Gross Anatomy and Ultrasonography of Spleen and Pancreas in Rabbit (Oryctolagus cuniculus) and Cat (Felis catus domesticus)

Maher MA¹, Haithem AM Farghali², Alaa H Elsayed¹ and Reem RT¹

¹Anatomy and Embryology Department, Faculty of Veterinary Medicine, Cairo University, Egypt
²Surgery Department, Faculty of Veterinary Medicine, Cairo University, Egypt

*Corresponding author: dr.maher85@yahoo.com

ABSTRACT

The current investigation was performed on nine adult apparently healthy native breeds of rabbits and nine domestic cats of both sexes weighing about 2,800 – 3,500 kg. There were great differences in shape, length, thickness and weight of spleen and pancreas between both species. The spleen of rabbit only attached through gastrosplenic ligament while it was attached through gastroplenic and splenopancreatic fold in cat. The splenic hilus divides the visceral surface into unequal portions in rabbits while into equal portions in cats. The pancreas was divided into three parts; left, right lobes and a body, where it was of compact type in cat but in rabbit only the body and left lobe were compact type while right lobe was of mesenteric type. The main pancreatic duct presents only in cat but the rabbit has only accessory pancreatic duct. The accessory pancreatic duct distribution in rabbit was never described in any of previous literatures, therefore the current description provides a novel guide to researchers afterwards. Sonographically, the spleen appeared small an elongated mass hyperechoic to renal cortex in rabbit but long tongue-shaped isoechoic to renal cortex in cat. Meanwhile, the echogenic pancreatic parts were scanned in the left, right and middle mesogastric regions in rabbit, but in right medial epigastric and left paralumbar mesogastric regions in cat. The aim of the present study is to provide precise description of spleen and pancreas with its duct system which is critical for surgical guidance in small animal practice.

Key words: Spleen, Pancreas, Ultrasonography, Rabbits and Cats

INTRODUCTION

The Rabbit (Oryctolagus cuniculus) is considered as a model for medical experiments and education. Recently, these animals are also preferred as pets. The rabbit is used as the main model animal in researches concerned with regulating blood sugar. It enzymatically digests proteins, fats, and carbohydrates in the intestine in addition to production of insulin and glucagon hormones. Knowledge of the exact location of the pancreatic ducts aids in surgical interferences related to collection of pancreatic juice, cannula practices, ligation of common biliary duct or pancreatic duct (Page et al., 2000).

In order to closely focus on such valuable organs, we must have knowledge of their problems such as splenomegaly and rupture of spleen as a result of an accident and those of pancreas which are pancreatitis, pancreatic cancer and diabetes. However, less knowledge is known about chronic pancreatitis rather than the acute form, but chronic pancreatitis is more common in cats than dogs (Armstrong and Williams, 2012).

The topography of internal organs in rabbits and cats is scarcely described in the available literatures and there is no detailed information about their anatomical relationships. So, we aim to identify the topographic anatomy which is a necessary application for veterinary medical diagnostics and medical experimentation, besides supporting our investigation by accurate ultrasonographic appearance and interpretations.

MATERIALS AND METHODS

The present study was constructed on nine adult apparently healthy native breeds of rabbits and nine adult domestic cats of both sexes. They were obtained from local markets and transported to the laboratory of Anatomy and Embryology Department, Faculty of Veterinary Medicine, Cairo University. The average body weight of rabbits and cats used in this study ranged from 2.800 – 3.500 kg.

A. The Anatomical study

All rabbits and cats were observed to be in a good nutritional status. They were euthanized by lethal dose of Diazepam at 10 mg/kg introduced intravenously through external jugular vein. The experiments were conducted by the international ethical standards set by the institutional animal care and use committee (Vet. CU. IACUC) VetCU1111201808. Then anatomical dissection was carried out via mid laparotomy. For studying the topography, three (3) specimens each, rabbits and cats, were used for the morphoanatomical investigation, through Fixation either by freezing or by arterial perfusion with 10% neutral buffered formalin. The organ isolation was performed for further observations. For recording the biometrical dimensions and weight of pancreas and spleen, a Vernier caliper and a sensitive digital balance were used. In order to study the pancreatic duct system, organs from three (3) rabbits and (3) cats were flushed with normal saline and injected with colored latex neoprene into the major duodenal papilla and the minor duodenal papilla in cats and rabbits, respectively. The specimens were photographed using Olympus digital camera SP-600UZ 12 mega pixel. The anatomical nomenclature used in this study was in accordance with the Nomina Anatomica Veterinaria 2017 (6th edition).

