STUDIES ON ULTRASONOGRAPHY OF ADRENAL GLANDS OF DOGS

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF VETERINARY SCIENCE

IN

VETERINARY SURGERY AND RADIOLOGY

BY

AKASH

(Enrollment No. V–1645/16)

COLLEGE OF VETERINARY SCIENCE AND ANIMAL HUSBANDRY

U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura-281 001 (UP)

2018

CERTIFICATE

This is to certify that thesis entitled, **"STUDIES ON ULTRASONOGRAPHY OF ADRENAL GLANDS OF DOGS"**, submitted by **Dr. Akash,** Enrollment No.V-1645/16 in partial fulfillment of the requirements for the award of the **Master of Veterinary Science** in **Veterinary Surgery & Radiology,** of the **U P Pandit Deen Dayal Upadhyay Pashu-Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, 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.

Dated. 12.06.2018

(Gulshan Kumar)
Major Advisor and Chairman
Asst. Professor,
Department of Veterinary
Surgery & Radiology

CERTIFICATE

It is certified that the thesis entitled **"STUDIES ON ULTRASONOGRAPHY OF ADRENAL GLANDS OF DOGS"** submitted by **Dr. Akash,** Enrollment No. V-1645/16 in partial fulfillment of **Master of Veterinary Science Degree** in **Veterinary Surgery and Radiology** at College of Veterinary Science & Animal Husbandry, U. P. Pandit Deen Dayal Upadhyaya Pashu-Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura, 281001 (UP), India, embodies the original work done by the candidate himself. The candidate has carried out his work sincerely and methodically.

We have carefully gone through the contents of the thesis and are fully satisfied with the work carried out by the candidate, which is being presented by him for the award of the degree of this University.

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LIST OF ABBREVIATIONS USED

ACTH	:	Adrenocorticotropic hormone
AG	:	Adrenal gland
CA	:	Celiac artery
Cd. Pole	:	Caudal pole
cm	:	Centimeter
CMA	:	Cranial mesenteric artery
CPT	:	Caudal pole thickness
Cr. Pole	:	Cranial pole
CT	:	Computed tomography
FIG	:	Figure
IHAC	:	Iatrogenic hyperadrenocorticism
MHz	:	Mega hertz
ml	:	Milli liter
MRI	:	Magnetic resonance imaging
PDH	:	Pituitary dependent hyperadrenocorticism
SE	:	Standard error
Sq. m.	:	Square meter

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Date: 12.06.18
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CONTENTS

ABSTRACT

The present study was undertaken in dogs to standardize ultrasonographic examination protocol 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, II and III. Part II comprised of patients reporting to the TVCC with symptoms like lethargy, anorexia vomiting, weight loss, bradycardia, weak femoral pulse and abdominal pain, or polydipsia, polyuria hyper-glycaemia etc. Ultrasonographic examination was done in lateral recumbency in all the dogs without using any sedative or anaesthetic agent. Ultrasonographic images of adrenal glands were recorded only in sagittal plane because adrenal glands could not be differentiated from the surrounding structures in transverse plane. The left adrenal was best visualised by keeping transducer at left paralumbar fossa just behind the last rib. The right adrenal was best visualised by keeping transducer at right paralumbar fossa just behind the last rib. The length of left adrenal gland was 1.61 ± 0.17 cm in Group I, 2.2 ±0.177 cm in Group II and 2.44±0.30 cm in Group III. The cranial pole diameter of left adrenal gland was 0.32±0.033 cm, 0.49±0.048 cm and 0.54±0.08 cm in Group I, II, III, respectively. The caudal pole diameter of left adrenal was 0.35± 0.037 cm, 0.54 ± 0.029 cm and 0.52±0.08 cm in Groups I, II, III, respectively. The left adrenal gland was at a distance of 1.1±0.107 cm from the skin in Group I, 2.02±0.43 cm in Group II and 2.05±0.25 cm in Group III. The volume of gland was 0.60± 0.155 ml, 1.85±0.29 ml and 2.32±0.52 ml in group I, II, III respectively. The length of right adrenal gland was 1.57 ± 0.12 cm, 2.1 ± 0.10 cm and 2.20 ± 0.27 cm in Groups I, II and III, respectively. The cranial pole diameter of right adrenal gland was 0.36±0.03 cm, 0.48±0.03 cm and 0.61±0.07 cm in Groups I, II and III, respectively. The caudal pole diameter of right adrenal gland was 0.39±0.04 cm, 0.54±0.05 cm and 0.56±0.08 cm in Groups I, II and III, respectively. The right adrenal gland was at a distance of 1.1±0.13cm from the skin in Group I, 1.56±0.27 cm in Group II and 1.86±0.21 cm in Group III. The volume of gland was 0.63±0.14 ml, 1.68±0.24 ml and 2.06±0.44 ml in Groups I, II and III, respectively.

The left adrenal gland appeared as a peanut shaped hypoechoic area, and was homogenous in all the groups. The outline of the left adrenal was clear. The difference in the echotexture of cortex and medulla were not discernible. The cranial and caudal poles of the left adrenal were easily discernible. The left adrenal gland was the first structure to appear in ultrasonogram beneath the skin, aorta appeared as an anechoic pulsating oblong structure below the left adrenal gland. The right adrenal gland was almost oval shaped hypoechoic structure as compared to the surrounding tissue, and was homogenous in all groups. The outline of the adrenal was smooth but the cortex could not be differentiated from the medulla as in case of the left adrenal. The right adrenal gland appeared either dorsal to the caudal vena cava or at the level of caudal vena cava.

In Part II of the study, which comprised of clinical cases, the adrenal measurements and the echotexture of both the adrenal glands were well within the normal ranges and comparable to those of the Part I of the study. However, in one animal, the ultrasonographic examination of left adrenal revealed enlargement of caudal pole thickness (2.09 cm) and the echotexture of the gland was slightly heterogenous. So it was suspected for the adrenal carcinoma.

Ultrasonography of adrenal glands in dogs does not require anaesthesia. Subcostal approach is the best approach to scan left and right adrenals, the scanning of adrenal can be easily done using a 7.5 MHz Linear transducer, in lateral recumbency by placing the probe caudal to the last rib and ventral to the lumbar process. The dimensions and the echotexture of the adrenal glands may assist in the diagnosis of pathologies of the adrenals or other organs.

Introduction

CHAPTER-1

INTRODUCTION

Ultrasound has quickly become an important modality for the evaluation of adrenal glands in the small animal patient. The adrenal glands are key components of the endocrine system, and their deranged function can produce a wide range of clinical signs. Adrenal glands cannot be detected with radiography (Kealy *et al.*, 2012), unless severely enlarged or mineralized. The ultrasonographic assessment of the glands is now considered part of a complete abdominal scan in dogs. The advantages of ultrasonography include the ability to image both normal and abnormal glands, 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 adrenal glands should not be underestimated. Even for an experienced sonographer, the small size of the glands; the deep and sometimes variable position of the glands are the factors of difficulty in evaluation of adrenal glands. Different parameters such as size, shape, margins, echogenicity and structure can be evaluated with ultrasonography. However, ultrasonography is equipment and user-dependent and multiple influencing factors may disturb the examination (Tidwell *et al.*, 1997).

The adrenal glands are retroperitoneal structures. The left adrenal gland is situated cranio-medial to the left kidney, ventro-lateral to aorta, between the origin of cranial mesenteric and left renal arteries. The right adrenal is situated cranio-medial to the hilus of right kidney, dorsal or dorso-lateral to caudal vena cava, cranial to right renal artery and cranial mesenteric artery. The phrenico-abdominal artery is dorsal to each adrenal gland, whereas the phrenico-abdominal vein is ventral. The adrenal glands are small, elongated, structures surrounded by fat. The left adrenal gland is centrally constricted with enlarged extremities, having a “dumbbell” or “peanut” shape. The right adrenal gland is “comma”, “wedge”, or “boomerang” shaped. The extremities of the adrenal glands (cranial and caudal poles) are often asymmetric. The range of normal length has been documented from 10.7-50.0 mm, the maximum transverse diameter up to 16.0 mm, and the minimum transverse diameter down to 3.0 mm. In practice, the transverse maximum diameter is generally the most sensitive and specific for adrenal gland enlargement. In his monograph on ‘Ultrasonography of the adrenal glands' Anderson, (2011) has mentioned that an upper limit of the caudal pole thickness of 7.4 mm has been proposed as a cut-off for the normal adrenal gland. It is important to remember that there is a population of normal dogs which will have greater measurements. The left adrenal gland is generally larger in both length and transverse diameter than the right adrenal gland.

Most of the cases of adrenal affection remain undiagnosed due to improper knowledge of clinical signs and improper diagnosis. The most common clinical signs of hyperadrenocorticism are polydipsia, polyuria, polyphagia, heat intolerance, lethargy, abdominal enlargement or potbelly, panting, obesity, muscle weakness, and recurrent urinary tract infections. Dermatoligic manifestations of canine hyperadrenocorticism can include alopecia, thin skin, phlebectasias, comedones, bruising, cutaneous hyperpigmentation, calcinosis cutis, pyoderma, dermal atrophy, secondary demodicosis, and seborrhea.

The common clinical signs of hypoadrenocorticism are progressive decrease in blood volume contributing to hypotension, weakness,and microcardia. Increased excretion of water by the kidneys, because of decreased reabsorption of sodium and chloride, results in progressive dehydration and hemoconcentration. Emesis, diarrhea, and anorexia are common and contribute to the animal's deterioration. Weight loss is frequently severe. Blood in faeces, hair loss, painful abdomen are also seen in hypoadrenocorticism in dogs.

Ultrasonography is a standard procedure for visualizing the adrenal glands, because they are usually not visible radiographically (Kealy *et al.*, 2012). The main peculiarity of ultrasonography is the possibility of obtaining sectional images in real time, in different spatial orientations, allowing the study of the movement of body structures (Cerri and Rocha, 1993). Kantrowitz *et al.* (1986) described the clinical use of the ultrasonographic examination in cases of adrenal disease in small animals. Furthermore, there are other advantages such as accessibility, low cost and rare need for anaesthetizing the animal for the examination. Alves *et al.* (2007) have reported that the disadvantages such as formation of artifacts and blurring of texture and echogenicity alterations in certain pathophysiological causes can be overcome with technique expertise combined with detailed anatomical knowledge of the region to be analyzed.

Kantrowitz *et al.* (1986) have opined that the ultrasonographic appearance of normal canine adrenal gland was not described till 1986, due to small size and shape of the canine adrenal glands, overlying abdominal viscera, similar acoustic texture of surrounding tissue, frequent abundant peri-renal fat, and lack of patient compliance. A lot has changed since, and times have seen magnanimous improvements in machine and methods.

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

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

Review of Literature

CHAPTER-2

REVIEW OF LITERATURE

In the recent years, diagnostic imaging has become an important adjunct to conventional endocrine testing in the evaluation of adrenal gland dysfunction. The strength and limitations of radiography, ultrasonography, scintigraphy, CT scanning and MR imaging may be put to use (Tidwell *et al.,* 1997*).*

Hypoadrenocorticism is a common canine endocrinopathy that frequently presents a diagnostic dilemma to the small animal practitioner. Poor specificity of screening tests, such as ACTH stimulation and low-dose dexamethasone suppression tests, often makes it difficult to distinguish between hyperadrenocorticism and non-adrenal disorders that cause similar signs Peterson and Smiley (1991) and Chastain *et al.* (1986).

Kantrowitz *et al.* (1986) described the clinical use of the ultrasonographic exam in cases of adrenal disease in small animals. From these reports, the ultrasonographic exam became an important diagnostic imaging procedure for visualizing the adrenal glands in small animals, with possible observation of the glands and structural abnormalities, such as alterations in size, shape and echogenicity.

Barthez *et al.* (1995) determined normal adrenal gland size by means of ultrasonography in dogs and the value of ultrasonography in the diagnosis of pituitary- dependent hyperadrenocorticism in dogs. In this study they found a significant linear relationship between adrenal gland length, but not maximum and minimum diameters, and body weight, aortic diameter, and kidney length in healthy dogs and in dogs with nonendocrine diseases. They found that length, maximum diameter of the right adrenal and maximum and minimum diameters of the left adrenal gland were significantly greater in dogs with PDH than in healthy dogs and in dogs with non-endocrine diseases. They have opined that as a diagnostic test for PDH, ultrasonographic measurement of maximum or minimum diameter of the left adrenal gland gave the best combination of sensitivity and specificity.

Grooters *et al.* (1996) performed ultrasonography in 10 dogs with pituitary dependent hyperadrenocorticism (PDH) and in 10 age- and weight-matched healthy control dogs. Thickness, shape, and echogenicity were determined for each adrenal gland. Their study confirms the difference in sonographic appearance between PDH-induced bilateral cortical hyperplasia and functional adrenocortical neoplasia. They have demonstrated a difference in sonographically determined adrenal size between healthy dogs and dogs with PDH.

Peterson et al. (1996) in their studies have reported that females dogs at a significantly higher relative risk of developing hypoadrenocorticim as compare to male. Great Danes, Portuguese water dogs, Rottweilers, Standards poodles, WH white terriers etc had a significantly relative risk of developing hypoadrenocorticism as compare to other breeds of dogs.

Similarly, O'brien *et al.* (1996) have reported that the mean dimensions of the right and left glands in 20 normal ferrets were similar. They have also reported that both adrenal glands were wider in males as compared to those in females when examined sonographically.

