DIAGNOSTIC ULTRASONOGRAPHY OF AN EQUINE ABDOMEN

THESIS

By

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LIST OF ABBREVIATIONS USED AND THEIR MEANINGS

Abbreviations	Meaning
%	Per cent
<	Less than
>	Greater than
4D	Four dimensional
ALKP	Alkaline Phosphatase
ALT	Alanine Aminotransferase
AST	Aspartate Aminotransferase
BUN	Blood Urea Nitrogen
Cm	Centimeter
Co.	Company
CRT	Capillary Refill Time
CST	Culture Sensitivity Test
DC	Descending Colon
DD	Descending Duodenum
DLC	Differential Leukocyte Count
DNS	Dextrose Normal Saline
E.g.	For Example
ECG	Electrocardiography
EDTA	Ethylene Diamine Tetra Acetic acid
et al.	And others
Etc.	ec cetra (and many more)
°F	Degree Fahrenheit
g/dL	Gram per decilitre
GFR	Glomerular Filtration Rate
GIT	Gastrointestinal tract
GPT	Gum Perfusion Time
Hb	Hemoglobin
Hrs	Hours
i.e.	That is
ICM	Intercostal Muscle
ICS	Intercostal Space
ICS’s	Intercostal spaces
Kg	Kilogram (s)
LA	Left Arm
LDC	Left Dorsal Colon
LL	Left Leg
Ltd.	Limited
Ltr.	Litre
LVC	Left Ventral Colon
mg	Milligram
mg/dL	Milligram per decilitre
MGI	Mucosal Gas Interface
MHz	Megahertz
Min	Minute

Ml	Millilitre
Mm	Millimeter
Mv	Millivolt
NS	Normal Saline
PCV	Packed Cell Volume
PF	Peritoneal Fluid
PM	Post Mortem
RA	Right arm
RDC	Right Dorsal Colon
RL	Right Leg
RL	Ringer Lactate
Rt.	Right
RVC	Right Ventral Colon
SE	Standard Error
TLC	Total Leukocyte Count
u/L	Microlitre
Viz.	Namely
USG	Ultrasonography

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ABSTRACT

The present work on equine abdominal ultrasonography was conducted in two phases. In standardization phase, detailed abdominal ultrasonographic scan was performed on native 10 adult (5horses and 5 mules) healthy equines of either sex to develop baseline topographical data of various organs. In this phase, the organs of right and left hemi-abdomen were topographically located, their echo-architecture was described. A baseline data of landmarks for locating different abdominal organs was elucidated. The sonographic calliper measurements of different organs were generated along with dynamic parameters of alimentary tract to help delineate the pathology. In clinical application phase, 14 clinical cases of equines suspected for abdominal disorders were subjected to ultrasonography for assisting the diagnosis. Colonic impactions were imaged as hyperechoic intraluminal structure casting a strong acoustic shadow. Bull's eye or sandwich like appearance of intestinal loops was characteristic of intussusceptions and can be imaged transabdominally. Descending colon obstructions were imaged as a large hyperechoic intraluminal masses casting a strong acoustic shadow with loss of normal sacculations and peristaltic movement of descending colon. In case of peritonitis the peritoneum could be imaged as thin echogenic layer with lot of peritoneal fluid present inside the abdominal cavity with marked thickening of jejunal wall. It was concluded that thorough clinical investigation combined with ultrasonography was found to be an important diagnostic imaging aid for diagnosing different abdominal disorders in equines and equips the surgeon/clinician to identify the exact etiology, which helps reach at an accurate diagnosis and formulate a precise and efficient therapeutic plan.

(Signature of Student with date) (Signature of Major Advisor)

Head of Department

CHAPTER 1

INTRODUCTION

The state of Himachal Pradesh has sizeable number of equine population which includes 10063 horses, 19015 mules, 7383 donkeys and 3136 ponies (according to the animal census 2007). Simultaneously, the incidences of equine abdominal emergencies are very common. There are numerous factors responsible for these abdominal emergencies, but the most predominant factors are:

1. Geographical topography of the state
2. Feed scarcity
3. Poor care and hygiene of the animals
4. Self medication by owners

Due to the topography of the state these animals are quite common in use for transportation of construction materials and as public transport. Due to the feed scarcity these animals are not fed properly and they are deprived even from the maintenance ration. So in order to meet their physiological demands, these animals get habit of eating unusual things like horses working at construction sites are found habitual of eating sand and gravel. Similarly, horses used for public transportation have been seen peeping into garbage bins and eating whatever they get there like polythene bags, ropes, metallic objects etc. At the same time owners do not provide them proper care like deworming, dental hygiene, palatable water which further increases the risk for abdominal emergencies and they end up with obstruction or impaction of the gastrointestinal tract. Finally it becomes a challenge for the Veterinarian to diagnose the exact etiology as there are very few diagnostic techniques available with the Veterinarians which include radiography and rectal examination. But unfortunately these techniques have their own limitations, like due to the large size of abdomen the radiography is of no use and only 40 to 50% of the cases can be diagnosed by rectal examination, that too if the etiology lies within the caudal abdomen. So keeping these points in mind the present study was designed to search for newer diagnostic techniques which are 100% successful and can diagnose the exact etiology. Ultrasonography seems to fulfill that promise without wasting the time in symptomatic treatment because time is the important factor for the survival of the animal in case of equine abdominal emergencies.

Ultrasonography, a non-invasive real time imaging modality, is a useful diagnostic tool for Veterinary Medical applications. It offers better contrast resolution than radiography and is capable of viewing the internal organs in different planes in real time. Further, it is free from radiation hazards, portable and very economical compared to other imaging modalities. The diagnostic abdominal ultrasonography is increasingly used in Veterinary practice and has an important role in decision making in equines with abdominal disorders. In nut shell, ultrasonography is recognized as an invaluable aid to diagnostic imaging in the equines. It has the potential for wide spread use in diagnosis of disorders of several body systems in horses viz. musculoskeletal, urogenital, cardiothoracic, gastrointestinal which mainly include gastric distension, small intestinal ileus, inflammation of large intestine, right dorsal colitis, intra-abdominal masses and neoplasms, intra-abdominal abscesses, intussusceptions, ileal muscular hypertrophy, impaction, entrapment of large colon in the nephrosplenic space, displacement of colon, coleolithiasis and bowel rupture. In addition to this, intestinal diameter, gut motility, liver abscesses, splenic tumors, renal changes in pyelonephritis, urolithiasis, etc. can be diagnosed easily with the help of sonography.

