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Original Scientific Paper

DISTRIBUTION OF THE HEPATIC BLOOD VESSELS OF THE GROUND SQUIRREL (*SPERMOPHILUS CITELLUS*)**

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Abstract: The aim of this paper was to study distribution of the hepatic artery and portal vein of the portal system of the liver in ground squirrels (Spermophilus citellus) and compare these data with those concerning the rats, rabbits, guinea pigs and nutrias. The liver of the ground squirrel receives the oxygen and nutrients through blood from two large blood vessels: portal vein and hepatic artery (*a. hepatica propria)*. The portal vein is formed by the confluence of three main venous blood vessels: *v. gastropancreaticoduodenalis*, *v. gastrolienalis* and *v. mesenterica cranialis*. It collects venous blood from the stomach, pancreas, spleen and all of intestines except the rectum. The portal vein enters the porta hepatis on the liver together with the hepatic artery. Five venous branches of different size separate from the portal vein and ramify into the respective liver lobes.
Blood leaves the liver through the hepatic veins that start with the central veins. Three large hepatic veins and two venous trunks drain lobes of the liver and enter the caudal vena cava as it passes through the liver.
A. hepatica propria supplies the liver and gallbladder with oxygenated blood. It raises from the hepatic artery (*a. hepatica*) wich is the third branch of the celiac artery. A. hepatica propria in the portal fissure is divided into two branches, of which the left branch brings arterial blood to the left hepatic lobe, and the right branch brings it into other liver lobes.
Key words: Spermophilus citellus, liver, portal vein, hepatic artery

INTRODUCTION

Ground squirrel, also known as European ground squirrel (Spermophilus citellus), is a small rodent from the squirrel family (Ramos-Lara et al., 2014). Its body length is up to 20 cm and the body weight is between 200 and 300 g (Spitzenberger and Bauer, 2001). They live in colonies beneath the ground in the branched tunnels which they excavate themselves. (Turrini et al., 2008; Helgen et al., 2009). Ground squirrels tend to come out of their burrows to look for seeds and plant fruits as well as to play on grassy fields (Koshev and Pandourski, 2008). Ground squirrel is a real hibernator and its hibernation lasts from October

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to March (Millesi et al., 1998; Matějů, 2008). Most of the population in Serbia is located in Vojvodina, on the unploughed steppic pastures. Due to the intensive development of agriculture, their habitats have decreased, and many have disappeared, and the ground squirrel has become a protected species. We have received the approval of the Ethic Committee of the Faculty of Veterinary Medicine in Belgrade (No 01-218, 21/04/2008) and The Ministry of Environmental Protection of the Republic of Serbia (Br / N0 353-01-752 / 2008-03) for the procurement of ground squirrels.

Ground squirrel is used as an experimental animal for biology, physiology, immunology, microbiology and other scientific disciplines. As they are members of the rodent group, they are interesting for anatomical research of organs and systems of organs that would be compared with the same organs in other experimental animals. Numerous authors examined the morphology of the liver of experimental animals such as rat (Hebel and Stromberg 1976; Lorente et al., 1995; Kogure et al., 1999; Komárek, 2000; Martins and Neuhaus, 2007), rabbit (Seo et al., 2001; Khristov et al., 2006; Stamatova-Yovcheva et al., 2012) and nutria (Pérez and Lima, 2007).

The liver of experimental animals has two afferent blood supplies, The hepatic artery (a. hepatica propria) and portal vein (v. portae) and one efferent system, hepatic vein (Vv. Hepaticae). In the literature there are papers referring to the liver blood vessels of the rats (Janković and Stanojević, 1962; Innocenti et al., 1978; Brand et al., 1995; Mehran et al., 2000; Miyaki et al., 2006; Kresakova et al., 2019), rabbit (Seo et al., 2001; Kresakova et al., 2019), guinea pig (Kresakova et al, 2019) as well as man (Dukanovic et al., 2007).

There is little data in the literature on the liver of ground squirrels and this paper represents an extension of the study of organ vascularization in this rodent.

MATERIAL AND METHODS

The tests were carried out on 10 ground squirrels, both sexes, weighing 250-300 g and of different ages. They are caught in the field of southern Banat (Deliblatska peščara). The animals were clinically healthy. With compulsory anesthesia using ketamine 10 ml / kg b.m., i.m. and premedication with xylazine 1.1 ml / kg b.m., i.m. (Rompun, Bauer, Canada) the animals were sacrificed. The examination of liver morphology was performed on liver fractions conserved in 4% formalin. Latex was injected into the portal vein in order to obtain corrosion casts of the hepatic vein. In order to get arterial blood vessels of the liver, the initial part of the abdominal aorta was injected with gelatin.