Douglass *et al.* (1997) conducted a clinical study on 193 dogs with a weight range of 1.8-72 kg and body surface area range of 0.2-1.8 sq m. In dogs where both adrenal gland lengths were measured (n = 74)**,** the right adrenal gland length was less than that of the left in 46 dogs, equal to the left in one dog, and greater than the length of the left in 27 dogs. The strongest linear association was noted between the left adrenal gland length and body weight or body surface area**.** Similar significant association was noted between the right adrenal gland length and body weight. A significant positive association was also noted between age and left adrenal gland length. The summation of all four adrenal measurement values (left length and width, right length and width) did slightly improve the correlation when compared with body weight. There was not a significant difference in the adrenal measurements with regard to sex.

Conventional radiography has limited value for evaluating normal glands or glands that are only moderately enlarged. Scintigraphy, linear tomography and computed tomography allow imaging of normal adrenal glands and may be useful in distinguishing bilateral adrenal gland hyperplasia from unilateral neoplasia. Nevertheless, these techniques can be time consuming, may not be available to the practitioner and require the use of radiation safety precautions or anaesthesia. Over the last ten years, ultrasonography has become an important modality for the evaluation of adrenal glands in small animals because both normal and abnormal adrenal glands can be imaged, the procedure can be perform quickly and without anaesthesia and ultrasonographic equipment has become more available to practitioners (Barthez et al., 1998).

Hoerauf and Reusch (1999) conducted a clinical trial to measure adrenal glands in 6 dogs with hypoadrenocorticism and have reported a significant reduction in size of the left adrenal gland in dogs with hypoadrenocorticism compared to the left adrenal gland in normal dogs. The results of this study show that atrophy of the adrenal glands in dogs with hypoadrenocorticism seems to lead to an ultrasonographic-measurable reduction in size of the adrenal glands. They have opined that it must be emphasized that due to the reduction in size of the organ, it is more difficult to visualise the adrenal gland in dogs with hypoadrenocorticism than it is in healthy dogs. This emphasizes the need for high quality equipment and a level of experience on the part of the operator.

Barberet *et al.* (2010) noted that measurements of adrenal gland thickness at the caudal pole in a sagittal plane have the least intra-observer and inter-observer variability.

Wenger *et al.* (2010) measured adrenal glands of 30 dogs with primary adrenal insufficiency (hypoadrenocorticism) and compared with those of 14 healthy dogs and those of 10 dogs with diseases mimicking hypoadrenocorticism. They have also reported that dogs with primary hypoadrenocorticism had significantly thinner adrenals as compared to the other groups and their adrenals were also significantly shorter than those of healthy dogs. They have opined that adrenal ultrasonography may be of diagnostic value in dogs with clinical signs suggestive of primary hypoadrenocorticism, as a left adrenal gland measuring less than 3.2 mm in thickness is strongly suggestive of disease.

Choi *et al.* (2011) conducted a study on 189 normal dogs and 22 dogs with pituitary-dependent hyperadrenocorticism (PDH). They recorded a median gland width of 4.20 mm in normal dogs, and 6.30 mm in the PDH group. They believe that a cut-off of 6.0 mm could be used as the criterion for differentiating a normal adrenal gland from adrenal hyperplasia. They have opined that the adrenal width is the primary factor differentiating a normal adrenal gland from adrenal hyperplasia. They also mention that their results were clinically significant in that adrenal width in small breed dogs was smaller than the data from previous studies suggested.

Sandhya *et al.* (2015) conducted an ultrasonographic study on twenty apparently healthy dogs and twenty-four clinical cases. According to their study the shape of adrenal glands of PDH (pituitary dependent hyperadrenocoticism) and IHAC (iatrogenic hyperadrenocorticism) dogs were similar to that of control dogs. They also conclude that both the adrenal glands were bilaterally enlarged in PDH dogs and atrophied in IHAC dogs.

Lobetti *et al.* (2016) conducted an ultrasonographic study on 56 client owned dogs presented for a variety of medical reasons suspicious for possible hypoadrenocorticism. They concluded that ultrasound detection of small, flattened, isoechoic adrenal glands should be an alert for possible hypoadrenocorticism, prompting further testing and therapeutic intervention.

A study by De Chalus *et al.* (2013) found a correlation between thickness of the caudal pole of the adrenal gland in a sagittal plane. They suggested an upper threshold for the thickness of left and right adrenal glands, respectively, of 0.79 cm and 0.94cm (Labrador retriever) and 0.54cm and 0.67cm (Yorkshire terrier). They have further reported the sensitivity and specificity of these threshold for these two breeds as an ultrasonographic test for PDH must still be established in further studies.

Santos *et al.* (2013) compared ultrasound characteristics of adrenal glands between healthy puppies and kittens. The puppy's adrenal gland, both right and left, were found bigger in length and width in relation to kittens' adrenal gland. They further say that the glands are limited by a hyperechogenic line and there is no distinction between cortical and medullary regions. They have also reported that both the adrenal glands in puppies and kittens are hypoechogenic in relation to adjacent fat and the left adrenal gland is hypoechogenic to spleen as well.

Soulsby *et al.* (2014) examined adrenal gland dimensions according to body weight in healthy dogs in three weight categories namely, small, medium, and large breeds, respectively and have reported that the adrenal gland size correlates with body weight in normal dogs. They further reported that their proposed new cut-off values should be used cautiously until additional studies involving a large number of dogs, older dogs and dogs with non hyperadrenocorticism divide into similar weight groups can be performed to support or refute their conclusion

Pagani *et al.* (2016) conducted an ultrasonographic study on 119 dogs of which, 50 dogs had normal adrenal glands whereas 69 showed pathological lesions.

They further classified the lesions based on histology as cortical adrenal hyperplasia, adenocarcinoma, pheochromocytoma, metastases, adrenal adenoma, and adrenalitis. They have also opined that abnormal appearance the structural features on ultrasound images (e.g. adrenal gland lesion size, shape, laterality and echotexture) may aid in diagnosis for these features alone were not pathognomonic. Lesion size was the most direct ultrasound predictive criterion. Large and irregular masses seemed to be better predictors of malignant neoplasia and lesions < 20 mm in diameter and nodular in shape were often identified as cortical hyperplastic nodules or adenomas.

Shaghayegh *et al.* (2011) conducted an ultrasonographic study on 10 mix breed dogs. They conducted 3D ultrasonography to detect enlarged adrenal gland in dogs. According to their study differential diagnosis of adrenal enlargement should include PDH and adrenal tumors which apparently cannot be diagnosed by 2D nor 3D Ultrasound but in detection of mild enlargements, 3D Ultrasound volumetric evaluation can make a better and more accurate role than 2D.

Rose *et al.* (2017) described the effect of recumbency position on measurement of canine adrenal gland in adrenal gland illness. This prospective study, performed in dogs with non-adrenal illness, compared ultrasonographic AG measurements made in dogs placed in dorsal recumbency with those made in left or right lateral recumbency. AG length, height and width measurements made in the longitudinal image plane, and height and width measurements from the transverse image plane were assessed. The level and limits of agreement between the dorsal and lateral recumbency for each of the measurements were determined using the Bland–Altman analysis. The measurement with the best agreement between the dorsal and lateral recumbency was the caudal pole thickness (CPT) from the longitudinal image plane. Agreement between lateral and dorsal recumbency was poorer for the measurements derived from the transverse image plane and poorest for measurements of AG length in the longitudinal plane. This study demonstrates that there is some difference in the measurements acquired in dorsal compared with lateral recumbency; however, the difference is small for the CPT from the longitudinal plane. This finding suggests that the CPT from the longitudinal image plane is the most reliable measurement in terms of agreement between dorsal and lateral recumbency in dogs with non-AG illness.

Materials and Methods

CHAPTER-3

MATERIALS AND METHODS

Place of study:

The study entitled Studies on **" STUDIES ON ULTRASONOGRAPHY OF ADRENAL GLANDS OF DOGS"** was carried out in the department of veterinary surgery and radiology at the Teaching Veterinary Clinical Complex (TVCC), (Kothari veterinary hospital), College of Veterinary Science and Animal Husbandry, U. P. Pt Deen Dayal Upadhyaya Pashuchikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura (UP).

Subjects of Study:

The study was proposed in two parts.

In Part I of the study, apparently healthy dogs of all age groups were subjected to ultrasonographic examination of both adrenal glands. These dogs were divided into three groups as under:

Group I	:	Animals of 01 month to 09 months of age
Group II	:	09 months to 6 years of age
Group III	:	Above six years of age

There were six animals in each group.

In Part II of the study ultrasonographic examination of both adrenal glands of patients reporting to the TVCC with symptoms like lethargy, anorexia vomiting, weight loss, brady cardia, weak femoral pulse and abdominal pain, or polydipsia, polyuria hyper-glycaemia etc.

Ultrasound machine:

In this study, the Esaote® MyLab30vetGold, Esaote Europe B.V., Philipsweg 1, 6227 AJ Maastricht, The Netherlands with 7.5 MHz transducer LA523, was used for per-cutaneous scanning of the adrenal glands (Fig. 1 and 2).

Restraint and Anaesthetic protocol:

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

Fig. 1: Esaote® MyLab30vetGold ultra-sound machine

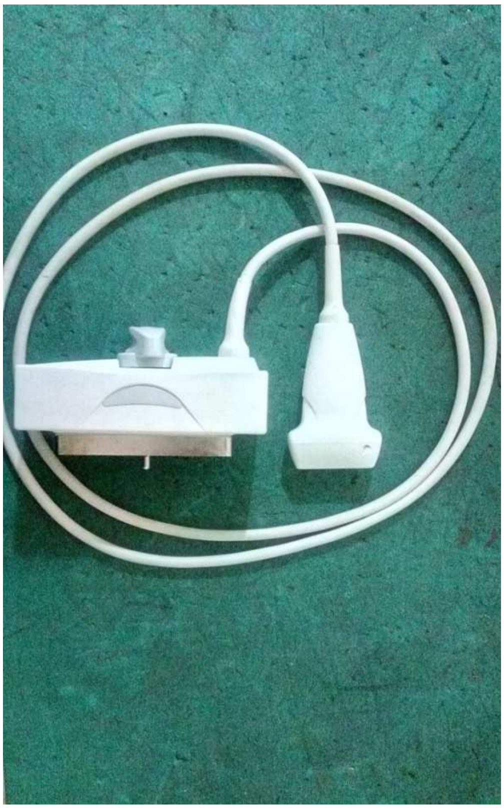

Fig. 2: Linear transducer LA523

Site preparation:

An area immediately behind the last rib, cranially below the tips of lumber transverse process dorsally was shaved neatly, for scanning the left adrenal. Similarly, for right adrenal gland the area extended cranially up to the last intercostal space. The animals were restrained in the lateral recumbency to scan the adrenal glands. 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.

Method:

The left adrenal gland was scanned by placing the transducer in the subcostal area (immediately behind the last rib) in the dorsal plane (along the body length parallel to the dorsum of the dog) and locating the aorta and caudal vena cava in long axis. The transducer was then slid cranially along to the level of the left kidney keeping the aorta in view and the left renal artery and vein were located. The transducer was rotated 45 degrees clockwise and gently swept cranial to the renal artery and vein to locate the left adrenal gland in long axis. The aorta and kidney were not always visible in the same field of view when the adrenal gland was imaged but in some ultrasonograms many structures, namely, the adrenal gland along with aorta and kidney were visualized in the same field. For locating of the right adrenal gland, the dog was placed in left lateral recumbency. The transducer was placed behind the last rib in the sub-lumbar area, in all the animal and intercostal approach was not needed to locate the right adrenal gland. The aorta and caudal vena cava were again located in the long axis in the dorsal plane. The transducer was then slid cranially, keeping the caudal vena cava in view. The adrenal gland was located along side and dorsal to the caudal vena cava. For measuring the length, the longitudinal sectional views of each adrenal were frozen when maximum length was visible. Similarly, for width measurement the image was frozen when maximum width of either of the poles was visible. The length, width of the cranial pole and the width of the caudal pole were measured on these frozen images of adrenal using the in-built *callipers* (Fig. 3, 4 and 5).

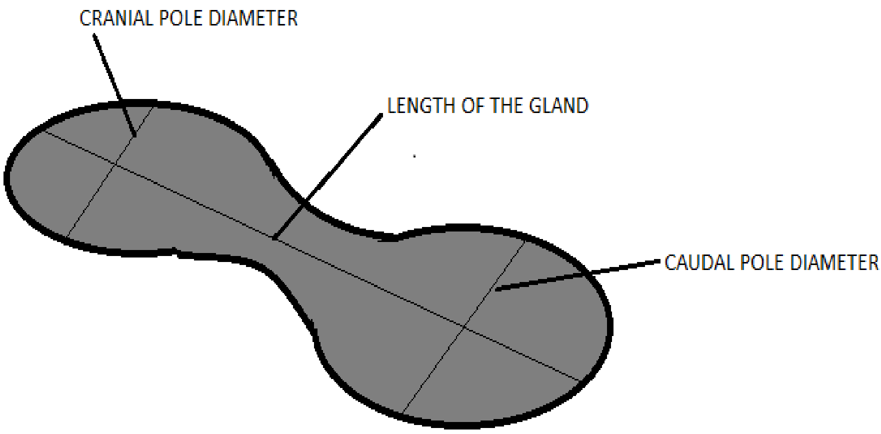

Fig. 3: The different measurements of adrenal gland

Fig 4: Ultrasonogram showing measurements taken of left adrenal gland with the help of measuring calliper. +1 of the calliper is showing the length taken of the gland. +2 of the calliper is showing the diameter of cranial pole. +3 of the calliper is showing the diameter of caudal pole.