Ultrasonography has a number of advantages over other imaging techniques. It can distinguish between soft tissues of different echogenicity. It enables different regions of the gastrointestinal tract to be identified and their location, size, anatomical features (such as sacculations), luminal contents and motility to be assessed. Fluid and soft tissue can be differentiated using ultrasonography. The small intestine wall can therefore be distinguished from its fluid contents, and parameters such as wall thickness and the nature of intestinal contents can be evaluated. The ultrasound image is constantly updated, producing a real-time moving image. Consequently, the position and movement of the structures relative to each other can be assessed. The frequency, amplitude and velocity of the peristaltic contractions can also be evaluated by B- mode, M- mode and Doppler ultrasonography. Furthermore, it is easy to perform and allows immediate interpretation that is essential in the colic patients. Other methods of imaging the gastrointestinal tract, such as radiography and endoscopy, are of limited value in the adult horses due to the large size of the abdomen.

One of the problems of gastrointestinal ultrasonography in horses is acoustic shadowing from gas and ingesta within the large intestine and gas within the lungs. In horses, large intestine is located along most of the lateral and ventral abdominal wall and the lungs overlie much of the cranial and dorsal abdomen. These structures reflect most or the entire ultrasound beam making imaging of any underlying structures difficult. In human ultrasonography, the reflection of ultrasound beam from the large intestinal contents is reduced by administering large volumes of oral fluids prior to imaging but this is not practical in equines and instead different techniques such as combining transrectal and transcutaneous imaging may have to be used to visualize most of the abdomen.

It is always not possible to evaluate the deeper cranial abdominal structures in horses. This is a particular problem in patients with large intestinal distension and when feasible, sequential ultrasonographic examinations are of value. Nonetheless, deeper structures may remain inaccessible and some lesions may not be identified.

Patient preparation for equine non-reproductive ultrasonography is a big drawback because hair of the scanning area need be shaved. This is a constraint in terms of time and also alters the animal visually which is sometime unacceptable to owners apprehensive of its adverse effect on sale of animals. And last but not the least, a thorough knowledge of topographic anatomy of animals is the critical factor for accurate interpretations of the images on screen.

Despite of its great potential as a broader diagnostic utility, the use of ultrasonography in equine practice has largely remained limited to developed countries. Though of late, some work on equine ultrasonography has started in India but its use has been reported for reproductive applications and for diagnosis of tendinopathies in race horses.

However, detailed systematic ultrasonographic studies to develop baseline data of equine abdomen is still lacking. Therefore, keeping in view the referral practice of equine in Teaching Veterinary Clinical Complex of CSKHPKV, the present study was undertaken to develop baseline data of ultrasonographic observations of equine abdomen and its clinical applications. The present study consisted of standardization of ultrasonographic technique of the normal equine abdomen and the clinical application comprised of image analysis of diseased organs. The examination of diseased animals consisted of all equine patients suspected for abdominal disorders. Sonography will be performed after routine clinical examination and investigations with an aim to reach at an accurate diagnosis to equip the surgeon/clinician with precision and efficiency for the intervention. Therefore, the basic objectives of the present study were:

1. To standardize the technique of scanning the different organs of equine abdominal cavity.
2. To evaluate the use of ultrasonography as a diagnostic tool in equine abdominal disorders.

CHAPTER 2

REVIEW OF LITERATURE

Abdominal ultrasonography is increasingly used in Veterinary practice and has an important role in decision making in horses with abdominal disorders. The technique has been used predominantly in foals and smaller horses too, where rectal palpation is not possible, but it is a valuable diagnostic aid in the adult horses. It enables the veterinary surgeon to image the regions of the abdomen that are inaccessible to rectal palpation. It allows abnormal rectal findings to be confirmed and, in many cases, provides further information. Ultrasonography enables different regions of the gastrointestinal tract to be identified, and their location, size, anatomical features, luminal contents and motility to be assessed. The relevant organ wise work on equine non-reproductive diagnostic ultrasonography has been reviewed as under:

2.1 Liver

Rantanen (1986a) stated that only a small portion of the right side of the liver could be imaged and estimates of size rely on its expense across ICS. It is unusual for liver to be seen beyond the fifteenth ICS or in the same transverse plane as the right kidney, except at the most rostral aspect of the kidney. The ventral edges of the normal liver are sharp. Like the spleen, the architecture of the liver is relatively homogenous, though more vessels are visible in the liver and the general echogenicity of the liver is less than the spleen, portal veins have more connective tissue in their walls and thus have more echogenic walls than the hepatic veins.

Reef (1998) stated that the right lobe of the liver extends from the sixth or seventh intercostal space (ICS) to the fourteenth or fifteenth ICS. The left lobe of the liver is smaller and usually extends from the sixth to the ninth intercostal spaces. The liver is immediately adjacent to and caudal to the diaphragm. The right dorsal colon is deep to the liver on the right side of the abdomen with the duodenum between the right dorsal colon and liver in the cranial to mid portion of the abdomen. The right kidney is caudal and lateral to the caudate process of the right lobe of the liver. On the left side of the abdomen the cranial pole of the spleen is located medial to the liver, usually in the eighth to ninth intercostals space. Atrophy of the right liver lobe occurs in older horses.

Reef *et al.* (2004) found that liver is recognizable by its branching vascular pattern. The bile ducts are not normally visualized. The majority of the liver is not visible ultrasonographically, nor is the caudal vena cava, in a normal adult horse. Thus estimations about hepatic size are based on the amount of hepatic parenchyma visualized ventral to the ventral lung margins. Hepatic atrophy commonly occurs with increasing age in the horse; therefore, in older horses, only a small amount of hepatic parenchyma is normally visualized.

