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DETAILED MORPHOLOGICAL DESCRIPTION OF THE LIVER AND HEPATIC LIGAMENTS IN THE GUINEA PIG (*CAVIA PORCELLUS*)

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Abstract

The paper aimed to present the gross anatomy of liver and its ligaments in guinea pigs. The liver is located into intrathoracic part of abdominal cavity, having six separate lobes (right lateral, right medial, left lateral, left medial, caudate, and quadrate) but well connected one with each other. The falciform ligament which apparently divides the diaphragmatic surface of the liver in two territories –the right and left hepatic territories, was complete, being attached to the undersurface of the diaphragm and the dorsal surface of the abdominal wall at the level of the umbilicus. Its free edge contains the round ligament. The coronary ligament was well delineated being composed by an upper and a lower layer. Both the right and left triangular ligaments were present. The left triangular ligament was well developed connecting the left lateral lobe to the diaphragm. Cranial insertion of hepatorenal ligament was visualized on the ventral border of the caudate process, then run to the medial aspect of the right kidney, and to the descending loop of the duodenum. The liver is also attached to the stomach and to the duodenum by hepatogastric and hepatoduodenal ligament. A free edge of the hepatoduodenal ligament, whose cranial insertion was on the cystic duct, down along the common bile duct to be inserted on right lobe of pancreas, it was clearly visualized.

Key words: *liver, hepatic ligaments, anatomy, guinea pig.*

INTRODUCTION

There is a general agreement about the presence of two main hepatic territories, right and left provided by portal vein bifurcation in mammalian liver (Rex 1888, McIndoe and Counseller 1927, Couinaud, 1954; Abdel-Misih et al., 20110; Bismuth, 2013; Fasel, and Schenk, 2013). The liver lobes, the number and their nomination, each with its own vascular and biliar system are still subject of debate, both in human and veterinary medicine. Also, the biliar system, especially the extrahepatic billiary tract shows anatomical differences within the same species. From rodents order, the most studied is rats liver due to their use as an experimental model in surgical hepatectomy (Higgins 1931; Madrahimov et al., 2006; Martins and Neuhaus, 2007; Martins et al., 2008). The rat liver is composed of four lobes and resembles the sector delimitation of the human liver (Kogure et al., 1999; Vdoviaková et al., 2016) and presents the same ligaments as in humans (Martins and Neuhaus, 2007). From caviomorphs, the description of chinchillas liver, point out the presence of four lobes with a little lobulation which is grossly visible at the surface (Lyon 2003, Spotorno et al., 2004). The gallbladder is located between the right and medial lobes, having 2-3 cystic ducts and a complex hepatic ducts system (Nowak et al., 2014). The guinea pigs liver was described having six lobes (Cooper and Schiller, 1975; Breazile and Brown 1976) and a well developed gallbladder. In rabbit, anatomical books described the presence of five liver lobes (Barone, 2009) while in scientific literature are reports who claim the presence of four liver lobes (Brewer, 2006) along the absence of the common hepatic duct. The hepatic ligaments in rabbits and nutria were detailed described by Perez (Pérez et al., 2005; Pérez and Lima 2007). The aim of this study is to describe the macroscopic anatomy of the liver and its ligaments in guinea pigs.

MATERIALS AND METHODS

Ten adult guinea pigs, four male and six female (mean body weight 420±50g) were used. The Institutional Bioethics Committee of University of Agricultural Science and Veterinary Medicine in accordance to Directive 2010/63 /EU of the European Parliament and of the Council on the protection of animals used for scientific purposes approved the study. Euthanasia was performing by administration of an overdose of isoflurane. The abdominal cavity was opened and the wall of it were carefully removed in order to visualize and to photograph the hepatic ligaments and lobulation.

