

Studies on Ultrasonography of the Pancreas of Dogs



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REQUIREMENTS FOR THE AWARD OF THE DEGREE**

OF

MASTER OF VETERINARY SCIENCE

IN

VETERINARY SURGERY AND RADIOLOGY

BY

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(2019)

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This is to certify that the thesis entitled, “**STUDIES ON ULTRASONOGRAPHY OF THE PANCREAS OF DOGS**”, submitted by **Dr. Pradeep Kumar**, Enrollment No. V-1082/12 in partial fulfillment of the requirements for the award of the **Master of Veterinary Science in Veterinary Surgery and Radiology** of the **U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan (DUVASU), Mathura (UP), India**, is a bonafide research work carried out by him under my supervision and guidance and no part of the thesis has been submitted for any other degree or diploma.

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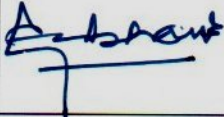

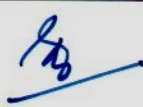
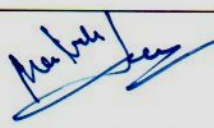
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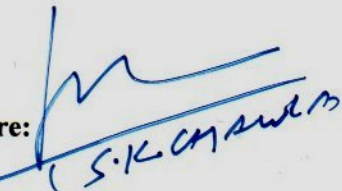
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LIST OF ABBREVIATIONS USED

AP	:	Acute pancreatitis.
cm	:	Centimeter
CP	:	Chronic pancreatitis.
cPL	:	Canine pancreatic lipase.
cPLI	:	Canine pancreatic lipase immunoreactivity.
CT	:	Computed tomography.
DUO	:	Duodenum.
EUS	:	Endoscopic ultrasound.
Fig	:	Figure.
g	:	Grams
Gr	:	Group
MHz	:	Mega hertz.
mm	:	Millimeter.
MRI	:	Magnetic resonance imaging.
PDV	:	Pancreaticoduodenal vein.
PLI	:	Pancreatic lipase immunoreactivity.
S.E	:	Standard error.
SP	:	Spleen.
Spec CPL®	:	Canine pancreas specific lipase.
ST	:	Stomach
SV	:	Splenic vein.
TC	:	Transverse colon.
U/L	:	Units per liter.
US	:	Ultrasound

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ABSTRACT

The present study was undertaken to standardize ultrasonographic examination protocol in dogs and generation of reference images. This study was conducted in two parts. Part I of the study was conducted on 18 apparently healthy dogs, divided into three groups of six animals each namely, Group I comprising of animals of 01 to 09 months of age, Group II comprising of animals of more than 09 months to 06 years of age and Group III comprising of animals above six years of age. Part II comprised of patients reporting to the VCC with symptoms like lack of appetite, weight loss, acute vomiting, diarrhoea, dehydration, abdominal pain, tucked-up belly were enrolled to assess echoarchitecture and size.

Ultrasonographic examination was done in lateral recumbency in all the dogs, but in some cases ultrasonography was also done in dorsal recumbency without using any anaesthesia or sedatives. In all the dogs (except one) not all the regions of the pancreas were visualized by ultrasound, only the thickest portion of the pancreas was identified by ultrasound and was measured by in-built caliper of the ultrasound machine.

Ultrasonographic images of pancreas were recorded in sagittal plane and transverse plane. The right limb of pancreas was visualized in a transverse view in right cranial abdomen by placing the transducer just behind the last rib. Direct visualization of the pancreas was not possible. The right limb of the pancreas could be seen dorsomedial to the duodenum, ventral to the right kidney and lateral to portal vein.

The left limb of pancreas could be identified in a sagittal plane in left cranial abdomen by keeping transducer midway between the xiphisternum and last rib beneath the subcostal arch. The left pancreatic lobe was visualized in a triangular region cranial to the left kidney, caudal to stomach, and medial to the spleen in left cranial abdomen.

The pancreas appeared to be hypoechoic to isoechoic as compared to the surrounding structures in all the groups. The echoarchitecture of both limbs of pancreas were homogeneous in the animals of all the groups and lacked capsular marginations.

The mean width of right limb of pancreas was 1.2 ± 0.03 cm in Group I, 1.31 ± 0.06 cm in Group II and 1.5 ± 0.06 cm in Group III, being highest in Group III and least in Group I. The mean width of left limb of pancreas was 1.47 ± 0.16 cm in Group I, 1.77 ± 0.10 cm in Group II and 1.92 ± 0.15 cm in Group III, mean thickness of left limb of pancreas was 1.17 ± 0.06 cm in Group I, 1.35 ± 0.09 cm in Group II and 1.5 ± 0.10 in Group III. The mean width of left limb of pancreas was maximum in Group III and minimum in Group I.

In the second part of the study, the echoarchitecture of both limbs of pancreas were different from those of part I of the study. In part II the pancreas were larger, with irregular demarcation and appeared hypoechoic whereas; the mesentery adjacent to it was hyperechoic. In one animal the width and thickness were 3.22 cm and 2.31 cm respectively, which were considerably higher than group II (mean width 1.77 ± 0.1 cm, mean thickness 1.35 ± 0.09 cm) and in another case the width and thickness were 3.57 cm and 2.62 cm respectively, which were considerably higher than the values of animals in group III (mean width 1.92 ± 0.15 cm, mean thickness 1.5 ± 0.1 cm). These ultrasonographic changes corroborated the clinical findings and suggested pancreatic inflammation.

On the basis of this study it can be concluded that pancreas in dogs can be scanned without sedation and anaesthesia. Subcostal approach is the best approach to scan right and left limb of pancreas, using a 7.5 MHz curvilinear transducer in lateral recumbency by placing the probe caudal to the last rib and ventral to the lumbar process. The dimensions and the echoarchitecture of the pancreas may assist in the diagnosis of pathologies of the pancreas or other organs.



Introduction

The pancreas is a complex exocrine-endocrine organ responsible for the manufacture of enzyme-rich digestive secretions and hormones which aid in regulating carbohydrate metabolism. It is a pink, lobulated glandular mass situated in the dorsal aspect of the epigastric and mesogastric regions of the abdominal cavity, caudal to the liver. It accounts for approximately 0.22% of the total body weight and averages 25 cm in length for a 30 pound dog (Miller et al., 1964). In the human the length of the pancreas averages 12.5 to 15 cm (Gray, 1930) and averages 85 grams (Morris, 1942), or approximately 0.12% of the total body weight. There are no apparent significant differences between the human pancreas and that of the dog with reference to the blood supply, duct system and general histology. The pancreas is yellowish gray when preserved and pinkish gray in life. It is a rather coarsely lobulated and elongate gland. The lobules, as Revell (1902) has pointed out, produce a nodular surface with irregularly crenated margins. The pancreas is located in the dorsal part of both the cranial and right lateral abdominal regions, caudal to the liver. The pancreas is a small, v-shaped organ divided into three portions: right lobe, left lobe and body. The left lobe lies between the greater curvature of the stomach and the transverse colon and the right lobe lies in the mesoduodenum, between the medial surface of the duodenum and the lateral surface of the ascending duodenum. The body of the pancreas connects the two lobes in the angle of the pylorus and the duodenum (Webster, 2008). Ultrasonographically, the normal pancreas is a small, inconspicuous organ of comparable echogenicity to surrounding mesentery and may be difficult to identify. Therefore, knowledge of anatomic landmarks such as portal vein and contributing vessel, duodenum, and stomach is necessary to facilitate identification and examination (Hecht and Henry, 2007).

The weight of the pancreas averaged 31.3 g in 76 dogs, with an average weight of 13.8 kg. The pancreas weighs approximately 1 ounce in a dog whose weight is approximately 30 pounds. These data compare favorably with Mintzloff's (1909) findings in 30 dogs, although his specimens were, on average, larger. The average total length of the pancreas in a 30-pound dog is approximately 25 cm, or 10 inches.

The pancreas, when hardened in situ, is in the form of a V that lies in a dorsal plane with the apex pointing cranially and to the right. The gland is basically divided into a thin, slender right lobe, and a shorter, thicker, and wider left lobe. The two lobes are united at the body, formerly called the pancreatic angle, which lies caudomedial to the pylorus. The endocrine pancreas of the dog has served as the classic model for the exploration of insulin-deficiency diabetes by Banting and Best (1922). The endocrine pancreas is a composite of many thousands of small endocrine racemi (insulae pancreaticae) scattered randomly among the exocrine pancreatic acini. Each racemus is composed of several endocrinocyt, the normal functioning of which is essential for the proper regulation of blood sugar levels. The endocrine pancreas is essential for maintaining life.

While abdominal radiographs are of little use, abdominal ultrasonography is a highly specific diagnostic procedure when stringent criteria are used, but the highest reported sensitivity for dogs is only 68% (Hess et al., 1998). Veterinary sonography is utilized in many different instances. In general practice veterinary clinics, sonography is usually indicated for any chronic disease process in which the cause is unknown, as it serves as a comprehensive screening tool. The most common indication for ordering an ultrasound in general veterinary practices is chronically elevated liver enzymes (Tyrrell and Beck, 2006).

Ultrasound is a very important modality for the evaluation of pancreas in the small animal patient. The advantages of ultrasonography include the ability to image both normal and abnormal pancreas, the ease and rapidity of the procedure, the lack of the need for anesthesia, and the availability of ultrasound to practitioners. However, the challenge of imaging the pancreas should not be underestimated. Radiography is also a modality of diagnostic imaging for the organs in the abdominal cavity. However, under normal circumstances, the pancreas is not visible on plain radiographs (Simpson and Lamb, 1995; Bischoff, 2003).

It is of utmost significance to underline the fact that the performance of abdominal ultrasonography in the diagnosis of pancreatitis is highly dependent on the expertise of the ultrasonographer and the quality of the equipment used. In most reported studies, abdominal ultrasonography has been performed at teaching hospitals by board certified radiologists, and therefore, the performance of abdominal ultrasound for pancreatitis is expected to be considerably lower when less experienced

clinicians are performing the ultrasound examination and the equipment used is of lower quality. In addition, the lack of standardised criteria for the ultrasonographic evaluation of the pancreas in dogs and cats leads to great variation in the interpretation of imaging results even among radiologists and makes the need for specialised ultrasonographers even greater (Xenoulis, 2015).

Specific indications for examination of the pancreas include, but are not limited to, vomiting, anorexia, weight loss, abdominal pain, icterus, therapy-resistant diabetes mellitus and hypoglycemia. Pancreatic diseases may be associated with concurrent disorders of other organs such as hepatobiliary system, gastrointestinal tract, or kidney. Also, pancreatic disease may result in complications affecting other organs (e.g, metastatic disease or extrahepatic biliary obstruction). Therefore, the ultrasonographic examination should not be limited to the pancreas but should include the entire peritoneal cavity (Hecht and Henry, 2007).

Larson (2013) has suggested that the canine pancreas is isoechoic or slightly hypoechoic to surrounding mesenteric fat, with indistinct margins, and is not usually visualized as a discrete organ. Due to edema, pancreatic swelling and peri-pancreatic fat necrosis, the inflamed pancreas is easier to localize than the normal pancreas (Watson, 2004). The most common ultrasonographic observation is a loss of echodensity that is compatible with edema. Other ultrasonographic findings include: increased echodensity suggestive of fibrosis, nonhomogeneous masses, and less commonly, fluid filled cyst-like structures (Burrows, 2002).

Pancreatic diseases and abnormalities frequently investigated by means of ultrasonography include pancreatitis, pseudocysts, abscesses, neoplastic lesions and nodular hyperplasia. Disorders less commonly seen include exocrine pancreatic insufficiency, pancreatolithiasis, congenital anomalies, and pancreatic edema. Unfortunately, ultrasonographic findings in various pancreatic disorders overlap, and incidental findings or age-related changes may mimic pancreatic disease (Hecht and Henry, 2007).

French et al. (2019) have opined that the current methods of diagnosing acute pancreatitis in dogs include a combination of abdominal ultrasound (US) examination, clinical history, physical examination, and serum biochemistry, including the Spec cPL[®] assay for canine pancreatic lipase (cPL).

Pancreatic ducts are not typically visualized sonographically, but the pancreaticoduodenal vein can usually be seen in the right limb in a dog. Small animals can be affected by pancreatitis just like humans, causing marked enlargement and a hypoechoic appearance in the acute stage (Hess et al., 1998); (Jaeger et al., 2003) and (Nyland and Mattoon, 2014).

Albury (2015) has found that sonographically pancreatitis presents as an enlarged hypoechoic gland. Two recent pathological studies of pancreatic lesions in dogs favour the human definition of chronicity and classed all dogs with fibrosis as chronic pancreatitis (CP), even if they had superimposed acute inflammation (Newman et al. 2004, Watson et al. 2007). A follow-up study by Newman et al. (2006) suggested a histological grading system for canine pancreatitis in which a number of histological features were graded on each histological section between 0 and 3 where grade 0=none of the section affected; grade 1 was up to 10% of the section affected; grade 2 was 10–40% of the section affected and grade 3 was over 40% of the section affected. The histological features graded were: neutrophilic inflammation; lymphocytic inflammation; pancreatic necrosis; fat necrosis; oedema; fibrosis; atrophy and nodules. This grading system has subsequently been used by others in canine studies (Watson et al. 2011, Mansfield et al. 2012, Bostrom et al. 2013) but is yet to be extensively validated by independent pathologists.

Schrope et al. (2014) noted that evaluating the pancreas is part of the standard diagnostic ultrasound examination of the abdomen in human being. While CT, MRI and EUS are perhaps preferred modes of imaging the pancreas, transabdominal ultrasound remains an indispensable tool as an initial examination, in a sense acting as a gateway to the more invasive and / or expensive modalities. Furthermore, ultrasound in all its forms is invaluable in image-guided procedures, where CT or MRI may prove to be unwieldy. Very little efforts are required to scan the pancreas, while abdominal ultrasound is already underway in canine patients.

Ultrasonographic examination of the pancreas is best performed in fasted animals to prevent interposition of gas and ingesta-filled gastrointestinal tract with resultant artifacts due to its close proximity to stomach and duodenum. Most commonly, a ventral abdominal approach with the patient in dorsal recumbency is used. Thorough evaluation of the pancreas should be part of every abdominal

ultrasonographic examination, even if there is no clinical suspicion of pancreatic disease (Hecht and Henry, 2007).

OBJECTIVES

The present study is being proposed to be undertaken with the following objectives:

1. To standardize a protocol for ultrasonographic examination of the pancreas in apparently healthy dogs and generation of reference images of pancreas for comparison with those of pathological pancreas.
2. To measure the dimensions and study the echoarchitecture of the pancreas of apparently healthy dogs for obtaining reference values.
3. Ultrasonographic evaluation of clinical cases with symptoms of potential pathology of the pancreas.



Review

of

Literature

The exocrine part of the pancreas develops from epithelial outgrowths of foregut endoderm. The origin of pancreatic islet cells has been described as either or both foregut endoderm and neural crest ectoderm. The islets are distributed randomly among the exocrine acini, but there are differences in the cellular components of the endocrine islets. The pancreas develops from a dorsal and ventral pancreatic anlage. These two differing sites of origin may play a determining role in the cytogenesis of the alpha endocrine cell (endocrinocytus alpha); Bencosme and Liepa (1955) reported that the ventral pancreas in the dog, the right lobe, is devoid of alpha endocrine cells. The alpha endocrine cells produce glucagon and the beta endocrine cells produce insulin. The endocrine islets vary in size from approximately 1500 to 20,000 μm^2 and are composed of from 10 to 120 epithelioid cells (Acosta et al., 1969; Saladino and Getty, 1972). Davis et al. (1988) reported dogs have an average volume fraction of endocrine parenchyma of 1.8% but that it varies with regions of the pancreas. The number and size of the islets increase progressively from the right lobe to the left lobe of the pancreas.