Desrochers (2005) found that the liver is imaged in the right 6^{th} to 15^{th} ICS and from the left 6^{th} to 9^{th} ICS. Atrophy of the right lobe of the liver is common in older horses. The liver has sharp, well demarcated margins and a homogenous parenchyma of medium echogenicity containing a branching vascular pattern. The biliary system is not normally visualized unless distended.

Porter and Ramirez (2005) concluded that liver is seen ventral to the lung margins between the sixth and fifteenth ICS on the right and between the sixth and ninth ICS on the left. In foals less than 8 weeks of age, the cranial ventral portion of the liver is in contact with the abdomen and therefore can be imaged just caudal to the xiphoid. Normally, the hepatic parenchyma is of uniform medium echogenicity (i.e., hyperechoic to the kidneys, hypoechoic to the spleen), with the hepatic and portal veins interrupting the uniform echo pattern. The bilary and hepatic arteries are not normally visualized unless abnormal. The portal vasculature has echogenic walls and therefore can be differentiated from the hepatic veins, which lack echogenic walls.

Borton (2011) found that liver extends from the sixth to the fourteen ICSs between the diaphragm and the right dorsal colon on the right side of the abdomen. Air in the lungs dorsally interferes with the hepatic imaging.

Reef *et al.* (1990) found that there is mild to marked distension of the biliary tree usually detected sonographically in horses with biliary obstruction associated with hepatolithiasis and cholelithiasis. The biliary distension becomes more severe in the caudal dorsal portions of the liver, the areas usually farthest away from the obstruction; all affected horses had distended bile ducts detected in the right lobe of the liver, where as only 50% had these findings in the left liver lobe.

Reef (1991) reported increase in parenchymal echogenicity in several horses with diffuse granulomatous liver disease. The increase in parenchymal echogenicity is heterogeneous in most horses, with a more multifocal miliary distribution and liver has been markedly enlarged in all horses with slightly irregular and rounded margins.

Chaffin *et al.* (1992) reported that in hepatic lymphosarcomas, there is a diffuse increase in the echogenicity of the liver, with loss of the normal parenchymal architecture, rounding of ventral margins of liver and liver often extends ventrally to the level of the costochondral junctions on the right side of the abdomen.

2.2 Spleen

Rantanen (1986a) reported that the only measurement of the spleen that is reliable is its central thickness or depth, which is usually less than 15cm.

Porter and Ramirez (1995) reported that the location of the spleen is variable depending on gastric distention and the size of adjacent organs, such as liver. Normally it is seen from left sixth ICS to the paralumbar fossa. It is usually located lateral, caudal, and ventral to the left kidney and medial to the left lobe of liver.

Reef (1998) reported that the spleen is visualized adjacent to the body wall from the left 8^{th} ICS to the paralumbar fossa, extending in the ventral abdomen. The splenic parenchyma has a granular homogenous appearance and contains a few blood vessels. The spleen is the most echogenic abdominal organ.

Freeman (2002b) reported that the spleen is imaged along the left abdominal wall. It can extend ventrally to the level of the midline and occasionally across the midline into the right ventral abdomen. The nephrosplenic space is imaged transcutaneously by following the spleen dorsally to the level of the transverse processes of the lumbar vertebra.

McAuliffe (2004) reported that the spleen is imaged between the 7^{th} ICS and the paralumbar fossa on the left side and in the 9^{th} ventral ICS on the right side in contact with the liver. The splenic vein is imaged on the medial aspect of the spleen, caudal and dorsal to the stomach in the 11^{th} to 12^{th} mid-ICS.

Barton (2011) reported that the size and location of the spleen is highly variable and is identifiable immediately adjacent to the body wall, from the left ventral 8^{th} ICS to paralumbar fossa and sometimes extends slightly beyond the right of the ventral midline. Normally the spleen's ultrasonographic architecture is homogenous with vessels rarely visible. The general echogenicity of the spleen is greater than that of liver and kidney.

Reef (1991) reported that splenic abnormalities are most common in horses with abdominal neoplasia and lymphosarcoma is the most common splenic neoplasm in horses. He also reported that in most affected horses the majority of the spleen is affected, with little normal splenic parenchyma remaining, and also reported that the spleen may exceed 25 cm in thickness and extend from the left paralumbar fossa into the cranial most portion of the left abdomen, across the ventral midline. The cranial pole of the spleen in horses with marked splenic enlargement can often be imaged in the right cranial ventral portion of the abdomen. Splenic masses may be well marginated or irregular in shape. These masses are usually sonographically complex and contain anechoic to hyperechoic areas often with acoustic shadowing associated with calcification.

Chaffin *et al*. (1992) found that in several horses with splenic lymphosarcomas, the splenic masses were hypoechoic, with interspersed normo-echoic and hyperechoic reflections.

Reef (1998) reported that the splenic hematoma appear as a loculated anechoic mass within otherwise normal splenic parenchyma or may contain echogenic to hyperechogenic masses representing clot formation within the hematoma. If the hematoma is recent, hypoechoic loculated areas may be imaged in the hematoma associated with the recent bleeding into the splenic parenchyma. The remaining spleen in these horses is smaller than normal, associated with splenic contraction. The anechoic loculated hematomas also represent more longstanding injuries to the spleen. The amount of normal splenic parenchyma in horses with splenic hematomas older than 3 to 4 months is usually within normal limits.

2.3 Kidneys

The right kidney is located more cranially in the abdomen and can usually be found in the retroperitoneal space just beneath the abdominal wall and immediately ventral to the transverse processes between the fourteenth and seventeenth ICS's at the level of tuber coxae. The left kidney is located further caudally and ventrally in the abdomen and is usually found in the 17th ICS and the paralumbar fossa between a line parallel to the tuber coxae and the tuber ischii Rantanen (1986b), Kiper *et al.* (1990) and Reef (1991).

