Bulgarian Journal of Agricultural Science, 24 (No 3) 2018, 497–502
Agricultural Academy

RADIOGRAPHIC STUDY OF THE TOPOGRAPHY OF THE HEPATIC VASCULATURE AND BILE DUCTS OF THE RABBIT

KAMELIA STAMATOVA-YOVCHEVA[1*]; ROSEN DIMITROV[1]; ÖMER GÜRKAN DILEK[2]
[1]*Trakia University, Faculty of Veterinary Medicine, Department of Veterinary Anatomy, Histology and Embryology, BG-6000 Stara Zagora, Bulgaria*
[2]*University of Mehmet Akif Ersoy, Faculty of Veterinary Medicine, Department of Anatomy, Örtülü Burdur, Turkey*

Abstract

Stamatova-Yovcheva, K., R. Dimitrov and Ö.G. Dilek, 2018. Radiographic study of the topography of the hepatic vasculature and bile ducts of the rabbit. *Bulg. J. Agric. Sci.*, 24 (3): 497–502

The aim of the present study was to describe and illustrate the ramification patterns of the hepatic artery, portal vein, hepatic veins and bile ducts within the rabbit liver by means of postmortem angiography performed in 40 New Zealand white rabbits. The hepatic artery bifurcated into the left and right hepatic branches. The portal vein received a separate tributary from the caudate lobe before it separated into the right branch and the left branch. Five hepatic visceral tributaries of the caudal vena cava were identified: the left dorsal hepatic vein, left hepatic vein, right hepatic vein, middle hepatic vein and a proper vein of the caudate lobe. Postmortem cholangiography demonstrated the presence of a common hepatic duct. The anatomical nomenclature of the various intrahepatic blood vessels and bile ducts is critically reviewed and compared with the terminology used in radiographic studies.

Key words: hepatic arteries; portal vein; hepatic veins; bile ducts; rabbit

Introduction

The rabbit liver is used as an anatomical model for investigation of the topography and ramification patterns of the hepatic vessels in humans, carnivores and some wild mammals (Nowicki et al., 2010). The anatomical features of the abdominal vessels of the rabbit have been studied by Abidu-Figueiredo et al. (2008) and by selective hepatic angiography and mesentericoportography by Kónya et al. (1997).

The arterial blood of the rabbit liver is supplied by the hepatic artery which is a branch of the celiac artery (Barone, 2011) or the left gastric artery (Abidu-Figueiredo et al., 2008). Seo et al (2001) described one rabbit in which the hepatic artery arose from the cranial mesenteric artery.

The anatomical features of the proper hepatic artery have been described by Seo et al. (2001), Tam et al. (2014), Stamatova-Yovcheva (2016) and Stamatova-Yovcheva et al. (2016). Its first branch enters the caudate lobe. The intrahepatic continuation of the proper hepatic artery, beyond the caudate lobe, is the main hepatic artery, which divides into a right and left branch. The latter subsequently splits into medial and lateral segmental branches.

According to Barone (1997, 2011) the hepatic artery splits in a right branch which supplies the caudate lobe and the cystic artery (*A. cystica*), a left medial branch which gives off a branch to the quadrate lobe and a left lateral branch.

The rabbit portal vein, which starts at the level of the 1st lumbar vertebrae, has been studied by contrast angiography (Kónya et al., 1997; Seo et al., 2001). After entering the porta hepatis it receives a tributary from the caudate lobe and then bifurcates in a right branch (*Ramus dexter*) and a larger left branch (*Ramus sinister*), which will be

**E-mail:* kameliastamatovayovcheva@gmail.com (*corresponding author), rosstefdimitrov47@gmail.com, ogdilek@gmail.com

further designated as the right and left portal vein branch, respectively. The left portal vein branch ramifies in the left medial, left lateral and quadrate lobes (Barone, 1997) and receives a large left ventral tributary which is specific for the rabbit, as well as a lateral and a medial tributary (Seo et al., 2001).

Páramo et al. (2017) describe the anatomical specifics of the rabbit portal vein, using direct portography and computed tomography. They name the vein as "original portal vein" which is subdivided into caudate portal vein and main portal vein.

Individual and breed variations of the portal vein and its tributaries have not been described in rabbits.