RESULTS AND DISCUSSIONS

Topograpy and surfaces

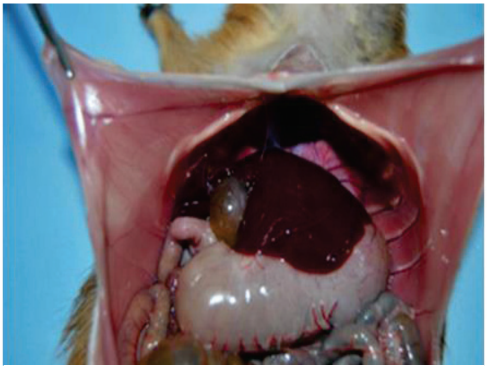

Figure 1. The liver topography. The liver occupied two thirds of the intrathoracic part of abdominal cavity

The guinea pig liver (*Hepar*) occupied two thirds of the intrathoracic part of abdominal cavity (Figure 1). It was multilobulated, having deep fissures, being composed of six lobes, light brown in colour and the average weight was 20.3 g. The liver mass represents 6% from the total body weight. The transverse diameter measured 9.8 cm ± 0.7 cm and the longitudinal diameter measured 6.2 ± 0.4 cm (Table 1).

Table 1. Liver morphometry

	Weight	Transversal diameter	Longitudinal diameter	Depth
Liver	20 g	9.8±0.7 cm	6.2±0.4 cm	1.8±03 cm

Concave diaphragmatic (*Facies diaphragmatica*) and convex visceral (*Facies visceralis*) surfaces were recognized. The visceral surface of the liver was in relation with the stomach, duodenum, pancreas, right colic flexure and right kidney (Figure 2). The liver lobes were clearly delimitated on the visceral surface and the porta hepatis (*Porta hepatis*) contained the principal's structures namely: hepatic artery, portal vein and hepatic ducts. On the diaphragmatic surface, the liver shows only four lobes (Figure 3).

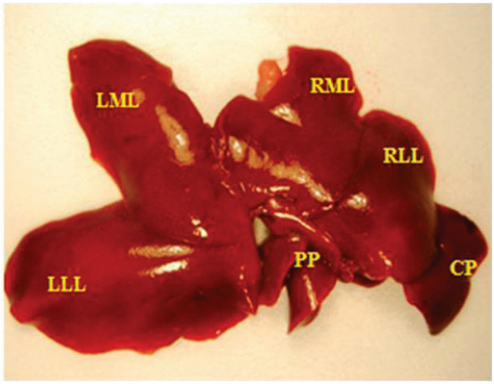

Figure 3. Diphragmatic surface of the liver. LLL-left lateral lobe; LML-left medial lobe; RML-right medial lobe; RLL-right medial lobe; CP-caudate process; PP-papillary process

The falciform ligament apparently divides the diaphragmatic surface in two territories –the right and left, each territory showing only two lobes on this surface. The dorsal margin (*Margo dorsalis*) was rounded and presents the imprint of inferior cava vein and esophagus. The lateral and ventral (*Margo ventralis*) margins were sharp, the lateral margins were interposed between the diaphragm and the hypocondrium and the ventral margin was in relation with the ventral surface of the stomach for the left lobes and with the duodenum and ascendant ansa of the proximal colon for the right lobes.

Liver lobes

We considered that the portal vein and its branches, the billiary tract and the arterial supply of the liver divided the liver in right and left territories. The right lobe (*Lobus hepatis dexter*) was subdivided by a deep fissure into right medial lobe (*Lobus hepatis dexter medialis*), and right lateral lobe (*Lobus hepatis dexter lateralis*). On the diaphragmatic surface, from the medial border of the right medial lobe, the falciform ligament connects the liver with the diaphragm (Figure 4).

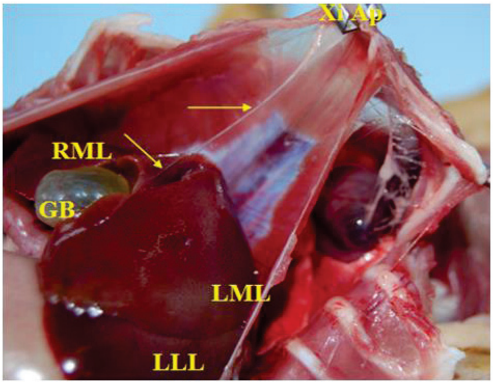

Figure 4. The falciform ligament connect the liver to the diaphragm. Posterior insertion was made on the aponevrotic region of diaphragm, being in contact with the upper layer of the coronary ligament