The right lobe of the pancreas (*lobus pancreatis dexter*) lies in the mesoduodenum near or in contact with the dorsal portion of the right abdominal wall, the paralumbar fossa. It extends from a transverse plane through the middle of the ninth intercostal spaces to one through the fourth lumbar vertebra. The right lobe varies in width from 1 to 3 cm and in thickness up to 1 cm. Its length is approximately 15 cm, or 6 inches, in a Beagle-type dog. The right lobe is positioned in the mesoduodenum in such a way that its round, flat, caudal extremity lies in the concavity of the duodenal loop. By traction the gland can be separated for a distance of approximately 3 cm from the various parts of the duodenum that form the loop, because the mesoduodenum at this site is loose. As the right lobe runs obliquely cranially toward the pylorus it becomes narrow and flattened dorsoventrally, so that dorsal and ventral surfaces are formed. On contacting the initial part of the descending duodenum, it becomes molded to this organ. The caudal part of the right lobe of the pancreas is related to the sublumbar fat containing the ureter and to the ventral

surfaces of the right kidney and the caudate process of the liver. The right lobe of the pancreas is related ventrally to the ileum and cecum caudally, and to the ascending colon cranially. Loops of the jejunum contact those portions of its ventral surface that are not already in contact with more fixed viscera. In some specimens the right lobe of the pancreas and the adjacent descending part of the duodenum have gravitated lateral and even ventral to the jejunal coils. The body of the pancreas (*corpus pancreatis*) unites the two lobes of the pancreas in an angle of approximately 45 degrees, which is open sinistrocaudally. Cranially, it lies closely applied to the caudosinistral portion of the pyloric region, which forms a large concave impression on the cranial portion of the body. Caudal to this impression, the pancreas is approximately 1 cm thick and 3 cm wide. The portal vein crosses the dorsal portion of the body. As the pancreaticoduodenal artery and gastroduodenal vein disappear into the pancreas at this place, they are crossed on their right side by the bile duct, which lies adjacent to the duodenum. The left lobe of the pancreas (*lobus pancreatis sinister*) lies in the deep wall of the greater omentum. It begins at the body and runs caudosinistrally. It is approximately two-thirds as long and half again as wide as the right lobe, measuring 10 cm, or 4 inches, in length, and 4 cm, or 1.6 inches, in width. Its dorsal surface (*facies dorsalis*), on the right, is related to the caudate process of the liver and then, in succession on the left, to the portal vein, caudal vena cava, and aorta. It ends in the left part of the sublumbar region in close relation to the cranial pole of the left kidney and the middle portion of the spleen. A full stomach alters these relations. The ventral surface (*facies ventralis*) of the left lobe of the pancreas is related ventrocaudally to the transverse colon and ventrocranially to the dorsal wall of the stomach. An accessory pancreas (*pancreas accessorium*) is occasionally found in the dog. Baldyreff (1929) cites cases in which the aberrant gland was located in the wall of the gallbladder and in the caudal part of the mesentery. Pancreatic bladders have been described by various authors as occurring in the cat, but none have been recorded in the dog (Boyden, 1925).

The pancreas nearly always has two excretory ducts, in conformity with the dual origin of the gland, one anlage arising dorsally from the duodenum and the other ventrally at the termination of the bile duct (Revell, 1902). Within the pancreas, these two ducts usually intercommunicate, or they may cross within the gland, because the parenchyma of the whole gland is elaborated around them. In the adult, the two

portions of the gland are fused without any demarcation to indicate their dual origin. Revell, however, points out that, when the two ducts do not communicate within the gland, the pancreatic duct drains the right lobe, or embryonic ventral pancreas, and the accessory pancreatic duct drains the left lobe, or embryonic dorsal pancreas. Although this is the basic pattern by which the pancreatic ducts form in the domesticated mammals, great variations exist among the different species and within the same species. The largest excretory duct of the pancreas in the dog is the accessory pancreatic duct (ductus pancreaticus accessorius), which opens into the duodenum on the minor duodenal papilla. The pancreatic duct (ductus pancreaticus) is the smaller duct in the dog and may occasionally be absent. The latter is associated with the opening of the bile duct and usually enters the duodenum on the major duodenal papilla alongside the bile duct. From its formation at the union of the ducts from the two lobes in the dog to the site where it perforates the intestinal wall, the accessory pancreatic duct is approximately 3 to 4 mm long and 2 mm wide. The union of the two lobar ducts to form the main duct (accessory pancreatic duct) may occur at any level up to the intestinal wall, or rarely, the two lobar ducts may open separately (Revell, 1902). According to Bottin (1934), the pancreatic and the accessory pancreatic duct open separately into the duodenum in approximately 75% of dog specimens, and they always communicate with each other in the gland. Other variations of the ducts of the canine pancreas exist, as Revell (1902) and Mintzloff (1909) have shown. The main duct from each lobe occupies the approximate center of the lobe and is joined at right angles by tributaries from the adjacent parenchyma. Because the gland is ribbonlike, the small ducts from the adjacent parenchyma enter largely on opposite sides, the openings being spaced at 0.5 to 1.5 cm intervals. The opening of the pancreatic duct is closely associated with that of the bile duct. In two out of three specimens Eichhorn and Boyden (1955) found the slitlike orifice of the pancreatic duct located distal to that of the bile duct; others have described this opening as proximal to that of the bile duct. The accessory pancreatic duct usually opens into the duodenum 28 mm from the opening of the bile duct into the duodenum, or approximately 8 cm from the pyloric sphincter (Nielsen and Bishop, 1954). Its entry into the duodenum resembles that of the bile duct in that a ridge of mucosa is formed, with a slight elevation at its distal end on which the opening is located. The accessory pancreatic duct, like the pancreatic duct, but unlike the bile duct, runs through the duodenal wall rather directly. The opening through the mesenteric wall of

the proximal portion of the descending duodenum is frequently located to the left of the cranial pancreaticoduodenal vessels, whereas the bile and pancreatic ducts open to the right of these vessels. Eichhorn and Boyden (1955) described and illustrated the musculature of the pancreatic and bile ducts of the dog (sphincter of Oddi). Kyösola and Rechartd (1974) described its innervation.

The main vessels to the right lobe of the pancreas are the pancreatic branches of the cranial and caudal pancreaticoduodenal arteries that anastomose in the gland. The left extremity of the left lobe of the pancreas is supplied primarily by the pancreatic branch of the splenic artery. It also receives small branches from the hepatic artery, as this vessel may groove the dorsal surface of the organ, and the left lobe regularly receives, near the pancreatic body, one or two branches from the gastroduodenal artery. Small pancreatic branches directly from the celiac artery may supply a small portion of the left lobe of the pancreas near its free end. The caudal pancreaticoduodenal vein, a satellite of the artery of the same name, is the principal vein from the right pancreatic lobe. It is the last tributary to enter the cranial mesenteric vein and, unlike the intestinal veins that empty into it, it enters the larger vessel from the cranial side. The left lobe of the pancreas is drained primarily by two veins that terminate in the last 2 cm of the splenic vein. The venous satellite of the small branch of the cranial pancreaticoduodenal artery that supplies the left lobe near the pancreatic body drains this part of the gland. The lymphatics from the pancreas drain into the duodenal lymph node, if present, and into the hepatic, splenic, and jejunal lymph nodes. Nerves Most sympathetic axons come from the celiac plexus and reach the organ by following the pancreatic branches of the cranial pancreaticoduodenal and celiac arteries. It is probable that the caudal part of the right lobe receives sympathetic axons from the cranial mesenteric plexus that follow the caudal pancreaticoduodenal artery and its pancreatic branches. McCrea (1924) states that, in the dog, vagal (parasympathetic) axons reach the pancreas as fine branches that run with the splenic branch of the celiac artery and with the cranial mesenteric artery, presumably along the caudal pancreaticoduodenal branch.

The pancreatic region is examined by scanning the area just caudal to the stomach, gastric outflow tract and medial to the duodenum (Walker, 1996; Mattoon et al., 2002a). Hecht and Henry (2007) have opined that due to small size of the pancreas and its indistinct margins, the examination should be performed with the highest

frequency transducer possible. In small dogs, a linear or curvilinear 8-15 MHz transducer may be used. In large dogs, use of a lower frequency transducer 5-8 MHz may be required to achieve the necessary penetration depth. Webster (2008) has suggested a frequency of 5 MHz for large dogs and 7-10 MHz for medium dogs and cats. Mekkawy et al. (2012) have used 8-12 MHz, 5-7 MHz, 4-7 MHz and 9-12 MHz transducers in their study on dogs and cats. Similarly, Robben et al. (2005) have used 5-3 and 7-4 MHz frequency transducers in their study for scanning pancreas in dogs.

Hecht and Henry (2007) have further added that most commonly, a ventral abdominal approach with the patient in dorsal recumbency is used. Especially in deep chested dogs, examination in left lateral recumbency with a right intercostal approach is occasionally helpful to visualize the right lobe of the pancreas and the duodenum. Similarly, Mekkawy et al. (2012) have also scanned pancreas with dogs in dorsal recumbency, whereas, Robben et al. (2005) performed the ultrasound examination in dogs in dorsal as well as lateral recumbency.

The left limb of the pancreas is best visualized by examining the area of the cranial left side of the abdomen. The transducer is positioned to visualize the spleen, stomach and colon in cross section. The left limb of the pancreas may be found within the area of the triangle formed by these structures. Identification of the duodenum allows identification of the right limb of the pancreas. The duodenum may be examined from the left or right side depending on preference. However, with the animal in right lateral recumbency and placing transducer underneath the animal, angled upwards towards the left side, will help to reduce the amount of gas in the duodenum. The duodenum is examined in both longitudinal and cross section, and the pancreas is identified slightly medial to the duodenum. The body of the pancreas connects the left and right limbs of the pancreas and is located dorsal to the portal vein. The pancreas is the most difficult abdominal organ to image routinely, and in some patients is not seen at all. Therefore, a complete examination of the region of the pancreas should be part of every abdominal ultrasound, even if the pancreas itself is not identified as a discrete organ Webster (2008).

Hecht and Henry (2007) propounded that the normal pancreas is an ultrasonographically inconspicuous organ, which can usually be visualized in cats and small dogs but may be difficult or impossible to identify in large dogs. Indistinct margins and similar echogenicity and echo texture of pancreatic parenchyma

compared with surrounding mesenteric fat contribute to the difficulty in identifying this organ. Gas or ingesta in adjacent gastrointestinal segments may interfere with ultrasonographic evaluation. Knowledge of the location and appearance of relevant anatomic landmarks is essential for the ultrasonographic identification and examination of the pancreas.

According to Larson (2013) the canine pancreas is isoechoic or slightly hypoechoic to surrounding mesenteric fat, with indistinct margins. Because it is not usually visualized as a discrete organ, it is desirable to be familiar with the anatomy and anatomic landmarks used to identify the pancreatic region. The use of a higher frequency transducer helps in visualization of pancreatic tissue. The right pancreatic lobe is the easiest to visualize in the dog. It lies dorsomedial to the duodenum, ventral to the right kidney, and lateral to the portal vein. The right lobe may be imaged by scanning longitudinally along the right lateral abdomen, using the descending duodenum and right kidney as landmarks. Cross-sectional images of the duodenum are very helpful in imaging the pancreas (located dorsomedial to the cross section of the duodenum). In large or deep chested dogs, a lateral intercostal approach may be needed. Using a right lateral transverse view through the dorsal aspect of the 10-12th intercostal space, the right pancreatic lobe will be located ventral to the right kidney, ventro-lateral to the portal vein, and dorso-medial or dorsal to the descending duodenum. The pancreatic body joins the two lobes and is located immediately ventral to the portal vein and cranio-ventral to the right kidney. The body lies caudal to the pyloric region. The left pancreatic lobe may be more difficult to visualize due to surrounding gas-filled structures (stomach and transverse colon). It lies dorsal and caudal to the stomach, extending to the left between the stomach and transverse colon. It may also be located in a triangular region cranial to the left kidney, caudal to the stomach, and medial to the spleen in the left cranial abdomen.

Hecht and Henry (2007) have noted the basic differences in ultrasonographic appearance of the pancreas in cats and dogs. In dogs, the right lobe of the pancreas is more easily seen than the body or left lobe whereas, in cats, the body and left lobe of the pancreas are more easily seen than the right lobe. In dogs, the pancreatic ducts are rarely observed, whereas the ducts are commonly observed in the cat. The major duodenal papilla is the primary connection of the pancreatic duct system in the cat whereas, in the dog, the minor duodenal papilla is the primary connection and is

infrequently seen. In dogs, visualization of the right lobe of the pancreas is best achieved by first identifying the duodenum as a target like structure on transverse image adjacent to right abdominal wall and right kidney. The pancreas is found adjacent to the medial and ventral aspects of the duodenum. The right lobe appears triangular in shape, and isoechoic or slightly hypoechoic to surrounding mesenteric fat.

Any insult to pancreas incites inflammatory reaction which leads to swelling and hence an increased size of parenchyma. Findings suggestive of acute pancreatitis in dogs include a diffusely enlarged pancreas (more than 2 cm in diameter) with hypoechoic parenchyma, hyper echoic surrounding mesentery and generalized or local peritoneal effusion. (Simpson and Lamb, 1995; Hess et al., 1998; Ruaux, 2003; Mansfield, 2004; Watson, 2004; Mix and Jones, 2006). Ultrasonographic findings in dogs and cats with pancreatitis include hypoechoic areas within the pancreas (possibly indicating necrosis or fluid accumulation), increased echogenicity of the surrounding mesentery (due to necrosis of the peripancreatic fat), enlargement and/or irregularity of the pancreas, dilation of the pancreatic or biliary duct and abdominal effusion (Hess et al., 1998; Lamb, 1999b; Swift et al., 2000; Saunders et al., 2002; Ferreri et al., 2003; Hecht & Henry, 2007). The most common ultrasonographic observation is a loss of echodensity that is compatible with edema. Other ultrasonographic findings include: increased echodensity suggestive of fibrosis, nonhomogeneous masses, and less commonly, fluid filled cyst-like structures (Burrows, 2002).

Alteration in size of pancreas resulting from inflammatory changes, therefore, make it essential to measure the dimensions of the pancreas during ultrasonography. While making measurements on the pancreas, Evans (1993) found that the size of the pancreas is variable and ranges from 1 to 3 cm in width and up to 1 cm in thickness, in beagle type dogs. In most dogs, one or two circular anechoic structures can be visualized in the center of the pancreas, which are tubular on sagittal view and show flow signal on Doppler examination. These represent branches of the pancreaticoduodenal vein and artery. Once the right lobe of the pancreas has been examined, it can be traced to the body and the left lobe. The pancreatic body is located dorsocaudal to the pylorus in close proximity to the portal vein, and left lobe is located between stomach and transverse colon (Hecht and Henry, 2007). Similarly, Rajapakshage et al. (2016) found the mean thickness of right pancreatic lobe to be

14.2 ± 3.3 mm (range, 9.4 to 20.8 mm). They recorded the thickest dimension of 20.8 mm in a 28 kg, 8 months old Labrador Retriever.

Mekkawy et al. (2012) in their study, found acute pancreatitis in 11 dogs and 5 cats. Ultrasound examination of these cases showed irregular hypoechoic mass of mixed echogenicity ventral to portal vein and medial to right kidney in close proximity to the descending duodenum. The size was measured 3.7 x 1.7 cm. The surrounding fat became more hyperechoic with indistinct edges of pancreas.