The hepatic veins of the rabbit have been documented by phlebography (Kónya et al., 1997), like in similar studies in human medicine (Grozmann et al., 1979). According to Seo et al. (2001) the rabbit hepatic veins are arranged in a constant pattern: the left, middle and right hepatic veins drain directly and together into the caudal vena cava, a large tributary from the caudate liver lobe discharges separately in the right side of the caudal vena cava, and a smaller vein draining the ventral part of the left liver lobe joins the left side of the caudal vena cava.

In contrast, Barone (2011) describes only four hepatic veins, including a large dorsal vein which drains the caudate lobe, the small right hepatic vein and the large left hepatic vein which emerges from the liver together with the middle hepatic vein.

The anatomical data concerning the rabbit bile ducts are contradictory. According to Barone (1997), a common hepatic duct is lacking in the rabbit. *Ductus choledochus* is formed by the junction of the cystic duct and the left hepatic duct. It collects the right hepatic duct along its course towards the cranial part of the duodenum, where it opens separately close to the pylorus.

In contrast, Seo et al. (2001) described a common hepatic duct which is formed where the bile duct from the caudate lobe joins the main bile duct formed by the left and right hepatic ducts. The left hepatic duct receives lateral and medial segmental branches. An additional ventral left hepatic duct discharges usually in the main bile duct, less frequently in the left hepatic duct or may be lacking. The gallbladder communicates with the right hepatic duct.

As the anatomical data of the rabbit hepatic blood vessels and bile ducts are contradictory and incomplete, the aim of the present study is to provide a detailed and illustrated description of the pertaining structures, which is useful for the interpretation of the liver structure in the rabbit and might also be used as an animal model for investigations in laboratory animals and humans.

Materials and Methods

Materials

Forty cadavers of New Zealand white rabbits have been included in the present study. They were supplied by a commercial slaughterhouse regulated for meat processing of lagomorphs in compliance with the legal requirements regarding the hygiene and inspection at slaughter (Regulation No 36 of 23/03/2006, prom. SG No. 35 of 28/04/ 2006). The study was carried out in accordance with the European convention for protection of vertebrates used for experimental and other scientific purposes (Strasbourg/16/05/1986), the European convention for protection of companion animals, and the Law on Animal Protection in Bulgaria (Section IV – Experiments on animals, art. 26, 27 and 28, adopted on 24.01.2008 and published in SG. 13 of 2008).

Methods

Contrast enhanced radiography of the hepatic arteries

Following the protocol described by Stamatova-Yovcheva (2016), the abdominal aorta and its branches were exposed in ten rabbits and flushed with physiological solution (0.9% NaCl, Balkanfarma) by cannulation of the abdominal aorta at the level of Th12 to L1. Subsequently, the cranial mesenteric artery, celiac artery and abdominal aorta were ligated at the level of L1 to L3. An X-ray positive solution was made by stirring 10 g of suspension DC-BAR-MILVE (Milve, Biala Slatina, Bulgaria) one package containing 90 g BaSO4, 8.37 g excipients (saccharose, hydroxyethyl cellulose, silicone oil and korigensi), 30 g gypsum (Natural gypsum universal "GIPS", Bulgaria) and 100 mL water. This solution was injected in the cannulated aorta and after extirpation of the liver arteriography of the abdominal aorta and hepatic arteries was performed with stationary radiographic equipment TuR-Dresden 800 D-1 with digital touch screen (iQ-CR ACE). Lateral (right and left) and ventrodorsal radiographs were taken before and after contrast administration with focus-film distance of 100 cm. The radiographs were taken with DICOM 3.0 cassettes measuring 24 x 30 cm (2328 x 2928 px matrix size) or 18 x 24 cm (1728 x 2328 px matrix size). Exposure time was 10 mS. The spatial resolution was 10 px/mm, depth of scanning 20 bit/px, and depth after the CPU processing 16 bit/px. The used software was Windows XP SP3. The software utilized for reading and measuring of the X-rays structure was iQ-VIEW Version 2.7.0 BETA INT EN 002R, Copyright© 2006-2011 IMAGE Information Systems Ltd (Dimitrov and Chaprazov, 2012; Yonkova, 2014).