RESULTS

In order to understand the liver blood flow in ground squirrels, one needs to know hepatic lobar architecture. In ground squirrels as with other experimental animals, there is a great anatomical variability in the number of liver lobes, branching of blood vessels and bile ducts. However, in the largest percentage of ground squirrels, liver consists of 4 lobes: the left lobe of the liver (lobus hepatis sinister), the quadrate lobe (lobus quadratus), the right lobe of the liver (lobus hepatis dexter) and the caudate lobe (lobus caudatus).The left lobe of the liver is

divided by deep fissure into the large, left lateral (lobus hepatis sinister lateralis, Figure 2A) and five times smaller left medial lobe (lobus hepatis sinister medialis, Figure 2B). The quadrate lobe (Fig. 2C) lies ventrally from the porta hepatis and it is separated from the left medial lobe by a deep fissure and from the right medial lobe by a smaller fissure. Gallbladder lies along the right edge of the quadrate lobe of the liver. (Figure 2-Vf). The lobe caudatus lobe is located above the portal groove and is subdivided into the caudate (processus caudatus, Figure 2-F) and the papillar process (processus papillaris, Figure 2-B) with the latter one being divided into 2 parts.

There are two functionally separate circulation systems in the liver – nutritive and functional. Functional circulation is provided by the portal vein which brings substances to be processed in the liver, while nutritive circulation is provided by a hepatic artery, which delivers oxygen and nutrition.

The liver has two afferent blood vessels, portal vein (v. Portae) and hepatic artery (a hepatica propria) and an efferent vessel, hepatic vein (v. Hepaticae). The portal vein in ground squirrels is formed by the confluence of three venous blood vessels (V. gastropancreaticoduodenalis, V. gastrolienalis and V. mesenterica cranialis) which lead venous blood from the stomach, pancreas, spleen, small intenstine and colon, except from the real intestine (rectum). Portal vein runs towards the portal fissure in the area of the right lateral lobe together with the hepatic artery. The branching pattern of the portal vein depends on lobular architecture of the liver. Portal vein in the portal fissure divides into 5 vein branches which enter the lobes of the liver and branch intrahepatically into sinusoids.

The first branch is a common venous trunk for the right lateral lobe and the caudate process of the caudate lobe. After 5-6 mm from the beginning, it ramifies into two branches: one ramifies in the right lateral lobe, and the other in the caudate process of the caudate lobe; the other branch of the portal vein leads to the right middle lobe ramifying in it into several branches; the third branch of the portal vein enters the papillary process of the caudate lobe and divides into several small branches; the fourth branch of the portal vein is a common venous trunk for the quadrate lobe and left middle lobe. This trunk lies between the quadrate and the left middle lobe and then divides into two branches for the mentioned lobes, and the fifth branch of the portal vein represents 4 veins that are located between the left lateral and the left middle lobe. These four veins bring venous blood into the entire left lateral lobe, which is the largest lobe of the liver in ground squirrels.

The hepatic veins (v. Hepaticae) represent an efferent drainage system that begins with central veins in the liver and empties into the vena cava caudalis (v. Cava caudalis) during its passage through the liver. After the formation of the smaller veins, three large veins and two venous trees are formed that drain the blood from the lobe of the liver into the vena cava caudalis. Hepatic veins are named after the lobes from which they drain blood into the vena cava caudalis.