Fig 5: Ultrasonogram of left adrenal is showing the volume (area under green dots) taken by measuring calliper.

Fig. 6 : Ultrasonogram of left adrenal gland showing depth of the gland taken from the surface with the help of measuring calliper

The adrenal gland (*glandula suprarenalis*) is composed of two structurally and functionally different tissues that have unique developmental histories. Each adrenal gland is composed of an outer cortex and an inner medulla. The adrenal gland is located near the cranio-medial border of the kidney. In man the topographic relationship of the adrenal gland in the standing position led to the use of the term “suprarenal gland” for humans.

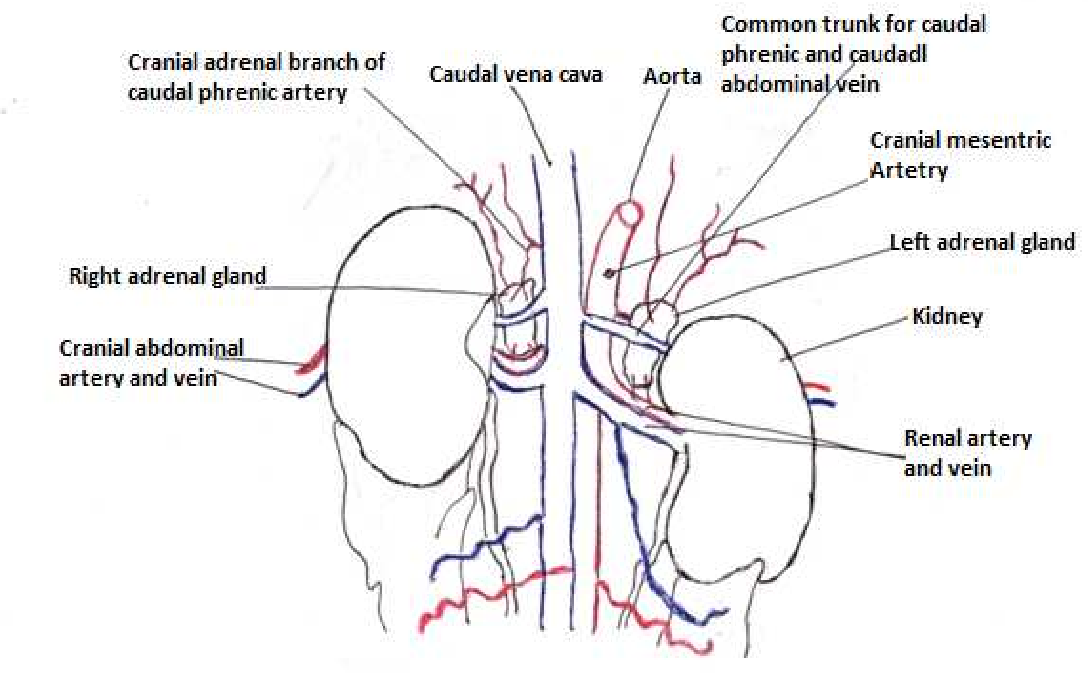

Fig. 7: A schematic representation of the adrenal glands

Developmental anatomy:

The adrenal cortex and adrenal medulla have different developmental origins. The cortex is the first to develop, originating from mesenchymal cells of the celomic mesoderm. The initial mass of these mesodermal cells proliferates near the genital ridge and accumulates to form an elongate, spherical group of cells termed the fetal cortex. Almost immediately, a second migration of mesenchyme begins, and it eventually envelops the fetal cortex and differentiates to form the permanent or adult cortex while the fetal cortex regresses. The medullary parenchyma arises from neural crest cells, which migrate from their point of origin into the developing mesodermal mass, penetrate into this mesenchyme, and assume a central position characteristic of the adrenal medulla in the adult. The adrenal medulla is in many respects similar to a sympathetic ganglion, and it develops by a process similar to that of the ganglia of the sympathetic trunk. Numerous ganglionic cells can be seen in the medulla at birth, but their number decreases with age. This migration of ectodermal cells of the neural crest is not completed until after birth, and often, even in the adult, islets of medullary tissue can be found within the cortical parenchyma, within the capsule, or as satellite structures of the adrenal glands (Appleby and Sohrabi-Haghdoost, 1980; Hullinger, 1978; Saleh *et al.*, 1974). The adrenal capsule (*capsula adrenalis*) develops as a condensation of mesenchyme at the periphery of the cortex. The outer portion, *pars fibrosa,* becomes a fibrous supportive stroma. The inner portion of the capsule at birth and in the young remains quite cellular and during that period is termed the *pars cellulosa.* Until the development, in the perinatal period, of the outer cortical zone, the *zona arcuata,* this inner cellular layer of the adrenal capsule can serve as the stem cell population for the generation of additional adrenal corticalparenchyma (Hullinger, 1978). Masses of neural crest cells develop elsewhere in the abdomen as sympathetic ganglia. These so-called *paraganglia* and the adrenal medulla react histochemically to reduce the salts of chromium and other heavy metals and, because of that property, are called *chromaffin tissues.* Adrenal cortical tissue also occurs randomly as accessory aggregates, satellite to or incorporated within various abdominal organs. Those aggregates associated with the gland occur as nodules, owing to compensatory hyperplasia and increase in size and number with advancing age.

The left adrenal gland is the larger of the two glands. Its cranial portion is somewhat flattened dorsoventrally and oval in outline, and its caudal projection is cylindrical. The right adrenal gland has an acute angular bend with its cortex projecting cranially. Positioned near the kidney, its longer segment projects caudally along the caudal vena cava, and the shorter segment projects toward the cranial pole of the right kidney. The left adrenal gland, lying ventral to the transverse process of the second lumbar vertebra, is not as cranial in position as the right, which is ventral to the transverse process of the last thoracic vertebra. The left and right glands generally differ in weight, but this difference has not been found to be statistically significant. The left adrenal gland is retroperitoneally positioned near the craniomedial border of the left kidney. This adrenal gland is firmly bound in the loose collagenous connective tissue of the fascia. Thus it is more structurally related by position to the abdominal aorta than to the left kidney. Its dorsal border is applied closely to the body of the psoas minor muscle and the transverse process of the second lumbar vertebra. Medially, it is bounded by the abdominal aorta at a position just caudal to the origin of the cranial mesenteric artery and adjacent to the origin of the common trunk for the caudal phrenic and cranial abdominal arteries. This latter vessel courses over its dorsal surface at the midpoint of the gland. The caudal border of the left adrenal gland is formed by the renal artery and vein. Its ventral surface is bisected by the common venous trunk accompanying the above artery, and is covered to varying degrees by the spleen. Laterally, its boundary is formed by the kidney. The right adrenal gland is also retroperitoneal in position, but it is near the hilus of the corresponding kidney. Its firm connective tissue attachments bring it into close proximity with the caudal vena cava as its immediate medial boundary. Often, the capsule of the right adrenal gland is continuous with the tunica externa/adventitia of the caudal vena cava. This presents a special challenge for removal of the right gland when surgically indicated. The psoas minor and the crus of the diaphragm form its dorsal border. The right common trunk for the caudal phrenic and cranial abdominal arteries crosses its dorsal surface, and the mass of the right kidney covers this adrenal gland on its ventrolateral surface. As a result of these organ relationships, this gland assumes a triangular or wedge shape in transectional profile. Its ventral surface is bisected by the common venous trunk accompanying the above artery, and the cranial two thirds of this adrenal gland is covered by the caudal extension of the right lateral hepatic lobe of the liver. Both glands lie in a generous bed of retroperitoneal fat. The adrenal cortex usually completely invests the adrenal medulla. The medulla comes closest to the outer surface at the hilus of each gland. Subtle and easily overlooked, the hilus is located near the midpoint of the medial surface and serves as the exit point for the adrenal vein or veins. In some instances the medulla may extend to the capsule, especially near the hilus. As with the hypophysis, the major subdivisions of the adrenal cortical parenchyma can be resolved with the unaided eye. In the fresh preparation the cortex is white or faintly yellow owing to the large amount of lipid storage in the cortical parenchyma; the medulla is dark brown or black.

The mesoscopic organization of the adrenal gland is based on concentric lamellae or shells of cortical parenchyma that envelop a central medulla The medulla, or heart of the gland, is separated from the cortex by a delicate network of reticular and loose collagenous connective tissues, the septum corticomedullae. Unlike the cortex, the parenchyma of the medulla cannot be partitioned into zones according to cellular or tissue morphologic characteristics. The innermost cortical layer is applied to all surfaces of the undulating medullary contour. The parenchyma of this inner zone is disposed in a relatively random and loose network and is termed the zona reticularis. In most dogs this zone composes the innermost 25% of the cortex. On examination with the unaided eye, the zona reticularis appears as the darker zone of the cortex. This appearance is due to the relatively greater numbers and size of the sinusoids in the parenchyma of this zone and a correspondingly lesser amount of lipid storage in the cytoplasm of these cells. The next cortical zone, moving from inner to outer cortex, is the largest. It typically composes 50% or more of the cortex. This zona fasciculata is so named because of its appearance in two dimensions. It is actually composed of anastomosing plates or muralia of cells that radiate toward the periphery (Elias and Pauly, 1956). This zone appears yellow to white in the fresh specimen. The cells of the outer one third of this zone store more lipid and are somewhat larger than those of the inner two thirds. These regions are called pars externa and pars interna, respectively. A narrow zona intermedia corticalis is at the outer surface of the zona fasciculata. This small, dark-appearing region composes less than 5% of the total cortex and in the dog functions as a blastemic region for replacement cells of the adult cortex (Hullinger, 1978; Hullinger and Getty, 1971; Nussdorfer, 1986). The outermost cortical zone is the zona arcuata. This zone, constituting approximately 25% of the adrenal cortex, is composed of cells arranged in arches and nestled into a stromal template provided by the inner surface of the capsule.

As with the hypophysis, the blood supply and venous drainage of the adrenal cortex and medulla are structurally and perhaps functionally interrelated (Vinson *et al.,* 1985). The arterial supply of the adrenal gland arises from several major vessels (Flint, 1900; Ljubomudrov, 1939). The branches from these vessels passing to the adrenal gland are numerous and of small caliber. They include cranial adrenal branches from the caudal phrenic and cranial abdominal arteries or their common trunk, middle adrenal branches from the abdominal aorta, caudal adrenal branches from the lumbar and renal arteries. These provide 20 to 30 contributing arterioles that approach the gland from all surfaces, enter the fibrous portion of the capsule, and anastomose to form a network (rete arteriosum capsulare). Numerous vessels plunge from the capsular network into the cortex. Some of these according to Flint (1900), approximately 50-pass as larger arterioles and small muscular arteries in the trabeculae and septa and descend directly to the corticomedullary boundary. Here they supply oxygen-rich blood to the medullary parenchyma. The supply to the sinusoids of the cortex is via small arterioles from the capsular network that pass in the smaller trabeculae and septa that separate the arches of the zona arcuata. These vessels pass to the zona intermedia and form a second network in the connective tissues there (rete arteriosum subcapsulare). From this network arise the sinusoids of the zona arcuata and the inner zones of the cortex (rete hemocapillare sinusoideum). The sinusoids of the cortex and medulla become confluent, as outlined previously and join to form the large medullary sinuses and a plexus venosus medullae. These sinuses, which may mediate cortical control of epinephrine synthesis (Pohorecky and Wurtman, 1971), pass toward the hilus of the adrenal glan and are drained via the adrenal vein. Smithcors (1964) describes a venous tree in the medulla that is independent of the medullary sinuses and that joins with the sinuses to form the adrenal vein. The adrenal veins of each gland terminate differently because of their position relative to the caudal vena cava. The right adrenal vein joins directly with the caudal vena cava, but the left adrenal vein enters the left renal vein. According to Verhofstad and Lensen (1973), lymphatic vessels in the adrenal gland form extensive plexuses in the capsule, cortex, corticomedullary boundary, and medulla. There is also a well-developed lymphatic plexus surrounding the central vein of the medulla.

The innervation of the adrenal cortex has been difficult to demonstrate (Wilkinson, 1961). Saleh *et al.* (1974) reported multipolar neurons in all regions of the adrenal cortex. They propose a hypothalamic control of cortical secretion by nervous as well as humoral means. The parenchyma of the adrenal medulla is actually a modified sympathetic ganglion, specialized for neurohumoral release. Axons passing to the medulla travel through the cortex, accompanying the medullary arteries in the major cortical trabeculae and septa. These fibers are, for the most part, preganglionic sympathetic axons that can be traced from the splanchnic supply through the celiac, splanchnic, and adrenal ganglia. The medullary cells are the modified neuronal cell bodies of postganglionic axons but without any development of axons. These cells release their neurotransmitters directly into the perivascular space and are distributed systemically, rather than acting on local receptors or a synapse.

