

## Helical computed tomography application in rabbit liver anatomy: comparison with frozen cross-sectional cuts

Kamelia STAMATOVA YOVCHEVA<sup>1\*</sup>, Rosen DIMITROV<sup>1</sup>, Yuliana TONEVA<sup>2</sup>, Penka YONKOVA<sup>1</sup>,  
Dimitar KOSTOV<sup>1</sup>, Anton RUSENOV<sup>3</sup>, Krassimira UZUNOVA<sup>4</sup>, Violeta YORDANOVA<sup>5</sup>

<sup>1</sup>Department of Veterinary Anatomy, Histology, and Embryology, Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

<sup>2</sup>Department of Medical Physics, Biophysics, Roentgenology, and Radiology, Faculty of Medicine, Trakia University, Stara Zagora, Bulgaria

<sup>3</sup>Department of Non-Infectious Diseases, Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

<sup>4</sup>Department of General Animal Breeding, Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

<sup>5</sup>Faculty of Veterinary Medicine, Trakia University, Stara Zagora, Bulgaria

Received: 05.11.2012 • Accepted: 19.12.2012 • Published Online: 26.08.2013 • Printed: 20.09.2013

**Abstract:** Our focus has been to study and compare the anatomical helical computed tomography (CT) features of the normal rabbit liver with its native cross-sectional anatomy. Helical CT was used for scanning the cranial part of the abdominal cavity. The slice thickness was 5 mm. Frozen transversal anatomic cross-sections with a thickness of 10 mm were obtained from the cranial abdominal part of 4 animals following euthanasia. They were compared with the corresponding helical CT scans. At Th9 (thoracic vertebra), the helical CT images showed in the whole aspect a normal liver. It was a massive, heterogeneous, soft tissue, with normal attenuating findings and distinguished edges. The gallbladder was hypoattenuated compared to the liver parenchyma. At the level of Th11 the liver was in sharp distinction to the fundus and body of the stomach. At Th12 the rabbit liver was found in close contact with the stomach, duodenum, and ascending colon. Only the right hepatic lobe was visible at the level of Th13, outlined by the right kidney impression. The right hepatic and caudate lobe were observed at L1 (lumbar vertebra). The frozen cross-sections have analogues to the corresponding helical CT images. That motivated us to conclude that helical CT is an accurate mode for studying the rabbit liver anatomy.

**Key words:** Rabbit, liver, helical computed tomography, cross-sectional anatomy

### 1. Introduction

Computed tomography (CT) is a suitable anatomic imaging technique for providing detailed information about internal organ morphology in small animals and humans without contrast enhancement (1).

The rabbit liver consists of 4 lobes: right hepatic lobe, left hepatic lobe (separated in lateral and medial parts), quadrate lobe, and caudate lobe. The quadrate lobe is underdeveloped and a marker for its position is the fossa of the gallbladder. The caudate process of the caudate lobe carries the right kidney impression. The rabbit liver is situated in the epigastric region. It touches the stomach fundus, caudal, and caudate process and covers the cranial part of the duodenum (2,3).

Frank et al. (4) performed a helical anatomic CT study of the liver and portal system in clinically normal dogs in order to create a base for normal imaging features of this organ. This particular technique could help in surgical interventions tremendously, with a decrease of time and degree of necessary invasive dissections. The canine

liver has been observed at the level of Th12–13 (thoracic vertebra) or Th13–L1 (lumbar vertebra).

In feline viscera imaging anatomy, CT is widely applied because of the accurate results obtained by this mode. For best visualization of the feline heart and its adjacent structures, the animals should be positioned in supine and sternal recumbency with a thickness of slices of 5 mm, as observed by Vladova et al. (5,6), Vladova (7), and Pazvant et al. (8).

Samii et al. (9) performed a CT study of the feline thorax and abdomen and proved the correspondence between the results obtained by this imaging modality and regional cross-sectional anatomy of the scanned structures. The same approach is being used for the atlas of normal cross-sectional, gross, and CT anatomy of the feline thorax and abdomen for interpretation of any cross-sectional imaging modality.