Biopsy of the pancreas is considered the most reliable test for diagnosing acute pancreatitis in dogs and cats and is often used in publications as the golden standard for evaluating the accuracy (sensitivity, specificity) of a diagnostic test (Watson, 2004; Mix and Jones, 2006; Zoran, 2006; De Cock et al., 2007; Watson, 2007b). While working on abscesses in dogs and cats, Salisbury et al. (1988) have reported that abscesses were more frequent in dogs than in cats and appeared as hypoechoic structure surrounded by hyperechoic area and echogenic irregular wall.

Larson (2013) concluded that Inflammation, edema, necrosis, and hemorrhage associated with acute pancreatitis result in an enlarged, irregular, hypoechoic pancreas. The affected areas may be diffuse, or patchy and poorly defined. The surrounding mesenteric fat is usually hyperechoic secondary to inflammation and saponification. Other associated changes occur in the descending duodenum, which can appear thickened, dilated and fluid-filled (ileus), or corrugated secondary to duodenitis. Focal peritoneal effusion often accompanies acute pancreatitis. In the dog, the right lobe seems to be the most commonly affected portion of the pancreas with acute disease. Chronic, low grade, or resolving pancreatitis appears as a slightly more echogenic pancreas (although still hypoechoic) with better defined, smooth borders. Occasionally, foci of mineralization may be present, and the echogenicity may be nonhomogeneous. Pancreatic atrophy may result in decreased size of the pancreas. Associated changes such as hyperechoic peripancreatic fat, duodenitis, and abdominal effusion usually are absent.

Hecht and Henry (2007) have suggested that acute pancreatitis is a relatively common disorder in dogs. On ultrasonographic examination, the pancreas is enlarged, irregular, hypoechoic and on occasions may appear mass like. (Nylan et al., 1983; Murtaugh et al., 1985; Steiner, 1986; Lamb and Simpson, 1995; Hess et al.,

1998). Surrounding hyperechoic mesentery indicating peripancreatic steatitis, fat necrosis, and focal abdominal effusion is commonly seen. Other potential ultrasonographic findings include corrugation of the duodenum, fluid /gas distended, hypomotile intestines (indicative of paralytic ileus) and ultrasonographic signs of extrahepatic biliary obstruction (Hecht and Henry, 2007).

Choi et al. (2012) concluded that endocrine test data from a 13-year old intact female Maltese was indicative of the presence of an insulinoma, however ultrasonography identified a pancreatic mass only 10 months after the first admission.

Mekkawy et al. (2012) in their study ultrasonographically examined a total number of 19 dogs and 9 cats and diagnosed pancreatic surgical affection in them. In dogs, the most commonly encountered cases were acute pancreatitis with thickened irregular hypoechoic tissue of mixed echogenicity in the pancreas. They diagnosed abscess in 3 dogs with hypoechoic mass surrounded by hyperechoic area with echogenic irregular wall. They also diagnosed chronic pancreatitis (2 cases), tumour (2 cases), and cyst (1 dog). Similarly, in cats acute inflammation was the common affection while the rest were cysts (2 cases), abscess (1 case) and chronic inflammation (1 case).

Xenoulis (2015) has reported that Pancreatitis is the most common disorder of the exocrine pancreas in dogs. In clinical practice, a combination of careful evaluation of the animal's history, serum PLI concentration and abdominal ultrasonography, together with pancreatic cytology or histopathology when indicated or possible, is considered to be the most practical and reliable means for an accurate diagnosis or exclusion of pancreatitis compared with other diagnostic modalities. In their study, Moon et al. (2003) found pancreatitis to be the most common cause of corrugated small intestine (especially involving the duodenum) in both dogs and cats. Chang and Steiner, (2016) could diagnose pancreatitis through ultrasonography however, in doing so, they also depended on history, physical examination findings, nonspecific findings on general blood analysis, abnormal pancreatic lipase immunoreactivity (cPLI), abdominal radiographs, and ultrasonographic findings in arriving at this diagnosis.

Insulinoma is a rare malignant neuroendocrine neoplasia of the β -cells of the canine pancreas (Madarame et al., 2009). However, Elie and Zerbe (1995) have

reported that Insulinoma is recognized as the most common islet cell tumour of the endocrine pancreas. Leifer et al. (1986) have said that the breeds most commonly affected with pancreatic neoplasia are German Shepherd, Irish Setter, Boxer, Golden Retriever and Terrier. Insulinoma occurs most often in middle-aged to old dogs with an average age of nine years (Cohen, 2003; McDermott et al., 1999). Recently, Uwagie - Ero et al. (2017) have successfully diagnosed a case of malignant neoplasia of the pancreas in a female dog.



Materials

and

Methods



CHAPTER- 3

MATERIALS AND METHODS

Place of Study:

This study was conducted at the Veterinary Clinical Complex (VCC), (Kothari Veterinary Hospital), College of Veterinary Science and Animal Husbandry, UP Pt Deen Dayal Upadhyaya Pashu-Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura (UP).

Subjects of Study:

The study was conducted in two parts namely, Part I & Part II.

In Part I of the study, eighteen apparently healthy dogs of all age groups were enrolled to be subjected to ultrasonographic examination of both limbs of pancreas.

These dogs were divided into three age groups as under:

Group I: animals of 01 month to 09 months of age

Group II: more than 09 months to 6 years of age

Group III: above six years of age.

There were six animals in each group.

Dogs with fracture, castration, cherry eye, which were otherwise healthy were assessed ultrasonographically with due consent from the respective owners prior to surgery.

In Part II of the study ultrasonographic examination of both limbs of pancreas of patients reporting to the VCC with symptoms like lack of appetite, weight loss, acute vomiting, diarrhoea, dehydration, abdominal pain, tucked-up belly were performed to assess the abnormalities, if any, of the pancreatic echoarchitecture and size.

Ultrasound machine:

In this study, the Esaote[®] My Lab30 with 7.5 MHz transducers C5-2 was used for scanning of the pancreas.

Restraint and Anaesthetic protocol:

The animals were subjected to ultrasonographic examination without using any anaesthesia or sedatives with animals restrained in lateral and/or dorsal recumbency.

Site preparation:

The animals were prepared as per the preparation procedure suggested by Larson (2013) for scanning the right pancreatic lobe, an area immediately caudal to last rib (right cranial quadrant of abdomen) and para vertebral lumbar region extending caudally up to tuber ischii and ventrally from xiphoid process up to midline (umbilical region) was shaved and cleaned with mild soap. Similarly, for scanning the left pancreatic limb an area in the left cranial abdomen located in a triangular region cranial to the left kidney, caudal to the stomach, and medial to the spleen was shaved and cleaned in a similar manner. The site in question was smeared with ultrasound gel liberally prior to ultrasound examination after restraining the animal in desired recumbent position (dorsal or lateral). Adequate amount of coupling gel was applied over the transducer as well as the area of interest in order to ensure an intimate contact between skin and transducer head. Animals were left undisturbed throughout the examination procedure in order to get optimum results. Mattoon et al. (2014) have suggested that the animal being subjected to an abdominal sonogram needs the abdomen to be completely shaved, from the xiphoid to the pubis, to eliminate the effects of air trapped within the fur and to increase sound wave conductivity.

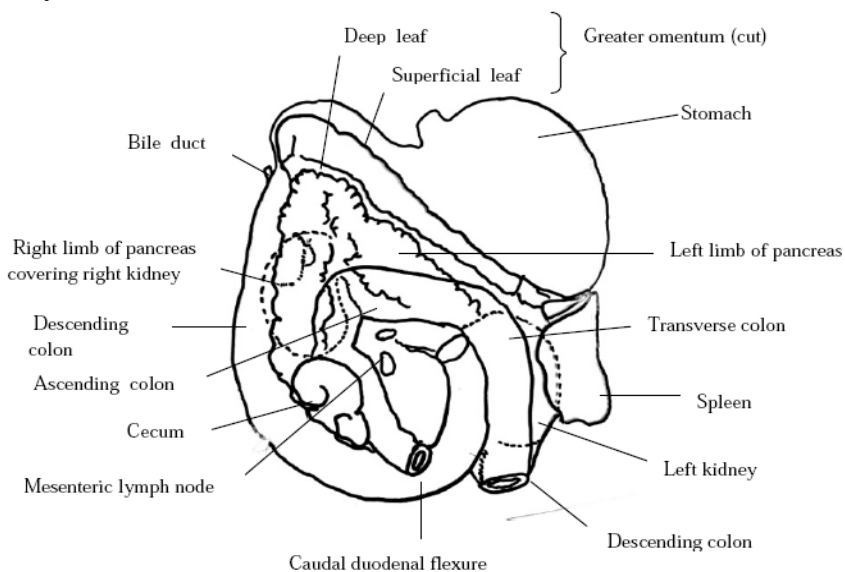


Fig 1: Schematic representation of canine pancreas.

Ultrasonography:

The scanning method was adopted from Nyland et al. (2002) wherein right limb of the pancreas was located along the mesenteric (medial) border of the duodenum within the mesoduodenum. After identification of the duodenum it was easy to assess the region of the right limb of the pancreas by directing the plane of the ultrasound beam medial from the duodenum. Once the duodenum and right pancreatic lobe region were identified in long axis, the transducer was rotated counterclockwise approximately 90° degrees to a transverse body plane wherein, the duodenum was seen in cross section on the left of the screen (lateral), the cross-sectional image of the right kidney medially positioned in the right field of view. The right limb of the pancreas was located in the tissues between the duodenum and the right kidney.

The area just caudal to the stomach and gastric outflow tract and medial to the duodenum was scanned for landmarks, in the sagittal body plane, the stomach and colon were identified in cross section as two curved echogenic structures (gas reverberation artifact) in the near field. A cross-sectional image of the left limb of the pancreas was observed between these two structures (Fig.6). The length of the left pancreatic limb may be studied in cross section by moving the transducer from left to right along the axes of the stomach and transverse colon. The pancreas appeared as a poorly marginated hypoechoic organ. It was, somewhat triangular in appearance on this cross-sectional view. The transducer was rotated 90° to obtain a long axis view of the left limb of pancreas, just caudal to the stomach and cranial to the transverse colon. It required a gentle fanning of the ultrasound beam cranially and caudally to view the left pancreatic limb in the area between these two structures.

The pancreas could be identified by using the landmarks surrounding abdominal organs. Direct visualization of the pancreas was not possible. Animal was restrained in left lateral recumbency, then the right kidney was located first by placing the transducer immediately behind the second last rib. Thereafter, the duodenum was located by dorsomedially fanning towards the right quadrant. The pancreas was finally identified in between the duodenum and right kidney.

Transverse localization of pancreas required the animals to be restrained in dorsal recumbency. Examinations performed in transverse view are few because of the considerable discomfort and non cooperation of animal in this recumbency

position. For right limb of pancreas in transverse view, gastric fundus was visualized by placing the transducer in sagittal view thereafter, the probe was slid toward the right lateral quadrant below the subcostal arch. Then turned to 90° anticlockwise and consequently the cross section of duodenum was achieved resembling a ‘target’ like appearance. The pancreaticoduodenal vein was visualized in cross section within the pancreas.

For the left limb of pancreas, animals were restrained in right lateral recumbency. Attempt was made locate the left kidney first. Then the transducer was slid beneath the subcostal arch towards the xiphisternum, to locate the stomach. On gradual fanning both the caudal part of stomach and left kidney and transverse colon were visualized together in the left side of the screen with in the same field, and the pancreas could be identified as triangular silhouette.



Fig. 2: Esaote® MyLab30VetGold Ultrasound machine.



Fig. 3: Curvilinear transducer C5-2.

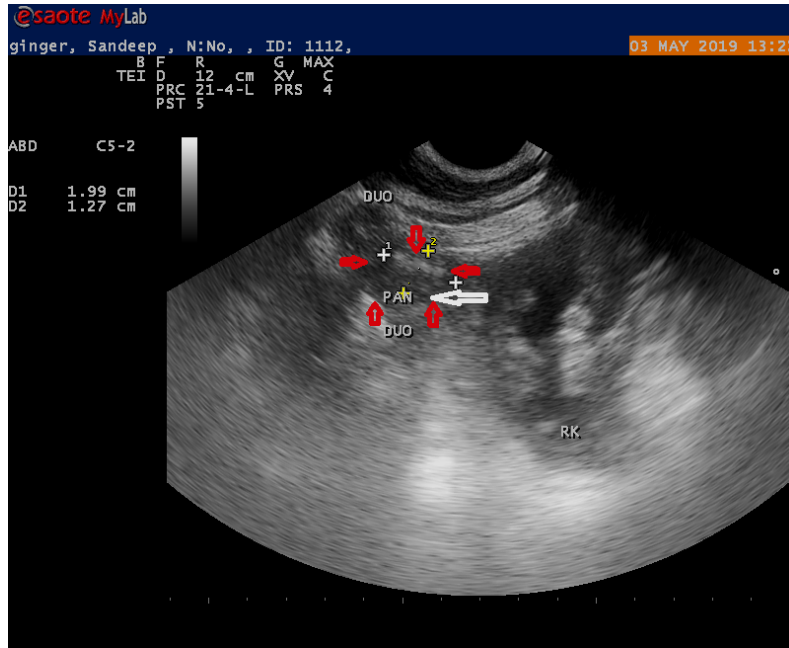


Fig. 4: Transverse ultrasonogram showing measurements of right pancreatic limb, with help of measuring caliper. +1 of caliper is showing the width taken of the limb.+2 of the caliper is showing the thickness of the pancreas. The pancreaticoduodenal vein (white arrow) is often visualized in cross section within the pancreas.The duodenum(DUO) and right kidney(RK) serve as a useful landmarks for localizing the pancreas (red arrows) even if the pancreas is poorly seen.

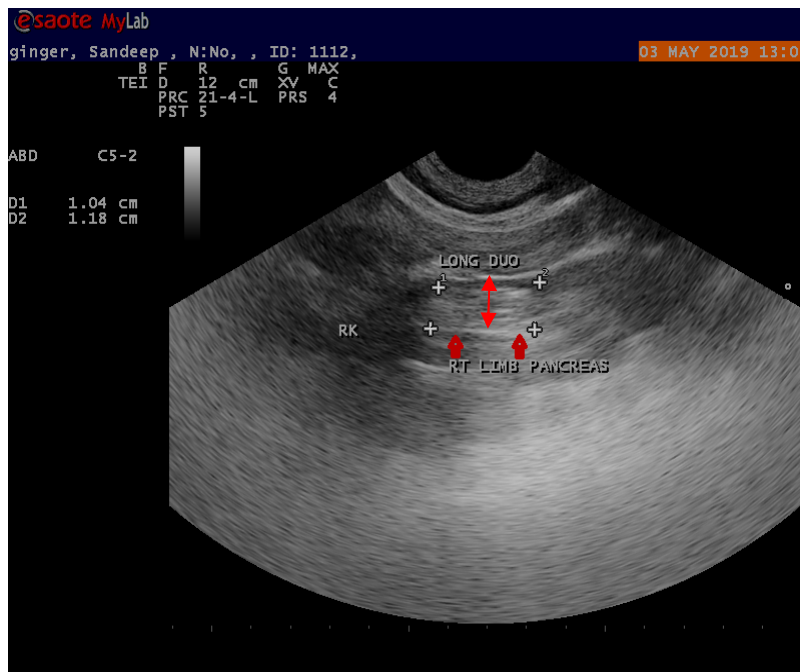


Fig. 5: Sagittal view of ultrasonogram of right limb of pancreas, showing the thickness (red arrow) obtained using the in- built calipers.