Results

CHAPTER-4

RESULTS

PART - I

Ultrasonographic examination was done in lateral recumbency in all the dogs. Ultrasonographic images of adrenal glands were recorded only in sagittal plane because adrenal glands could not be differentiated from the surrounding structures in transverse plane. The left adrenal was best visualised by keeping transducer at left paralumbar fossa just behind the last rib. The right adrenal was best visualised by keeping transducer at right paralumbar fossa just behind the last rib and intercostal approach was not preferred. Both left and right adrenal glands were hypoechoic to the retroperitoneal fat (hyperechoic). They could be differentiated from the adjacent vessels as the adjacent vessels were anechoic and pulsating as compared to the adrenal glands. In the scanning of left adrenal gland, in the sagittal plane, with the animal head on left of the monitor, the top most organ was left adrenal gland located about 2 cm (maximum) deep from the skin. On the left side of left adrenal gland cranial mesenteric artery and celiac artery were located. Aorta was visible just below the left adrenal gland. Similarly, while scanning the right adrenal gland, the adrenal gland appeared either above the caudal vena cava or just parallel to the caudal vena cava, about 1.8 cm (maximum) deep from the skin.

Ultrasonographic measurements of left adrenal gland:

The measurements of the left adrenal gland, namely, the length, cranial pole diameter, caudal pole diameter, depth of the gland from skin and volume of the adrenal gland were measured using the in-built *callipers* of the ultrasound machine. The mean ± standard error values of various measurements are presented in Table-1.

The length of left adrenal gland was 1.61 ± 0.17 cm in Group I, 2.2 ±0.177 cm in Group II and 2.44±0.30 cm in Group III. The cranial pole diameter of left adrenal gland was 0.32±0.033 cm, 0.49±0.048 cm and 0.54±0.08 cm in Group I, II, III, respectively. The caudal pole diameter of left adrenal was 0.35± 0.037 cm, 0.54 ± 0.029 cm and 0.52±0.08 cm in Groups I, II, III, respectively. The left adrenal gland was at a distance of 1.1±0.107 cm from the skin in Group I, 2.02±0.43 cm in Group II and 2.05±0.25 cm in Group III.

Table.1: Mean ± SE values of various ultrasonographic measurements of left adrenal gland in different group of dogs.

Units in Parenthesis		Mean±SE	
	Group I	Group II	Group III
Length of gland (cm)	1.61± 0.17	2.2± 0.177	2.44±0.30
Cranial pole diameter (cm)	0.32± 0.033	0.49± 0.048	0.54±0.08
Caudal pole diameter (cm)	0.35± 0.037	0.54±0.029	0.52±0.08
Distance from skin (cm)	1.1±0.107	2.02±0.43	2.05±0.25
Volume (ml)	0.60± 0.155	1.85±0.29	2.32±0.52

The volume of gland was 0.60± 0.155 ml, 1.85±0.29 ml and 2.32±0.52 ml in group I, II, III respectively.

The left adrenal gland was longest in Group III and shortest in Group I. Similarly, the cranial pole diameter was thickest in Group III and thinnest in Group I. However, the caudal pole diameter was thickest in Group II and thinnest in Group I. the distance of the gland from the skin was maximum in Group III and minimum in Group I. The volume of the gland was maximum in Group III and minimum in Group I.

Echotexture of the left adrenal gland:

The ultrasonograms of the left adrenal gland of the animals of Group I are presented in Fig. 8 to Fig. 13.

The ultrasonograms of the left adrenal gland of the animals of Group II are presented in Fig. 14 to Fig. 19.

The ultrasonograms of the left adrenal gland of the animals of Group III are presented in Fig. 20 to Fig. 25.

The left adrenal gland appeared as a peanut shaped hypoechoic area, and was homogenous in all the groups. The contour of the gland was smooth. The outline of the left adrenal was clear but the cortex could not be differentiated from the medulla. The cranial and caudal poles of the left adrenal were easily discernible. The left adrenal gland was the first structure to appear in ultrasonogram beneath the skin, Aorta could be seen as an anechoic pulsating oblong structure appearing below or in some cases, adjacent to the left adrenal gland. The cranial mesenteric artery and celiac artery could not be visualised in all the ultrasonograms but in some Ultrasonograms (Fig. 10 & Fig. 14) they were differentiated as having a distinct hypoechoic or anechoic pulsating structures cranial to the left adrenal gland. The phrenicoabdominal vein could not be differentiated in most of the ultrasonograms but in one animal of Group II it was clearly visualized as anechoic or hypoechoic oblong area having hyperechoic margins running through the mid-body of the adrenal (Fig. 15).

Ultrasonographic measurements of right adrenal gland:

The mean ± SE values of various measurements of right adrenal gland are presented in Table.2.

Table 2: Mean ± SE values of various ultrasonographic measurements of right adrenal gland in different groups of dogs.

Units in Parenthesis		Mean±SE	
	Group 1	Group II	Group III
Length of gland (cm)	1.57±0.12	2.1±0.10	2.20±0.27
Cranial pole diameter (cm)	0.36±0.03	0.48±0.03	0.61±0.07
Caudal pole diameter (cm)	0.39±0.04	0.54±0.05	0.56±0.08
Distance from skin (cm)	1.1±0.13	1.56±0.27	1.86±0.21
Volume (ml)	0.63±0.14	1.68±0.24	2.06±0.44

The length of right adrenal gland was 1.57 ± 0.12 cm in Group I, 2.1 ± 0.10 cm in Group II, and 2.20 ± 0.27 cm in Groups III. The cranial pole diameter of right adrenal gland was 0.36±0.03 cm, 0.48±0.03 cm and 0.61±0.07 cm in Groups I, II and III, respectively. The caudal pole diameter of right adrenal gland was 0.39±0.04 cm, 0.54±0.05 cm and 0.56±0.08 cm in Groups I, II and III, respectively. The right adrenal gland was at a distance of 1.1±0.13cm from the skin in Group I, 1.56±0.27 cm in Group II and 1.86±0.21 cm in Group III. The volume of gland was 0.63±0.14 ml, 1.68±0.24 ml and 2.06±0.44 ml in Groups I, II and III, respectively.

The length of the gland was longest in Group III and shortest in Group I. The cranial pole diameter was thickest in Group III and thinnest in Group I. Caudal pole diameter was thickest in Group III and thinnest in Group I. The distance of the gland from the skin was maximum in Group III and minimum in Group I. The volume of the gland was maximum in Group III and minimum in Group I.

Echotexture of the right adrenal gland:

The ultrasonograms of the right adrenal gland of the animals of group 1 are presented in Fig. 26 to Fig. 31.

The ultrasonograms of the right adrenal gland of the animals of group II are presented in Fig. 32 to Fig. 39.

The ultrasonograms of the left adrenal gland of the animals of group III are presented in Fig. 40 to Fig. 44.

The right adrenal gland was almost oval shaped hypoechoic structure as compared to the surrounding tissue, and was homogenous in all groups. The contour of the gland was smooth. The outline of the adrenal was clear but the cortex could not be differentiated from the medulla as in case of the left adrenal. The right adrenal gland appeared either dorsal to the caudal vena cava or at the level of caudal vena cava.

PART -II:

In Part II of the study, comprising of clinical cases, the adrenal measurements and the echotexture of both the adrenal glands were recorded. A total of four cases were selected for this part of study on the basis of reporting symptoms.

- Animal 1 and 2 were about 9 years old and had polydipsia, polyuria and polyphagia. Of these, animal 2 was a female and was potbellied and thin-skinned.
- Animal 3 and 4 were found to have large adrenal glands when being scanned for other medical conditions. Animal 3 was 8 years old and animal 4 was 13 years old. Neither of the two showed any clinical symptoms of hyperadrenocorticism.
- The fifth animal, a 2½ year old female, was a confirmed case of osteosarcoma brought to the TVCC in terminal stage requesting for comfort from abdominal pain and respiratory distress, hence scanned ultrasonographically. In the middle of scanning the owner of the animal refused to allow any further scanning as

she could not withstand her pets pain any more. Therefore, only the left adrenal could be scanned and not all measurements could be made.

Ultrasonograpihic measurements of left adrenal gland of clinical cases:

The mean ± SE values of various measurements of left adrenal gland are presented in Table.3**.**

Table 3: Mean (cm) ± SE values of ultrasonographic measurements of left adrenal gland of clinical cases.

	Length (cm)	Cranial pole diameter (cm)	Caudal pole diameter (cm)	Distance from skin (cm)	Volume (ml)
Mean ± SE	2.79 ± 0.28	0.66 ± 0.05	0.59 ± 0.10	2.31 ± 0.31	2.77 ± 0.49

The mean length of left adrenal gland in the animals of the clinical part of this study was 2.79 ± 0.28 cm, mean cranial pole diameter was 0.66 ± 0.05cm, caudal pole diameter was 0.59 ± 0.10cm and mean volume of the left adrenal gland was 2.77 ± 0.49 ml. The distance of the left adrenal gland from skin was 2.31 ± 0.31cm. However, in one animal, the ultrasonographic examination of left adrenal revealed enlargement of caudal pole thickness (2.09 cm) and the echotexture of the gland was slightly heterogenous. So it was suspected for the adrenal carcinoma.

Ultrasonograpihic measurements of right adrenal gland of clinical cases:

The mean ± SE values of various measurements of right adrenal gland are presented in Table.4**.** The mean length of right adrenal gland in the animals of the clinical part of this study was 2.55 ± 0.21 cm, mean cranial pole diameter was 0.71 ± 0.06 cm, caudal pole diameter was 0.66 ± 0.10 cm and mean volume of the left adrenal gland was 2.72 ± 0.19 ml. The distance of the left adrenal gland from skin was 1.96 ± 0.29 cm.

Table 4: Mean (cm) ± SE values of ultrasonographic measurements of right adrenal gland of clinical cases.

	Length (cm)	Cranial pole diameter (cm)	Caudal pole diameter (cm)	Distance from skin (cm)	Volume (ml)
Mean ± SE	2.55 ± 0.21	0.71 ± 0.06	0.66 ± 0.10	1.96 ± 0.29	2.72 ± 0.19

Echotexture:

Echotexture of all the clinical cases 1, 2, 3, and 4 was similar to those in part I of the study. No anomaly could be found in margin of gland, size of the gland, echotexture and homogenecity of the gland. Echotexture of the left adrenal gland (Fig. 45) of the 5th clinical case was not homogenous, showing hyperechogenic specks in the stroma. Only the dimensions of the cranial and caudal poles could be measured. The caudal pole diameter was 2.09 cm which was beyond the cut-off range suggesting left adrenal pathology

Ultrasonograms of the left adrenal gland of Group-I

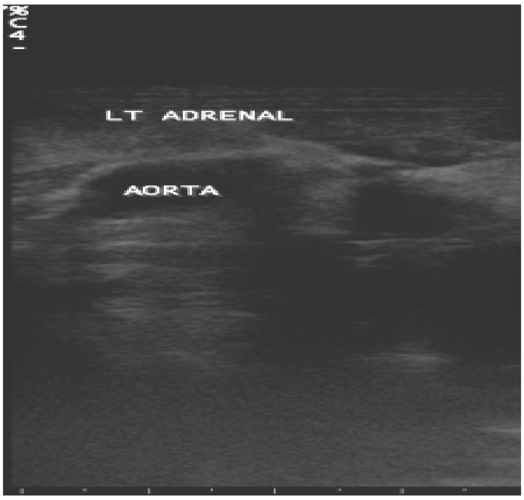

Fig. 8: Ultrasonogram of left adrenal gland of Animal 1. Showing hypoechoic left adrenal on the top of the sonogram.

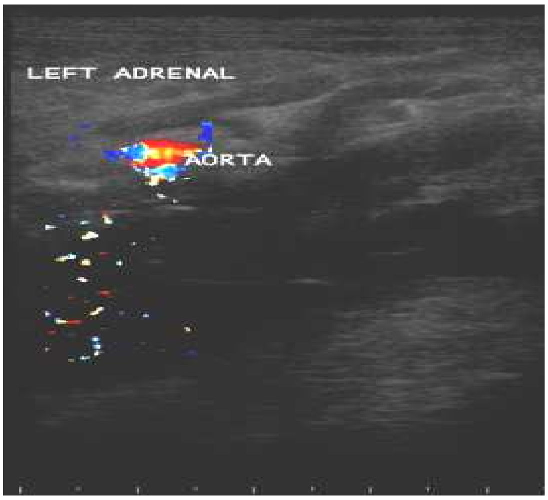

Fig. 9: Ultrasonogram of left adrenal gland of Animal 2, showing hypoechoic peanut shape left adrenal gland along with aorta shown by color Doppler.

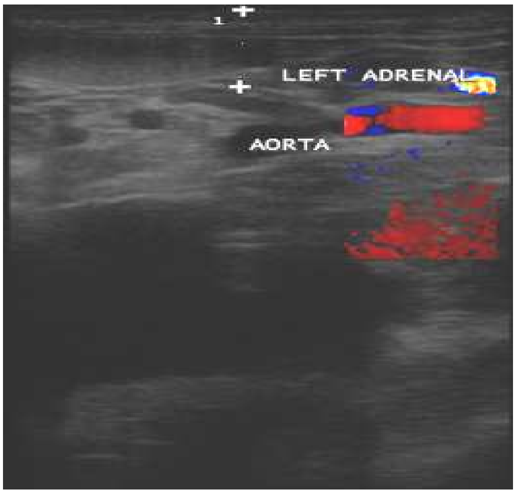

Fig. 10 : Ultrasonogram of the left adrenal gland of Animal 3, showing hypoechoic left adrenal gland along with aorta shown by color Doppler and shadow of left kidney

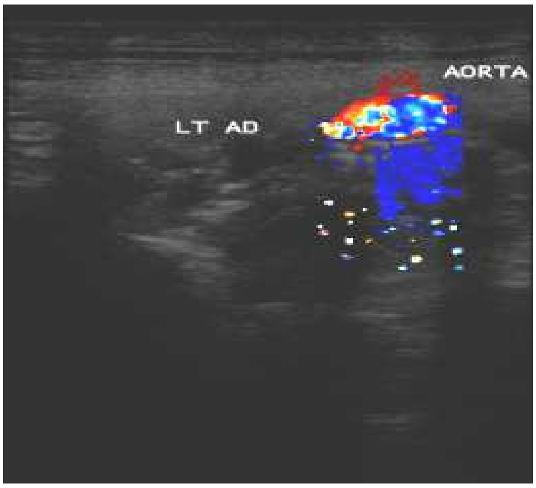

Fig. 11: Ultrasonogram of left adrenal of Animal 4.