Smallwood and George (10) produced an atlas of CT anatomy from the thorax and cranial abdomen in dogs. The animals were positioned in sternal recumbency with

\* Correspondence: kameliayovcheva@abv.bg

a slice thickness of 13 mm. The CT anatomical features of the organs were then compared with the frozen cross-sectional cuts of 13 mm thickness.

A helical CT and cross-sectional anatomical study of the canine abdomen was performed (11). The dogs were posed in sternal recumbency with 5-mm scan thickness. Bone markers for canine liver scanning were the vertebrae from the 9th thoracic to the 1st lumbar. The canine liver was in close contact with the stomach, duodenum, ascending colon, and right kidney according to the authors.

There were few case reports concerning abdominal CT imaging using helical scanners. Compared to other imaging modalities, which were often used for abdomen imaging, helical CT provided more detailed anatomic information (12).

Ivancev et al. (13), Ducommun et al. (14), and Sun et al. (15) used the rabbit liver as an imaging CT model. These authors obtained significant results using the rabbit liver model for CT imaging of the human liver.

Zotti et al. (16) carried out a CT anatomic study in rabbits in sternal recumbency using a slice thickness of 5 mm for interpretation of any cross-sectional imaging modality in this species.

The rationale of the present study was to investigate and prove the correspondence between helical CT imaging modality of rabbit normal liver with its regional cross-sectional anatomy.

## 2. Materials and methods

### 2.1. Animals

Seven mature, clinically healthy rabbits (4 male and 3 female), 8 months of age, from the New Zealand white rabbit breed with weight between 2.8 kg and 3.2 kg were studied. The experimental animals were housed at 25 °C, with a 12-h dark/light cycle (17).

### 2.2. Anesthetic protocol

The precision of the investigation protocol required the movements of the studied animals to be minimized. The rabbits were anesthetized intramuscularly with Ketaminol 10 solution (Intervet; ketamine hydrochloride 100 mg/mL and benzethonium chloride 0.1 mg/mL) of 0.5 mL/kg.

### 2.3. Imaging protocol

A whole-body multislice helical CT scanner (LightSpeed QX/I GE, General Electric) was used for the scanning. Seven animals were placed on the CT table in the ventrodorsal (supine) position. For each studied rabbit, a total of 16 transversal slices were captured from the body at Th9 (thoracic vertebra) to L1 (lumbar vertebra). Bone markers were used from Th9 to L1 and the sternum. Slice thickness was 5 mm (8,15). The anatomic helical CT scans were done by the following protocol: electric current intensity, 200 mA; anode tension, 120 kV; scanning time, 0.8 s, 1 maximum to 2 s; rotational speed, 360° in 0.8, 1,

2, 3, and 4 s; pitch, 6; converting filter, standard; tilt, 0.5; exposure time, 1981 s; zoom, 6.97; level, 35, window (W), 350; high resolution, 512; scan field of view, 50; modulation transfer function 10 in lp/cm, 13.6. The films were obtained by printing device (Drystar AXYS, AGFA Healthcare) with film size DT 2B 14/17 inches. The images were documented and interpreted by DICOM (Digital Imaging and Communications in Medicine). CT density of the rabbit liver was detected informatively for the protocol.

### 2.4. Transversal native study

Four of the studied animals were euthanized with 150 mg of Thiopental (50 mg/kg, intravenously) (thiopental sodium 1000 mg, Biochemie). The cadavers were subsequently frozen at -20 °C. For the purpose of the cuts, a MAX RTR RTM908 electrical saw was utilized. Transversal cuts with a thickness of 10 mm were obtained, starting from the cranial abdominal region following the imaging protocol. The frozen sections were cleaned and then photographed on each side. Anatomical structures, identified from the frozen sections, were compared with the corresponding CT images (15).