B. The Ultrasonographic and Radiologic study

Concerning the Ultrasound examination, we evaluated 3 live rabbits and 3 live cats, by using two devices according to availability at the time of study; B-mode scan (Pie medical) and Doppler device (EXAGO, Echo control medical, France) with a linear multifrequency transducer using a frequency of 5-7.5 MHz in rabbits and 7.5 MHz in cats. The animals used for the sonographic study, were later used as specimens for the radiological examination of pancreatic duct system using the radiographic device (Fisher imaging, Chicago, USA). The animals were euthanized as mentioned before and injected by lead oxide dissolved in turpentine oil into the major duodenal papilla in cat or the minor duodenal papilla in rabbit to obtain X-ray films.

RESULTS AND DISCUSSION

A. Anatomical study

A.1. Morphology and Topography of Spleen

Our investigation was similar to (Barone, 1997; Hristov et al., 2006 and Dimitrov et al., 2012) that rabbit spleen appeared small, elongated, flat and fusiform in shape having parallel borders with a length of 4-7 cm, width of 1-3 cm and a thickness of 0.3-0.5 cm depending on the age and body weight, having a light reddish-brown color (Fig. 1A,B). While (Kauffman and Bard, 2000) had described that the mouse spleen was narrow ribbon-like in shape but (Qasem et al., 2015) reported that rabbit spleen was tongue shaped and the guinea pig spleen was quadrilateral in shape, dark red to blackish in color.

Our reports were in accordance with that asserted by (Bacon and Kamstock, 2014 and Huynh and Berry, 2017) in domestic cats that the spleen was large, tongue-shaped, dark red in color in fresh state with a wide base and pointed apex, having a length of 10-15 cm, width of 3-4 cm and a thickness of 1 cm with the body constricted at the middle (Fig. 1D).

Our results were in agreement with (Hristov, 2006, Dimitrov et al., 2012 and Qasem et al., 2015) that the splenic hilus in rabbit divided the organ into two unequal parts which attached to stomach greater curvature by only one ligament called gastrospenetic ligament (Fig. 1C). Whenever, confirmed that in cat, the splenic hilus divided the organ into two equal parts which attached to stomach through the gastrospenetic ligament (Fig. 1E), a result which simulate our observations. Moreover, the present study showed presence of another fixation, the splenopancreatic fold attaching the base of spleen to left pancreatic lobe (Fig. 1F).

Fig. 1: (A, B, C) Photographs showing the rabbit spleen as small, elongated, flat and fusiform in shape with parallel borders and a length of 4-7 cm, width of 1-3 cm as well as a thickness of 0.3-0.5 cm, having a light reddish-brown color and located on the caudomedial aspect of stomach where it related to the jejunal loops caudally and left pancreatic lobe laterally. Its parts were a body, dorsal extremity (apex) and ventral extremity (base). The splenic hilus was divided into two unequal parts attached to the stomach greater curvature by the gastro-splicenic ligament. (D, E, F): Photograph showing the cat spleen as large, tongue-shaped, plumpy organ appearing dark red in color in fresh state with a wide base, pointed apex, and the body constricted at the middle with a length of 10-15 cm, width of 3-4 cm and a thickness of 1 cm. It is located in the left cranial and lateral abdomen, caudolateral to the stomach and caudodorsal to the left kidney. The splenic hilus divided the organ into two equal parts which attached to stomach through the gastro-splicenic ligament. Noted the spleno-pancreatic fold attaching the base of spleen to the left pancreatic lobe.
On the other hand, (Kaufman and Bard, 2000) in mouse observed two splenic attachments; gastroplenic and renosplenic ligaments. While (Qasem et al., 2015) in guinea pig demonstrated three attachments; gastroplenic, splenorenal and renosplenic ligaments. A result which did not meet our observations in rabbit or cat.