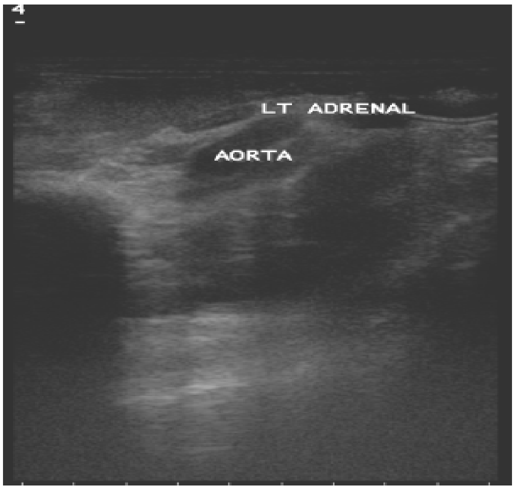

Fig. 12: Ultrasonogram of left adrenal gland of Animal 5, showing left adrenal, aorta, kidney in a view.

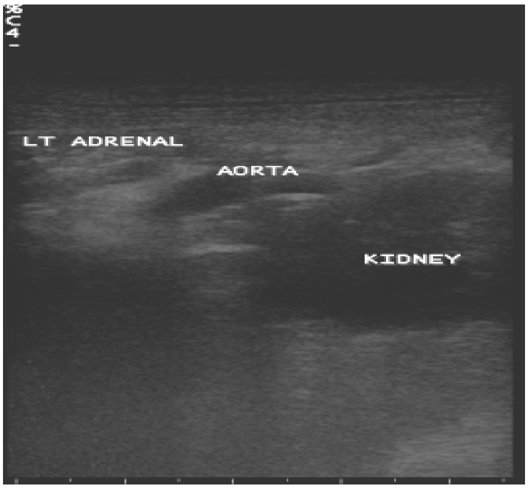

Fig. 13: Ultrasonogram of left adrenal of Animal 6.

Ultrasonogram of the left adrenal gland of group II

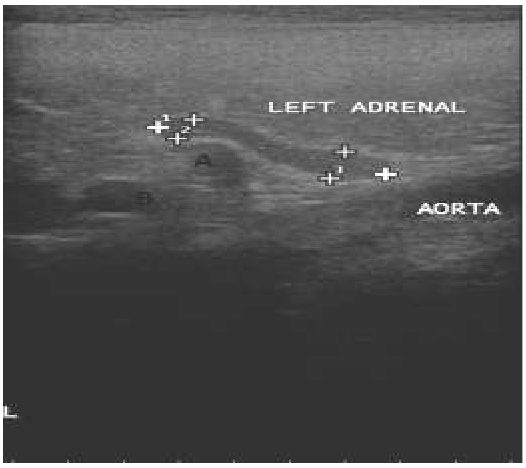

Fig. 14: Ultrasonogram of the left adrenal gland of Animal 1, showing hypoechoic left adrenal gland with the measurements. A= CMA (cranial mesenteric artery), B= CA(celiac artery).

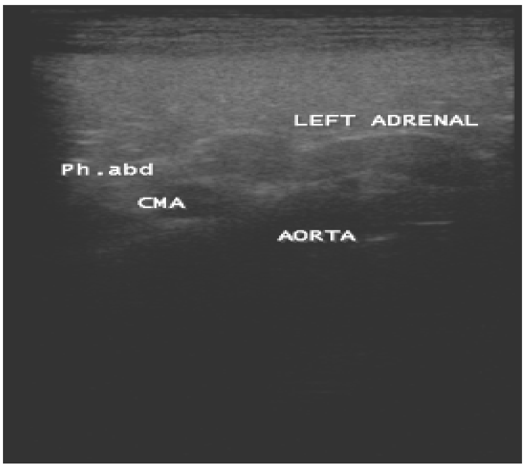

Fig. 15: Ultrasonogram of the left adrenal of Animal 2, showing left adrenal gland along with Aorta, CMA(cranial mesenteric artery), and phrenico-abdominal artery.

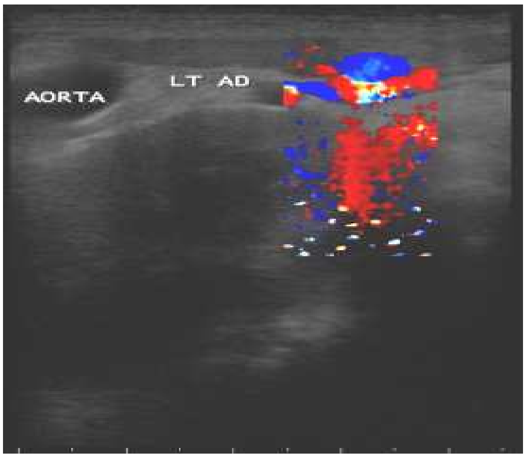

Fig. 16: Ultrasonogram of left adrenal gland of Animal 3.

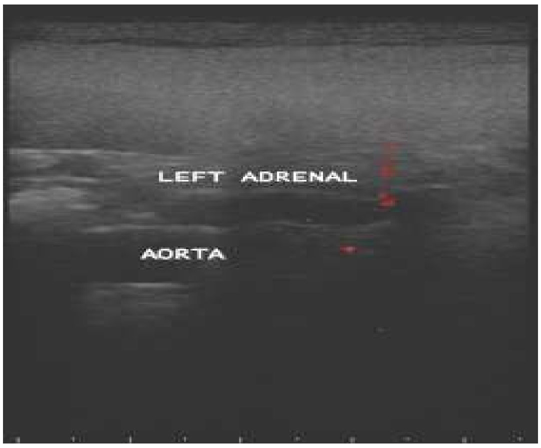

Fig. 17: Ultrasonogram of left adrenal gland of Animal 4.

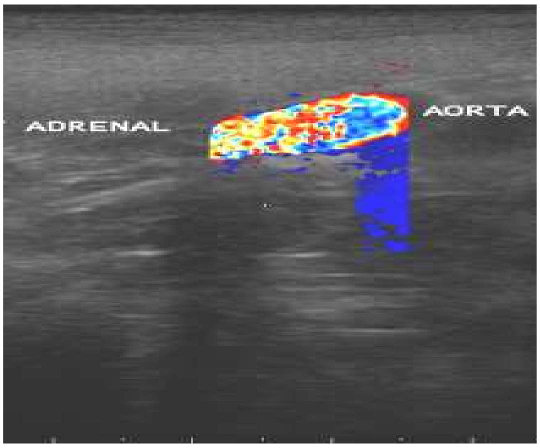

Fig. 18: Ultrasonogram of left adrenal gland of Animal 5.

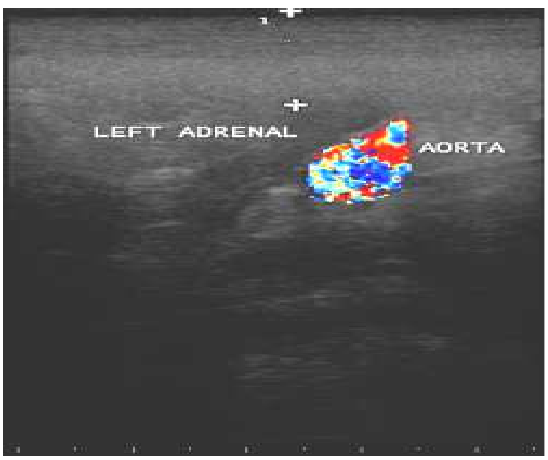

Fig. 19: Ultrasonogram of left adrenal gland of Animal 6.

Ultrasonograms of the left adrenal gland of the dogs of group III

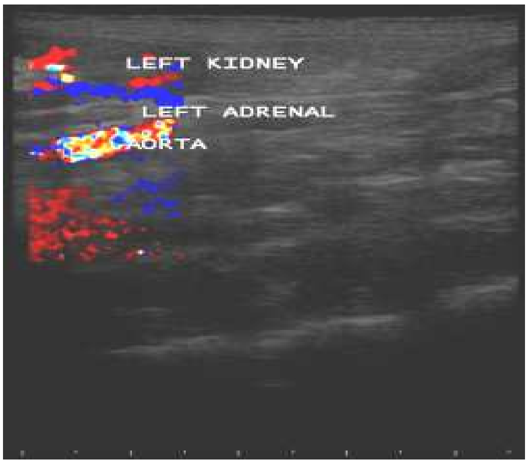

Fig. 20 : Ultrasonogram of left adrenal of Animal 1, Showing color Doppler Ultrasonogram of left adrenal along with left Kidney and aorta.

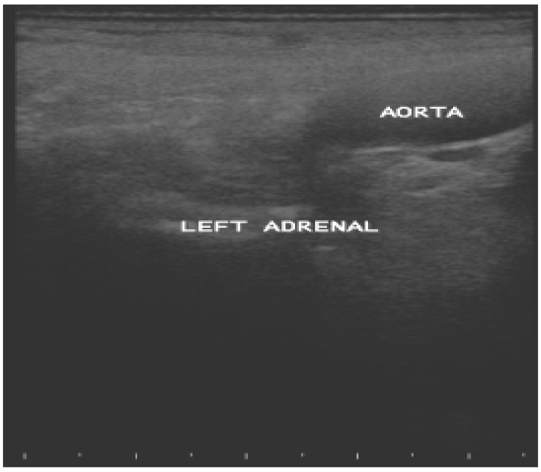

Fig 21: Ultrasonogram of left adrenal gland of Animal 2, Showing hypoechoic (lawn chair) shape left adrenal gland.

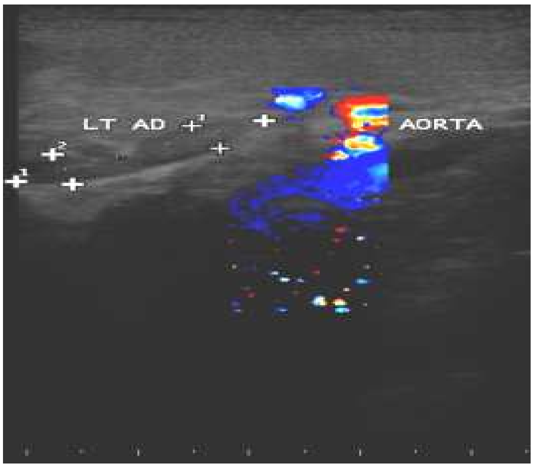

Fig. 22: Ultrasonogram of left adrenal gland of Animal 3.

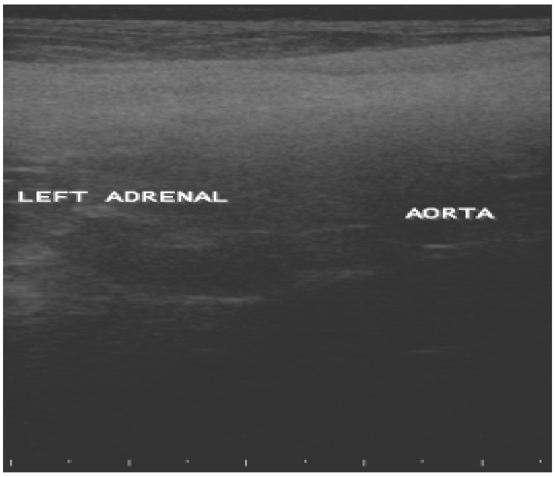

Fig. 23: Ultrasonogram of left adrenal gland of Animal 4.

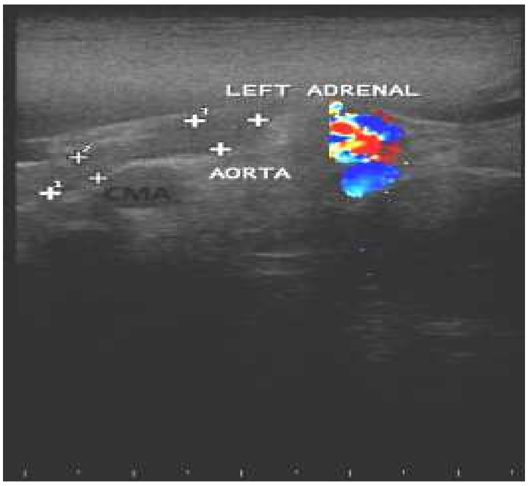

Fig. 24 : Ultrasonogram of left adrenal gland of Animal 5, Showing color Doppler of left adrenal along with aorta and CMA=cranial Mesenteric artery.

Fig. 25: Ultrasonogram of left adrenal gland of Animal 6.