On the diaphragmatic surface of the right medial lobe a small groove corresponding to the inferior vena cava was noted. The ventral edge of the right medial lobe circumscribes the gallbladder fundus. In the left territory of the liver, (*Lobus hepatis sinister*) the left medial lobe (*Lobus hepatis sinister medialis*) and the left lateral lobe (*Lobus hepatis sinister lateralis*) were well delimited by a deep fissure. The left lateral lobe was the largest lobe and it was covered on the diaphragmatic surface by the left medial lobe. On the visceral surface, medial from the gallbladder, between the gallbladder fossa, porta hepatis and round ligament, the small quadrate lobe (*Lobus quadratus*) was visualised (Figure 5).

Dorsal from the porta hepatis, the connection pedicle of caudate lobe (*Lobus caudatus*) was seen, making the bond of this lobe with the right lateral lobe. The caudate lobe was composed of two parts: a well developed caudate process (*Processus caudatus*), behind to the right lateral lobe, having an obvious right kidney imprint and a papillary process (*Processus papillaris*) subdivided in two triangular segments, one of these segments reaching the small curvature of the stomach, on the right side of the esophagus. On the visceral surface, on the medial edges of the left lateral lobe and of the caudate process, small notches were visualized.

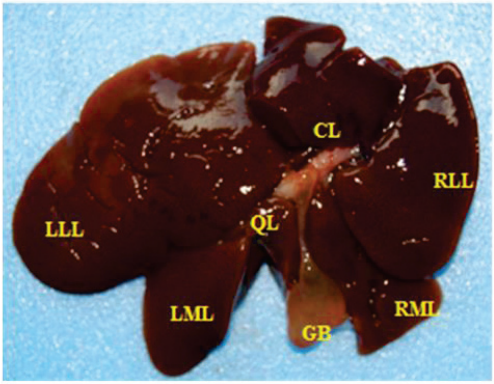

Figure 5. Delineation of liver lobes on the visceral surface. The most developed left lateral lobe - LLL; LML - left medial lobe; GB - gall bladder in gall bladder fosa between the quadrate lobe – QL and right medial lobe – RML; RLL – right lateral lobe; CL – caudate lobe.

Hepatic ligaments

The falciform ligament (*Lig. falciformes hepatis*) was well developed under the diaphragm surface, appeared like a thin fold, had a slightly oblique position making the connection of the liver to the under surface of the diaphragm (Figure 6).

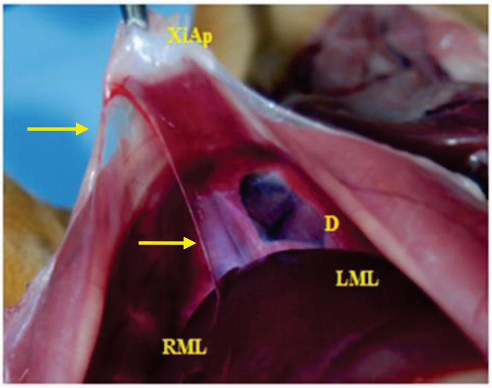

Figure 6 Complete falciform ligament in guinea pig. The falciform ligament extends from the xiphoid appendix, backward to the ventral abdominal wall -arrows

Its liver insertion was made by the union of the two folds from the diaphragmatic surface of the medial lobes, at the level of the main fissure. Posterior insertion was made on the aponevrotic portion of diaphragm and to the upper layer of the coronary ligament.

Anterior, the falciform ligament runs to the xiphoid appendix extending backward to the ventral abdominal wall. The falciform ligament was complete in all subjects. In the free margin of the falciform ligament, ascending from the umbilicus, the round ligament (*Lig. teres heaptis*) was visualised. On the visceral surfaces, the ligament provides a demarcation through its fissure (*Fissura lig. teres*) between the quadrate lobe and the left medial lobe of the liver (Figure 7).