A.2. Morphology and Topography of Pancreas:

According to the observations of (Eifler et al., 2009, Treuting et al., 2012 and Al-Saffar and Al-Hasnawy, 2014), among the laboratory animals, the pancreas had been classified as mesenteric or compact types; the mesenteric type was diffusely distributed in the mesentery of small intestine as in rabbit, rat and mouse. Whereas, the compact type was recognized in hamster, dog and cat. But our results confirmed that both types present in rabbit where the left lobe and body were of compact type (Fig. 2A, B) and the right lobe was of mesenteric type (Fig. 2B), while the pancreas of cat was only of compact type (Fig. 3A).

The left lobe of rabbit pancreas extended as a thin, flattened ribbon between the two extremities of the spleen (Fig. 2A), running along the splenic gastric surface, crossing the visceral surface of the stomach to reach the ventral surface of left kidney. A result which is confirmed by (Barone, 1997; Dimitrov et al., 2013 and Al-Saffar and Al-Hasnawy, 2014) in rabbits.

Our observations in cats were similar to that of human pancreas where the main pancreatic duct joined the common bile duct and connected to the duodenum by the ampulla of Vater (Slack, 1995, Hagai, 2003 and Kimura, 2003).

Fig. 2: (A, B): Photographs showing the pancreas in rabbit was divided into left lobe and body of compact type and right lobe of mesenteric type. (C, D, E, F): Photographs showing the presence of only the accessory pancreatic duct in rabbits, formed by the union of right and left ducts, the former drained only the right pancreatic lobe via 3-4 branches and two small right ductules which drained the same lobe directly into the parent duct, and the latter drained the left pancreatic lobe and sent a middle duct to drain the pancreatic body and emptied into the ascending duodenum on minor duodenal papilla approximately 20-45 cm distal to the entrance of the common bile duct on the major duodenal papilla.
and Lamb (1990), Mannion and Frame (2008) and Diana et al. (2015) in dorsal or right lateral recumbency.

**B.1. Spleen**

In our study, the sonographic approach in rabbit and cat was percutaneous transabdominal left paracostal epigastric and left paralumbar mesogastric regions (Fig. 4A, B), in contrary to Dimitrov (2012) and Dimitrov et al. (2012) in rabbits who pursued a percutaneous transabdominal epigastric approach and Lamb (1990) and Burk and Feeney (2003) in cats stating that the normal spleen varies in size and may be too small to be imaged. While Banzato et al. (2015) recommended that the spleen was best evaluated in a para-sagittal scanning plane, our observation revealed it could be imaged sagittally as well as transversally, in consent with Burk and Feeney (2003).

Regarding the left paracostal sagittal scan in rabbits (Fig. 5III), elongated homogenous echogenic spleen appeared with a hyperechoic splenic capsule, this was confirmed by Dimitrov et al. (2012). In the left paralumbar scan (Fig. 5IV), the left kidney was an anatomic landmark appeared hypoechoic to the Spleen. Moreover, left paracostal transverse scan (Fig. 5V) showed the echogenic spleen triangular in cross-section, simulating the observation of Dimitrov et al. (2012).

In cats, the costal arch and the cranial border of the left kidney, were used as anatomic landmarks to visualize the spleen. This was confirmed by Lamb (1990) and Kealy et al. (2011). Unlike other authors who depended on different landmarks; the liver (Lamb, 1990 and Burk and Feeney,2003), gastric fundus (Burk and Feeney, 2003, Mannion, 2008 and Huynh and Berry, 2017), urinary bladder (Burk and Feeney, 2003) or the descending colon (Mannion, 2008 and Huynh and Berry, 2017).

In the left paracostal sagittal scan (Fig. 5VI), the apex of the normal feline Spleen appeared, following caudally from there in the left paralumbar sagittal scan (Fig. 5VII), the splenic body and the base where the splenic base was related to the cranial border of the left kidney to which it was isoechoic, Similar opinion was given by Santos (2014), unlike Hanson et al. (2001), Dennis et al. (2010) and Kealy et al. (2011) who designated the spleen to be more echogenic to renal cortex. In the left paralumbar sagittal scan, a splenic vein appeared rounded anechoic -as agreed with (Burk and Feeney, 2003, Kealy et al., 2011 and Diana el al., 2015) - left the splenic hilus through the hyperechoic splenic capsule surrounded by hyperechoic fatty aggregations around its point of departure, in agreement with Mannion (2008).