Ultrasonograms of the right adrenal gland of dogs of group. I

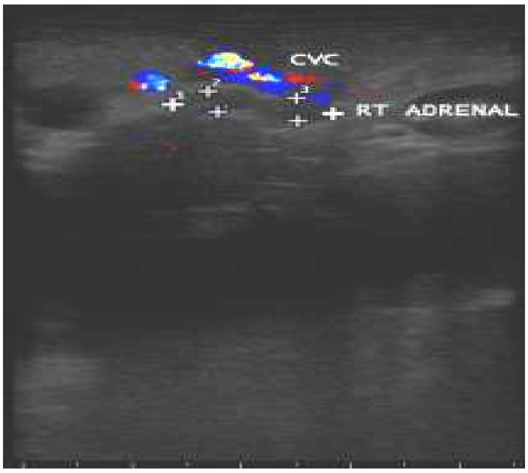

Fig. 26: Ultrasonogram of right adrenal gland of Animal 1.

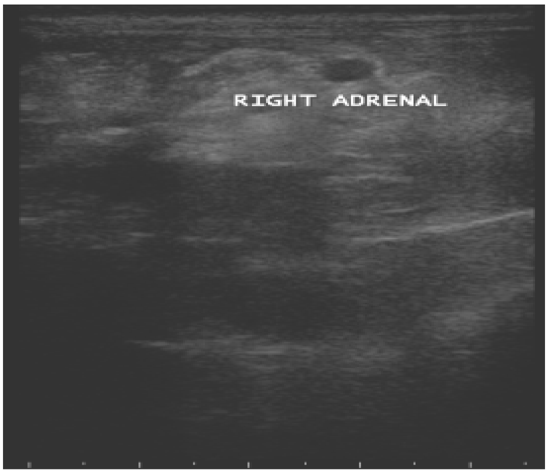

Fig. 27: Ultrasonogram of right adrenal of Animal 2.

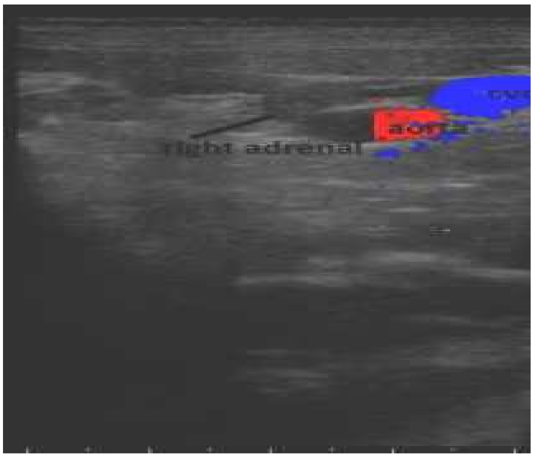

Fig. 28: Ultrasonogram of right adrenal gland of Animal 3.

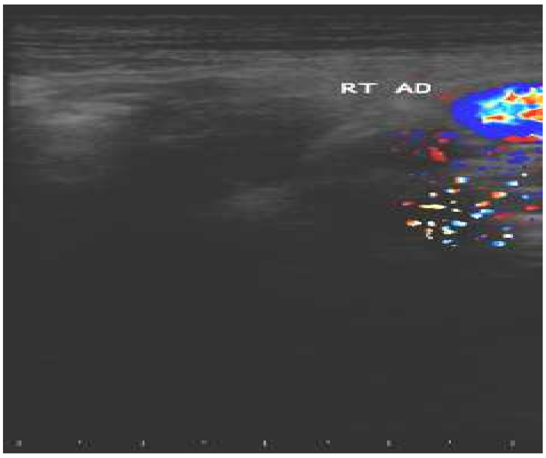

Fig. 29: Ultrasonogram of right adrenal of Animal 4.

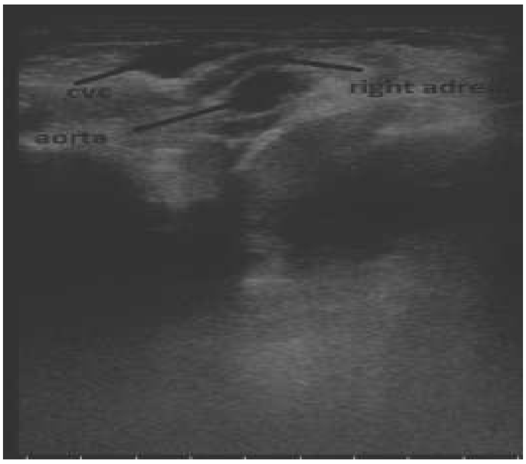

Fig. 30: Ultrasonogram of right adrenal of Animal 5.

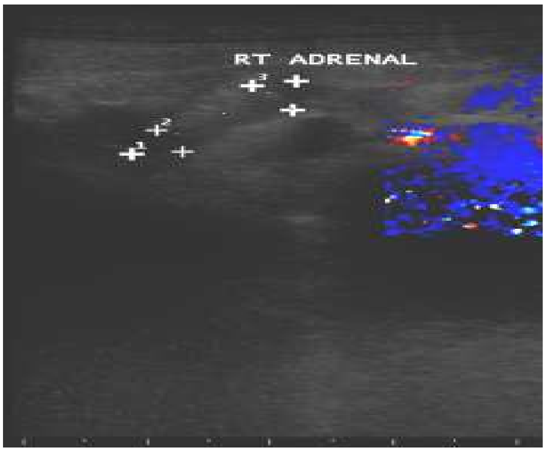

Fig. 31: Ultrasonogram of right adrenal of Animal 6.

Ultrasonograms of right adrenals of dogs of group II

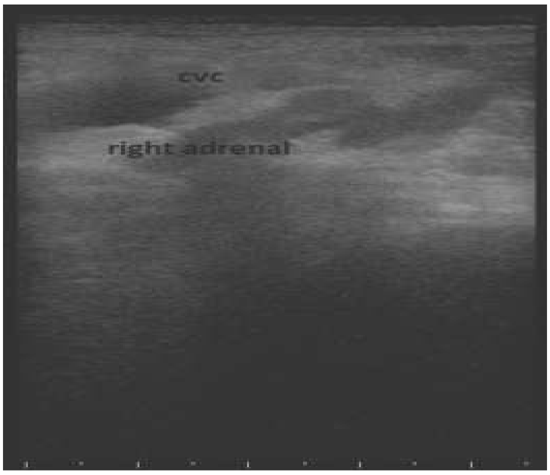

Fig. 32 : Ultrasonogram of right adrenal of Animal 3.

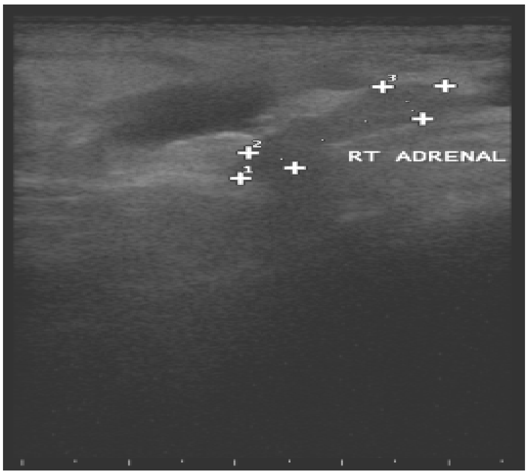

Fig. 33 : Ultrasonogram showing measurements taken of right adrenal

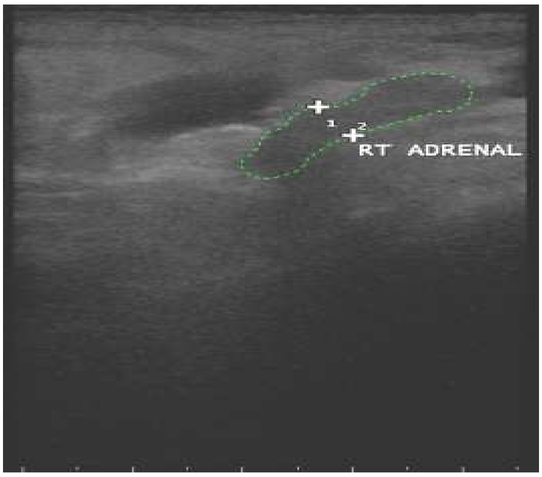

Fig. 34 : Ultrasonogram showing the volume taken of right adrenal gland

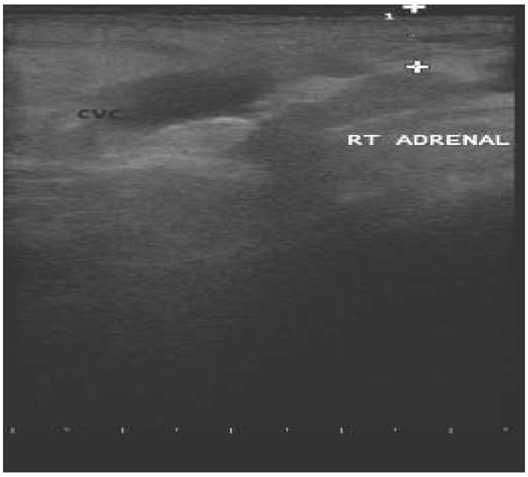

Fig. 35 : Ultrasonogram showing depth taken of right adrenal gland

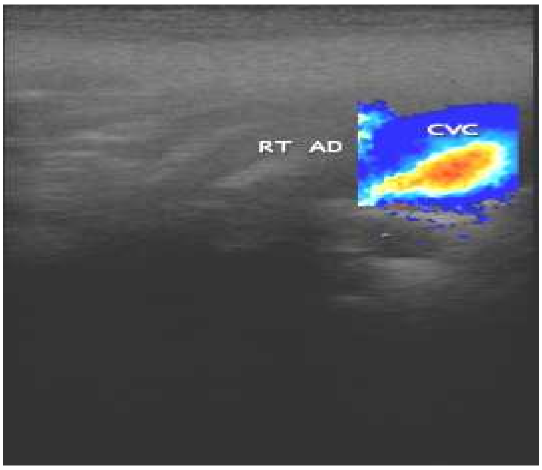

Fig. 36: Ultrasonogram of right adrenal of Animal 4.

Fig. 37: Ultrasonogram of right adrenal gland of Animal 5.

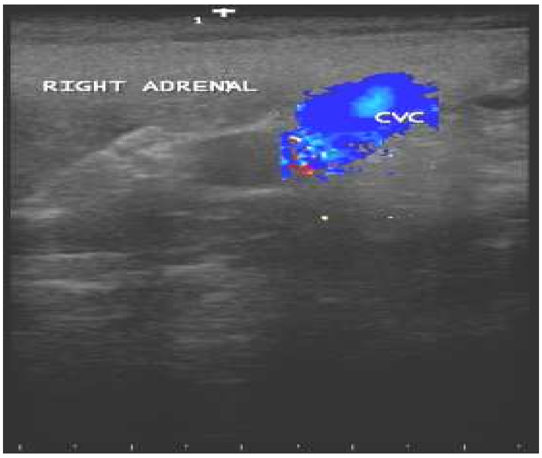

Fig. 38: Ultrasonogram of right adrenal of Animal 6.

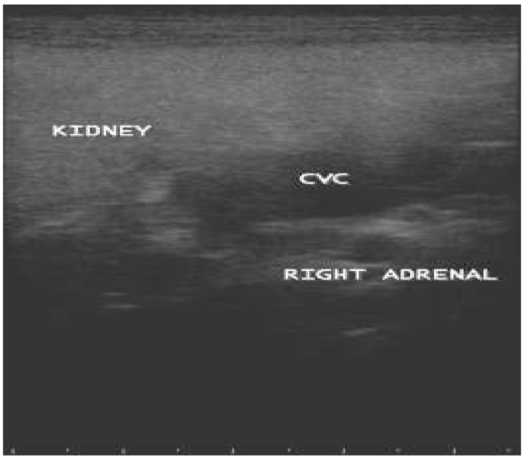

Fig. 39: Ultrasonogram of right adrenal of Animal 2.

Ultrasonograms of right adrenal glands of dogs of group III

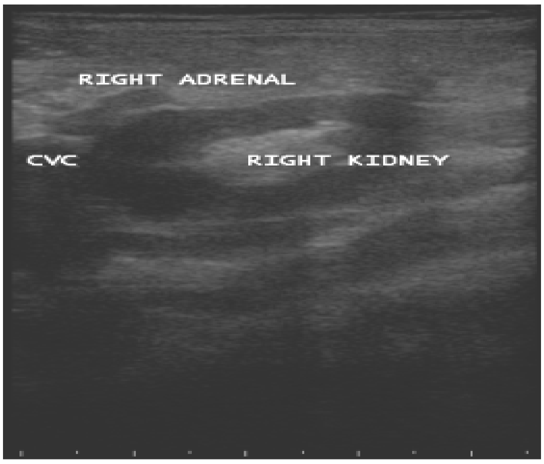

Fig. 40: Ultrasonogram of right adrenal of Animal 1.

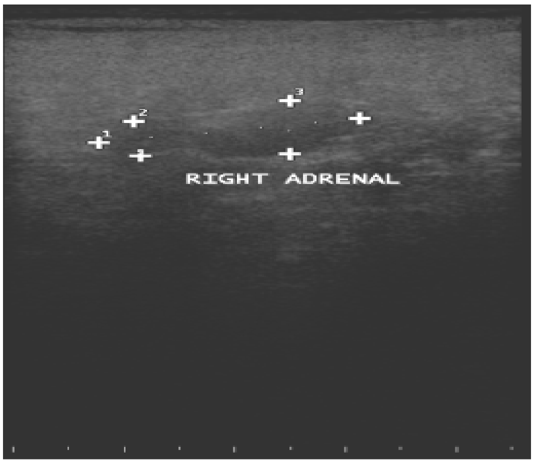

Fig. 41: Ultrasonogram of right adrenal gland of Animal 2.

