature of the embryonic liver in the first half of embryogenesis is the presence of numerous foci of hematopoiesis. In the last week of embryogenesis there is a gradual replacement of the reticular structure of the liver by the lobular one, with significant changes in both the structure and cytochemistry of the parenchymatous cells [11]. Differentiation of hepatocytes and cholangiocytes in rats ends in the postnatal period at 50-60 days [10]. In humans, the formation of the final structure of the hepatic lobules ends by 8-10 years of age.

Anatomy of the liver and biliary tract The human liver is located directly below the diaphragm in the upper part of the abdominal cavity on the right, so that only a relatively small part of the organ in an adult extends to the left of the midline; in a newborn it occupies most of the abdominal cavity. The weight of the adult liver is 1.5-2 kg, which is 2-3% of the human mass. The human liver is divided into two lobes, the right lobe and the smaller left lobe, which are separated from each other on the diaphragmatic surface by the crescentic ligament of the liver. Each lobe of the liver is divided into sectors, which are in turn divided into segments. The organ is thus divided into two lobes, 5 sectors and 8 segments. The liver is distinguished by 2 surfaces and 2 edges. The upper, or more precisely the antero-upper, surface is convex according to the concavity of the diaphragm to which it adjoins; the lower surface faces downwards and backwards and bears a series of impressions from the other abdominal organs to which it adjoins. The upper and lower surfaces are separated from each other by a sharp lower edge. In contrast, the other edge of the liver, the upper posterior

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edge, is so blunt that it can be regarded as the posterior surface of the liver. The intrahepatic ducts of the liver lobes merge to form the left and right hepatic ducts. They join to form the common hepatic duct, which connects the bile duct system to the gallbladder. When the common hepatic and gallbladder ducts are connected, the common bile duct is formed. The common bile duct enters the duodenum (most frequently in the middle third of the descending colon), and not just in the colon wall, but in the centre of a special papilla-like bulge (fater nipple). Before this, in most cases (about 75%) the terminal part of the common bile duct joins the main duct of the pancreas. At their junction a hepatic-pancreatic ampulla is formed where bile and pancreatic juice mix, which has a certain physiological significance. Sometimes the common bile and pancreatic ducts do not merge and do not form an ampulla, but open at the greater duodenal papilla with separate openings; other variants are also possible (for example, the common bile duct merges with an additional pancreatic duct). Thehumanliverproduces 250-1000 mlofbileperday. The gallbladder is part of the human biliary system, a small hollow organ that accumulates bile between digestions, concentrates it and excretes it during meals and digestion. It is a thin-walled pear-shaped sac (its size varies - length 5-14 cm and maximum diameter 3.5-4 cm), which contains about 30-70 ml of bile. It should be noted that all parts of human bile-excretory system are anatomically very variable (number of liver ducts, length of separate parts, connection places, location, etc.). The weight of the rat liver ranges from 6.5 g (in rats weighing 150 g) to 10-12 g (in rats weighing 250 g), which is 4-6% of the animal weight. It is a rounded, irregularly shaped, red-brown organ, the largest in the abdominal cavity. Most of the organ is in the right subcostal area. A distinction is made between the cranial (diaphragmatic) surface of the liver and the caudal (visceral) surface in contact with the stomach. In the centre of the visceral surface is the hepatic gate - an area where blood vessels, nerves and hepatic ducts enter and exit. The liver is divided into six lobes: right (lateral and central), left (lateral and central), caudal, and supplementary [7]. The supplementary (median) lobe of the rat's liver is the most cranial. The right lobe of the liver is larger, cranially adjacent to the median lobe and caudally adjacent to the duodenum. The left lobe of the liver is the largest, with its caudal edge resting on the stomach and the caudate lobe located more ventrally. The caudate lobe is the smallest, situated around the oesophagus and adjacent to the median and left lobes [7,9]. A hepatic duct is derived from each lobe and they merge to form a common bile duct. The latter duct is translucent, about 1 mm wide, runs from the liver gate, where it receives the hepatic ducts from the lobes, passes through the pancreatic tissue a few millimeters below the duodenum and flows into its caudal end. Numerous pancreatic ducts flow into the common bile duct [7, 9, 14]. The rat liver produces and secretes an average of 11.6 ml of bile per day. The hepatic bile has a pH of 8.3. A characteristic feature of the rat bile-excreting system is the absence of a gallbladder, so the bile produced in the liver is not deposited, but immediately enters the intestine. In addition, rats have peculiarities in bile formation, bilirubin metabolism and liver regeneration processes [8]. Rats are able to rehydroxylatelithocholic acid into di- and trihydroxybile acids, which is not observed in humans [7]. Microstructure of the liver The microscopic organization of the human and rat livers is very similar. The stroma is formed by a connective-tissue capsule covering the exterior of the organ and closely fused with the visceral peritoneum. Connective tissue layers departing from the capsule divide the organ parenchyma into lobules, which are its structural and functional units. Classical liver lobules in the liver are shaped as hexahedral prisms up to 1.5 mm in size; number of lobules in the organ reaches 500 thousand. In rats and humans on histological preparations classic lobules have no clear borders, but their presence and outline can be judged by the location of the central vein and portal zones. Human and rat hepatocytes have an irregular polygonal shape and make up 60% of all liver cellular elements. Their diameter reaches 20-25 µm. Many of them (up to 20% in human liver) contain two or more nuclei. Rat and human hepatocytes are polygonal in shape and their borders are clearly distinguishable even on hematoxylin and eosin stained preparations. It is interesting that rat hepatocytes are much larger than in humans. A comparative cytological analysis of vertebrate hepatic parenchyma has been carried out in recent years and has shown that the electron microscopic organization and cytophysiological features of rat and human hepatocytes are not fundamentally different [8, 10, 14]. It is known that different parts of the hepatic lobule perform unequal functions. Two functional fields - central (perivenous) and peripheral (periportal) - are distinguished. On the basis of histochemical and electron microscopic studies the concept of heterogeneity, hepatocytes heterogeneity in the lobule was introduced. Due to the peculiarities of blood supply in the hepatic lobule hepatocytes are in unequal conditions: the cells of peripheral lobules receive blood, more oxygenated and containing more nutrients. Accordingly, these cells have better developed organelles and higher activity of various enzymes. Therefore, the ability to resist the action of adverse factors is also higher. Under the influence of the latter, the cells of the central parts of the lobules are usually the first to be affected [12]. The rat and human liver are also similar in these parameters.

Conclusions: Thus, in spite of the evident differences in sizes and shape of the organ, the above data confirm homologous structure of the liver and biliary tracts of humans and rats (excluding the gallbladder), and similar dynamics of morphological transformation of the organ during embryogenesis, which allows using this experimental animal for studying regularities of liver development and modelling various human diseases and pathological conditions.

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