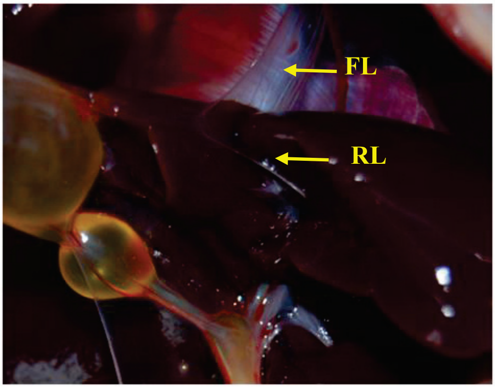

Figure 7. The round ligament – RL. On the visceral surface of the liver its fissure provides delineation between the quadrate lobe and the left medial lobe.

The coronary ligament (*Lig. coronarium hepatis*) bordered the inferior vena cava being the direct continuation of the falciform ligament on the dorsal margin of the liver (Figure 8).

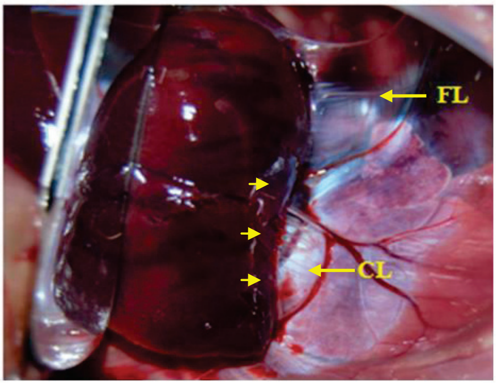

Figure 8. The coronary ligament – CL is a direct continuation of falciform ligament – FL, on the dorsal margin of the liver. The two layers of coronary ligament delineates a small bare area between them – small arrows.

It was composed of two layers, upper and lower layer which demarcates a small bare area between them, the upper layer being the direct continuation of the falciform ligament to the right. Dorsal and toward to the right, the two layers formed a short and tight right triangular ligament (*Lig. triangulare dextrum*). The left triangular ligament (*Lig. triangulare sinistrum*) was well developed in all subjects, having a conspicuous insertion on the lateral diaphragmmatic surface of the left lateral lobe including the dorsal edge of this lobe (Figure 9).

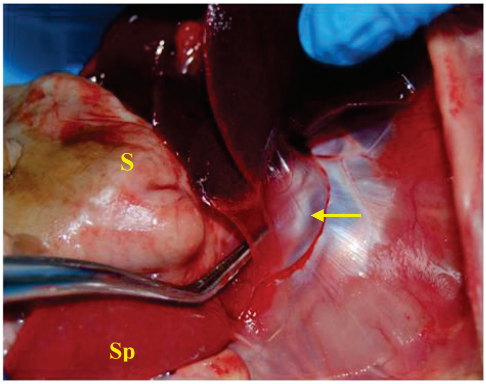

Figure 9 The well developed left triangular ligament connecting the lateral diaphragmatic surface and the dorsal edge of left lateral lobe to the diaphragm. S – stomach; Sp – spleen.

The hepatorenal ligament (*Lig. hepatorenale*) had a particular insertion. Cranial insertion of hepatorenal ligament was visualized on the ventral border of the caudate process, then run to the medial aspect of the right kidney, caudal insertion being on the terminal segment of ascending duodenum (Figure 10).
Hepatogastric ligament (*Lig. hepatogastricum*) was well individualized connecting the lesser curvature, near to the right side of the esophagus, with the papillary process of caudate lobe (Figure 11). The cranial part of the lesser omentum extend from the left side of the porta hepatis, near to the right side of the esophagus to the lesser curvature of the stomach, as the hepatogastric ligament. The caudal insertion of the hepatogastric ligament attaches the lesser curvature of the stomach to the papillary process of the liver, to the right of which the hepatogastric ligament continues as the hepatoduodenal ligament (*Lig. hepatoduodenale*) (Figure 11).