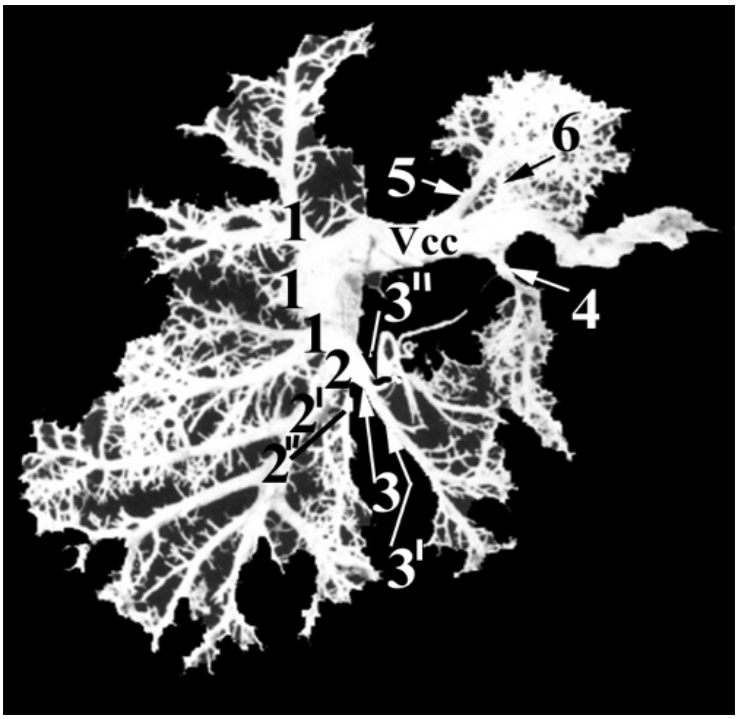

Figure 1. Corrosion cast of the hepatic vein (*Vv. hepaticae*) in ground squirrels
Vcc- Vena cava caudalis, 1,1,1- Vv. hepaticae lobi sinistri lateralis, 2- Truncus communis for V. hepatis lobi sinistri medialis (2') and V. hepatis lobi quadrati (2"), 3- Truncus communis for V. hepatis lobi dextri medialis (3') and V. hepatis lobi dextri lateralis (3"), 4- V. hepatis processus caudati, 5,6- Vv. hepaticae processus papillaris

Vv. hepaticae lobi sinistri lateralis (Figure 1- 1,1,1) are the three veins that carry blood from the largest lobe of the liver to the vena cava caudalis.

The common trunk (Figure 1- 2), formed from venous branches from the left middle lobe (Figure 1- 2) and the quadrate lobe of the liver (Figure 1- 2), drains blood into the vena cava caudalis.

The common trunk (Figure 1-3), formed from the venous branches from the right middle lobe (3 ') and the right lateral lobe of the liver (3 "), drains blood into the vena cava caudalis.

Vv. hepaticae processus caudate (Figure 1- 4) drains blood from the the caudate process into the vena cava caudalis.

Vv. hepaticae processus papillaris (Figure 1- 5,6) are two veins that drain the blood from both parts of the papillary process into the vena cava caudalis.

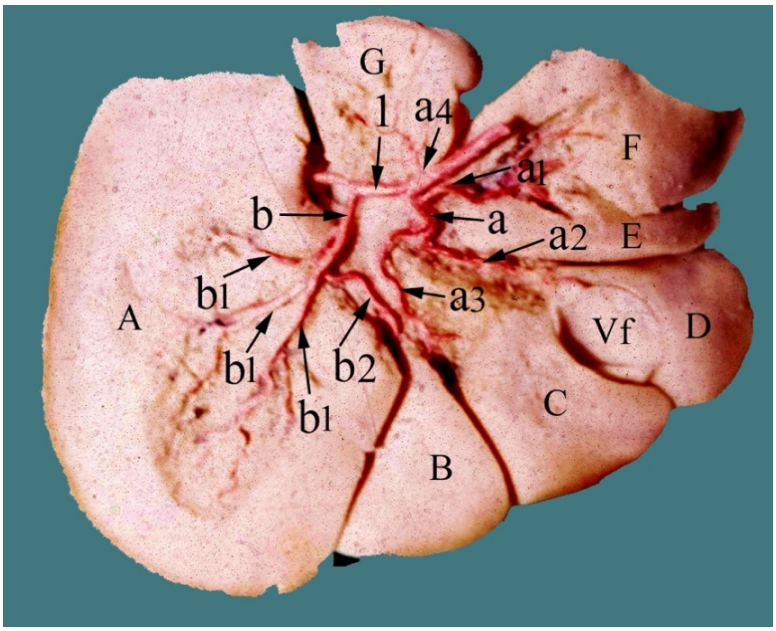

Figure 2. A. Hepatica propria and its branches in ground squirrels
1- A. hepatica propria, a- Ramus dexter, a1- Ramus lobi dextri lateralis et processi caudati, a2- A. cystica, a3- Ramus lobi quadrati, a4- Ramus processus papillaris, b- Ramus sinister, b1, b1, b1- Rami lobi sinistri, b2- Ramus lobi sinistri medialis, Vf- Vesica fellea

A. hepatica propria (Figure 2- 1), branch of hepatic artery (a. Hepatica), brings arterial blood in the liver of the ground squirrels. A. hepatica propria bifurcates in a right branch (ramus dexter) and a left branch (ramus sinister). Right branch (Figure 2- a) of a. hepaticae propria gives four branches for the corresponding lobes of the liver. The first branch brings arterial blood into the caudate process (Figure 2- a1); the second branch brings it to the gallbladder (Figure 2- a2); the third branch to the square lobe (2-a3) and the fourth branch brings blood to the papillary process of the caudate lobe (Figure 2- a4).

DISCUSSION

In ground squirrels as with other experimental animals, there is a great anatomical variability in the number of liver lobes and branching of blood vessels. In most experimental animals deep fissures divide liver into a left, right, quadrate and caudate lobe. The left and right lobes of the liver in ground squirrels are divided into the lateral and medial lobes. The caudate lobe consists of the caudate and papillary processes with the latter one being divided into two parts.