The manipulation was in accordance with the requirements of the American Veterinary Association for euthanasia. The obtained data were used to compare the liver imaging anatomical features with those of its topography in situ.

### 2.5. Ethical protocol

The study was approved by the decision of the Institutional Animal Care and Use Committee (No. 51, 29 September 2012). The experiments were done in strict compliance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 16 May 1986), European Convention for the Protection of Pet Animals (Strasbourg, 13 November 1987), and Animal Protection Act in the Republic of Bulgaria (Section IV, Experiments With Animals, articles 26, 27, and 28, received on 24 January 2008 and published in Government Gazette No. 13, 2008).

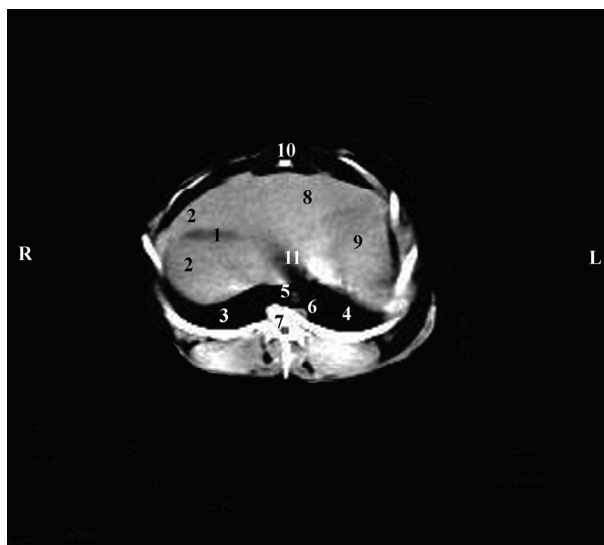
## 3. Results

Transversal helical CT images at the level of Th9 showed that the rabbit liver was situated in the epigastric region. The normal rabbit liver was a massive, heterogeneous, soft tissue structure. It showed normal attenuation. The right lobe of the liver was observed as a single structure, while the left one was separated in medial and lateral parts. There were not any visible borders between the right and left lobes of the liver. The gallbladder (to the right) was observed as an ellipsoidal structure, with low attenuation, compared to the liver parenchyma. The quadrate lobe was not seen because of its small size. The point of its position was the gallbladder. The liver edges were sharply distinguished from the adjacent soft tissue structures.

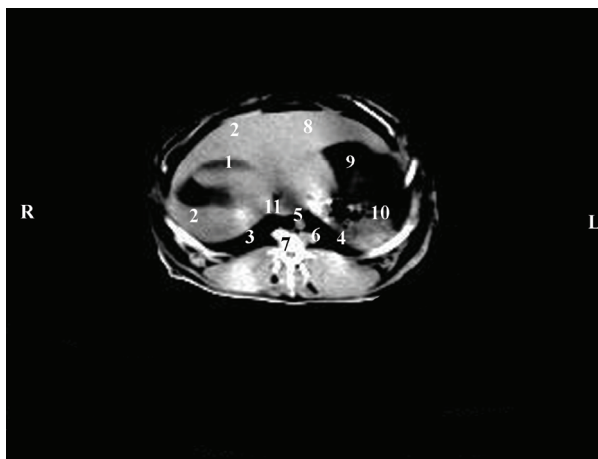
Parts of both lungs (right and left) were visible at the level of Th9. They showed lower attenuation compared to the liver. The dorsal edge (to the right) of the liver was in close contact with the caudal vena cava, as the last was observed as a hypoattenuated structure with irregular shape to the liver parenchyma. The esophagus (to the left) was observed between the liver and both lungs. It showed low attenuation and regular ovoid shape. The aorta was visualized dorsally (on the left), in close contact to Th9 with similar density to the liver parenchyma and regular elliptical shape, and in sharp distinction to the other soft tissue findings (Figure 1).