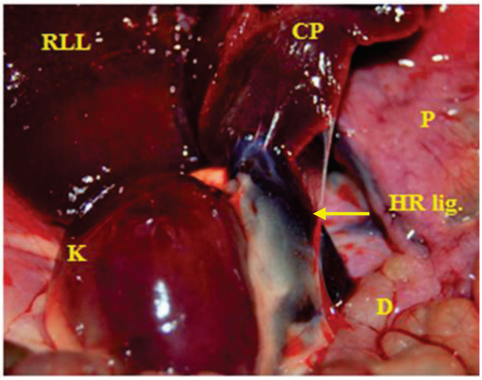

Figure 10 The hepatorenal ligament (arrow) connects the ventral border of caudate process- CP to the medial border of the right kidney – K; RLL – right lateral lobe; D – duodenum; P – pancreas.

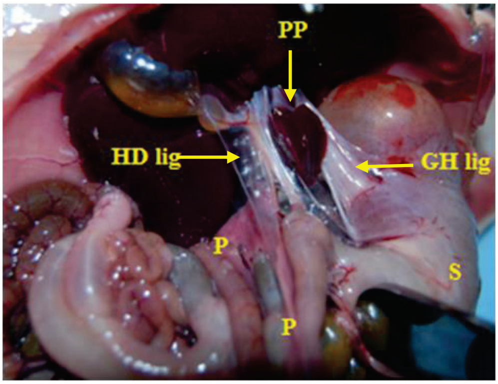

Figure 11 The hepatoduodenal ligament – HD lig. and the hepatogastric ligament – GH lig. P-pancreas; S – stomah; PP-papillary process.

In its thickened margin on the right side were identified three important structures: the common bile duct (*Ductus hepaticus communis*), hepatic artery (*A. hepatica*), and portal vein (*V. portae*).

These structures have the following relationship: the common bile duct lies ventrally and to the right, the hepatic artery lies ventrally and to the left, the portal vein lies dorsally to the above mentioned structures and the inferior vena cava lies more dorsally, behind the portal vein. Also, a free edge of this ligament whose cranial insertion was on the cystic duct, down along the common bile duct to be inserted on right lobe of pancreas, it was clearly visualized (Figure 12).

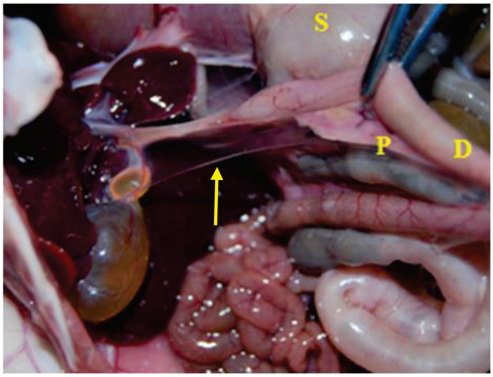

Figure 12 The hepatoduodenal ligament (arrow). Its caudal insertion was made on the right lobe of the pancreas – P. D – duodenum; S - stomach

The anatomies of liver and hepatic ligaments in domestic animals are well described in scientific literature (Barone 2009). Also, the liver, hepatic ligaments, biliary tract and gallbladder was intensively studied in humans both in terms of gross anatomy and vascularrisation (Aharinejad and Lametschwandtner, 1992; Lamah et al., 2001; Ellis, 2011; Mahadevan, 2014). Comparing to the humans liver, the most studied experimental model, from the rodent order is the rat liver – Wistar rat (Kogure et al., 1999). Studying the topographical anatomy, portal, arterial and biliary branching system, it was found that the rat liver is composed of four lobes: the left lobe, the middle lobe, the right lobe and the caudate lobe, the later three being subdivided (Martins and Neuhaus 2007; Martin et al., 2008). The same division was assessed in chinchillas (Nowak et al., 2014) and hamster (Nettlebad, 1954). The subdivision of the middle lobe was different between the mentioned species in the sense that the right medial lobe was the smallest in chinchillas, compare to the rat and hamster, in which the right medial lobe was the largest. Our results show that in guinea pigs there is no such a division of liver lobes, each of the six lobes being well individualized, the largest liver lobe being the left lateral lobe. This feature is in concordance with the description of nutria (*Myocastor coypus*) and rabbit liver (Perez and Lima, 2007; Stamatova et al., 2012). Concerning the liver anatomy in rabbit, our results are similar to Perrez et al 2007, who report the same division in two territories- left and right- of the liver and presence of five lobes in rabbit. Regarding the differences of visualized lobes on the diaphragmatic and visceral surfaces, the literature is controversial, in terms of number of visualized lobes. According to Barone (2009) in rabbit, the diaphragmatic surface shows three lobes, the right undivided lobe covering the left medial lobe and the left lateral lobe. On the visceral surface the five lobes are described, the right, left medial, left lateral, quadrate and caudate lobes. The quadrate lobe was attached to the gallbladder fossa, without any further demarcation. The smallest lobe in rabbit was the quadrate lobe, this feature being recognized by the Stamatova in a study realized on twenty rabbits (Stamatova et al., 2012). Our results pointed out the location of the quadrate lobe in guinea pigs, in which the quadrate lobe was well visualized located in the left side of the gall bladder, between the gallbladder fossa, porta hepatis and round ligament. The caudate lobe in rabbits has a narrow attachement and because of this together with its projection, dorsally toward to the right kidney, in rabbits the torsion of this lobe has been reported (Taylor and Staff 2007; Wenger et al 2009; Stanke et al., 2011). Also, in rabbits the acute angle of the duodenum and liver compression due to hepatomegaly contribute to stomach distension in many cases, misinterpreted like gastric disorder instead of hepatic disease. Compare to nutria, in which the both kidney are in relation with the liver (Perez and Lima 2007) in guinea pigs only the right kidney make the renal imprint on the caudate process of the liver, similar with the most of rodents and reabbit.