In ground squirrels, as in rabbits (Hristov et al., 2006), guinea pigs (Kresakova et al., 2019) and nutrias (Pérez et al., 2007) the left and right lobes are divided into the lateral and medial segments, and caudate lobe into the caudate and papillary

processes. However, Stamatov-Yovchev et al. (2012) found that in rabbits the left lobe of the liver is divided into the medial and lateral lobe, which is in agreement with the results from Christ et al. (2006), while the right lobe is compact.

Compared to the results obtained by Pérez et al. (2007) who claim that the liver in nutrias touches both kidneys, the liver of ground squirrels and rabbits touches only the right kidney. In ground squirrels and rabbits there is a concavity on the caudate process of the caudate lobe in which the right kidney fits.

In rats the liver is divided into: left lateral lobe, median lobe divided into the right and left parts, caudate lobe and left lateral lobe (Komárek, 2000, Martins and Neuhaus, 2007, Dong et al., 2010). In ground squirrels, nutrias and rabbits the gallbladder its inside the quadrate lobe while in rats there is no gallbladder.

V. gastropancreaticoduodenalis, v. gastrolienalis and v. mesenterica cranialis form the portal vein in ground squirrels. However, in rats v. gastropancreaticoduodenalis drains blood into the cranial mesenterial vein (v. mesenterica cranialis) so that the portal vein of the rat originates from v. gastroduodenalis, v. gastrolienalis and v. mesenterica cranialis (Innocenti et al., 1978; Martins and Neuhaus, 2007). Contrary to the above-mentioned authors, Dong et al. (2010), by using an injection method, found that the portal vein of the rat is formed by two large branches: v. mesenterica cranialis and v. lienalis and one small branch, v. pylorica. Portal vein branching in the liver is conditioned by its lobular structure.

In ground squirrels 5 venous branches that carry blood into the corresponding liver lobes, separates in the portal fissure from the portal vein. Kogure et al. (1999) described that the portal vein in rats gives off three main branches that ramifies into the corresponding liver lobes. However, Martins and Neuhaus (2007) have shown that the portal vein in rats first gives off branches for the right lobe, then a short branch for the caudate lobe, then a branch for the middle lobe and the last branch for the left lateral lobe. In rats and guinea pigs, the main structure of the liver venous system is identical with the lobar segmentation of their liver. In rats (Kogure et al., 1999; Miyaki et al., 2006) and guinea pigs (Kresakova et al., 2019), the right lobe of the liver is drained by 3, and in the rabbits by 2 hepatic veins (Kresakova et al., 2019). The middle lobe of the liver in rats has two or three large hepatic veins: the right hepatic vein, middle hepatic vein and left hepatic vein (Kogure et al., 1999). Left median vein can enter the vena cava caudalis separately or together with the left hepatic vein that drains the left lateral lobe of the liver (Lorente et al., 1995). The left lobe and caudate superior lobe are drained by two large hepatic veins, left and right one, which enter the vena cava caudalis separately or joined into a venous trunk (Martins and Neuhaus, 2007). Seo et al. (2001) state that in all examined rabbits (100%) vein blood from the liver is drained by four veins, which separately enter the vena cava caudalis. These are: v. hepatica dextra, v. hepatica media, v. hepatica sinistra and v. hepatica lobi caudati. Kresakova et al. (2019) found that the right hepatic venous system of rats and guinea pigs consists of 3 hepatic veins that drain venous blood from the right lateral lobe, right median lobe and caudate process of the caudate lobe into the vena cava caudalis. A. hepatica propria transfer blood to the liver of ground squirrels and rats (Brand et al., 1995; Martins and Neuhaus, 2007) rabbits (Seo et al., 2001) and nutrias (Pérez and Lima, 2007). This artery originates from the hepatic artery (a. Hepatica propria) in ground squirrels and nutrias (Pérez and Lima, 2007), and from the common hepatic artery (a. Hepatica communis) in rats and rabbits. In ground squirrels a.hepatica propria first gives off left and right branches that branch intrahepatically into the corresponding liver,

while a.hepatica propria in rabbits (Seo et al., 2001) first gives off a branch for the vascularization of the caudate lobe and then ramifies into left and right branches which provide blood supply for other lobes.

CONCLUSION

Based on a study of the liver blood vessels distribution in ground squirrels, it can be concluded that a. hepatica propria with the right and left arterial branch supply oxygen and nutrients to the liver. The hepatic portal vein is formed by the confluence of three main vessels: v. gastropancreaticoduodenalis, v. gastrolienalis and v. mesenterica cranialis. Portal vein together with its two venous trees and two veins brings venous blood to all liver lobes. In ground squirrels the blood from the liver is drained by three large hepatic veins and two venous trees into the vena cava caudalis. Differences in blood vessel branching the liver of ground squirrel on the one side and rats, rabbits, guinea pigs and nutrias on the other side, exist in the distribution of lobular structure of their livers.

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