The feline spleen as a whole, appeared thick elongated tongue-shaped in sagittal scan, in consent with Mannion (2008) and Huynh and Berry (2017), but in disagreement with Burk and Feeney (2003) and Mahoney (2012) who described the spleen to be a short-axis triangular shaped. However, it was the left paralumbar transverse scan (Fig. 5VIII) that showed the spleen slightly triangular with rounded borders.

The spleen parenchyma appeared grainy homogenous hypoechoic with hyperechoic smooth well-defined capsule, as recorded by (Lamb, 1990, Hanson et al., 2001 and Kealy et al., 2011). On the other hand, Huynh and Berry (2017) concluded that when using a high-frequency linear array transducer, the spleen appeared heterogeneous.

**B. Ultrasonographical study:**

In the present study, a linear multifrequency transducer with working frequency range from 5 to 7.5 MHz was used in rabbit and 7.5 MHz in cat to scan the spleen and pancreas. The same data was given by Hanson et al., (2001) and Dennis et al. (2010) in spleen and (Rademacher et al., 2008, Dennis et al., 2010 and Kealy et al., 2011) in pancreas of cats. However, Dimitrov et al. (2012) in spleen and (Dimitrov et al., 2013) in pancreas of rabbits recorded using 6.5 MHz micro-convex and 5 MHz linear probes, in addition (Hecht et al., 2006 and Rademacher et al., 2008) recommended micro convex probe with the same range of frequency in pancreas of cats or (Larson et al., 2005 and Williams et al., 2013) who recommended using either linear or convex transducers with frequency 8 MHz to 15 MHz.

The position of the animals under examination was dorsal recumbency as recommended by (Dimitrov et al., 2013) in rabbits and Etue et al. (2001), Hecht et al. (2006) and Rademacher et al. (2008) in cats. In contrary to Dennis et al. (2010) and Kealy et al. (2011) who positioned the animals in right and left lateral recumbencies, respectively.

Fig. 4: (I, II): A scheme of the ventral abdominal surface according to the topographic anatomy in rabbit (I) and in cat (II). The abdomen was divided into three main regions through drawing two transverse imaginary plans the first of which bilaterally connect caudal border of the costal arch and the second extended from right to left stifle folds. Each of the main three regions were subdivided into three sub-regions by drawing two sagittal imaginary planes as it passed from the costal arch to the coxal tubercle on each side. (A, B): Photographs showing the topographical position of spleen according to which the sonographic approach was taken. The spleen attained left para-costal epigastric and left paralumbar meso-gastric position to the last (12th) rib as well as left paralumbar meso-gastric one; (A) in rabbit, (B) in cat.