At the level of Th11, the left medial lobe of the liver was in sharp distinction from the stomach. The right hepatic lobe was a massive structure surrounding the hypoattenuated gallbladder. The stomach fundus and body (to the left) appeared at the level of Th11. At Th11 the end part of the esophagus (to the left) was visible between both hypoattenuated lungs. It had lower density compared to the liver and was round in shape (Figure 2).

Detailed helical CT images of the stomach (body, fundus, and pylorus, medial, to the left, and to the right) with the duodenum rising (to the right) were observed at the level of Th12. These were in close contact to the visceral surface of the normally attenuated right lobe of the liver. The lesser and greater curvatures of the stomach were observed as thin hyperattenuated lines, outlining the stomach structures from the adjacent structures. The caudal vena cava was visualized in close contact to the dorsal right edge of the liver. Stomach parts and duodenum



**Figure 1.** Transversal helical CT scan of rabbit liver at the level of Th9. (1) Gallbladder; (2) right lobe of liver; (3) right lung; (4) left lung; (5) esophagus; (6) abdominal aorta; (7) Th9; (8) left medial lobe of liver; (9) left lateral lobe of liver; (10) sternum; and (11) caudal vena cava.

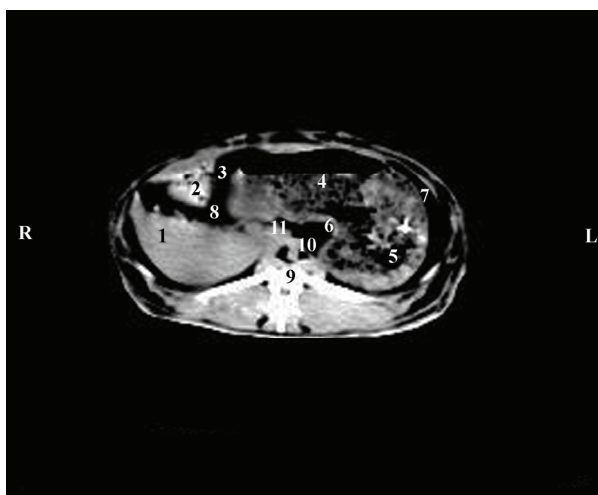


**Figure 2.** Transversal CT scan of the cranial abdominal region at the level of Th11. (1) Gallbladder; (2) right lobe of liver; (3) right lung; (4) left lung; (5) esophagus; (6) abdominal aorta; (7) Th11; (8) left lobe of liver; (9) body of stomach; (10) fundus of stomach; and (11) caudal vena cava.

showed a lower tissue density compared to the liver. At the level of Th12, the ascending colon was distinguishable (Figure 3).

At the level of Th11 and Th12 the caudal vena cava and the rising portion of the abdominal aorta were scanned. The abdominal aorta was observed close to Th11 and Th12 (Figures 2 and 3).

At the level of Th13, the rabbit liver was visible only with the end part of the right and caudate lobes, which showed normal attenuation. At Th13 the kidney impression (to



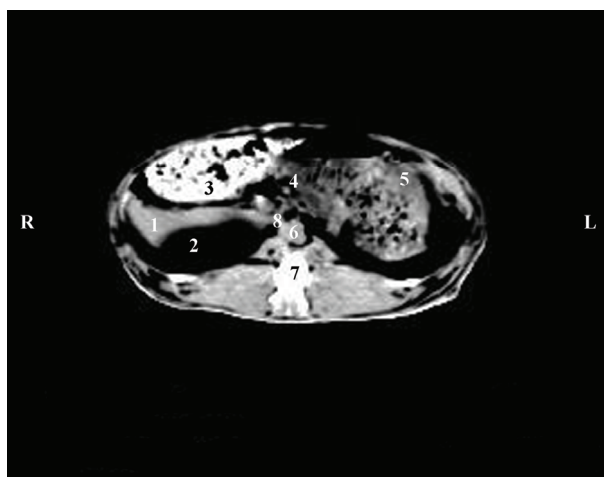
**Figure 3.** Transversal CT scan of the cranial abdominal region at the level of Th12. (1) Right hepatic lobe; (2) ascending colon; (3) pylorus of stomach; (4) body of stomach; (5) fundus of stomach; (6) lesser curvature of stomach; (7) greater curvature of stomach, (8) duodenum; (9) Th12; (10) abdominal aorta; and (11) caudal vena cava.