In this study, the term thickness was used to represent the height of the pancreas similar to that described by Penninck et al. (2013) that is, the pancreas has a variably amorphous to triangular shape and its position can shift on the basis of position of dog, the term thickness was considered an acceptable compromise to describe the measurement obtained perpendicular to the long axis of the pancreas.

French et al. (2019) suggested that not all regions of the pancreas were visualized by US in all dogs, the thickest portion of the pancreas identified on US images was measured.

In this study, the width of the right limb and width and thickness of left limb were measured ultrasonographically with the in-built caliper after proper visualization of the target organ.

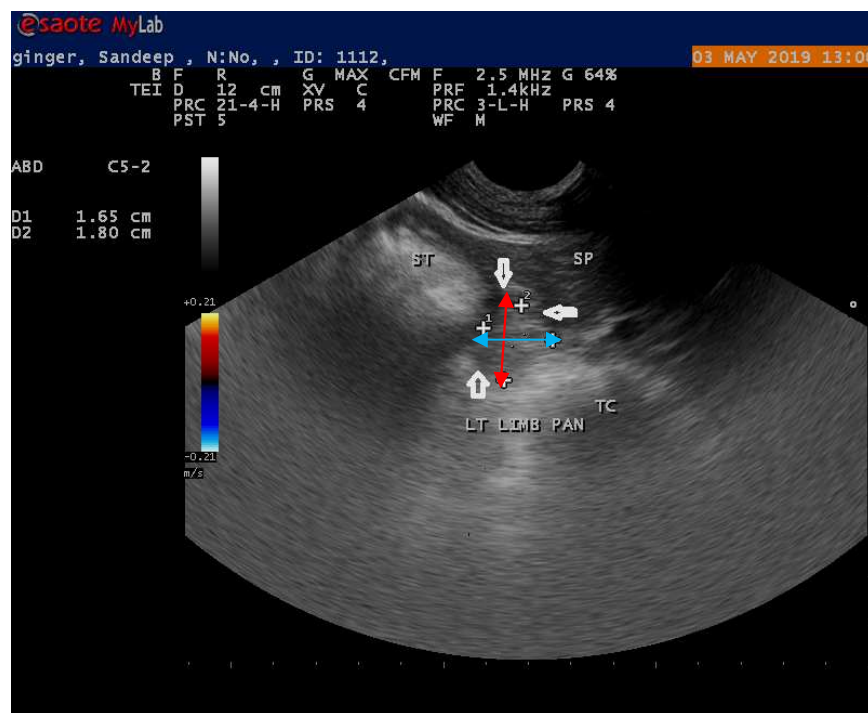


Fig. 6: Ultrasonogram showing measurements of left limb of pancreas (white arrow) using in- built calipers. +1 showing the width and +2 showing the thickness of the left limb of pancreas.

A decorative border composed of black and grey floral and butterfly motifs. The border features intricate scrollwork, leaves, and three butterflies with detailed wing patterns. The word "Results" is centered within this decorative frame.

Results

Ultrasonographic examination was done in lateral recumbency in all the dogs, but in some cases ultrasonography was also done in dorsal recumbency.

All examinations were performed in lateral recumbency (n =18). However, two animals of Group I, four of Group II and one animal of Group III were scanned in dorsal recumbency also.

The method of scanning pancreas described by Nyland et al. (2002) was adopted to scan the pancreas in this study. Ultrasonographic images of pancreas were recorded in transverse and sagittal planes. The right limb of pancreas could be visualized in transverse view by keeping transducer at right cranial abdomen just behind the last rib. The left limb of the pancreas could be identified while scanning the left cranial abdomen in a sagittal plane. The duodenum was found ventrolateral to the right kidney in approximately the 11-o'clock position on the display monitor. The liver, duodenum and right kidney were useful landmarks for localizing the pancreas. The visualization of pancreaticoduodenal vein helped in confirming the location of the pancreas. The left limb of the pancreas was found caudal to the stomach and extending towards left to the region of the cranial pole of the left kidney.

Echoarchitecture of the right limb of pancreas:

The ultrasonograms of the right limb of pancreas of the animals of Group I are presented in Fig. 8 to Fig. 13.

The ultrasonograms of the right limb of pancreas of the animals of Group II are presented in Fig. 14 to Fig. 19.

The ultrasonograms of right limb of pancreas of the animals of Group III are presented in Fig. 20 to Fig. 25.

The ultrasonograms of the right limb of pancreas in transverse view are presented in Fig. 26 to 31.

The right limb of pancreas appeared hypoechoic to isoechoic as compared to the surrounding structures in all the groups. The echoarchitecture of the right limb of

pancreas was homogeneous in the animals of all the groups. In cross-sectional view of right limb of the pancreas, the pancreas was seen as a sail-like structure medially (Fig.4). In longitudinal view of right limb of the pancreas, duodenum was seen coursing longitudinally across the top of the image. The right limb of the pancreas was identified as a poorly margined structure medial to the duodenum. The echoarchitecture of pancreas was similar to liver and isoechoic to surrounding peripancreatic fat, while having similar echoarchitecture to surrounding mesentery. The entire length of right limb could not be seen except in one case (Fig. 14). The pancreaticoduodenal vein (Fig. 4 & Fig. 31) could be visualized as anechoic round structure in cross section within the pancreas.

Ultrasonographic measurements of the right limb of pancreas

The measurements of the right limb of pancreas, namely, width were recorded using the in-built calipers of the ultrasound machine. The mean \pm standard error values of measurement (mean width) are presented in Table-1. The mean width of right limb of pancreas was 1.2 ± 0.03 cm in Group I, 1.31 ± 0.06 cm in Group II and 1.5 ± 0.06 cm in Group III.

Table. 1: Mean \pm SE values of ultrasonographic measurements of right limb of pancreas in different group of dogs.

Units	Mean \pm SE		
	Group I	Group II	Group III
Width of limb (cm)	1.2 ± 0.03	1.31 ± 0.06	1.5 ± 0.06

The mean width of right limb of pancreas was highest in Group III and least in Group in I.

Echoarchitecture of the left limb of pancreas:

The ultrasonograms of the left limb of pancreas of the animals of Group I are presented in Fig. 32 to Fig. 37.

The ultrasonograms of the left limb of pancreas of the animals of Group II are presented in Fig. 38 to Fig. 43.

The ultrasonograms of left limb of pancreas of the animals of Group III are presented in Fig. 44 to Fig. 49.

The left limb of pancreas appeared hypoechoic to isoechoic in relation to its adjacent structures and homogeneous pancreas was found in all the groups. The left limb of the pancreas was more difficult to visualize as compare to the right limb. It lay caudal or caudodorsal to the stomach and cranial or cranioventral to the splenic vein (SV). In cross-sectional view of left limb of the pancreas, the pancreas was seen as hypoechoic, homogeneous, triangular structure. The anechoic round structure dorsal to the pancreas is cross sectional image of the splenic vein (Fig.34). Landmarks include the stomach (ST) which contains echogenic gas, and transverse colon (TC) in this particular instance (Fig. 34) the left kidney is not in view.

Ultrasonographic measurements of the left limb of pancreas:

The measurements of the left limb of pancreas, namely, width and thickness were measured using the in-built calipers of the ultrasound machine. The mean \pm standard error values of measurement (mean width & mean thickness) are presented in Table - 2.

Table 2: Mean \pm SE values of various ultrasonographic measurements of left limb of pancreas in different group of dogs.

Units	Mean \pm SE		
	Group I	Group II	Group III
Width (cm)	1.47 \pm 0.16	1.77 \pm 0.10	1.92 \pm 0.15
Thickness (cm)	1.17 \pm 0.06	1.35 \pm 0.09	1.5 \pm 0.10

The mean width of left limb of pancreas was 1.47 ± 0.16 cm in Group I, 1.77 ± 0.10 cm in Group II and 1.92 ± 0.15 cm in Group III. The mean thickness of left limb of pancreas was 1.17 ± 0.06 cm in Group I, 1.35 ± 0.09 cm in Group II and 1.5 ± 0.10 in Group III.

The mean width of left limb of pancreas was maximum in Group III and minimum in Group in I.

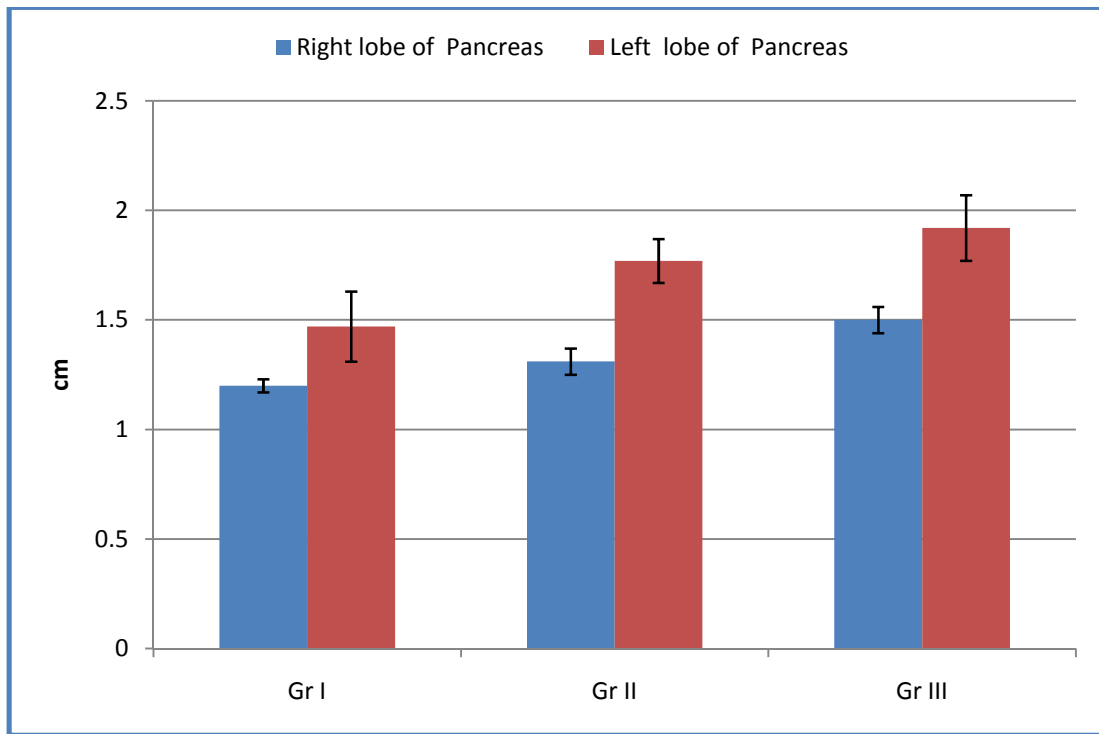


Fig 7: Comparison of mean width of right and left limb of pancreas.

PART – I

Ultrasonograms of the right limb of pancreas of Group – I.

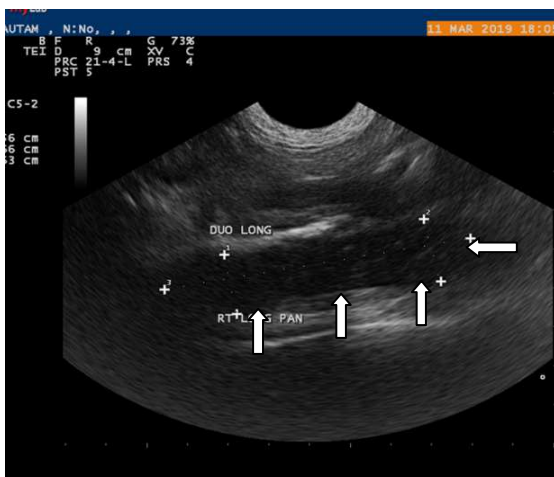


Fig 8. Ultrasonogram of the right limb of pancreas of Animal1, showing pancreas lies dorsomedial to duodenum (DUO) in sagittal view.

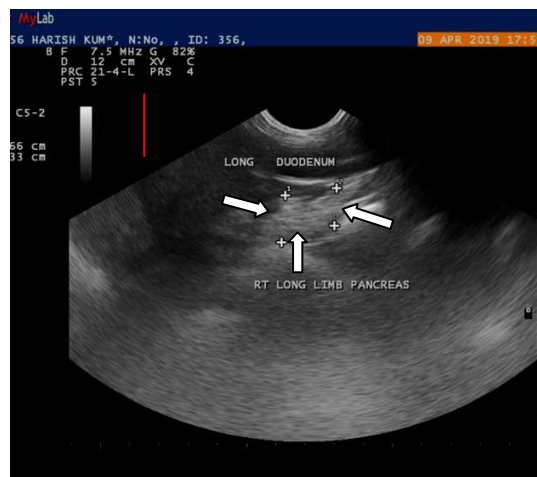


Fig 9. Ultrasonogram of the right limb of pancreas of Animal 2, showing pancreas lies dorsomedial to duodenum (DUO) in the mesoduodenum area.

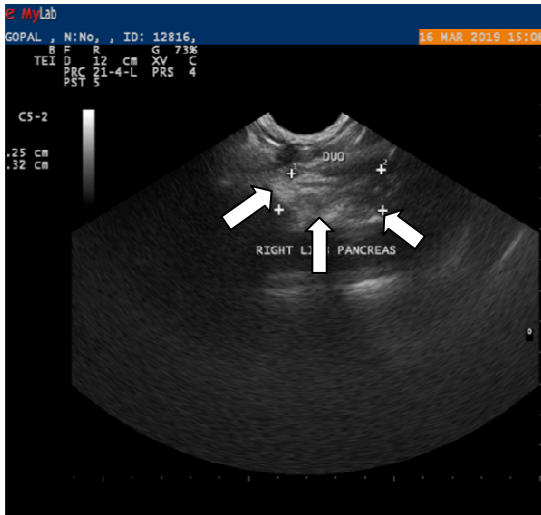


Fig. 10. Ultrasonogram of right limb of pancreas of Animal 3, showing pancreas lies dorsomedial to duodenum (DUO) in near field of screen.

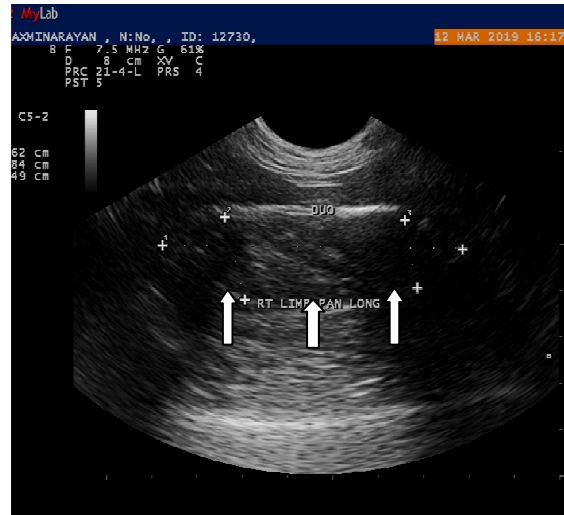


Fig. 11. Ultrasonogram of right limb of pancreas of Animal 4.