Fig. 5: (III, IV): Photographs showing the sagittal ultrasound scan of spleen in rabbit. (III)a: Left Paracostal Longitudinal (L.L. paracostal) scan showing elongated homogenous echogenic spleen with hyperechoic splenic capsule (red arrow) and the following dimensions; Length: 27.9mm and Depth:9.45mm. (IV)a: Left Paralumbar Longitudinal (L.L. paralumbar) scan showing the left kidney (red dots) used as an anatomic landmark and is hypoechoic to spleen. (V): A Photograph showing the left paracostal epigastric transverse (L.T. paracostal) scan in rabbit showing echogenic spleen appearing triangular in cross section. (III, IV, V)b: Location and direction of linear transducer. (VI, VII): Photographs showing the sagittal ultrasound scan of spleen in cat. (VI)a Left Paracostal Longitudinal (L.L. paracostal) scan showing grainy homogenous hypoechoic apex of the normal feline spleen (red dots) and hyperechoic smooth capsule (red arrow). (VII)a, b, c): Left Paralumbar Longitudinal (L.L. paralumbar) scan showing; (VII)a: The hypoechoic splenic body (red dots) and hyperechoic well-defined capsule (black arrow). (VII)b: Splenic vein identified as rounded anechoic structure leaving through the hyperechoic splenic capsule into the splenic hilus along the medial border of the splenic parenchyma (red dots). Noted the hyperechoic fatty aggregations around the point of its entrance (yellow arrow). (VII)c: The splenic base (red dots) which appeared isoechoic to the neighboring left renal cortex (yellow dots). (VI)b (VII)d: Location and direction of linear transducer. (VIII)a: Left Paralumbar Transverse (L.L.paralumbar) scan in cat showing the spleen (red dots) was slightly triangular in shape with rounded border isoechoic to left kidney which appeared circular in cross section. (VIII)b: Location and direction of linear transducer.
Fig. 6: (IXa,b,c): Overall view of Sagittal doppler ultrasound scan of pancreas in the meso-gastric region of domestic rabbit showing a yellow arrow pointed to the Gastroduodenal artery and a green one pointed to the cranial pancreatoduodenal branch. The margin of the uniformly echogenic Pancreas is outlined by red dots. (IX)a Left Paralumbar Sagittal scan of left pancreatic lobe, (IX)b Lumbar Sagittal scan of pancreatic body, (IX)c Right Paralumbar Sagittal scan of right pancreatic lobe. (IX a’,b’,c’): Location and direction of the linear transducer of (IXa,b,c), respectively. (X): Photographs showing the left paralumbar and lumbar meso-gastric transverse scan in rabbit. (X)a Left Paralumbar & Lumbar Transverse (L.T. paralumbar & T. Lumbar) scan without injection of intraperitoneal saline showing margin of the uniformly echogenic pancreas outlined by red dots and a red arrow pointed at a pancreatic artery appearing with anechoic lumen surrounded by well-defined echogenic wall as well as a blue arrow pointed at a pancreatic vein appearing with anechoic lumen and ill echogenic wall. (X)b Lumbar Transverse (L.T. paralumbar & T. lumbar) scan with injection of intraperitoneal saline showing parts of the uniformly echogenic pancreas appearing clearly after injection; the pancreatic body outlined by red dots fitting into the pyloro-duodenal angle (blue arrow) and a small part of the right pancreatic lobe outlined by green dots appeared along the apparent portion of the descending duodenum. (X)c: Location and direction of linear transducer.

B.2. Pancreas
The present results in rabbits and cats illustrated the percutaneous transabdominal left paralumbar scan as the best to localize pancreas, in addition to the lumbar meso-gastric region in rabbit and right medial epigastric in cat. On the contrary, in rabbit, Dimitrov (2012) and Dimitrov et al. (2013) suggested percutaneous transabdominal epigastric approach especially left hypochondriac and Hecht and Henry (2007), Dennis et al. (2010) and Kealy et al. (2011) in cat who stated that the pancreas was small organ of comparable echogenicity to surrounding mesentery and was difficult to identify.

In rabbits, the gastroduodenal artery and its cranial pancreatoduodenal branch were used as anatomic landmarks to access the pancreas in sagittal scan, the results which conflicted (Lamb, 1990) and Dimitrov et al. (2013) who demonstrated the spleen and splenic vein as markers for the left pancreatic lobe as well as the cranial mesenteric vein for the body of the pancreas.

The normal pancreatic left, right lobes and body were demonstrated in the left, right paralumbar, and lumbar sagittal scans, respectively (Fig. 6IX). Hypoechoic border areas appeared between the pancreatic lobes and its margin had homogenous echogenic character due to the pancreatic localization in the adipose tissue of mesoduodenum, as agreed with (Barone, 1997) and Dimitrov et al. (2013).

Moreover, an intraperitoneal isotonic solution was infused in rabbits as contrast media to easily demonstrate the abdominal organs. The transverse lumbar and left paralumbar scans (Fig. 6X) were the best to visualize distinct anatomic margins of the pancreatic body and right lobe as well as the pyloro-duodenal angle and part of the descending duodenum. Unlike (Dimitrov et al., 2013) who injected isotonic solution via esophageal gastric tube.

In cats, a study reported by Burk and Feeney (2003) showed that the pancreas was best examined in transverse plane, this statement disagreed with our findings since the feline pancreas was imaged successfully in transverse and sagittal scans and all its parts were well-imaged, these observations were not consistent with Etue et al. (2001), Larson et al. (2005), Dennis et al. (2010) and Williams et al. (2013) who confined their imaging only to the left pancreatic lobe and body.