Regarding the hepatic ligaments, there are some differences between the species belonging to the Rodent order and Lagomorphs. A whole large falciform ligament, extening to the ventral floor of the abdominal cavity from the abdominal surface of the diaphragm to the posterior surface of the right rectus abdominal muscle at the level of the umbilicus, it was found in rats (Martin and Neuhaus 2007), hamsters (Van Hoosier and McPherson 1987) and nutria (Perez and Lima 2007). The falciform ligament in guinea pigs was complete too. It made the connection between the medial lobes of the liver, diaphragm and xiphoid appendix extending on the abdominal wall up to the level of the umbilicus. Incomplete falciform ligament was reported in chinchillas (Nowak et. al 2014) and rabbits (Perez et. al 2005). On the visceral surface the fissure of the round ligament provide a demarcation for the quadrate lobe. The quadrate lobe was demarcated by the gallbladder fossa, porta hepatis and round ligament. This issue, in guinea pigs is the same with the reports regarding the quadrate lobe delineation in human's liver. A small coronary ligament in guinea pigs was well demarcated, being visible on the dorsal margin of the liver, making the connection of liver to the diaphragm, while in rabbits this ligament was almost indistinguishable (Barone 2009; Perez et al. 2005). The hepatorenal ligament in rabbit (Stan, 2014) and nutria had a long parietal insertion. In guinea pigs the hepatorenal ligament was inserted medial to the right kidney, toward to the right side of the mesoduodenum with caudal insertion on the decescending loop of duodenum, near to the ascending colon. Regarding the triangular ligaments, these ligaments vary both in presence and size. In guinea pig and rabbit the left triangular ligament is constantly present being well developed (Stan, 2014) and the right one is small and inconstant in some subjects, while in rats, hamsters and nutria, the triangular ligaments of liver are present on each side and with two layers for every ligament (Martin and Neuhaus 2007; Reznik et al 1979; Perez and Lima 2007). A particular feature of the hepatoduodenal ligament in guinea pig was its free edge with caudal insertion on the right lobe of the three lobes compound pancreas, issue that has been reported in other descriptions (Stan 2014).

CONCLUSIONS

The guinea pig liver is divided by deep fissures in six lobes. The liver is connected to the under surface of the diaphragm and to the ventral abdominal wall by five ligaments: the falciform the coronary, and the two lateral peritoneal folds as right and left triangular ligaments and by the round ligament. Attachment of the liver to the stomach is made by the hepatogastric ligament and to the duodenum and pancreas by the hepatoduodenal ligament. In guinea pigs, the caudal insertion of hepatoduodenal ligament was made on the right lobe of the pancreas. The hepatorenal ligament is well developed in guinea pigs, having a long insertion.

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