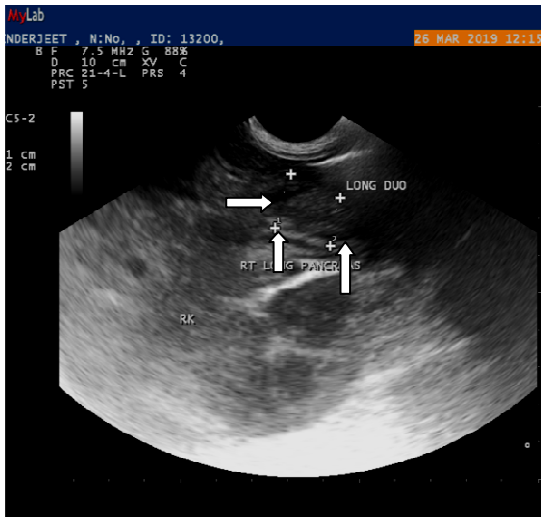


Fig. 12. Ultrasonogram of right limb of pancreas of Animal 5, showing pancreas, duodenum and right kidney in view.

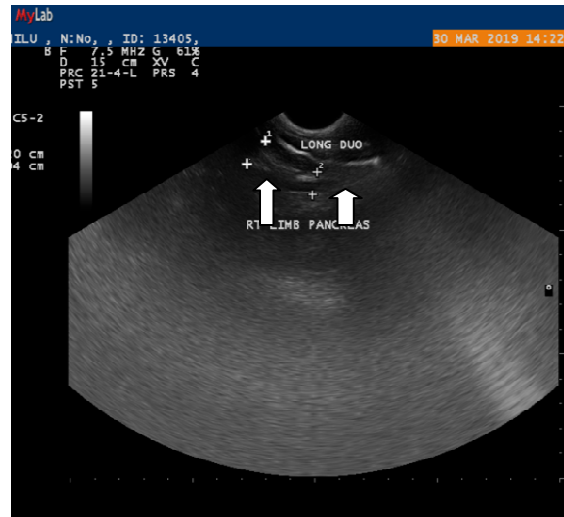


Fig. 13. Ultrasonogram of right limb of pancreas of Animal 6.

Ultrasonograms of the right limb of pancreas of Group – II.

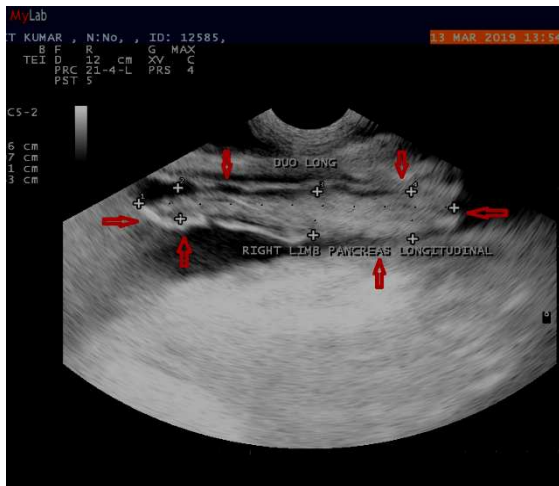


Fig. 14. Ultrasonogram of right limb of pancreas of Animal 1, delineating the entire silhouette of limb lies dorsomedial to duodenum in view.



Fig. 15. Ultrasonogram of right limb of pancreas of Animal 2, showing pancreas, duodenum and right kidney in view.

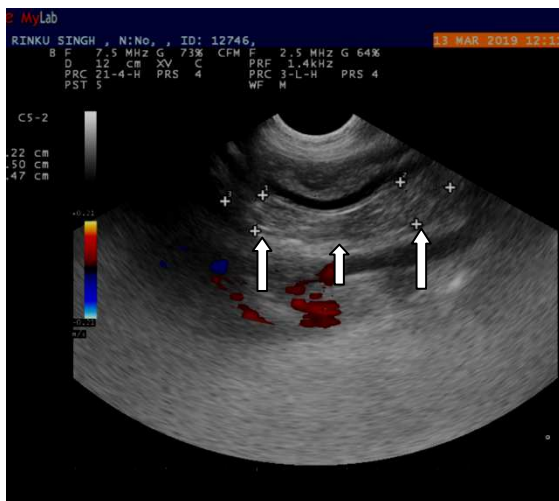


Fig. 16. Ultrasonogram of right limb of pancreas of Animal 3, showing pancreas in sagittal view.



Fig. 17. Ultrasonogram of right limb of pancreas of Animal 4, Showing pancreas in dorsomedial to duodenum.

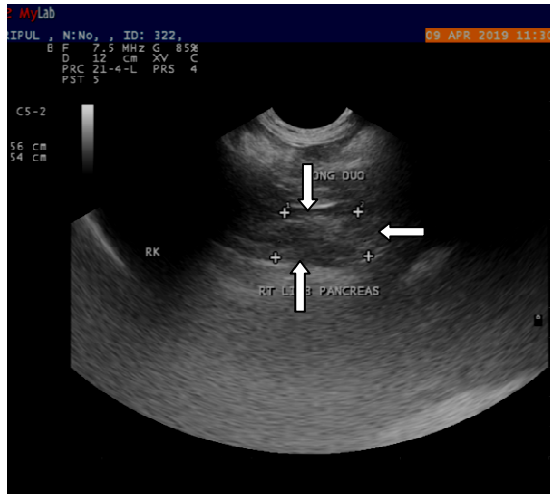


Fig. 18. Ultrasonogram of right limb of pancreas of Animal 5.

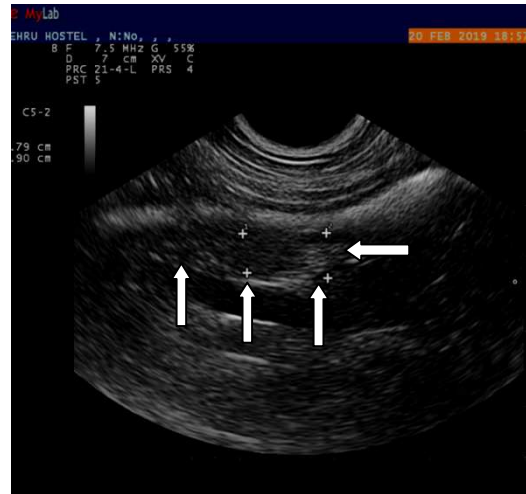


Fig. 19. Ultrasonogram of right limb of pancreas of Animal 6.

Ultrasonograms of the right limb of pancreas of Group – III.

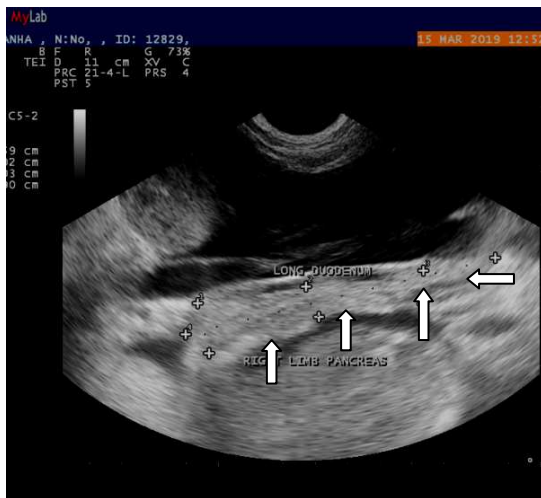


Fig. 20. Ultrasonogram of right limb of pancreas of Animal 1.

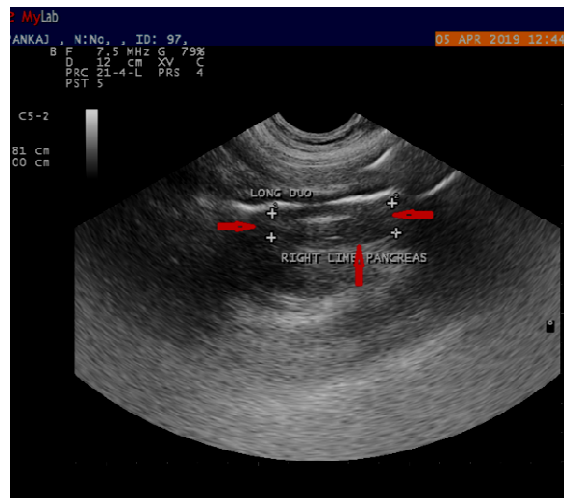


Fig. 21. Ultrasonogram of right limb of pancreas of Animal 2, showing pancreas in the area entrapped between the red arrows.



Fig. 22. Ultrasonogram of right limb of pancreas of Animal 3, showing pancreas in the area entrapped between the red arrows.



Fig. 23. Ultrasonogram of right limb of pancreas of Animal 4, showing pancreas in the mesoduodenum.

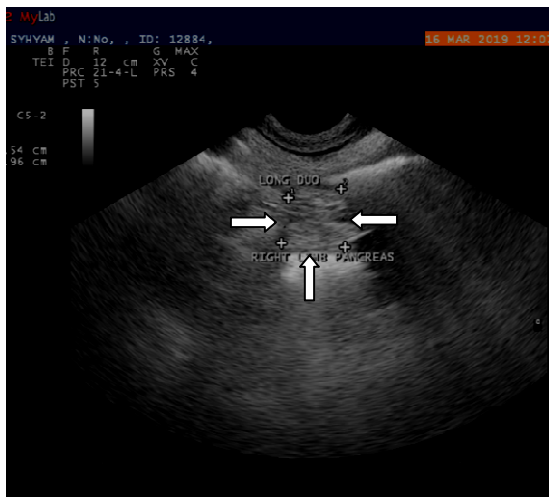


Fig. 24. Ultrasonogram of right limb of pancreas of Animal 5, showing isoechoic pancreatic parenchyma.

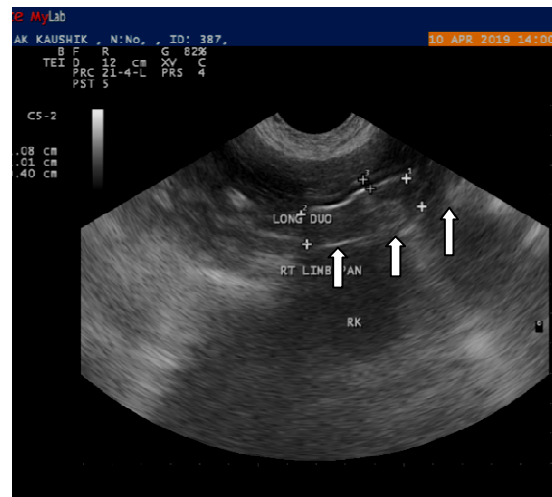


Fig. 25. Ultrasonogram of right limb of pancreas of Animal 6, showing duodenum (DUO) and pancreas in sagittal view.

Ultrasonograms of the right pancreatic limb of dogs in transverse view.



Fig. 26. Ultrasonogram of right limb of pancreas in transverse section. The pancreaticoduodenal vein (white arrow) is often visualized in cross section within the pancreas. The duodenum (DUO) and right kidney (RK) serve as useful landmarks for localizing the pancreas (red arrows) even if the pancreas is poorly seen.



Fig. 27. Ultrasonogram of right limb of pancreas in transverse section.

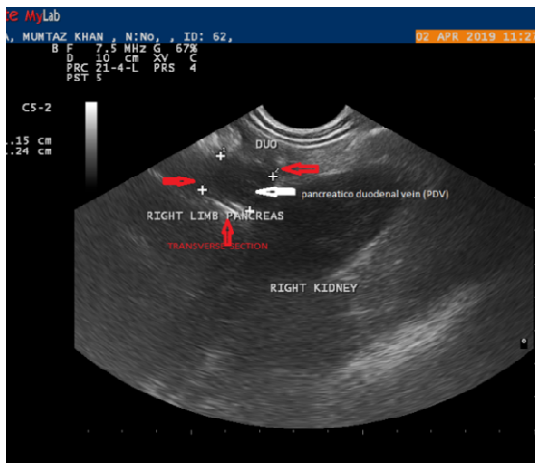


Fig. 28. Ultrasonogram of right limb of pancreas in transverse section, showing pancreas at 11'o clock position.

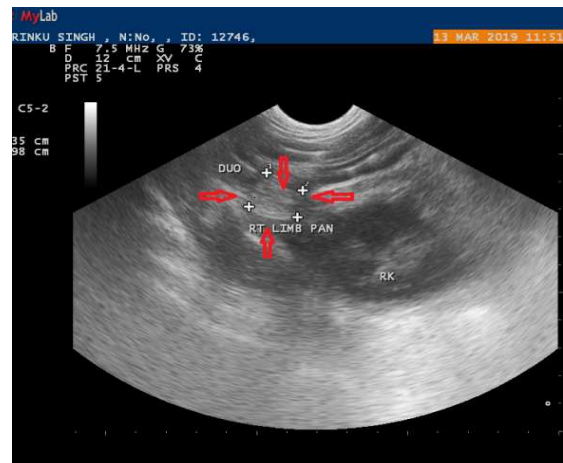


Fig. 29. Ultrasonogram of right limb of pancreas in transverse section, showing pancreas at 11'o clock position.

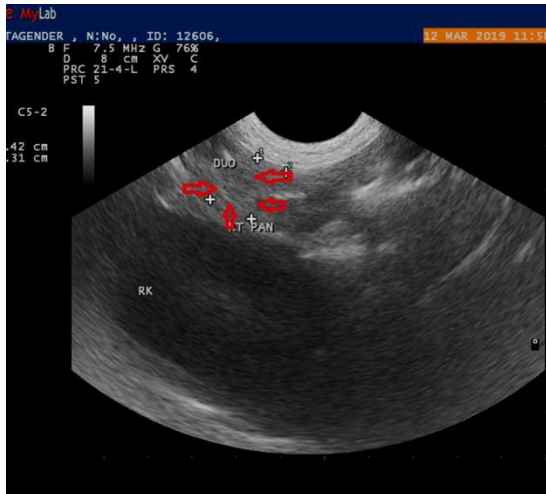


Fig. 30. Ultrasonogram of right limb of pancreas in transverse section.

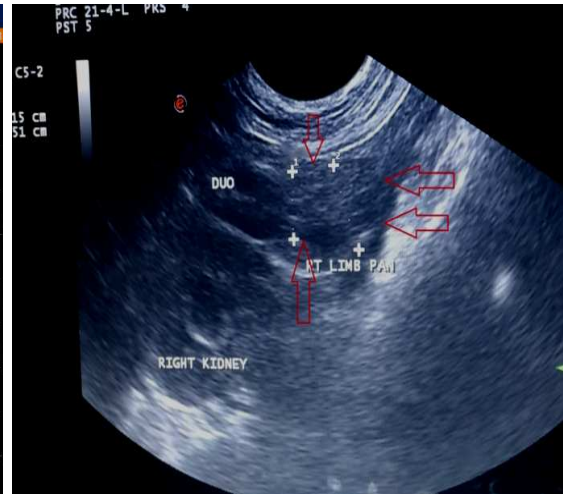


Fig. 31. Ultrasonogram of right limb of pancreas in transverse section, where pancreaticoduodenal vein (white arrow) is visualized in cross section within the pancreas. shown by colour Doppler.

Ultrasonograms of the left limb of pancreas of the dogs of Group I.

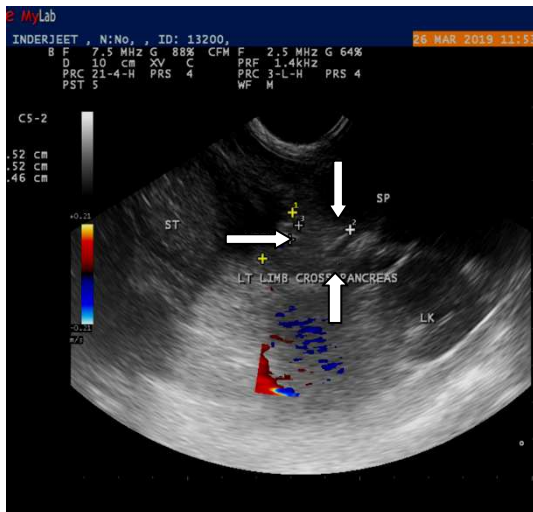


Fig. 32. Ultrasonogram of left limb of pancreas of animal 1, showing stomach (ST), spleen (SP) and left kidney (LK) in view.