Various anatomic landmarks were used to identify the feline left pancreatic lobe; stomach, spleen, and left kidney (Head et al., 2003, Larson et al., 2005 and Williams et al., 2013); transverse colon and stomach (Burk and Feeney, 2003, Dennis et al., 2010 and Kealy et al., 2011); the splenic vein (Saunders, 1991, Etue et al., 2001) or the portal vein (Hecht and Henry, 2007 and Dimitrov et al., 2013).

Regarding the left paralumbar meso-gastric sagittal scan (Fig. 7XJ) in cats, the left pancreatic lobe and left pancreatic duct were observed and the spleen was used as an anatomic landmark, same was offered by (Mannion and Frame, 2008), while others suggested that the left pancreatic limb was imaged just caudal to the last rib (Kealy et al., 2011). The left pancreatic lobe was echogenic
but appeared more hypoechoic to spleen, this observation agreed with (Etue et al., 2001, Head et al., 2003, Rademacher et al., 2008 and Santos et al., 2014) but contradicted Dennis et al. (2010) offering that the pancreas was isoechoic to spleen.

Concerning the right medial epigastric sagittal scan (Fig. 7XII), the feline pancreatic body appeared fitting in the pyloro-duodenal angle as well as the right pancreatic lobe presented along the proximal part of descending duodenum which were used as anatomic landmarks, similar results observed by (Etue et al., 2001, Head et al., 2003, Larson et al., 2005 and Williams et al., 2013) and a nearly similar opinion was given by Burk and Feeney (2003), Mannion and Frame (2008) and Kealy et al. (2011) that the right lobe could also be identified by localizing the portal and pancreaticoduodenal veins. Moreover, the right pancreatic lobe appeared dorsal to the right kidney, which was also used as an ultrasonographic window, the result which agreed with Dennis et al. (2010). In contrast to Mannion and Frame (2008) offering that the right lobe could only be imaged with the cat in right lateral recumbency using the gastric fundus and descending duodenum as an acoustic window.

The feline right pancreatic lobe and body was echogenic but appeared hypoechoic to the right kidney and hyperechoic to the liver. This simulated the description offered by Burk and Feeney (2003), Rademacher et al. (2008) and Santos et al., (2014). In contrast to the observation that the pancreas was hypoechoic to the liver (Head et al., 2003) or isoechoic to the liver (Larson et al., 2005, Hecht et al., 2006 and Dennis et al., 2010).

In the practical work, the main pancreatic duct in cats appeared within the pancreatic body, while the left and right pancreatic ducts appeared within left and right pancreatic lobes, respectively. Nearly similar findings were observed by Etue et al. (2001) and Larson et al. (2005) regarding the position of the pancreatic duct within the pancreatic body, however the former authors declared that the pancreatic duct was sometimes observed in the right pancreatic lobe and the latter authors identified it in the left pancreatic lobe in agreement with Dennis et al. (2010). Our results simulated the investigations of (Etue et al., 2001, Nyland et al., 2002 and Kealy et al., 2011) that the ducts appeared as a uniform linear structure with an anechoic lumen and well-defined hyperechoic wall.

Conclusions

Our anatomical observations revealed the variations between spleen of rabbit and cat in shape, size and attachment. The pancreas of rabbit was of two types according to lobes where the left lobe and body were compact while the right lobe was the mesenteric type, but the pancreas of cat was only of compact type. The pancreatic duct system is represented by the main pancreatic duct in cat and the accessory pancreatic duct in rabbit. Furthermore, the ultrasonographic observations of the hypoechoic spleen in rabbit and cat was in the left paracostal epigastric and left paralumbar meso-gastric regions with difference in relative echogenicity to the renal cortex, while the echogenic pancreas was observed in the left, right paralumbar and lumbar meso-gastric regions in rabbit as well as in the right medial epigastric and left paralumbar meso-gastric regions in cat.

Acknowledgment

We would like to express our great appreciation to Professor Doctor Salah Mohamed Hagrass; Professor of Anatomy and Embryology, Faculty of Veterinary Medicine, Cairo University, for his valuable and constructive work during the development of this research work. His willingness to give his time so generously has been very much appreciated.