Portography

After anatomical exposure, the portal vein *(V. portae)* in ten rabbits was cannulated caudal to the pancreas, ligated at the level of L1 and subsequently injected with X-ray positive contrast agent as described above for the hepatic arteries.

Phlebography

The caudal vena cava was cannulated in ten rabbits at the level of L1 and injected retrogradely with 7 ml of the above-mentioned X-ray solution. Following ligation of the caudal vena cava, the liver and caudal vena cava were removed and radiographed for visualization of the hepatic veins.

Cholangiography

The common bile duct (*Ductus choledochus*) was injected in ten rabbits through the major duodenal papilla with the same X-ray positive contrast solution as mentioned before. After dissection of the liver, stomach and cranial part of the duodenum, the liver was separated and the bile ducts were visualized radiographically.

Nomenclature

The terminology used for naming the various blood vessels and bile ducts is mainly based on the Nomina Anatomica Veterinaria (World Association of Veterinary Anatomists, 2012) but has been expanded by some additional terms based on data from clinical and radiographic studies (Seo et al., 2001; Abidu-Figueiredo et al., 2008).

Results

The postmortem arteriographic study of the rabbit liver showed that the artery which entered the Porta hepatis was the proper hepatic artery (*A. hepatica propria*) and its intrahepatic continuation was the main hepatic artery. *A. hepatica propria* collected a branch from the caudate lobe. The main hepatic artery bifurcated into a right branch (*Ramus dexter*) which supplied the right lobe of the liver, and a left branch (*Ramus sinister*) which subdivided into a medial branch and a lateral branch. The latter gave off a large branch (*Ramus dorsalis sinister*) to the dorsal part of the left lateral liver lobe (Figure 1). The cystic artery joined the main hepatic artery at the level of *Ramus dexter*.

When reaching the liver, the portal vein (*V. portae*) received a separate tributary from the caudate lobe and continued to the right and left liver lobe where it separated into a right branch (*Ramus dexter*) and a left branch (*Ramus sinister*). The left portal branch received a lateral and a medial tributary issued from left lateral lobe and the left medial lobe, respectively. The lateral tributary of the left portal branch collected a large tributary (*Ramus dorsalis sinister*) from the dorsal part of the left lateral liver lobe (Figure 2).

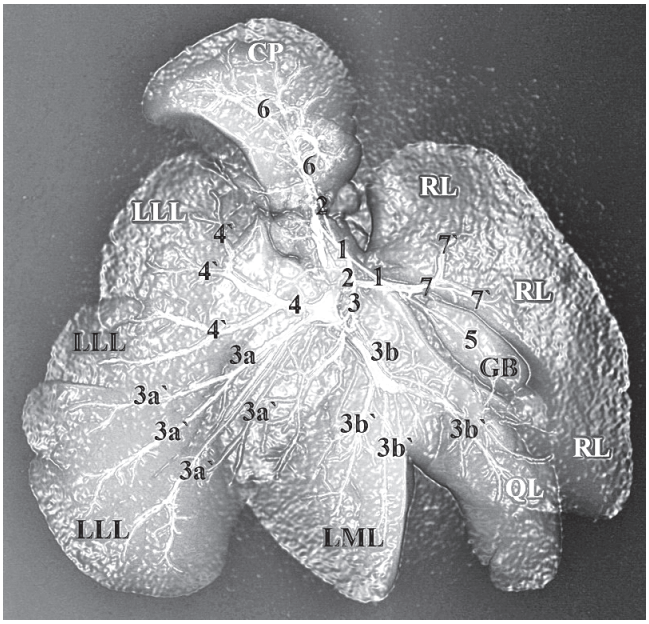

Fig. 1. X-ray post contrasted anatomical image of the rabbit hepatic arteries (LLL – left lateral lobe of the liver; LML – left medial lobe of the liver; QL – quadrate lobe; RL – right lobe of the liver; CP – caudate process). (1) common hepatic artery; (2) main proper hepatic artery; (3) *Ramus sinister*; (3a) lateral branch of *Ramus sinister*; (3a`) branches of the lateral branch of *Ramus sinister*; (3b) medial branch of *Ramus sinister*; (3b`) branches of the medial branch of Ramus sinister (4) *Ramus dorsalis sinister*; (4`) branches of *Ramus dorsalis sinister*; (5) cystic artery; (6) proper hepatic artery; (7) *Ramus dexter*; (7`) branches of *Ramus dexter*