The cranial pole of the right kidney sits in the renal fossa of the liver and lies deep to the diaphragm at the sixteenth ICS in most horses (range 14th to 17th ICS). The caudal extremity of the right kidney is located at the 17th ICS to the 1st lumbar vertebra. The duodenum courses ventrally around the caudal pole of the right kidney, and the caecum is imaged ventral and caudal to the right kidney and the duodenum. The right kidney is triangular curvilinear or heart shaped with a prominent hilar notch. This kidney measures approximately 15 to 18 cm wide, 13to 15 cm long and 5cm thick. The cranial extremity of the left kidney is usually at the level of the 17th rib (range 16th to 18th) but may lie caudal to the last rib in some normal horses. The left renal hilus is at the level of the caudal extremity of the right kidney. The caudal extremity of the left kidney is at the level of the 1st to 3rd lumbar vertebra. The left kidney has more of a bean shape and is longer and narrower than the right kidney. The left kidney is 15 to 18 cm long, 11 to 15 cm wide, and 5 to 6 cm thick. The left kidney lies medial to the spleen in the left caudal abdomen. The caudal vena cava and aorta lie medial to the left and right kidney along the ventral aspect of the dorsal midline. The kidney in the horse has a distinct cortex and medulla, but in the centre of the kidney fusion of the renal papillae forms the renal crest, a crescent shaped projection into the renal pelvis. The papillary ducts of the centre of the kidney open onto the renal crest whereas those from the extremities of the kidney open into the terminal recesses, which then drain into the renal pelvis Hoffman *et al*. (1995).

The entire right kidney cannot be imaged in a single field or view in the adult horse due to its superficial location. The left kidney is located deep to the spleen. Intervening gas-filled bowel may obscure the left kidney when imaging from the transcutaneous approach. Occasionally, intervening gas in the duodenum may also obscure visualization of the right kidney. More frequently, however the overlying lung may limit the visualization of the cranial and dorsal portions of the right kidney. The renal capsule, cortex, medulla, renal pelvic fat, intrarenal vessels, and the collecting system of the kidney can all be imaged ultrasonographically. The cortex is the homogeneously echoic outer layer of the kidney but appears less echoic than the adjacent hepatic parenchyma in young horses. The interlobar or arcuate vessels appear as circular structures with echoic walls and anechoic centers Hoffman *et al*. (1995) and Matthews and Toal (1996).

The kidneys are normally the least echogenic organs in the abdomen, normal older horses often have renal echogenicity similar to or even increased over that of liver. The renal cortex measures approx. 1 to 2 cm in thickness in the normal adult horse Rantanen (1990) and Matthews and Toal (1996).

There is a distinct corticomedullary junction visible between the more echoic cortex and the relatively more anechoic medulla. The renal pelvis and peripelvic fat are the most echoic tissue in the kidney and appear as an echoic band along the long axis of the kidney at its centre Matthews and Toal (1996).

Hoffman *et al.* (2000) reported that the renal pelvis and calices are hyperechoic, the renal cortex is hyperechoic in relation to the renal calices, and the renal medullary pyramids are relatively anechoic, allowing for a prominent corticomedullary junction. The renal capsule is imaged as a thin hyperechoic line surrounding the kidney. As in mature horses, the echogenicity of the renal cortex is less than that of the liver, which in turn is less than that of the spleen.

Aleman *et al.* (2002) reported that the right kidney is located ventral to the transverse spinous processes between the 14^{th} and 16^{th} ICS from 2 cm dorsal to the tuber coxae to 12 cm ventral. The left kidney is located from 15^{th} ICS to the caudal border of the left paralumbar fossa and from 2 cm dorsal to 15 cm ventral to the dorsal margin of the tuber coxae. Measurement of kidney length and width in foals up to 6 months of age showed a significant difference between right and left kidneys, with the left kidney being longer and the right kidney being wider for all age groups.

The left and right kidney can both be identified by transcutaneous ultrasonography. Transrectal ultrasonography produces higher quality images, allowing visualization of the renal vasculature and ureters. However, the transrectal technique is limited by the size of the horse and in large animals, only the caudal pole of the left kidney may be visualized. A combination of transcutaneous and transrectal techniques is necessary for optimal examination Freeman (2002b).

In case of acute renal failure sonographic examination of the kidneys usually reveals bilateral enlargement, with the renal parenchyma appearing less echogenic than normal Kiper *et al.* (1986) and Reef (1991). Chronic renal diseases in horses is characterized by increased parenchymal echogenicity and a smaller than normal kidney with an irregular contour. This increase in parenchymal echogenicity is associated with fibrosis of affected kidneys Rantanen (1986b) and Penninck *et al.* (1986). Poor differentiation of the internal architecture, particularly the cortex and the medulla, has been detected in adult horses with chronic renal diseases Rantanen (1986b). Renal calculi are frequently imaged in both the kidneys in horses with chronic renal diseases Schmidt (1989). A hyperechoic structure casting an acoustic shadow through deeper tissues is characteristic of a nephrolith. The more calcified nephrolith usually has an acoustic shadow that originates from the near surface of the calculus, whereas one with a more proteinaceous component has an acoustic shadow that originates from the deeper side of the nephrolith. Underlying renal diseases should always be suspected in horses with nephrolithiasis Marcharg *et al.* (1984).

Reef (1998) reported that the sonographic appearance of a renal or perirenal abscess is that of a hyperechoic to echogenic fluid filled cavity within renal or adjacent to (perirenal) the kidney. Hyperechoic structures casting acoustic shadows may also be detected in horses with renal abscesses associated with nephrolithiasis. A double linear echo may be detected in horses with a sub capsular hematoma. The outer linear echo represents the renal capsule, and the inner linear echo represents the outer surface of the renal cortex. The renal or perirenal hematoma is usually anechoic and often contains loculations. A blotchy renal parenchymal echogenicity may be detected with renal contusion. Clear anechoic fluid in the retroperitoneal space around the kidney suggests a ruptured renal pelvis, calyx or ureter.