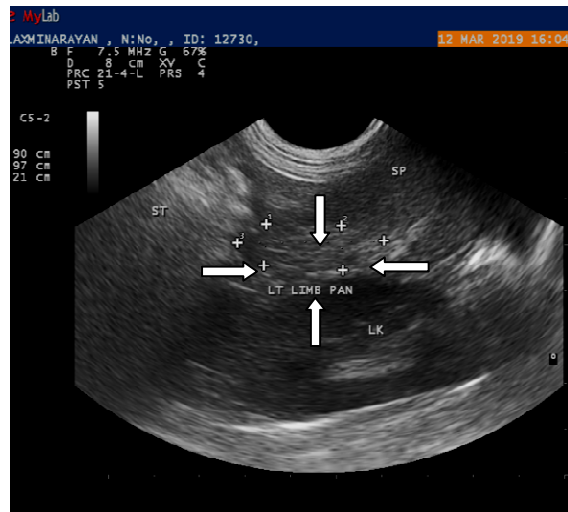


Fig. 33. Ultrasonogram of left limb of pancreas of animal 2, illustrating stomach (ST), spleen (SP), left kidney (LK), and transverse colon (TC) in a view.

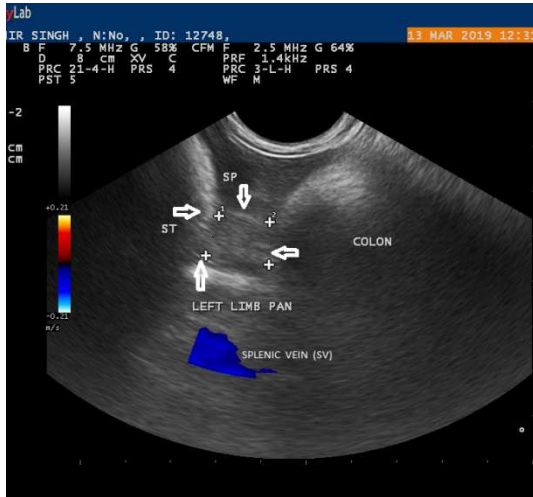


Fig. 34. Ultrasonogram of left limb of pancreas of animal 3, showing splenic vein (SV), stomach (ST), spleen (SP) and transverse colon (TC) in view.

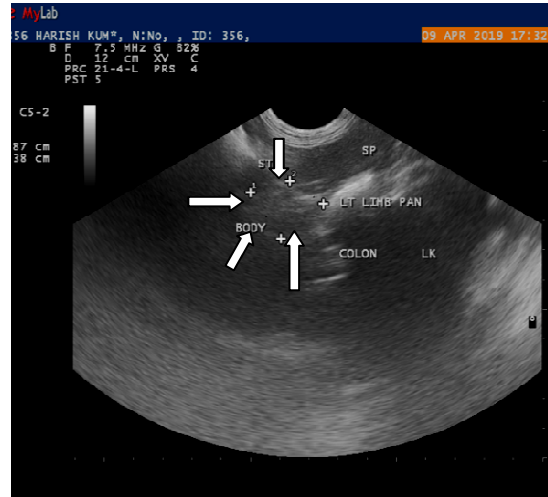


Fig. 35. Ultrasonogram of left limb of pancreas of animal 4, stomach (ST), spleen (SP) and transverse colon (TC) in view.

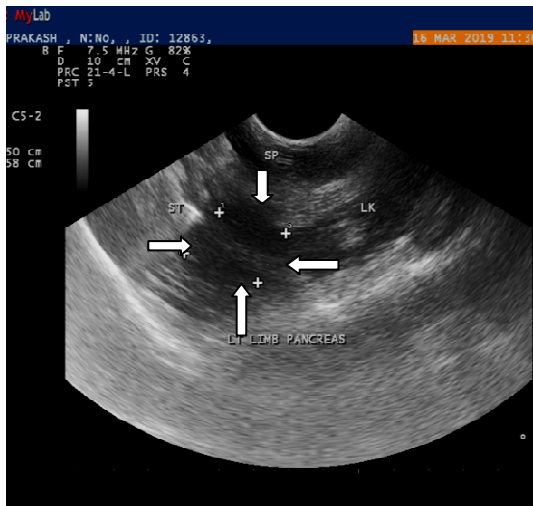


Fig. 36. Ultrasonogram of left limb of pancreas of animal 5.

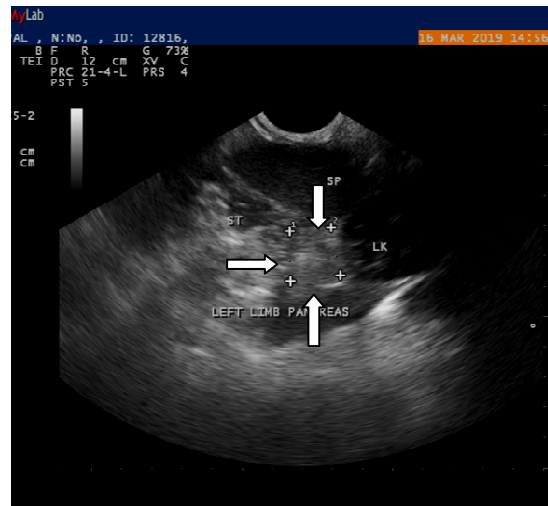


Fig. 37. Ultrasonogram of left limb of pancreas of animal 6, showing stomach (ST), spleen (SP) and left kidney (LK) in view.

Ultrasonograms of the left limb of pancreas of the dogs of Group II.

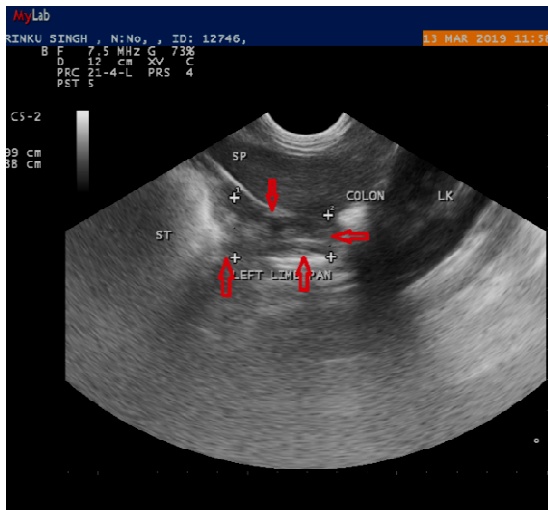


Fig. 38. Ultrasonogram of left limb of pancreas of animal 1, showing stomach (ST), spleen (SP), left kidney (LK) and transverse colon (TC) in view.

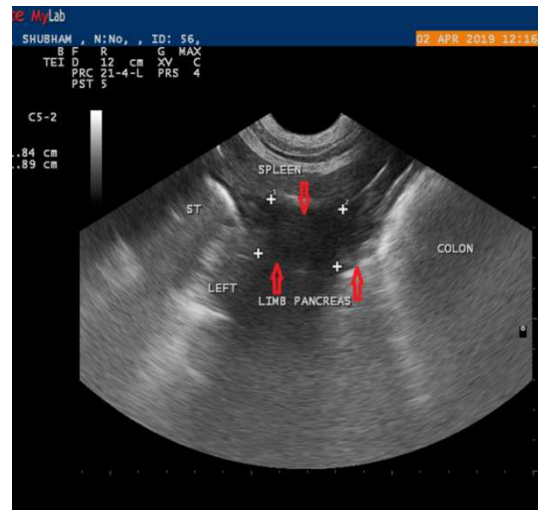


Fig. 39. Ultrasonogram of left limb of pancreas of animal 2, showing stomach (ST), spleen (SP) and left kidney (LK) in view.

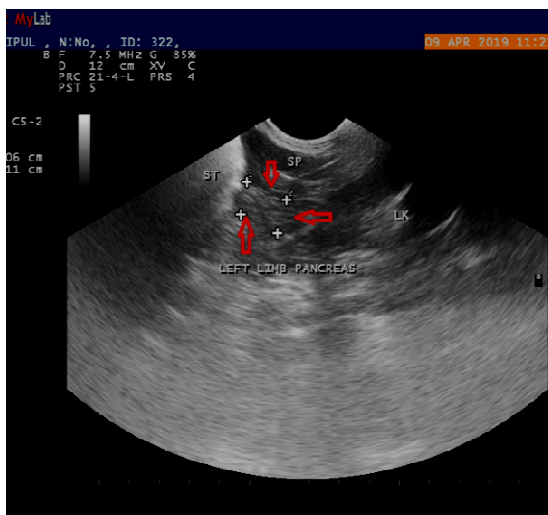


Fig. 40. Ultrasonogram of left limb of pancreas of animal 3. Showing stomach (ST), spleen (SP) and left kidney (LK) in view.

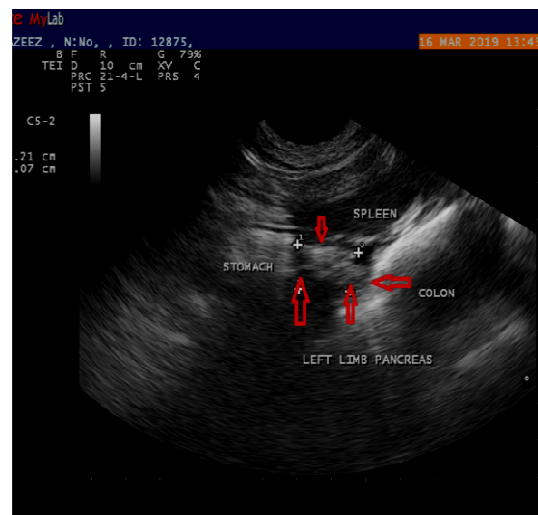


Fig. 41. Ultrasonogram of left limb of pancreas of animal 4.



Fig. 42. Ultrasonogram of left limb of pancreas of animal 5.



Fig. 43. Ultrasonogram of left limb of pancreas of animal 6.

Ultrasonograms of the left limb of pancreas of the dogs of Group III.

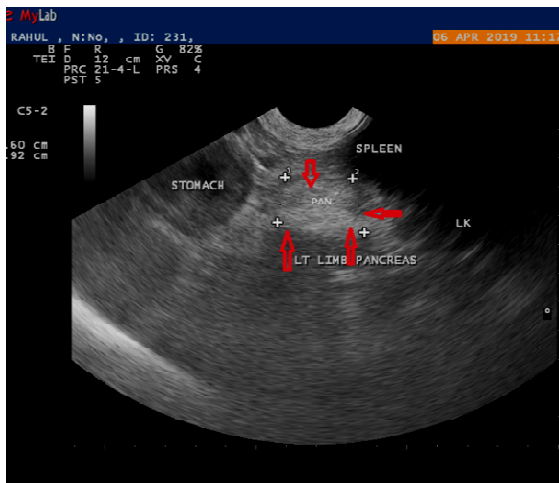


Fig. 44. Ultrasonogram of left limb of pancreas of animal 1, showing stomach (ST), spleen (SP) and left kidney (LK) in view.

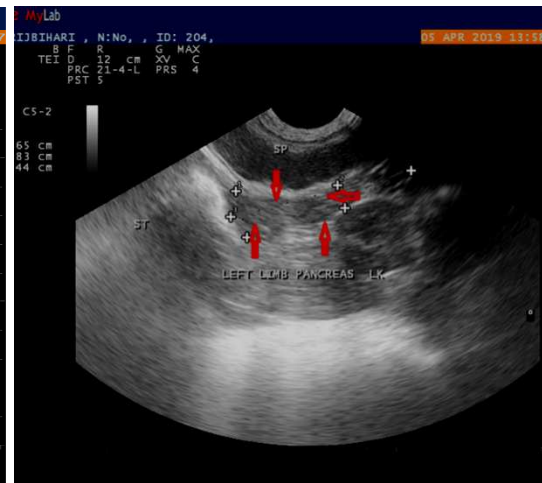


Fig. 45. Ultrasonogram of left limb of pancreas of animal 2, showing stomach (ST), spleen (SP) and left kidney (LK) in view.

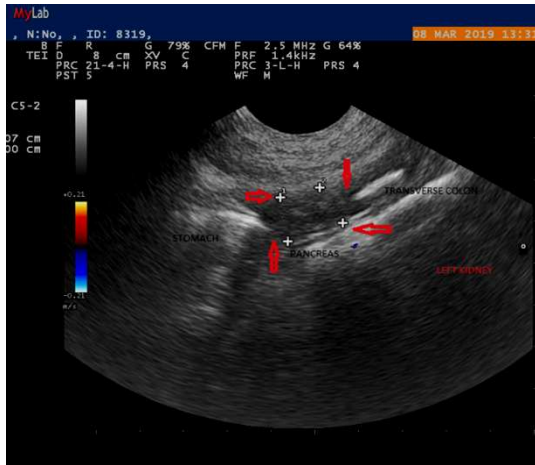


Fig. 46. Ultrasonogram of left limb of pancreas of animal 3.

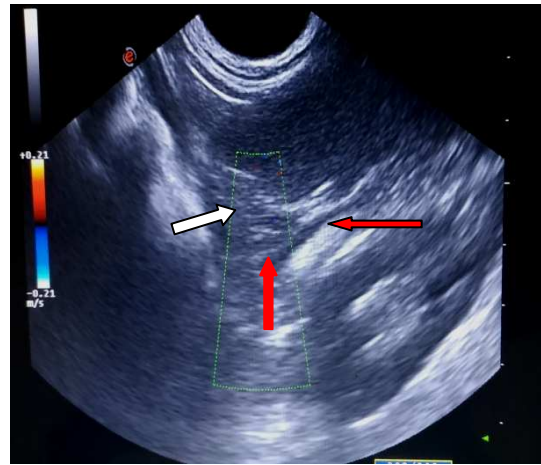


Fig. 47. Ultrasonogram of left limb of pancreas of animal 4.

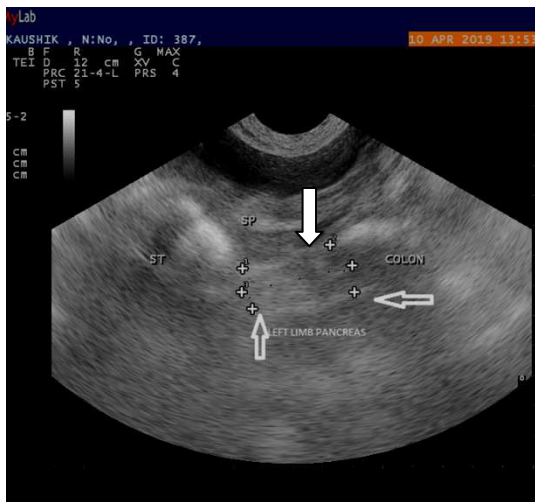


Fig. 48. Ultrasonogram of left limb of pancreas of animal 5.