By postmortem phlebography we found five hepatic veins which were visceral tributaries of the caudal vena cava: the left dorsal hepatic vein (*V. hepatica dorsalis sinistra*), left hepatic vein (*V. hepatica sinistra*), right hepatic vein (*V. hepatica dextra*), middle hepatic vein (*V. hepatica media*) and a hepatic vein of the caudate lobe (*V. hepatica lobi caudati*). The left dorsal hepatic vein received small tributaries from the dorsal, ventral and middle parts of the left lateral lobe. The left hepatic vein was situated in left medial lobe, whereas the right lobe of the liver contained two veins, viz. the middle hepatic vein which drained the right lobe of the liver and the gallbladder, and the right hepatic vein which drained the dorsal part of the right lobe (Figure 3).

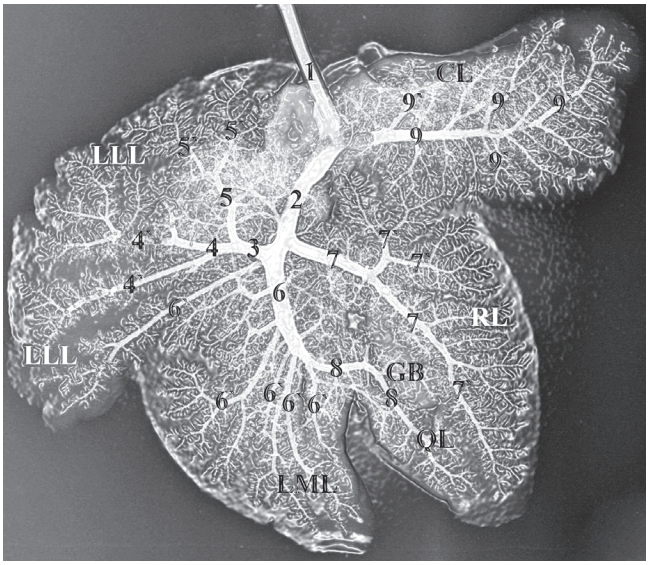

Fig. 2. X-ray post contrasted anatomical image of the rabbit portal vein and its tributaries. (LLL – left lateral lobe of the liver; LML – left medial lobe of the liver; QL – quadrate lobe; RL – right lobe of the liver; CL – caudate). (1) portal vein; (2) intrahepatic continuation of the portal vein; (3) *Ramus sinister*; (4) lateral tributary of *Ramus sinister*; (4`) tributaries of the lateral branch of *Ramus sinister* (5) *Ramus dorsalis sinister*; (5`) tributaries of *Ramus dorsalis sinister* (6) medial tributary of *Ramus sinister*; (6`) tributaries of the medial branch of *Ramus sinister* (7) *Ramus dexter*; (7`) tributaries of *Ramus dexter* (8) right tributary of *Ramus sinister*; (9) tributary of the portal vein in caudate lobe; (9`) tributaries of the portal vein in caudate lobe