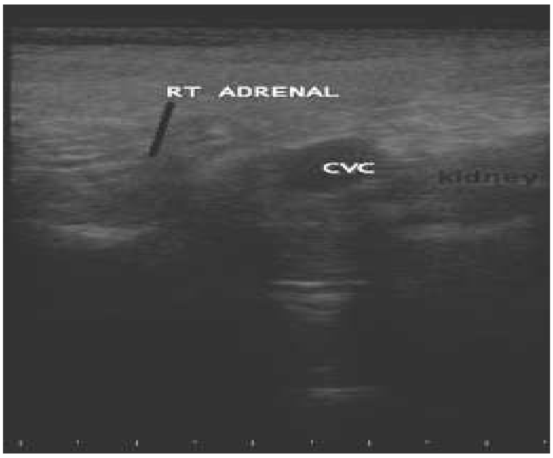

Fig. 42: Ultrasonogram of right adrenal gland of Animal 3.

Fig. 43: Ultrasonogram of right adrenal gland of Animal 6.

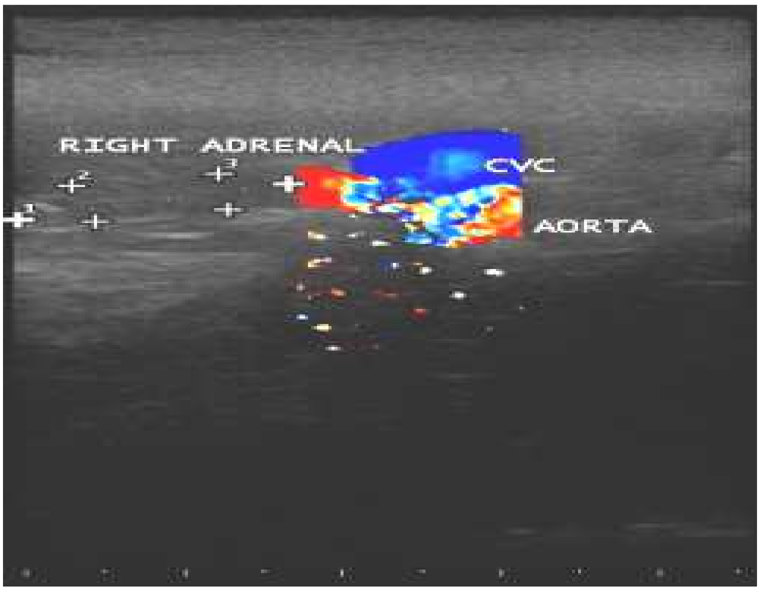

Fig. 44: Ultrasonogram of right adrenal gland of Animal 5.

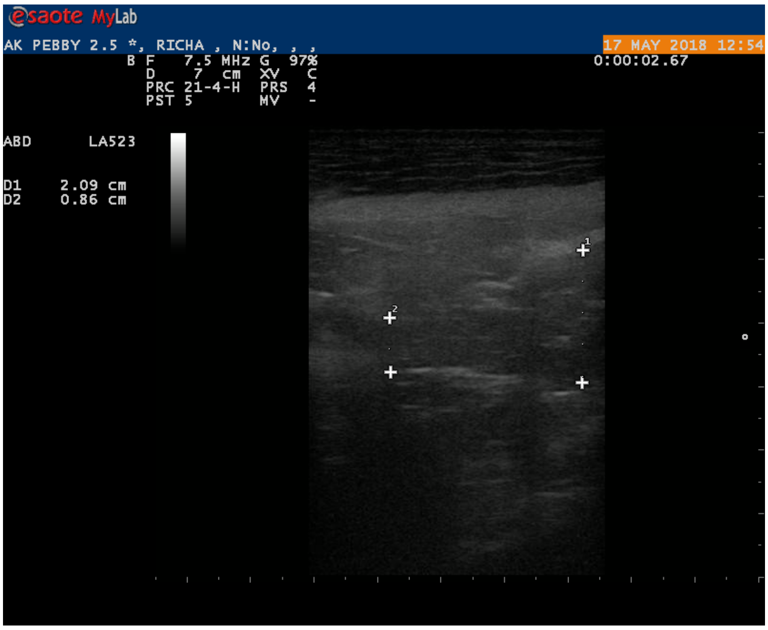

Fig 45: Ultrasonogram of left adrenal gland showing the enlargement of caudal pole

Discussion

CHAPTER- 5

DISCUSSION

Ultrasonographic examination:

The left adrenal gland:

In this investigation the left adrenal was scanned in lateral recumbency in all the animal groups as left adrenal gland in right lateral recumbency and right adrenal gland in left lateral recumbency. Grooters *et al.* (1996) have used dorsal recumbency for scanning adrenals, similarly Mogicato *et al.* (2011) have advocated dorsal approach whereas, Rose *et al.* (2017) have used both dorsal and lateral recumbent position for scanning the adrenal glands. However, Soulsby *et al.* (2014) and Douglass *et al.* (1997) have used lateral recumbency for scanning the adrenal glands. None of the animals was subjected to sedation or anesthesia. The method of scanning was similar as used by Barthez *et al.* (1998) and Sandhya *et al.* (2015).

In this study the rotation angle of transducer was approximately 40º- 45º to obtain a longitudinal view of the adrenal gland. Sandhya *et al.* (2015) have also used 45º rotation so as to obtain an optimum quality sonogram. However, Barthez *et al.* (1998) have reported the use of the rotation angle of transducer of approximately 10º to 15º.

In this study, the approach for both left and right adrenal gland was subcostal that is, immediately behind the last rib positioning the transducer slightly obliquely longitudinally. Some workers have also suggested an intercostal approach for scanning the right adrenal however this approach was not needed to scan the right adrenal gland in this study. Grooters *et al.* (1996) have also preferred subcostal rather than intercostal approach especially for measuring adrenal thickness. It was much easier to scan the left adrenal gland in comparison to right adrenal gland just because of the position of right adrenal gland. Grooters *et al.* (1996) and Barthez *et al.* (1995) have also reported that it is more difficult to visualize the right adrenal gland than the left one.

All the animals were scanned with the linear transducer at a 7.5 MHz frequency, which resulted in images of an optimum resolution. Besso *et al.* (1997) and Kealy *et al.* (2012) have also proposed that the frequency of 7.5 MHz with linear transducer allows a better resolution and anatomical details. Grooters *et al.* (1996) have used 7.5 and 5.0 MHz, Douglass *et al.* (1997) have used 7.0 and 5.0 MHz, Hoerauf and Reusch (1999) used only 7.5 MHz sector transducer, Wenger *et al.* (2010) also used 7.5 MHz, Mogicato *et al.* (2011) used 6 – 10 MHz convex probe, Choi et al (2011) used 10.0 MHz linear or 7.5 MHz convex, Pagani *et al.* (2016) used both, 7.5 – 12 MHz linear and 5.5 – 6.6 MHz micro-convex transducer, Soulsby *et al.* (2014) used 8 – 5 MHz or 5 – 2 MHz curved array transducer whereas, Rose *et al.* (2017) used 8 – 5 MHz curvilinear and occasionally a 13 – 5 MHz linear transducer, depending on the size of the dog. All the ultrasonograms were recorded in sagittal plane, because it was too difficult to differentiate the gland in transverse plane. Soulsby *et al.* (2014) have reported that they defined sagittal plane as the long axis of adrenal gland length and thickness were both maximal.

Ultrasonographic measurements:

The length, diameter of cranial pole, diameter of caudal pole, distance from skin surface and volume of gland were measured using the in-built *callipers*. The length of the left adrenal gland was 1.61 ± 0.17 cm, 2.2 ± 0.177 cm and 2.44 ± 0.30 cm in Groups I, II, III, respectively. Lobetti *et al.* (2016) have reported median left adrenal lengths to be 1.77 cm, 2.08 cm and 2.1 cm in 3 different group of dogs. The normal range of left adrenal gland length was 1.32 cm to 2.63cm in 20 dogs in a study conducted by Hoerauf and Reusch (1999), whereas the range for left adrenal gland length was 1.07 cm to 5.02 cm as reported by Douglass *et al.* (1997), in a study.

In this study the cranial pole diameter of left adrenal gland was 0.32 ± 0.033 cm, 0.49 ± 0.048 cm and 0.54 ± 0.08 cm in Groups I, II and III, respectively. The mean cranial pole diameter has been reported to be 0.42 ± 0.06 cm in a study done by Shaghayegh *et al.* (2011). Cranial pole diameter was not the reliable parameter to measure the thickness of the left adrenal gland.

In the present study the caudal pole diameter (thickness) of left adrenal gland was 0.35 ± 0.037 cm, 0.54 ± 0.029 cm and 0.52 ± 0.08 cm in Groups I, II and III, respectively. The range of caudal pole width was 0.19 cm to 0.124 cm in a study done by Douglass *et al.* (1997), whereas, Hoerauf and Reusch (1999) have reported the normal range of left adrenal gland thickness to be from 0.30 cm to 0.52 cm. Grooters *et al.* (1996) have reported a median left adrenal gland thickness in control dogs to be

0.6 cm, whereas Choi *et al.* (2011) found the mean value of left adrenal gland thickness to be 0.432 ± 1.00 cm. Lobetti *et al.* (2016) reported that the median left adrenal gland thickness was 0.31 cm, 0.4 cm and 0.6 cm in three groups studied by them.

The caudal pole diameter of an animal in the III Group of the present study was 0.89 cm which is far beyond the cut-off value for left adrenal caudal pole thickness proposed by several authors thereby giving an impression of hyperadrenocoticism. However, the animal was not showing any clinical signs of the disease. This may be due to old age. Similar findings have been reported (Grooters *et al.*, 1996; Douglass *et al.*, 1997). They have also proposed that systemic diseases are known to potentially induce adrenal enlargement, which could explain the effect of age on adrenal size since older dogs are more likely to have a systemic disease. Mogicato *et al.* (2011) have reported that age has a significant effect on left adrenal gland (the greater the age, the greater the width or length). De chalus *et al.* (2013) established the new upper threshold for the left adrenal gland height at the caudal pole measured in a longitudinal plane: 0.79 cm for the Labrador retrievers and 0.54 cm for Yorkshire Terriers.

In the present study, attempts were made to measure the distance i.e. the depth of both adrenal gland from skin surface to have an idea of emaciation, obesity, or young age. The left adrenal gland was at a depth of 1.1 ± 0.107 cm, 2.02 ± 0.43 cm and 2.05 ± 0.25 cm from the skin in Groups I, II and III, respectively. The depth of adrenal gland in Group I was minimum probably because of very young age, whereas it was maximum in the animal of Group III which comprise of older animals which could be because of accumulation of fat.

The volume of gland was 0.60 ± 0.155 ml, 1.85 ± 0.29 ml and 2.32 ± 0.52 ml in Groups I, II and III, respectively. The volume of gland was calculated by multiplying the total area of gland and the diameter of caudal pole. The sonographic volumetric measurements by other workers were not available but these measurements could help in diagnosing hypertrophy or hyperplasia or neoplasia of the adrenals resulting from endocrine or other systemic pathologies.

Echotexture of the left adrenal gland:

The left adrenal gland appeared as a peanut shaped structure which was hypoechoic as compared to surrounding tissue, and the echotexture was homogenous in all the Groups. The contour of the left adrenal gland was smooth. The difference in the echotexture of cortex and medulla were not discernible. The cranial and caudal poles of the left adrenal were easily distinguishable. Aorta was the anechoic pulsating oblong structure appearing below the left adrenal gland. The cranial mesenteric artery and celiac artery could not be visualised in all the ultrasonograms but in some ultrasonograms they were differentiated as hypoechoic or anechoic pulsating structures during scanning, cranial to the left adrenal gland (Fig. 14). The phrenicoabdominal vein could not be differentiated in most of the ultrasonograms but in one animal of Group II it was clearly visualized as anechoic or hypoechoic oblong area having hyperechoic margins running through the midbody of the adrenal (Fig. 15).

Similar findings have been reported by Grooters *et al.* (1996) wherein they observed that the left adrenal gland had a “peanut” shape when imaged in a sagittal plane. The adrenocortical parenchyma was homogenous and less echogenic than the adjacent renal cortex. According to a study performed by Santos *et al.* (2013), the adrenal gland of puppies and kittens was hypoechogenic to the surrounding fat, limited by a hyperechogenic line and without distinction of cortical and medullary region. In a study done by Choi *et al.* (2011) the adrenal cortex was hypoechoic to the renal cortex and adjacent fat.

Similarly, Barthez *et al.* (1998) have found that left kidney and aorta are the two abdominal structures which are useful landmarks for searching the left adrenal gland. They have reported that the normal left adrenal gland can be identified as a small, elongated, hypoechoic structure just lateral to the aorta. According to their study the parenchyma can sometimes be separated into a less echoic cortical region and a more echoic central medullary region. The left adrenal appears bilobed and is often referred to as being “peanut” shaped. The phrenico-abdominal vein (ventral) and artery (dorsal) course in the groove between the two lobes and are sometimes visible in cross section on longitudinal images of gland.

Hoerauf and Reusch (1999) have also reported the echogenicity of adrenal glands in their study. According to their study both adrenal glands of healthy dogs were hypoechoic as compared to the surrounding tissue.