2.4 Stomach

Reef (1998) reported that the horse's stomach is located medial to the spleen along the left abdominal wall from the eighth or ninth to the twelfth or thirteenth ICS. In most horses the stomach is adjacent to the spleen for three ICS only (9^{th}-11^{th}). He also reported that if the stomach is filled with gas, reverberation artifact and acoustic shadowing obscure deep portions of the stomach. Gastric wall thickness in adult horse can measure up to 7.5 mm and is usually thinner in foals. Freeman (2003) also reported that the wall thickness varies with the degree of gastric distension, but is usually less than 0.75 cm. Rantanen (1986a) reported that the stomach is adjacent to the spleen at the level of the splenic vein. Canon and Andrews (1995) found that there is constant relationship between the greater curvature of the stomach, the spleen, and the gastrosplenic vein, and the only part of the stomach that can be seen between 9th to 13th ICS is the wall of the greater curvature which can be reliably identified as a curved line with proximity to the adjacent spleen and the gastrosplenic vein. Barton (2011) reported that if the stomach extends beyond the 14th ICS in a horse that has not recently eaten, it would be an indication of the gastric distension or displacement by the liver or other viscera. He also found that the stomach has the thickest wall of the gastrointestinal tract, measuring roughly 7 mm from the serosal to the mucosal/ lumen interface. When the stomach is empty, the wall may be up to 1 cm thick. Since, only the dorsal portion of the greater curvature can be seen and the lumen generally contains gas in this location, often the contents of the stomach are not visible and the greater curvature appears hyperechoic. If the fluid is present ventrally, a distinct gas /fluid interface may be apparent in the lumen.

Aleman *et al.* (2002) reported that the stomach is located medial to the spleen in the mid- to ventral abdomen between 6th and 12th ICS on the left side. The ventral wall of stomach is in contact with the ventral abdomen up to 7 days of age in foals. The stomach wall is hyperechoic relative to surrounding structures. In foals less than 7 days, luminal contents are visible. In older foals the presence of gas prevents the imaging of the gastric contents, and at this stage, the foal's stomach resembles that of an adult with a large curvilinear echo medial to the spleen and caudal to the liver.

Colin *et al.* (2005) reported that in healthy fed horses, the stomach was seen between the 9th and 12th ICS on the left side, proximal to the costochondral junction. No contractions were observed and the stomach always contained gas, when these same horses were fasted, the stomach was not identified in its usual position, instead it was identified ventral to the costochondral junction.

Epstein *et al.* (2008) reported that the stomach was seen between 8th to 15th ICS in case of ponies and the conformation of ponies may change the locations for imaging the stomach. He also concluded that the wall thickness of the stomach in case of ponies was less (4.3mm) than the published normal values for horses (7.5mm).

Reef (1991) reported that sonographic examination of the stomach in horses with gastric squamous cell carcinoma reveals a large mural gastric mass in the left side of the abdomen associated with the greater curvature in all affected horses. The mural mass is heterogeneous with a complex pattern of the echogenicity. Rantanen (1986a) reported an echolucent mass superficial to the stomach gas echo has been described for horses with gastric squamous cell carcinoma. Hillyer (1994) reported increased thickening of the gastric wall and abnormal echogenicity of the wall are consistent with gastric squamous cell carcinoma.

Reef (1998) reported that gastric distension, ulceration and impaction can be evaluated sonographically. Distension of the stomach with anechoic to hypoechoic fluid is detected with small intestinal obstructions and ileus and gastric and duodenal distension is often detected in horses with anterior enteritis. Ulceration of both the squamous and glandular portions of the stomach has been described in horses, with gastric ulcers occurring more frequently in the nonglandular portion of the stomach. Perforated gastric ulcers located at the margo- plicatus or near the pylorus cause peritonitis and death. Gastric ulceration is difficult to document by ultrasonography in the mature horse. However, thickening, edema (distinct hypoechoic layer in the wall), or “pitting” of the wall are findings suggestive of gastric ulceration. The sonographic appearance of the gastric impaction is a markedly enlarged gastric echo extending over five or more ICS on the left side of the abdomen. The stomach is usually slightly less circular than normal, with hyperechoic material casting an acoustic shadow in the lumen of the stomach.

2.5 Urinary bladder

Reef (1991) reported that the urinary bladder is imaged in the caudal most portion of the ventral abdomen and may be imaged in adult horses when filled with urine, displacing the large colon. The urinary bladder can be examined from the transrectal window in all horses large enough to receive a rectal examination. The urinary bladder is round to oval in transverse section and oval in sagittal section. The urinary bladder usually contains echogenic urine in the adult horses, as a result of normal crystalluria (calcium carbonate) and mucus in the urine in adult horses.

Schmidt (1989) reported that the echogenicity of the contents of the urinary bladder varies among normal horses from anechoic to hyperechoic particles, with a homogeneous pattern similar to that of the spleen. The contents of the urinary bladder can be seen to swirl during a real-time examination and this helps to define the boundaries between the urinary bladder wall and its contents. The wall of the urinary bladder is hypoechoic to echogenic, and its thickness varies with the amount of the bladder distension (normally from 3 to 6mm). The mucosa and the muscular wall of the urinary bladder are not separable sonographically. The urinary bladder can be found anywhere from just cranial to the pubis when empty or cranial to the external umbilical remnant, if the bladder is much distended. The ureters are not normally imaged from a transrectal window. The urethra is easiest to visualize when filled with fluid after urination.

Reef (1991) found that diffuse thickening of the bladder wall is the most common sonographic abnormality detected in the horses affected with cystitis. Sometimes there is focal bladder wall thickening and irregularity of the wall of the urinary bladder in some affected horses. The urine imaged is usually echogenic to hyperechoic. Layering of the urine may occur with severe pyuria because the cellular debris settles to the most ventral aspects of the urinary bladder. Fibrin strands may also be imaged in the bladder in a horse with severe cystitis.