the right) had lower density compared to the liver. The cecum was in close contact to the ventral abdominal wall (to the right), hypoattenuated ascending colon (to the left), and normally attenuated right lobe of the liver. The mesenterium was observed as a hypoattenuated structure with irregular outlines. The abdominal aorta was in close proximity to the ventral surface of Th13 and near the caudal vena cava, showing low tissue opacity (Figure 4).

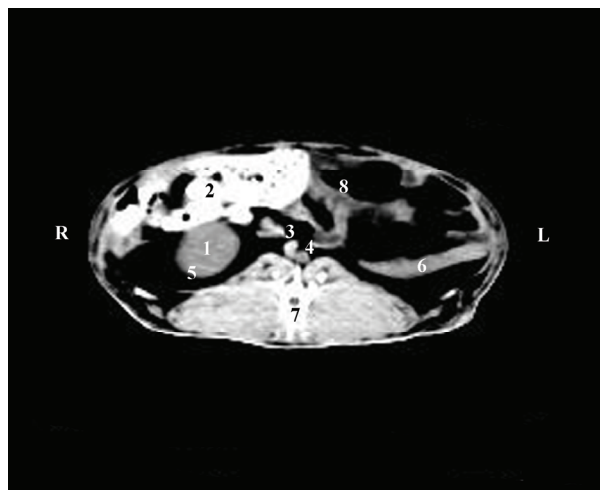
At the level of L1, the right hepatic and caudate lobes of the liver appeared as a single structure, distinguished from one another by a hypoattenuated line. At this level the visceral surface of the rabbit liver touched the cecum. The jejunal ansa appeared hypoattenuated, enveloped by the hyperattenuated mesenterium. At L1 the spleen was observed as a normally attenuated structure with elongated shape. The caudal vena cava and abdominal aorta were observed as soft tissue structures, well distinguished from one another (Figure 5).

The results of the anatomic transversal frozen cross-sectional study at the level of Th9 demonstrated the position of the rabbit liver lobes. The rabbit liver was situated in the epigastric region between both costal arches. The left and right lungs were in sharp distinction to the rabbit liver lobes. The right lobe of the liver and lateral and medial parts of the left lobe of liver were found, as well. The gallbladder was surrounded by the right hepatic lobe. It did not reach beyond the rabbit liver outlines. The quadrate lobe was small in size, positioned under the gallbladder. The dorsal edge of the organ was in close contact with the esophagus and the caudal vena cava. At the level of Th9, the beginning of the abdominal aorta was found close to the body of the vertebra (Figure 6).

The transversal cross-sectional frozen cuts at the level of Th12 showed the close contact of the right hepatic lobe



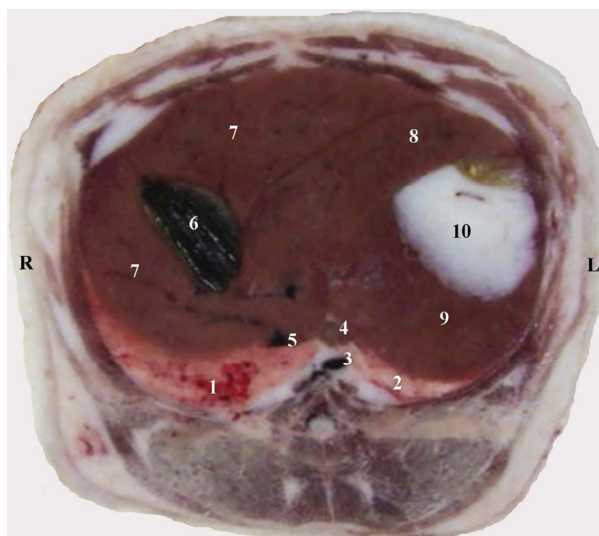
**Figure 4.** Transversal CT image of the cranial abdominal region at the level of Th13. (1) Right lobe of liver; (2) kidney impression; (3) cecum; (4) mesenterium; (5) ascending colon; (6) abdominal aorta; (7) Th13; and (8) caudal vena cava.