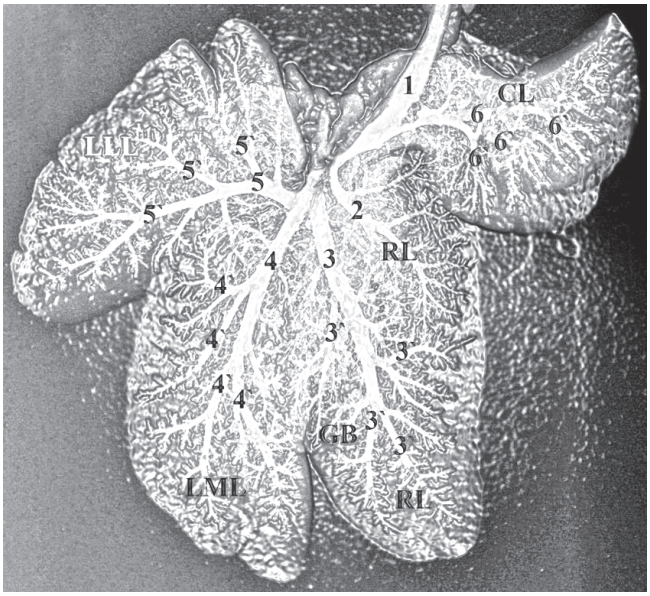

Fig. 3. Anatomical phlebography in the rabbit (LLL – left lateral lobe of the liver; LML – left medial lobe; RL – right lobe; CL – caudate lobe; GB-gall bladder). (1) caudal vena cava;; (2) *V. hepatica dextra*; (3) *V. hepatica media*; (4) *V. hepatica sinistra*; (4`) tributaries of *V. hepatica sinistra*; (5) *V. hepatica dorsalis sinistra*; (5`) tributaries of *V. hepatica dorsalis sinistra* (6) *V. hepatica lobi caudati*; (6`) tributaries of *V. hepatica lobi caudati*

Discussion

Postmortem cholangiography demonstrated the presence of a common hepatic duct (*Ductus hepaticus communis*). *Ductus hepticus dexter*, designated by number 6 came from the right lobe and joined the *Ductus hepaticus sinister* (3) to form the *Ductus hepaticus communis* (1). This *Ductus hepticus dexter* (6) received a duct from the caudate lobe (5) and continued further in the right lobe by the segment, indicated by number 4 in the figure. The common hepatic duct received a separate duct (*Ductus hepaticus dorsalis sinister*) from the left lateral lobe. *Ductus hepaticus sinister* was situated between the left medial and left lateral lobes of the liver before entering the left medial lobe, in which it bifurcated into a medial and lateral branch. The medial branch ramified in the left medial lobe and one of its branches reached the gallbladder fossa. The lateral branch was situated dorsal to the medial branch and ramified in the left medial lobe and quadrate lobe. The cystic duct (*Ductus cysticus*) joined the right hepatic duct (Figure 4).

Our results do not demonstrate variations between the various animals. In all of the studied organs, were found the same arterial, venous and biliary structures.

We propose new terms that are not listed in NAV. They are based on literature data and anatomical location and origin of the investigated structures.

In the present study the ramification pattern of the intrahepatic arteries of the rabbit is described and illustrated in detail.

We give detailed anatomical information, which concerns the branches of the proper hepatic artery in the rabbit liver. The hepatic, proper hepatic and main hepatic arteries are different not four different arteries, but these four terms are used for designating subsequent segments of the single “hepatic artery” .We adopt these terms from the literature (Seo et al., 2001; Abidu-Figueiredo et al., 2008; Barone, 2011) and propose them for acceptance in NAV.

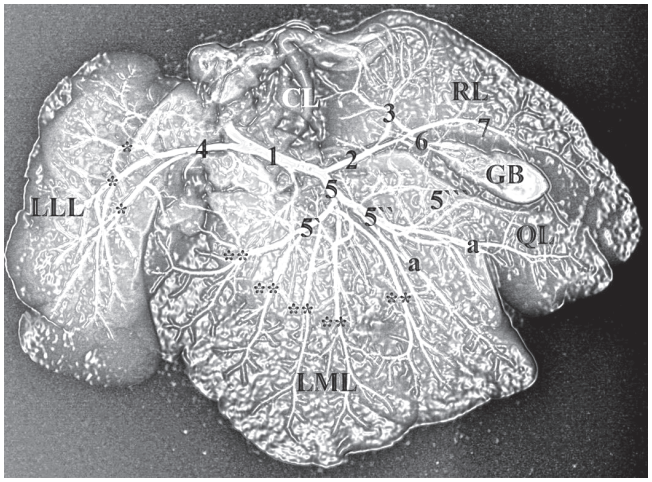

Fig. 4. Anatomical cholangiography in the rabbit (LLL – left lateral lobe of the liver; LML – left medial lobe of the liver; QL – quadrate lobe; RL – right lobe of the liver; GB – gall bladder). (1) *Ductus hepaticus communis*; (2) *Ductus hepaticus dexter*; (3) duct from the caudate lobe; (4) *Ductus hepaticus dorsalis sinister*; (8) branches of *Ductus hepaticus dorsalis sinister*; (5) *Ductus hepaticus sinister*; (5`) lateral branch of *Ductus hepaticus sinister*; (**) branches of the lateral branch of *Ductus hepaticus sinister*; (5``) medial branch of *Ductus hepaticus sinister*; (a) branch of the medial branch in the left medial lobe; (5```) branch of the medial branch in the gallbladder fossa; (6) *Ductus cysticus*; (7) segment of *Ductus hepaticus dexter* in the right lobe