Reef (1991) reported that sonographic appearance of the urinary bladder in horses with bladder atony usually reveals a markedly distended urinary bladder with echogenic urine and hyperechoic sludge accumulating ventrally in the bladder. The wall of the urinary bladder is usually normal in these horses unless a concurrent cystitis is present.

Reef (1998) found that cystic calculi are easy to image with transrectal ultrasonography. The calculi appear as large hyperechoic structures casting a strong acoustic shadow. The acoustic shadow begins at the near side of the calculus and extends through the deeper tissues. The urinary bladder wall often appears thickened. The cystic calculi are usually located in the trigone region of the bladder and these calculi are often embedded in the bladder mucosa and fill the entire bladder lumen in the trigone region. Hyperechoic concretion casting a strong acoustic shadow wedged in the lumen of urethra, with fluid distension detected proximal to the urolith is a typical sonographic appearance of a urethral calculus.

Byars and Halley (1986), Reef (1991) and Reef (1995) reported that with uroperitoneum the peritoneal cavity is filled with fluid and the gastrointestinal viscera are imaged floating in and on top of the fluid. The peritoneal fluid may become hypoechoic and contain strands of fibrin if a secondary peritonitis develops or may have increased echogenicity associated with concurrent cystitis. The urinary bladder is also imaged floating within the fluid. If the urinary bladder is ruptured, the bladder usually appears collapsed, flaccid and folded upon itself and contains no or little urine. The defect itself may not be directly imaged but in some affected horse, fluid may be imaged passing through the rent in the bladder wall from a partially filled bladder into the peritoneal cavity.

Traub *et al.* (1983) reported that sonographic examination of a horse with a transitional cell carcinoma revealed an irregular mass protruding into the bladder lumen with a composite pattern of echogenicity. An abrupt demarcation between the affected and unaffected portions of the urinary bladder was seen.

Sweeney *et al.* (1991) reported that the sonographic examination of the pelvic canal in the horse with lymphosarcoma revealed a homogeneous soft tissue density mass with thickening of the walls of the urinary bladder and vagina. Distension of the right ureter, enlargement of the right kidney, loss of the normal renal architecture and increased lobulation was also imaged.

2.6 Large colon

Freeman (2002b) reported that the large intestine has a similar ultrasonographic appearance as of caecum. The intestinal wall is visible but the underlying contents produce a bright hyperechoic shadow so that only the surface can be imaged. Sacculations can be identified ultrasonographically and these allow the distinction between the dorsal and ventral colon. Motility can be accessed from the movement of the wall and underlying hyperechoic shadow and by changes in the sacculations of the ventral colon. The right ventral colon arises from the lateral aspect of the caecum in the right ventral abdomen. It turns cranially to the sternal flexure before turning through 180° and continuing along the left flank as the left ventral colon. The ventral colon has the caudal abdomen at the pelvic flexure to form the left dorsal colon. At this point there is only a taenial band on the mesenteric border, and the sacculations disappear. These features allow the left dorsal ventral colon to be distinguished, both on rectal palpation and on ultrasonographic imaging. Freeman (2003) found that the peristaltic activity of the colons is normally subtle (2-6 contractions/ minute).

Jones *et al.* (2003) reported that the normal wall thickness of right dorsal colon ranges from 3.3 to 3.5 mm in the right 13^{th} and 11^{th} ICS, and the median wall thickness of the right ventral colon measured at 12^{th} ICS was 3.6 mm.

Barton (2011) reported that the left colon is located ventomedial to the spleen. The left ventral colon is sacculated and has sluggish motility. The wall of the colon should measure less than 4 mm, the left dorsal colon is not sacculated and is located dorsal, lateral, medial or even ventral to the left ventral colon. Gas in the left ventral colon may preclude identification of the left dorsal colon when it lies medial or dorsal to the left ventral colon. Gas in the colon typically generates a hyperechoic appearing wall with an indistinct luminal border and intraluminal acoustic shadowing that precludes identification of the contents and the medial wall. The right dorsal colon has no sacculations and consistently appears as a hyperechoic curved line adjacent to the liver. Once the right dorsal colon is located, often the junction between the right dorsal colon and right ventral colon is identifiable. The right ventral colon has sacculations. Like the left colons, the right colons, wall thickness should be less than 4 mm, motility is sluggish, and the contents and far walls are normally obscured by the presence of luminal gas.

Boles and Kohn (1977) stated that the large colon and cecal obstructions are mostly caused by feacoliths or trichophytobezoars and they usually have a somewhat irregular surface with many acoustic interfaces and should have an irregular hyperechoic to composite sonographic appearance in the lumen of the bowel. The feacoliths and trichophytobezoars cast acoustic shadows, but the shadows are likely to be dirty and irregular.

Blue (1979) reported that enteroliths are usually single and spherical but can be multiple and tetrahedral. The enteroliths are usually smooth and thus are imaged as a smooth circular or tetrahedral hyperechoic intraluminal structures casting a large acoustic shadow.

Baird *et al.* (1991) stated that the left dorsal and ventral colon migrate dorsally between the spleen and the left abdominal wall and subsequently become entrapped over the nephrosplenic ligament. Santschi (1993) reported that ultrasonographic diagnosis of nephrosplenic ligament entrapment has two critical components: the lack of visualization of the left kidney and a straight (horizontal) dorsal border of the spleen in the paralumbar fossa extending cranially from more caudal interspaces. The straight dorsal border of the spleen is caused by the dorsal displacement of colon over the nephrosplenic ligament. The gas in the entrapped large colon prevents the visualization of the underlying dorsal border of the spleen and creates the straight horizontal appearance of the dorsal splenic border. The most dorsal border of the spleen that can be imaged is also ventrally displaced by the entrapped large colon.