**Figure 5.** Transversal CT image of the cranial abdominal region at the level of L1. (1) Right lobe of liver; (2) cecum; (3) caudal vena cava; (4) abdominal aorta; (5) caudate lobe; (6) spleen; (7) L1; and (8) jejunal ansa.

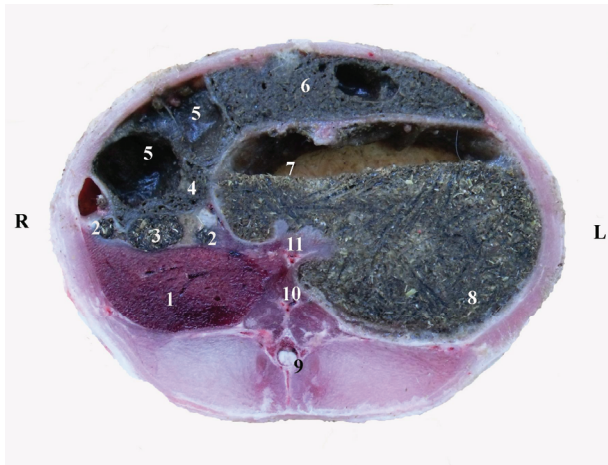
with the jejunal ansa and duodenum. Parts of the stomach (fundus and body) were situated left of the liver. At the visceral surface of the right lobe of the liver in the ventral direction the cecum and transverse and ascending colon were found, as they reached the ventral abdominal wall (Figure 7).

At the level of L1, on transversal frozen cross-sectional cuts, parts of the right lobe of the liver with the caudate lobe were found. They touched the duodenum ventrally.



**Figure 6.** Transverse anatomical topographic cut of rabbit liver at the level of Th9. (1) Right lung; (2) left lung; (3) abdominal aorta; (4) esophagus; (5) caudal vena cava; (6) gallbladder; (7) right lobe of liver; (8) left medial lobe of liver; (9) left lateral lobe of liver; and (10) adipose tissue.





**Figure 7.** Transverse cross-sectional cuts of the cranial abdominal region at the level of Th12. (1) Right hepatic lobe; (2) jejunum; (3) duodenum; (4) transversal colon; (5) ascending colon; (6) cecum; (7) body of stomach; (8) fundus of stomach; (9) Th12; (10) abdominal aorta; (11) caudal vena cava.

Left of the liver was the spleen. Ventral and lateral to the liver were the cecum with parts of the ascending colon. The jejunal ansae were posed ventral to the whole intestinal mass. To the right dorsal edge of the liver was the caudal vena cava. Close to the body of L1 was the abdominal aorta (Figure 8).

The investigated organs showed soft tissue characteristics that were measured in 40–50 Hounsfield units (HU).