Our angiographic data, which prove the presence of a proper hepatic artery in the rabbit, reject the hypothesis of Nowicki et al. (2010), which defines only the common hepatic artery as a single vessel which gives branches in the rabbit liver. Our thesis is that the proper hepatic artery enters the *Porta hepatis* and its intrahepatic continuation is the "main hepatic artery. Additionally we demonstrate the presence of a large left dorsal hepatic artery which is topographically related and a constant finding in all of the studied organs

Our theory, which concerns that the lobar hepatic arteries are branches of the proper hepatic artery does not confirm the literary data of Barone (2011), who propose another anatomical terminology, without designating segments of the single "hepatic artery".

The given data motivate us to confirm that the post contrasted selective postmortem angiography is a definitive method to study the topography and localization of the hepatic arteries. Our hypothesis corresponds to the theories for the application of this method to study the rabbit liver anatomy (Kónya et al., 1997; Seo et al., 2001; Abudi-Figueiredo et al., 2008; Tam et al., 2014).

Our thesis, which presents that the portal vessels in the rabbit are the left portal vein, the right portal vein, main portal vein and a tributary in caudate lobe, does not confirm the literature data (Barone, 1997; Barone, 2011), according to which in the rabbit liver there are only two portal veins: the right and left branches. In addition we identify the fifth portal vein branch (*Ramus dorsalis sinister*), which is not described by Barone (2011) and Páramo et al. (2017).

We claim that the topography and anatomical localization of the portal branches are similar to these of the hepatic arteries. Our results, concerning the portal vascularity of the left lateral lobe are motif to conclude that *Ramus dorsalis sinister* is specific for this lobe of the rabbit liver. According to us the left branch (*Ramus sinister*) is in the left medial lobe. The right tributary of the left branch and the right portal branch (*Ramus dexter*) move the blood from the quadrate lobe and the right lobe. Our anatomical description corresponds to the analysis of Seo et al. (2001) for the rabbit liver.

Our results demonstrate that the rabbit liver is drained by five hepatic veins: *V. hepatica sinistra*, *V. hepatica media*, *V. hepatica dextra*, *V. hepatica dorsalis sinistra* and *V. hepatica lobi caudati*. This hypothesis does not correspond to the anatomical data (Barone 1997; Barone, 2011) that only four hepatic veins move the blood from the rabbit liver.

We present another anatomical theory, that the caudate lobe and the left lateral lobe of the rabbit liver have a proper venous drainage, which is not associated with the middle hepatic vein. We assume that the main hepatic vein moves the blood only from the right lobe and the left medial lobe of the rabbit liver.

Our data which present the dorsal localization of the hepatic vein in the caudate lobe and the visualization of the latter left to the caudal vena cava are essential for the interpretation of the venous architectonic of the rabbit liver. We conclude that the middle hepatic vein and *Ramus dexter* (tributaries of the main hepatic vein) move the blood from the right lobe of the liver. Our results correspond to published data, state by Seo et al. (2001).

The obtained anatomical data allow us to conclude the presence of the common hepatic duct (*Ductus hepaticus communis*) in the rabbit. According to our anatomical results the right hepatic duct and the left hepatic duct form the common hepatic duct. These facts do not correspond to the literature data (Barone, 1997; McCracken and Kainer, 2008), that common hepatic duct does not exist in the rabbit.

We prove that the cystic duct joins the right hepatic duct as stated by Seo et al. (2001). This theory contradicts the published data of Barone (2011) that the cystic duct joins the left hepatic duct.

The left dorsal hepatic duct is specific for the left lateral lobe of the liver. This fact corresponds to the thesis of Seo et al. (2001) for the rabbit liver.