Reef (1998) stated that large colon and cecal impactions are frequently associated with mild persistent colic or intermittent colic. Impactions can be imaged in the large colon and caecum as hyperechoic intraluminal structure casting a strong acoustic shadow. Impactions can be imaged sonographically only when the impacted portion is adjacent to the body wall or fluid is interposed between the affected portion of the intestine and the body wall. Fluid distention of the more proximal small intestine may be detected in horses with large colon or cecal impactions. In sand impactions the large colon appears flattened against the ventral body wall with loss of normal sacculations. Little peristaltic movement of the large colon is detected because it is weighted to the floor of the abdomen by the accumulation of sand. The sand grains on the mucosal surface of the large intestine look like small, pinpoint hyperechoic structures casting small acoustic shadows in varying directions, depending upon the angle of the ultrasound beam.

Klohnen *et al.* (1996) and Scharner *et al.* (2002) found that the increased wall thickness in case of large colon torsion is diffusely hypoechoic and occurs with a loss of the normal layering of the wall of the gastrointestinal tract.

Pease *et al.* (2004) stated that in case of large colon torsion, detection of increased wall thickness of the large colon has been an accurate and reproducible method of determining the presence of large colon torsion in horses. A colon wall thickness of 9 mm or more obtained from a ventral abdominal window accurately predicted that large colon torsion was present.

2.7 Small colon

Schmidt (1989) and Reef (1998) found that the small colon is visualized in the left caudodorsal quadrant dorsal to the pelvic flexure.

Freeman (2002b) stated that the small colon is located in the dorsal abdomen and is most easily imaged using transrectal ultrasonography. It has similar ultrasonographic appearance to the large intestine in the normal horse, and reliable identification require palpation of its smaller diameter, sacculations and two mesenteric bands. The contents of the small colon can vary in consistency, depending on the diet and hydration status of the horse.

Barton (2011) stated that the small colon is located in the left paralumbar fossa medial or ventral to the spleen. With its small diameter, sacculations and packed serpentine loops that suspend from the dorsal mesocolon, often only small sections of the surface of loops are visible ultrasonographically as short sharply curving hyperechoic lines. Like the left colon, the motility is slow and luminal gas typically prevents visualization of the contents and the distal walls.

Reef (1998) reported that the small colon impaction is usually imaged as a hyperechoic intraluminal structure casting an acoustic shadow. Little or no peristaltic activity is seen surrounding the impaction and the normal sacculations of the small colon are difficult to image. He also reported that fecaliths can be successfully imaged in the small colon from the flank area in young horses. They appear as echogenic to hyperechoic masses that cast an acoustic shadow, and enteroliths in the small colon can be successfully imaged transrectally if the mass is palpable.

2.8 Small intestine

Rantanen (1986a) reported that the duodenum is imaged around the ventral and caudal aspects of the right lobe of the liver and the caudal pole of the right kidney. The duodenum is located between the liver and the right dorsal colon from the pylorus (located in the proximal to mid portion of the right side of the abdomen) to the mid to caudal abdomen. The right dorsal colon is adjacent to the duodenum from the fifteenth ICS cranially. The duodenum then courses caudodorsally to the caudal pole of the right kidney and lies between the liver and the caecum.

Kirkberger *et al.* (1995) reported that the duodenum is imageable medial to the ventral and caudal aspects of the right lobe of the liver. The duodenum is imaged from the right eleventh ICS to the cranial aspect of the paralumbar fossa along a line from the right olecranon to the tuber sacrale or slightly dorsal to this line. The duodenum is consistently imaged between the 14^{th} and 17^{th} ICS just ventral to the right kidney dorsal to the large bowel (cecal base). It would be unusual for the entire duodenal diameter to exceed approximately 4 cm in the normal horses during peristaltic propulsion of ingesta. The duodenum contracts between 1 to 4 times per minute in fed horses and contractions will be reduced in anorexic, starved or heavily sedated horses. The wall of the duodenum is less than 4 mm in thickness and has fluid lumen.

Freeman (2002b) found that the duodenum is consistently located along the right flank, accessible to the transcutaneous ultrasonography at the 16^{th} and 17^{th} ICS immediately ventral to the kidney. The normal duodenum has frequent contractions, ingesta is passed rapidly there is never persistent distension.

Barton (2011) stated that the small intestine is hard to visualize in normal horses unless a peristaltic wave generates transient expansion of the lumen from movement of fluid contents. The medial location of the ileum precludes distinct identification. The jejunum most reliably is found in the left inguinal area, medial to the spleen and the left ventral colon. The small intestine has the most visible motility of any part of the gastrointestinal tract, with peristaltic waves producing rhythms contractions. The fluid content of the lumen enables distinction of the wall thickness (2 to 4 mm) and visualization of the distal wall in either its long or short axis. In the normal horses, luminal diameters rarely exceed 3 cm and should be seen contracting down to obscurity.

Reef (1991) reported that duodenitis had a wide variety of sonographic appearances but it is usually characterized by fluid filled hypomotile bowel. The wall thickness of the affected intestine may be normal to near normal or increased. The intestinal wall thickening appears edematous (more hypoechoic than normal). In horses with anterior enteritis, the wall of the duodenum may have normal or increased thickness with a large fluid or fluid and gas distended compromised lumen. Mucosal irregularities may be imaged in horses with severe anterior enteritis/duodenitis. Shreds of mucosa may be imaged sloughing into the bowel lumen in horses with enteritis. Gastric distension is also detected in horses with anterior enteritis.

The small intestine appears as small tubular and circular loops. The contents of the small intestine vary from a hyperechoic shadowing gas echo to hypoechoic or hyperechoic fluid, mucus or ingesta (Desrochers 2005). The small intestine lack sacculations and has frequent peristaltic contractions i.e. 6-15 contractions/min (Freeman 2003). The duodenum is imaged around the caudal pole of the right kidney and medial to the right liver lobe. The jejunum is not normally seen ventrally owing to the interposed gas filled large colon. From the left side, the jejunum is usually visualized between the spleen and the stomach (Reef 1998). The ileum is inconsistently imaged in the ventral abdomen in the adult horses. The wall thickness of the duodenum and jejunum should be less than 0.3 cm, whereas the ileal wall can measure upto 0.4 to 0.5 cm (Klohnen *et al.*1996).