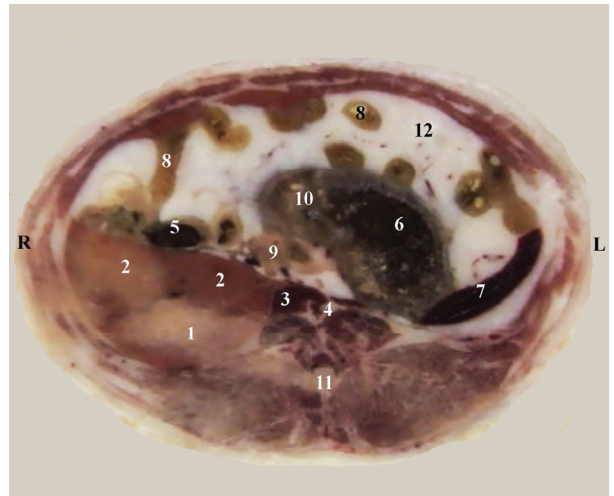
#### 4. Discussion

Our results confirmed the anatomical data of Barone (2,3) about rabbit liver topography and its morphological features. The rabbit liver consisted of the same lobes as those reported by Barone (2,3). On anatomic helical CT and cross-sectional study the liver quadrate lobe has been underdeveloped and a particular marker for its position has been the fossa of the gallbladder.

Similar to the work of Frank et al. (4) and Teixeira et al. (11), an anatomic helical CT study of the liver was performed in clinically normal animals in order to create data for its normal helical CT features. The bone markers used for visualization of the rabbit liver were the same thoracic and lumbar vertebra used by Frank et al. (4) for dogs.

The rabbit liver had the same CT and cross-sectional anatomic topography and closeness to other abdominal organs (stomach, duodenum, ascending colon, and right kidney) as was confirmed by Teixeira et al. (11) for the dog. Helical CT and cross-sectional anatomy of the rabbit abdomen was also previously performed (11).

In accordance with the findings of Vladova et al. (5,6), Vladova (7), and Pazvant et al. (8), the accuracy of the helical



**Figure 8.** Transverse cross-sectional cuts of the cranial abdominal region at the level of L1. (1) Caudate lobe; (2) right lobe of liver; (3) caudal vena cava; (4) abdominal aorta; (5) duodenum; (6) cecum; (7) spleen; (8) jejunal ansa; (9) mesenterium; (10) ascending colon; (11) L1; and (12) adipose tissue.

CT imaging modality for anatomical investigation of the small animal viscera (liver) was the grounds for carrying out the present study. Similar to the reports of Vladova et al. (5,6), Vladova (7), and Pazvant et al. (8), detailed helical CT imaging of the normal rabbit liver was obtained here with a thickness of CT slices of 5 mm. Contrary to Pazvant et al. (8), who used CT sternal recumbency in the cat, the position used here in rabbit was supine.

The present study aimed to compare the anatomic helical CT images of the rabbit liver with its regional cross-sectional anatomy. There was correspondence between data of the anatomic helical CT study and transversal native study, as also reported by Samii et al. (9) for the cat.

In the investigation of Smallwood and George (10) for the thorax and cranial abdomen of the dog, significant results were demonstrated using lower CT and transversal native straightforward thickness of slices at 5 mm and 10 mm. The used recumbency was supine.

The anatomic imaging results corresponded to those of Ivancev et al. (13), Ducommun et al. (14), and Sun et al. (15) for the use of rabbit liver as an animal imaging CT model for human and animal liver anatomy.

Similar to other authors who investigated rabbit viscera anatomy using CT (16), the slice thickness of the present study was 5 mm. Accurate data were collected by animals positioned in supine recumbency, contrary to Zotti et al. (16).

Our results give us motivation, in accordance with previous studies (1,12) of small animals, to draw the conclusion that helical CT imaging modality is suitable to be applied in the rabbit.

The present study proved the correspondence between helical CT imaging features of rabbit liver with its native cross-sectional anatomy.

In conclusion, the whole liver helical CT image was observed at the level of Th9. The marker of position of the quadrate lobe was the gallbladder. At the level of Th11 and Th12, the closeness of the rabbit liver to the other abdominal organs (stomach, cecum, colon, and small intestines) was observed. At the level of Th13, the right kidney impression appeared, which proved the close

contact between the liver caudate lobe and the right kidney. At the level of L1, the right hepatic and caudate lobe of the liver appeared as a single structure. Data of helical CT features of the normal rabbit liver demonstrated similarity to frozen cross-sectional cuts regarding morphology of organs and particular topography. That could facilitate the contemporary interpretation of liver anatomy in rabbits and serve as a source of data for diagnosing actual liver disorders and diseases in humans and small mammals.