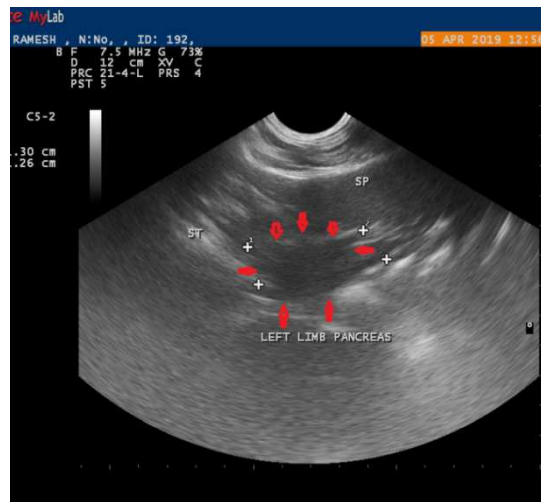


Fig. 49. Ultrasonogram of left limb of pancreas of animal 6.

PART - II:

In this part of the study, dogs reporting to VCC with symptoms namely, anorexia, acute vomiting, diarrhoea, pain on abdominal palpation, tucked-up belly were enrolled. After medical consult these animals were subjected to ultrasonographic examinations. A total of three cases qualified for this part of study. The case wise details of these animals (three) are as under -

- ❖ Case 1 was about 12 months old male and had anorexia, dehydration, diarrhoea, acute vomiting, pain on abdominal palpation.
- ❖ Case 2 and 3. Animal 2 was 6 years old and animal 3 was 8 years old.

The further test couldn't be done in case 1 because of deficit of facilities in near by pathology labs of Mathura.

In case of animal 2, test couldn't be done because of owners reluctance.

In case of animal 3, the value of serum Amylase was 3,580 U/ L (290- 1125) and serum Lipase 111 U/L (77- 695) was found.

Echoarchitecture:

Echoarchitecture of all the clinical cases 1, 2 and 3 was diffusely hypoechoic because of oedema, inflammation and necrosis unlike to those in part - I of the study. The right limb was homogeneous and anechoic in case 1 (Fig.50). The pancreas in case 2 and 3 showed ill-defined borders along with heterogeneous anechoic pancreatic parenchyma in left pancreatic limb (Fig.51 & Fig 52).

Animal 3 is having the serum amylase value beyond the cut off range suggesting of pancreatic pathology in left limb.

Ultrasonographic measurements:

Table. 3: Values of ultrasonographic measurements of pancreas in 3 clinical cases:

Units	Width (cm)	Thickness (cm)
Rt limb of pancreas case 1	1.32	-
Lt limb of pancreas case 2	3.22	2.31
Lt limb of pancreas case 3	3.57	2.62

The ultrasonographic examination of animal in case 1, the width of right limb was 1.32 cm which was comparable to healthy limbs. Similarly, on ultrasonographic examination of case 2, the measurements of width and thickness were found to be 3.22 cm and 2.31cm, respectively whereas, in case 3 the measurements of width and thickness were found to be 3.57 cm and 2.62 cm, respectively.

PART- II

Ultrasonograms of pancreas of part II of study (clinical cases).

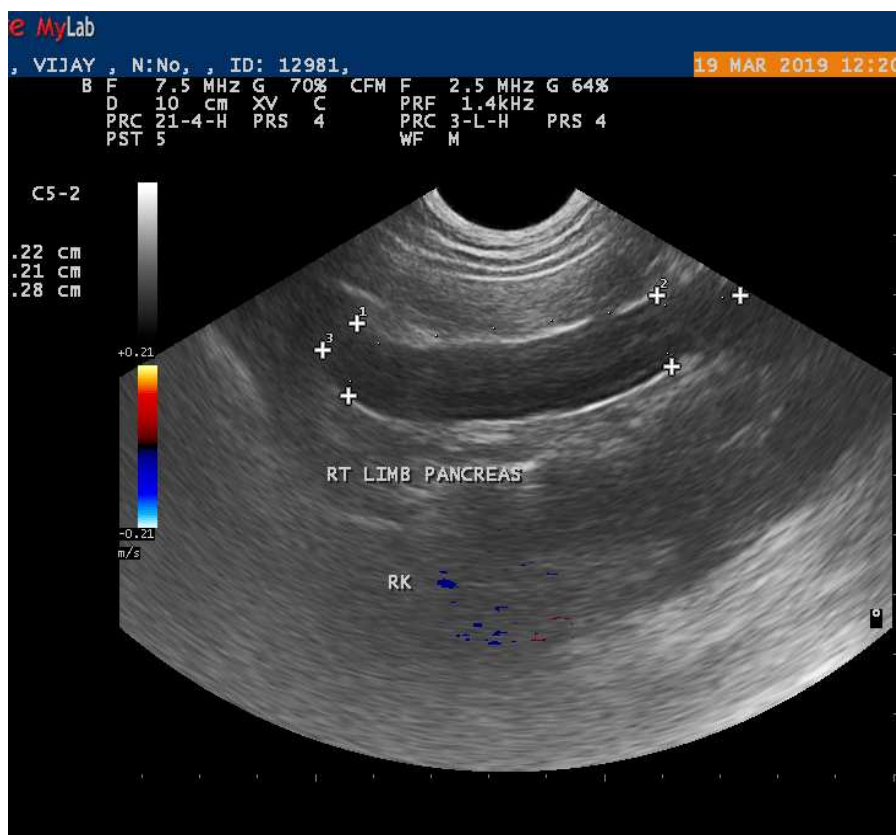


Fig. 50. The right pancreatic limb of clinical case-1, showing hypochoic right pancreatic limb in sagittal view.

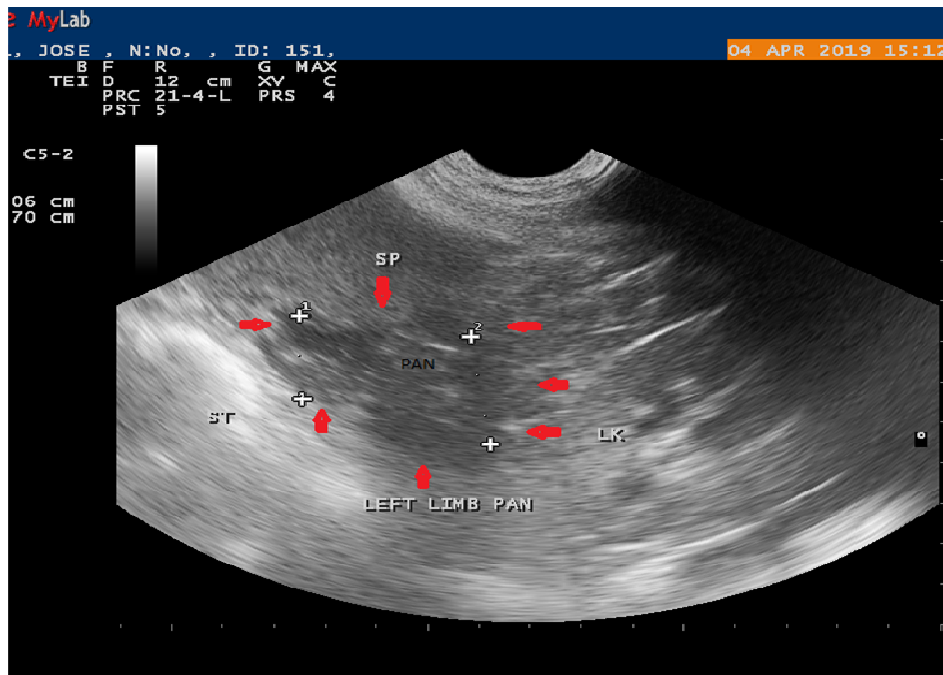


Fig. 51. The affected left pancreatic limb of clinical case-2 showing diffusely enlarged pancreas.

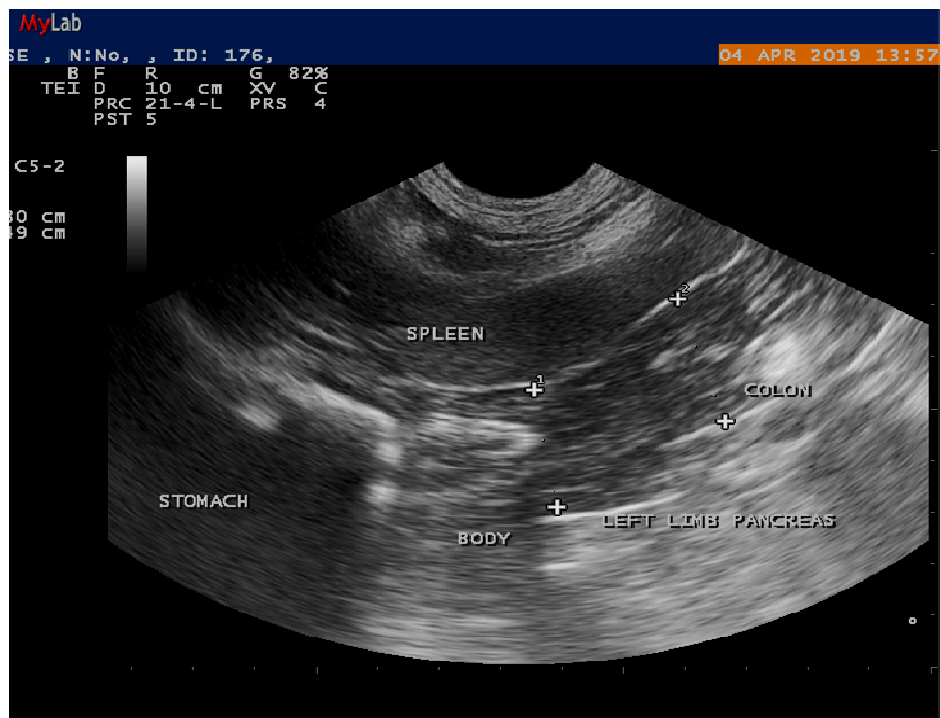


Fig. 52. The left pancreatic limb of clinical case-3 showing hypoechoic, enlarged pancreas, with surrounding hyperechoic mesentery.

In part II of study, echogenecity was found to be hypoechoic to anechoic whereas, echoarchitecture was non uniform parenchyma with ill defined border which was remarkable because in part I, we found isoechoic homogeneous parenchyma to the surrounding structure in all groups.

An animal of 10 months age presented with ascites of case 1 of group II of part I of study in which entire length and width of pancreas was localized. The echoarchitecture and size of pancreas was found to be normal.

The animal in case 1 of part II of study which was one year old. The width of right limb of pancreas in this animal was 1.32 cm which was comparable to the mean width (1.31 ± 0.06) in group II of part I study.

In case 2 and case 3 of part II of study the width and thickness increased, with respect to group II and group III respectively. In case 2 width and thickness were 3.22 cm and 2.31 cm respectively, which were considerably higher than the values of group II (mean width 1.77 ± 0.1 cm, mean thickness 1.35 ± 0.09 cm) whereas, in case 3 width and thickness were 3.57 cm and 2.62 cm respectively, which were considerably higher than the values of group III (mean width 1.92 ± 0.15 cm, mean thickness 1.5 ± 0.1 cm).

A decorative border composed of black and grey floral and butterfly motifs. The border features intricate scrollwork, leaves, and three butterflies with detailed wing patterns. The word "Discussion" is centered within this decorative frame.

Discussion

Ultrasonographic examination:

Feliciano et al. (2015) have opined that ultrasonographic evaluation of pancreas has some limiting factors, such as the patient's body condition, which may hinder the identification of the organ due to increased mesenteric fat; localized pain in patients with pancreatic disorders; gastrointestinal contents, which can impair organ visualization; and other factors particular to the pancreas such as its small size, poorly defined borders, and echogenicity similar to the adjacent mesenteric fat, giving it poor resolution (Penninck and D'anjou, 2011). Avante et al. (2018) have reported that patients subjected to ultrasonography should fast for at least 8 hours prior to the procedure so there are no interferences from gastric contents.

The pancreas of different age groups of apparently healthy dogs were scanned in this study in order to have an idea of best suitable approaches for ultrasonography of pancreas, to know the echo-structure of pancreas and make ultrasonographic measurements of the dimensions of the pancreas.

The right limb of pancreas:

In this study, the right limb of pancreas was scanned in lateral recumbency in all the dogs, but in some cases ultrasonography was also done in dorsal recumbency. All examinations were performed in lateral recumbency. Only, two animals of Group I, four of Group II and one animal of Group III were scanned in dorsal recumbency also. However, after some time of scanning in dorsal recumbency, the animals grew restless because of discomfort and inability of the owner/handler to provide comfort to the animal in this recumbency. It may therefore, be suggested that lateral recumbency could be preferred over dorsal recumbency.

The right pancreatic limb could be visualized in left lateral recumbency and the left pancreatic limb in right lateral recumbency. Robben et al. (2005); Webster (2008); French et al. (2019) performed the ultrasound examination in dogs in dorsal as well as lateral recumbency. The ventral or lateral recumbent position has been used as needed to avoid bowel gas by Nyland et al. (2002). However, Mekki et al. (2012) have also scanned pancreas with dogs in dorsal recumbency. The examinations

may be performed with the patients in lateral or dorsal recumbency. Feliciano et al. (2015) have advocated in most cases, the patient should be in supine position; however, right and left lateral recumbency can help scanning. Lim et al. (2013) positioned the animals on left lateral recumbency, and placed the US probe longitudinally between 2 ribs to image the transverse view of the right pancreatic limb and proximal portion of the descending duodenum.

Hecht and Henry (2007) propounded that especially in deep chested dogs, examination in left lateral recumbency with a right intercostal approach is occasionally helpful to visualize the right lobe of the pancreas and the duodenum. Similarly, Brinkman-Ferguson and Biller (2009) have concluded in their study that images of the right lobe of the pancreas were obtained in each dog using the right intercostal window or a right cranioventral approach. Avante et al. (2018) have opined that trichotomy should be broad, extending to the 8th and 9th intercostal spaces for organ visualization. In this study, the approach for both right and left limb of pancreas was subcostal that is, immediately behind the last rib positioning the transducers slightly obliquely longitudinally.

In the present study, all the animals were scanned with the curvilinear transducer at a 7.5 MHz frequency, which resulted in images of an optimum resolution. (Hecht and Henry, 2007) have opined that due to small size of the pancreas and its indistinct margins, the examination should be performed with the highest transducer frequency possible. In small dogs, a linear or curvilinear 8-15 MHz transducer may be used whereas, in large dogs, use of a lower frequency transducer 5-8 MHz may be required to achieve the necessary penetration depth. Webster (2008) has suggested a frequency of 5 MHz for large dogs and 7-10 MHz for medium dogs and cats. Mekki et al. (2012) have used 8-12 MHz, 5-7 MHz, 4-7 MHz and 9-12 MHz transducers in their study on 19 dogs and nine cats. Similarly, Robben et al. (2005) have used 5-3 and 7-4 MHz frequency transducers in their study for scanning pancreas in dogs.

Small dogs and cats can be effectively examined with 7.5- or 10.0MHz linear array transducer. Medium-sized dogs do best with a combination of 7.5-MHz linear array for more superficial examinations to 5.0 MHz or less curvilinear arrays for deeper structures. Large breed dogs may require a transducer to go as low as 3.0 MHz in frequency for optimal visibility (Mattoon and Nyland, 2014 and Pollard et al.,

2014). Rademacher et al. (2016) have reported that they scanned the entire abdomen using an 8–5 MHz curved array transducer to evaluate the echogenicity, texture, and contour of the entire pancreas.

Penninck and D'anjou (2011) found that in dogs, the right pancreatic lobe is usually the more prone for affections. Similarly, French et al. (2019) have reported that the most commonly affected portion of the pancreas as determined by US was the right lobe (16/26 dogs).