The right adrenal gland:

The right adrenal gland was scanned in left lateral recumbency in all the animals. Intercostal approach was not preferred to scan the right adrenal gland, and all the animals were scanned in subcostal approach. The scanning of right adrenal gland was not easy because the right adrenal is more cranially positioned. In this study the right adrenal of one of the animal in Group II could not be scanned because of the gland position. Grooters *et al.* (1996) and Barthez *et al.* (1995) have also reported that it is more difficult to visualize the right adrenal gland than the left one. All the animals were scanned with the linear transducer at a 7.5 MHz frequency for a better resolution. (Douglass *et al.*, 1997; Besso *et al.*, 1997; Kealy *et al.*, 2012) have also proposed that the frequency of 7.5 MHz with linear transducer allow a better resolution and anatomical details.

Ultrasonographic measurements:

All the ultrasonograms were taken in sagittal plane, because it was too difficult to differentiate the gland in transverse plane. The length, diameter of cranial pole, diameter of caudal pole, depth of the gland and volume of gland were measured.

The length of right adrenal gland was 1.57 ± 0.12cm, 2.1 ± 0.10 cm and 2.20 ± 0.27 cm in Groups I, II, III, respectively. Median right adrenal length has been reported to be 1.75 cm, 1.8 cm and 2.03 cm in 3 Group of dogs as reported by Lobetti (2016). The normal range of right adrenal gland length was 1.24 cm to 2.26 cm in 20 dogs as reported by Hoerauf and Reusch (1999) whereas, the range of right adrenal gland length was from 1.00 cm to 3.93 cm as reported by Douglass *et al.*, (1997), in a study.

In the present study, the cranial pole diameter of right adrenal gland was 0.36 ± 0.03cm, 0.48 ± 0.03cm and 0.61 ± 0.07 cm in Groups I, II and III, respectively. The mean cranial pole diameter has been reported to be 0.46 ± 0.06 cm. In a study done by Shaghayegh *et al.* (2011).

In the present study caudal pole diameter of right adrenal gland was 0.39 ± 0.04 cm, 0.54 ± 0.05 cm and 0.56 ± 0.08 cm in Groups I, II and III, respectively. The range of caudal pole width was 0.31 cm to 0.120 cm in a study done by Douglass *et al.* (1997) whereas, Hoerauf and Reusch (1999) have reported the normal range of right adrenal gland thickness from 0.31 cm to 0.60 cm. Grooters *et al.* (1996) have reported the median right adrenal gland thickness in control dogs was 0.6 cm. Similarly, Choi *et al.* (2011) found the mean value of right adrenal gland thickness to be 0.421 ± 1.00 cm. Lobetti *et al.* (2016) reported that the median right adrenal gland was 0.34 cm, 0.37 cm and 0.6 cm in three Groups studied by them. De chalus *et al.* (2013) established the new upper threshold for the right adrenal gland height at the caudal pole measured in a longitudinal plane which was 0.95 cm for the Labrador Retrievers and 0.67 cm for Yorkshire Terriers. The right adrenal gland was at a depth of 1.1 ± 0.13 cm, 1.56 ± 0.27 cm and 1.86 ± 0.21 cm from the skin in Groups I, II and III, respectively. The depth of adrenal gland in Group I was minimum probably because of very young age, whereas it was maximum in the animal of Group III which comprise of older animals which could be because of accumulation of fat. The volume of gland was 0.63 ± 0.14 ml, 1.68 ± 0.24 ml and 2.06 ± 0.44ml in Groups I, II and III, respectively. The volume of gland was calculated by multiplying the total area of gland and the diameter of caudal pole. The sonographic volumetric measurements by other workers were not available but these measurements could help in diagnosing hypertrophy or hyperplasia or neoplasia of the adrenals resulting from endocrine or other systemic pathologies.

Echotexture of right adrenal gland:

The right adrenal gland was almost oval shaped hypoechoic structure as compared to the surrounding tissue and was homogenous in all groups. The contour of the gland was smooth. The outline of the adrenal was clear but the cortex could not be differentiated from the medulla as in case of the left adrenal. The right adrenal gland appeared either dorsal to the caudal vena cava or at the level of caudal vena cava. Similar findings have been reported by Barthez *et al.* (1998) who found that the right adrenal gland is located just cranial and medial to the hilus of the right kidney and can be identified just to the right of caudal vena cava. Accodrding to their study the right adrenal gland appears as a small, elongated, hypoechoic structure with its longitudinal axis parallel to the caudal vena cava. According to a study performed by Santos *et al.* (2013) the adrenal gland of puppies and kittens was hypoechogenic to the surrounding fat, delimited by a hyperechogenic line and without distinction of cortical and medullary region. In a study done by Choi *et al.* (2011) the adrenal cortex was hypoechoic to the renal cortex and adjacent fat.

Hoerauf and Reusch (1999) also proposed the echogenecity of adrenal glands in their study. According to their study both adrenal glands of healthy dogs were hypoechoic compared to the surrounding tissue.

Part II

In Part II of the study, comprising of clinical cases, the adrenal measurements and the echotexture of both the adrenal glands were well within the normal ranges and comparable to those of the Part I of the study. However, in one animal, which was a confirmed case of osteosarcoma, the ultrasonographic examination of left adrenal revealed enlargement of caudal pole thickness (2.09 cm) and the echotexture of the gland was slightly heterogenous. So, it was suspected for the adrenal carcinoma.

Althouth metastases to the adrenals are common in humans, they have not been thoroughly studied in animals (Labelle and De Cock., 2005). Further they have said that the average rate of adrenal involvement in metastatic cancer was 112/534 (21.0%) in dogs. They have also said that in dogs, 26 different tumor types metastasized to the adrenals. Pulmonary, mammary, prostatic, gastric, and pancreatic carcinomas, and melanoma had the highest rates of metastasis to the adrenal glands in dogs.

Pagani *et al.* (2016) also reported in a study that all adrenal gland lesions > 20mm in diameter were histologically confirmed as malignant neoplasms (pheochromocytoma and adrenocarcinoma). Grooters *et al.* (1996) have reported that the acoustic texture of the adrenal gland in the majority of dogs with PDH was homogenous and less echogenic than the renal cortex, and thus was similar to that in the healthy dogs, however, in 2 dogs with PDH focal areas of hyperechogenecity were present within the adrenal parenchyma. These echogenic foci likely represent large nodules of cortical hyperplasia. Both nodular and diffuse patterns of bilateral cortical hyperplasia have been reported in association with PDH. Hoerauf and Reusch (1999) have reported that the length and thickness of the left adrenal gland in dogs with hypoadrenocorticism were significantly less than those of healthy dogs.

Summary and Conclusions

CHAPTER-6

SUMMARY AND CONCLUSIONS

The present study was proposed in two parts. In Part I of the study, apparently healthy dogs of all age groups were subjected to ultrasonographic examination of both adrenal glands. These dogs were divided into three groups as under:

Group I	:	Animals of 01 month to 09 months of age
Group II	:	09 months to 6 years of age
Group III	:	Above six years of age

There were six animals in each group.

In Part II of the study ultrasonographic examination of both adrenal glands of patients reporting to the TVCC College of Veterinary Science and Animal Husbandry, UP Pt Deen Dayal Upadhyaya Pashuchikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, Mathura (UP), with symptoms like lethargy, anorexia vomiting, weight loss, brady cardia, weak femoral pulse and abdominal pain, or polydipsia, polyuria hyper-glycaemia etc.

The animals of both parts of this study were subjected to sonographic examination of left and right adrenal gland with their measurements and echotexture.

PART-1

Ultrasonographic examination was done in lateral recumbency in all the dogs after proper restraining.

The left adrenal gland was imaged by placing the linear transducer having a frequency of 7.5 MHz in the subcostal area in the dorsal plane (along the body length parallel to the dorsum of the dog) and locating the aorta and caudal vena cava in long axis. The transducer was then slid cranially along to the level of the left kidney keeping the aorta in view and the left renal artery and vein were located. The transducer was rotated 45 degrees clockwise and gently swept cranial to the renal artery and vein to locate the left adrenal gland in long axis. The aorta and kidney were not usually in the same field of view when the adrenal gland was imaged but in some ultrasonograms structures in addition to the adrenal gland namely, the aorta and kidney were visualized in the same field.

The measurements of the left adrenal gland, namely, the length, cranial pole diameter, caudal pole diameter, depth of the gland from skin and volume of the adrenal gland were measured using the in-built *callipers* of the ultrasound machine. The mean length of left adrenal gland was 1.61 ± 0.17 cm in Group I, 2.2 ±0.177 cm in Group II and 2.44±0.30 cm in Group III. The left adrenal gland was longest in the animals of Group III and shortest in those of Group I. The cranial pole diameter of left adrenal gland was 0.32±0.033 cm, 0.49±0.048 cm and 0.54±0.08 cm in Group I, II and III, respectively. The caudal pole diameter of left adrenal was 0.35± 0.037 cm, 0.54 ± 0.029 cm and 0.52±0.08 cm in Groups I, II and III, respectively. The left adrenal gland was at a distance of 1.1±0.107 cm from the skin in Group I, 2.02±0.43 cm in Group II and 2.05±0.25 cm in Group III. The volume of gland was 0.60± 0.155 ml, 1.85±0.29 ml and 2.32±0.52 ml in group I, II and III respectively.

The left adrenal gland appeared as a peanut shaped hypoechoic area and was homogenous in all the groups. The outline of the left adrenal was clear. The difference in the echotexture of cortex and medulla were not discernible. The cranial and caudal poles of the left adrenal were easily discernible. The left adrenal gland was the first structure to appear in ultrasonogram beneath the skin, aorta appeared as an anechoic pulsating oblong structure below the left adrenal gland.

For locating the right adrenal gland, the dog was placed in left lateral recumbency. Linear transducer at a frequency of 7.5MHz was placed over the subcostal region in all the animal and intercostal approach was not needed to locate the right adrenal. Aorta and caudal vena cava were again located in the long axis in the dorsal plane the dorsal plane. The transducer was then slid cranially, keeping the caudal vena cava in view. The adrenal gland was located along side and dorsal to the caudal vena cava.

The mean length of right adrenal gland was 1.57 ± 0.12 cm in Group I, 2.1 ± 0.10 cm in Group II, and 2.20 ± 0.27 cm in Groups III. The right adrenal was thus longest in the animals of Group III and shortest in those of Group I. The cranial pole diameter of right adrenal gland was 0.36±0.03 cm, 0.48±0.03 cm and 0.61±0.07 cm in Groups I, II and III, respectively. The caudal pole diameter of right adrenal gland was

0.39±0.04 cm, 0.54±0.05 cm and 0.56±0.08 cm in Groups I, II and III, respectively. The right adrenal gland was at a distance of 1.1±0.13cm fron the skin in Group I, 1.56±0.27 cm in Group II and 1.86±0.21 cm in Group III. The volume of gland was 0.63±0.14 ml, 1.68±0.24 ml and 2.06±0.44 ml in Groups I, II and III, respectively.

The right adrenal gland was almost oval shaped hypoechoic structure as compared to the surrounding tissue and was homogenous in all groups. The outline of the adrenal was clear but the cortex could not be differentiated from the medulla as in case of the left adrenal. The right adrenal gland appeared either dorsal to the caudal vena cava or at the level of caudal vena cava.

PART II:

In Part II of the study, comprising of clinical cases, the adrenal measurements and the echotexture of both the adrenal glands were well within the normal ranges and comparable to those of the Part I of the study. However, in one animal, the ultrasonographic examination of left adrenal revealed enlargement of caudal pole thickness (2.09 cm) and the echotexture of the gland was slightly heterogenous. So it was suspected for the adrenal carcinoma.

The mean length of left adrenal, cranial pole diameter, caudal pole diameter, distance from skin and volume was 2.79 ± 0.28 cm, 0.66 ± 0.05 cm, 0.59 ± 0.10 cm, 2.31 ± 0.31 cm, 2.77 ± 0.49 ml, respectively.

The mean length of left adrenal, cranial pole diameter, caudal pole diameter, distance from skin and volume was 2.55 ± 0.21 cm, 0.71 ± 0.06 cm, 0.66 ± 0.10 cm, 1.96 ± 0.29 cm, 2.72 ± 0.19 ml, respectively.

CONCLUSIONS:

1. Ultrasonography of adrenal glands in dogs does not require anaesthesia. Subcostal approach is the best approach to scan left and right adrenals, the scanning of adrenal can be easily done using a 7.5 MHz Linear transducer, in lateral recumbency by placing the probe caudal to the last rib and ventral to the lumbar process. The dimensions and the echotexture of the adrenal glands were similar to the findings of previous workers and may assist in the diagnosis of pathologies of the adrenals or other organs. It requires a great degree of patience to scan adrenals because of their size and position. It is difficult to scan right adrenal gland because of the its cranial location.

2. The ultrasonograms collected during this study can be used as reference images
3. The measurements recorded during this study can be used as reference values.
4. Caudal pole diameter is a reliable measurement to assess the size of the gland. Hyperadrenocorticism and hypoadrenocorticism can be diagnosed by measuring the caudal pole thickness.
5. It is easy to locate adrenal gland in thin and geriatric animal because of less abdominal and perirenal fat.
6. In some of the clinical cases the caudal pole thickness was beyond the cut-off value but those animals were not showing any clinical symptoms similar hyperadrenocorticism, so we concluded that increment in the adrenal thickness might be due to the age factor.
7. Increment in the size of the gland is common in old age animal, because old animals are more likely to have a systemic disease and systemic diseases are the potential cause of adrenal enlargement.
8. Ultrasonography is non-hazardous, easily accessible and specific modality which does not require sedation or anaesthesia, to diagnose the pathological conditions of the adrenal glands.

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