## References

1. Bartling, S.H., Stiller, W., Semmler, W., Keissling, F.: Small animal computed tomography imaging. *Curr. Med. Imag. Rev.*, 2007; 3: 45–49.
2. Barone, R.: *Anatomie Comparée des Mammifères Domestiques*, Tome 3. Splanchnologie I. 3rd edn., Vigot, Paris. 1997.
3. Barone, R.: *Anatomie Comparée des Mammifères Domestiques*, Tome 4. Splanchnologie II. 3rd edn., Vigot, Paris. 2001.
4. Frank, P., Mahaffey, M., Egger, C., Cornell, K.: Helical computed tomographic portography in ten normal dogs and ten dogs with a portosystemic shunt. *Vet. Radiol. Ultrasound*, 2003; 44: 392–400.
5. Vladova, D., Georgiev, P., Toneva, Y., Georgiev, H., Sivrev, D., Stefanov, M.: Comparative anatomy of the heart in the cat in topographic, computer-tomographic and sonographic slices. *Trakia J. Sci.*, 2005; 3: 30–33.
6. Vladova, D., Stefanov, M., Toneva, Y.: Computed tomography study of thoracic aorta in the cat. *Bulg. J. Vet. Med.*, 2005; 8: 151–156.
7. Vladova, D.: Morphofunctional particularities of the heart vascularization in the cat. PhD, Trakia University, Stara Zagora, Bulgaria. 2007.
8. Pazvant, G., Gezer İnce, N., Bacınoğlu, D., Bakırel, U.: Examination of morphometry of feline thoracic aorta with computed tomography. *Turk. J. Vet. Anim. Sci.*, 2011; 36: 698–704.
9. Samii, V.F., Biller, D.S., Koblik, P.D.: Normal cross-sectional anatomy of the feline thorax and abdomen: comparison of computed tomography and cadaver anatomy. *Vet. Radiol. Ultrasound*, 1998; 39: 504–511.
10. Smallwood, J.E., George, T.F.: Anatomic atlas for computed tomography in the mesaticcephalic dog: caudal abdomen and pelvis. *Vet. Radiol. Ultrasound*, 1992; 33: 143–147.
11. Teixeira, M., Gil, F., Vasquez, J.M., Cardoso, L., Arencibia, A., Ramirez-Zarzosa, G., Agut, A.: Helical computed tomographic anatomy of the canine abdomen. *Vet. J.*, 2007; 174: 133–138.
12. Novelline, R.A., Rhea, J.T., Rao, P.M., Stuk, J.L.: Helical CT in emergency radiology. *Radiol.*, 1999; 213: 321–329.
13. Ivancev, K., Lunderquist, A., McCuskey, R., McCuskey, P., Wretling, A.: Experimental investigation of a new iodinated lipid emulsion for computed tomography of the liver. *Acta Radiol.*, 1989; 30: 407–413.
14. Ducommun, J.C., Goldberg, H.I., Korobkin, M., Moss, A.A., Kressel, H.Y.: The relation of liver fat to computed tomography numbers: a preliminary experimental study in rabbits. *Radiology*, 1979; 130: 511–513.
15. Sun, C., Liu, C., Wang, X.M., Chen, J., Wang, D., Merges, R.: Functional CT in a rabbit model: evaluation of the perfusion characteristics before and after Ar-He cryoablation therapy. *J. Med. Imag. Rad. Oncol.*, 2008; 52: 351–357.
16. Zotti, A., Banzato, T., Cozzi, B.: Cross-sectional anatomy of the rabbit neck and trunk: comparison of computed tomography and cadaver anatomy. *Res. Vet. Sci.*, 2009; 87: 171–176.
17. Uzunova, K.: *Hygiene, Ethology and Animal Protection*. Jemmy Stratus Ltd., Stara Zagora, Bulgaria. 2011.