We prove the presence of a large left dorsal hepatic arterial, hepatic venous, portal venous branch and bile duct in the left dorsal part of the liver. These topographically related vessels are a constant finding and they are novel for the anatomical science and terminology.

We summarize that the X-ray anatomical study of the rabbit blood and biliary vessels is suitable to obtain detail information for their architectonic characteristics. Therefore we propose our results to be used as a morphological base for postcontrasted investigation in other mammals and man.

References

Abidu-Figueiredo, M., B. Xavier-Silva, T. Cardinot, M. Babinski and A. Chagas, 2008. Celiac artery in New Zealand rabbit: anatomical study of its origin and arrangement for experimental research and surgical practice. *Pesqui. Vet. Bras.,* **28**: 237-240.

Barone, R., 1997. Chapitre VII – Foie. In: R. Barone (ed.), Anatomie Comparée des Mammifères Domestiques. Vol. 3. Splanchnologie I. Troisième edition, *Vigot*, Paris, pp. 507-560.

Barone, R., 2011. Anatomie comparée des mammifères domestiques. Tome 5. Angiologie. Deuxième edition, *Vigot*, Paris, pp. 904.

Dimitrov, R. and T. Chaprazov, 2012. An anatomic and contrast enchanced radiographic investigation of the rabbit kidneys, ureters and urinary bladder. *Rev. Med. Vet.,* **163**: 469-474.

Groszmann, R., M. Glickman and A. Blei, 1979. Wedged and free hepatic venous pressure measured with a balloon catheter. *Gastroenterology,* **76**: 253-258.

Kónya, A., K. Wright, I. Szwarc and R. Collins, 1997. Technical aspects of catheter-related interventions in the liver of the rabbit. *Acta Radiol.,* **38**: 332-334.

McCracken, O. and R. Kainer, 2008: The rabbit. In: O. McCracken and R. Kainer, (Eds.), Color Atlas of Small Animal Anatomy: The Essentials, *Blackwell Publishing LTD*, Oxford, pp. 64-75.

Nowicki, W., W. Brudnicki, M. Iwanczyk, R. Jablonski and B. Skoczylas, 2010. Variation in branches of the abdominal aorta in European rabbit. *Electronic Journal of Polish Agricultural Universities (EJPAU)* **13**: 1-9.

Páramo, M., P. García-Barquin, E. Santa María, J.M. Madrid, M. Caballeros, A. Benito, B. Sangro, M. Iñarrairaegui and J.I. Bilbao, 2017. Evaluation of the rabbit liver by direct portography and contrast-enhanced computed tomography: anatomical variations of the portal system and hepatic volume quantification. *European Radiology Experimental*, **1**: 7; DOI 10.1186/s41747-017-0011-8.

Seo, T., J. Oh, D. Lee, Y. Ko and Y. Yoon, 2001. Radiologic anatomy of the rabbit liver on hepatic venography, arteriography, portography, and cholangiography. *Invest. Radiol.* **3**: 186-192.

Stamatova-Yovcheva, K., 2016. The application of some imaging anatomical methods for investigation of the liver of the New Zealand white rabbit (*Oryctolagus cuniculus*). Doctoral dissertation, *Trakia University*, Stara Zagora, Bulgaria.

Stamatova-Yovcheva, K., R. Dimitrov, D. Kostov, D. Vladova, P. Yonkova and D. Yovchev, 2016. Contrast enhanced anatomical study of hepatic arteries in the rabbit (*Oryctolagus cuniculus*). *Anat. Histol. Embryol.,* **45** (1): 81.

Tam, A., M. Melancon, J. Ensor, Y. Liu, K. Dixon, A. McWatters and S. Gupta, 2014. Rabbit hepatic arterial anatomy variations: implications on experimental design. *Acta Radiol.,* **55**: 1226-1233.

World Association of Veterinary Anatomists, 2012. Nomina Anatomica Veterinaria, 5th ed. (revised version).
http:/www.wava-amav.org

Yonkova, P., 2014. Morphological studies on the mast depots of the New Zealand white rabbit. Doctoral dissertation, *Trakia University*, Stara Zagora, Bulgaria.

Received March, 13, 2018; accepted for printing May, 21, 2018