Echoarchitecture of pancreas:

In this study, the right and left limb of pancreas appeared to be hypoechoic to isoechoic as compared to the surrounding structures in all the groups. The echoarchitecture of both limbs of pancreas was homogeneous in the animals of all the groups and lacked capsular marginations. The normal canine pancreas is described as being similar to liver and isoechoic to surrounding peripancreatic fat, while having similar echoarchitecture to surrounding mesentery (Saunders 1991; Hecht and Henry, 2007). Similar findings have been reported by Avante et al. (2018) wherein they observed that the pancreas is a homogeneous organ, isoechoic to the mesenteric fat and the caudal lobe and slightly hyperechoic to the liver.

Ultrasonographic measurements of the right limb of pancreas:

The width of right limb of pancreas was measured using the in-built calipers. The mean width of right limb of pancreas was 1.2 ± 0.03 cm in Group I, 1.31 ± 0.06 cm in Group II and 1.5 ± 0.06 cm in Group III. Normal pancreatic size has been described in dogs of multiple breeds and weights and can measure up to 3 cm in thickness, depending on the reference; however, the largest case series reports 1.6 cm as an upper limit of pancreatic thickness (Miller and Evans 1993 ; Penninck et al., 2013).

While making measurements on the pancreas, Evans (1993) found that the size is variable and ranges from 1 to 3 cm in width and up to 1 cm in thickness, in beagle type dogs. The right lobe varies in width from 1 to 3 cm and in thickness up to 1 cm. Its length is approximately 15 cm, or 6 inches, in a Beagle-type dog as described by Evans and Lahunta (2013). Penninck and D'anjou (2011) and Mattoon and Nyland (2015) have described that the right lobe is long and narrow, 1 to 3 cm wide and 1 cm thick. Similarly, Rajapakshage et al. (2016) found the mean thickness of right

pancreatic lobe to be 14.2 ± 3.3 mm (range, 9.4 to 20.8 mm). They recorded the thickest dimension of 20.8 mm in a 28 kg, 8 months old Labrador Retriever. In a study done by French et al. (2019) eight of the 26 dogs had a thickened right lobe with a mean height of 18.9 mm and mean width of 20.0 mm.

The left limb of pancreas:

In this study, the left limb of pancreas was scanned in lateral recumbency in all the animals. Intercostal approach was not preferred to scan the left limb of pancreas, and all animals were scanned in subcostal approach. The scanning of left limb of pancreas was not easy because of presence of echogenic gas at the gastric-mucosal interface, which created acoustic shadows and reverberation artifacts. All the animals were scanned with curvilinear transducer at a 7.5 MHz frequency for a better resolution. Mekkawy et al. (2012) have used 8-12 MHz, 5-7 MHz, 4-7 MHz and 9-12 MHz transducers in their study on dogs and cats. Similarly, Robben et al. (2005) have used 5-3 and 7-4 MHz frequency transducers in their study for scanning pancreas in dogs. Rademacher et al. (2016) have reported that they scanned the entire abdomen using an 8–5 MHz curved array transducer to evaluate the echogenicity, texture, and contour of the entire pancreas.

Ultrasonographic measurements of the left limb of pancreas:

All the ultrasonograms were taken in sagittal plane, because it was difficult to visualize the left limb in transverse plane. The measurements of the left limb of pancreas, namely, width and thickness were measured using the in-built calipers of the ultrasound machine. In the present study, The mean width of left limb of pancreas was 1.47 ± 0.16 cm in Group I, 1.77 ± 0.10 cm in Group II and 1.92 ± 0.15 cm in Group III. The mean thickness of left limb of pancreas was 1.17 ± 0.06 cm in Group I, 1.35 ± 0.09 cm in Group II and 1.5 ± 0.10 in Group III.

Penninck and D'Anjou (2011); Mattoon and Nyland (2015) have reported that the left lobe is shorter and wider as compared to the right limb. Similarly, Evans and Lahunta (2013) advocated a shorter, thicker, and wider left lobe are united at the body (pancreatic angle), which lies caudomedial to the pylorus. However, Evans and Lahunta (2013) has suggested that the left lobe of the pancreas is approximately two-thirds as long and half again as wide as the right lobe, measuring 10 cm, or 4 inches, in length, and 4 cm, or 1.6 inches, in width. French et al. (2019) in their computerized

tomographic study on dogs, have found that nine of the 26 dogs had a thickened left lobe with a mean height of approximately 22.1 mm and mean width of 24.6 mm.


Part II

In part II of the study, comprising of clinical cases, the pancreatic measurements and the echoarchitecture of both limbs of pancreas were different as compared to those in normal pancreas of the part I of the study. The pancreas appeared to be enlarged with an irregular demarcation and appeared hypoechoic whereas; the mesentery adjacent to it was hyperechoic. These ultrasonographic changes are suggested to be associated with acute pancreatitis and are the most commonly reported pancreatic abnormalities in dogs (Hecht and Henry, 2007; Penninck, 2008 and Hess et al., 1998). Unfortunately, ultrasonographic findings in various pancreatic disorders overlap, and incidental findings or age-related changes may mimic pancreatic disease (Hecht and Henry, 2007).

In case 1 the width of right limb of pancreas was 1.32 cm which was comparable to group II (similar age group as that of the animal in case 1) of part I study. However, in case 2 the width and thickness were 3.22 cm and 2.31 cm respectively, which were higher than group II (mean width 1.77 ± 0.1 cm, mean thickness 1.35 ± 0.09 cm) and in case 3 width and thickness were 3.57 cm and 2.62 cm respectively, which were higher than the values of animals in group III (mean width 1.92 ± 0.15 cm, mean thickness 1.5 ± 0.1 cm).

Rademacher et al. (2016) also recorded B-mode ultrasound image in long axis of the right pancreatic limb of a 9-year-old male mixed breed dog with pancreatitis. The pancreas had irregular borders and was enlarged, measuring 1.8×2.3 cm. Similarly, Mekkawy et al. (2012) have also recorded an enlarged pancreas in their study, measuring 3.7×1.7 cm.

Rademacher et al. (2016) examined eight dogs with pancreatitis and found that the animals had an irregular, enlarged pancreas with a hypoechoic echoarchitecture in six dogs and heterogeneous in two animals. The surrounding mesentery was hyperechoic in six dogs and anechoic free fluid was present in four dogs. Similarly, French et al. (2019) in their study, found a hypoechoic, enlarged pancreas with surrounding hyperechoic mesentery with or without adjacent free fluid.

A decorative border composed of intricate black and white floral and scrollwork patterns. The border is shaped like a rounded rectangle and features three stylized butterflies with detailed wing patterns. The butterflies are positioned at the top-left, bottom-right, and bottom-center of the border. The background is white with a faint, light gray watermark of a diamond shape.

Summary
and
Conclusions

CHAPTER-6

SUMMARY AND CONCLUSIONS

The present study was conducted in two parts. In Part I of the study, apparently healthy dogs of all age groups were subjected to ultrasonographic examination of both limbs of pancreas. These dogs were divided into three groups having six animals in each group. Group I comprised of animals of 01 month to 09 months of age, Group II comprised of animals more than 09 months to 06 years of age whereas the Group III comprised of animals above six years of age.

Dogs reporting to the veterinary clinical complex for fracture, castration, cherry eye, were assessed ultrasonographically with due consent from the respective owners prior to surgery.

In Part II of the study, ultrasonographic examination of both limbs of pancreas of patients reporting to VCC, College of Veterinary Science and Animal Husbandry, U.P. Pt. Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura (UP), with symptoms like lack of appetite, weight loss, acute vomiting, diarrhoea, dehydration, abdominal pain, tucked-up belly etc.

The animals of both parts of this study were subjected to sonographic examination of left and right limbs of pancreas with their measurements and echoarchitecture.

Ultrasonographic examination was done in lateral recumbency in all the animals and in dorsal recumbency in seven animals after proper restraining and no anesthetic or sedative was required for scanning the pancreas, in part I of this study.

The right limb of pancreas was imaged by placing the 7.5 MHz curvilinear transducer in the subcostal area in the dorsal plane (along the body length parallel to the dorsum of the dog). The pancreas was identified by the surrounding abdominal organs rather than direct ultrasonographic visualization. The animals were restrained in left lateral recumbency, then the right kidney was located first by placing the transducer immediately behind the second last rib in costal arch. Thereafter,

duodenum was located by dorsomedially fanning towards the right quadrant. The pancreas was finally visualized between the duodenum and right kidney.

For transverse localization of pancreas animals were restrained in dorsal recumbency. Few images could be obtained in transverse view because of the considerable discomfort and non cooperation of animal. For right limb of pancreas in transverse view, gastric fundus was visualized by placing the transducer in sagittal plane, thereafter the probe was slided toward the right lateral quadrant below the subcostal arch, then rotated 90° anticlockwise to achieve the cross section of duodenum resembling a 'target' like appearance. The pancreaticoduodenal vein could be seen in cross section within the pancreas.

In this study the right and left limb of pancreas appeared to be hypoechoic to isoechoic as compared to the surrounding structures in all the groups. The echoarchitecture of both limbs of pancreas was homogeneous in the animals of all the groups and lacked capsular marginations.

The width of the right limb of pancreas, was measured using the in-built calipers of the ultrasound machine. The mean width of right limb of pancreas was 1.2 ± 0.03 cm in Group I, 1.31 ± 0.06 cm in Group II and 1.5 ± 0.06 cm in Group III. The mean width of right limb of pancreas was highest in Group III and least in Group in I.

For locating the left limb of pancreas, the animal was restrained in right lateral recumbency and the left kidney was located first. The transducer was then slided beneath the subcostal arch towards the xiphisternum, stomach was located. On gradual fanning both the caudal part of stomach and left kidney and transverse colon were visualized together in the left side of the screen with in the same field.

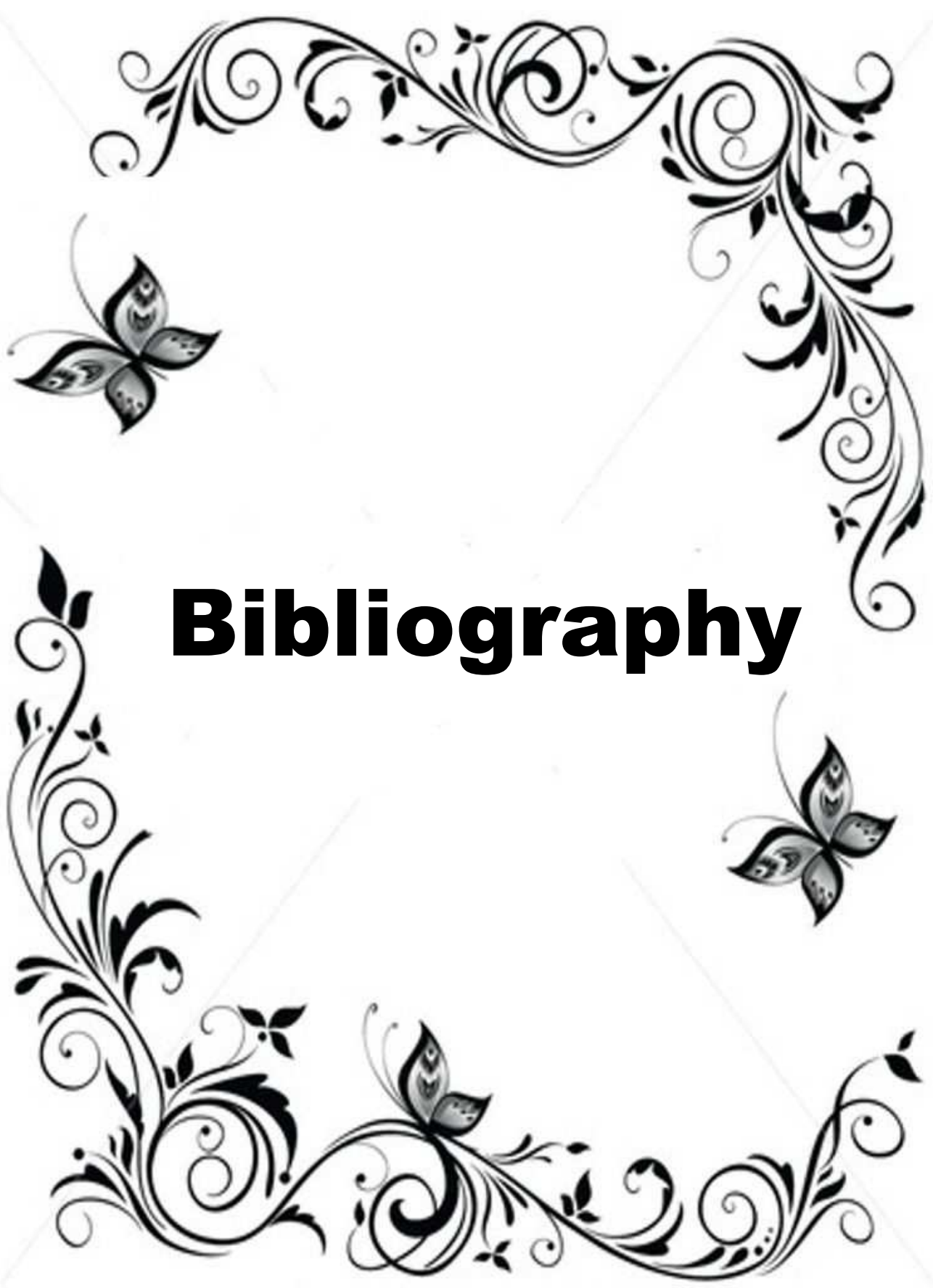
The mean width of left limb of pancreas was 1.47 ± 0.16 cm in Group I, 1.77 ± 0.10 cm in Group II and 1.92 ± 0.15 cm in Group III. The mean thickness of left limb of pancreas was 1.17 ± 0.06 cm in Group I, 1.35 ± 0.09 cm in Group II and 1.5 ± 0.10 in Group III. The mean width of left limb of pancreas was thickest in Group III and thinnest in Group I.

The Part II of the study, comprised of clinical cases. The pancreatic measurements and the echoarchitecture of both limbs of pancreas were different as compared to those in normal pancreas of the part I of the study. In case 2 width and thickness were 3.22 cm and 2.31 cm respectively, which were higher than those in

group II (mean width 1.77 ± 0.1 cm, mean thickness 1.35 ± 0.09 cm). whereas, in case 3 width and thickness were 3.57 cm and 2.62 cm respectively, which were higher than group III (mean width 1.92 ± 0.15 cm, mean thickness 1.5 ± 0.1 cm). In part II of study, echogenecity was found to be hypoechoic to anechoic whereas, echoarchitecture was non uniform parenchyma with ill defined border which was noticeable, because in part I we found isoechoic homogeneous parenchyma to the surrounding structure in all groups.

CONCLUSIONS:

1. Anaesthesia or sedation was not required for ultrasonography of pancreas in dogs.
2. Subcostal approach was the best approach to scan left and right limbs of pancreas, using a 7.5 MHz curvilinear transducer, in lateral recumbency by placing the probe caudal to the last rib and ventral to the lumbar process.
3. The dimensions and the echoarchitecture of the pancreas were similar to the findings of previous workers and may assist in the diagnosis of pathologies of pancreas or other organs.
4. It requires a great degree of patience to scan pancreas because of their size and position. It is difficult to scan left limb of pancreas because of the surrounding gas filled structures (stomach and transverse colon).
5. The ultrasonograms collected during this study may be used as reference images and the measurements recorded during this study can be used as reference values.
6. It is easy to locate pancreas in thin and geriatric animal because of less abdominal fat.



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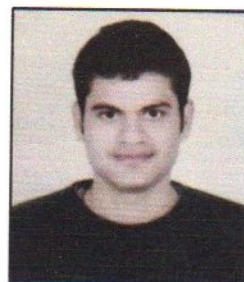
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