The small intestine is generally flaccid, characterized by little or transiently visible lumen contents Bernard *et al.* (1989). It has usually rhythmic contractions (Rantanen 1986a). Using a high frequency transducer, visualization of the hyperechoic mucosal surface, hypoechoic mucosa, hyperechoic sub mucosa, hypoechoic muscularis propria and hyperechoic serosal is possible. In the ileum, an additional thin hyperechoic layer, which represents connective tissue separating the longitudinal and circular muscular layers, can also be seen. Excluding the ileum, which is slightly thicker (4-5 mm), the small bowel wall thickness rarely exceeds 3 mm. it should be noted that large quantities of gas within the gastrointestinal tract cause reverberation and shadowing artifacts, resulting in difficulties in bowel wall measurement (Reef 1998).

Freeman (2002b) stated that small intestine can be recognized by its small diameter and frequent peristaltic contractions. It has a tubular appearance on ultrasonography, and images vary between transverse and longitudinal sections. The contents are predominantly fluid, but vary in echogenicity depending upon the fluid, ingesta and gas. Fluid has a hypoechoic appearance, ingesta is echogenic, often producing a heterogeneous pattern with mixed fluid and particulate matter visible, but without acoustic shadowing; gas is highly reflective, producing a hyperechoic reflection with acoustic shadowing. The location of the small intestine is very variable, and normally only a small proportion will be imaged. Jejunum cannot be consistently distinguished from ileum using ultrasonography. The ileum is located cranial and medial to the caecum, but can be difficult to image in larger horses.

In vitro, the wall of the ileum has a seven layered appearance (due to an additional muscle layer), compared with the five layered appearance of the jejunum; in vivo, this feature is difficult to identify.

Bernard *et al*. (1989) stated that the detection of a characteristic “target” or “bull’s eye” sign in case of intussusception is obtained by scanning through the apex of the intussusception, where the intussusceptum is surrounded by fluid and the intussuscipiens. This ultrasonographic appearance is created by the difference in acoustic impedance between the thick walled, congested, edematous inner intussusceptum and outer intussuscipiens and the interposed fluid layer. The intussusception may appear as two concentric rings with a central circular area or echogenic core representing the inner lumen of the intussusceptum, the “multiple ring” sign. This appearance occurs where the walls of the intussusceptum and intussuscipiens are less edematous. Occasionally fibrin may be imaged between the inner intussusceptum and the outer intussuscipiens. Fluid distention of the more proximal small intestine is detected, usually with normal or nearly normal wall thickness and little or no peristaltic activity.

Barton (2011) stated that with obstructive or strangulating lesions, the thickened small intestinal wall tends to be focal (i.e. at the level of the obstruction), with relatively uniformly thickened walls. The intestine proximal to the obstruction will be distended with either gas or fluid. With complete obstructions, the distended proximal loops will often be seen to have a “hair-pin” appearance, as distended loops of bowel stack upon each other.

Scharner *et al.* (2002) found in their study that there is gastric distention secondary to the small intestinal obstruction, the greater curvature appears less semicircular and can be imaged over an area of 5th or more ICS’s the spleen will often be displaced caudally, placing the stomach in contact with the abdominal wall. Contents of the stomach appear hypoechoic with small floating hyperechoic inclusions. The loops of the jejunum can be seen in the ventral abdomen and lower parts of both paralumbar fossae. Distended jejunal loops have a hyperechoic wall with hypoechoic contents. Peristalsis is absent. It has also stated that in case of small intestinal ileus, duodenum and stomach are often distended. The duodenum will appear round without noticeable peristalsis and with hypoechoic contents containing a few hyperechoic particles.

Reef (1998) stated that sonographic examination of foals with ileus usually reveals bowel with an increased diameter and little if any peristaltic activity.

McAuliffe (2004) found that mechanical ileus associated with intussusceptions, volvulus, mural masses and trichophytobezoars produces segmental dilation; whereas functional ileus associated with hypoxic bowel injury, surgery, or anesthesia produces generalized distension.

McAuliffe (2004) stated that in umbilical hernias fat contained within the omentum gives a heterogeneous hypoechoic to echogenic appearance. Strangulated ileum (most common) or jejunum has a thickened, edematous wall with decreased or absent motility and if the large bowel is involved, only a portion of the ventral colon or caecum is incarcerated within the hernia and is imaged as an outpouching of the large intestine with thickened, edematous and amotile walls.

Kumar *et al.* (2011) found that ultrasonography assisted in examination of different layers of muscles of abdomen, size and direction of the tear and extent of damage to muscles and their sheath thereby facilitating to decide the proposed incision on swelling while attempting for correction of defect.

CHAPTER 3

MATERIALS AND METHODS

3.1 Plan of the work

The plan of the work was divided into 2 phases' viz. standardization phase and clinical phase.

3.1.2 Standardization phase

The standardization phase was carried out utilizing native 10 adult (5 horses and 5 mules), clinically healthy animals. The horses were between 8-17 years old and weighed approximately 120-165 kg, whereas mules were between 8-15 years old and weighed approximately 90-110 kg. The normal equine abdomen was subjected to ultrasonographic examination for standardizing the technique and machine settings. Transabdominal and transrectal ultrasonography was performed to scan and document images of various organs, to delineate their topographical anatomy in different planes, to define their echotexture, to determine their thickness and site for placement of the transducer at various locations for respective organs.

3.1.3 Clinical application phase

14 equine patients presented to Teaching Veterinary Clinical Complex, DGCN College of Veterinary & Animal Sciences, Palampur suffering from abdominal disorders were subjected to systematic evaluation for diagnosis of the disease condition using ultrasonography.

3.2 Equipments, preparation of animal and technique:

Ultrasonography was carried out using Siemens Acuson X300 ultrasound system premium edition (a grey scale, B + M-mode and 4D scanner).

Plate-1. Siemens Acuson X300 ultrasound system premium edition (a grey scale, B + M-mode and 4D scanner).

Plate-2. Prepration of animal for ultrasonography

Plate-3. Ultrasonographic scanning of the animal in progress

Contact gel was liberally applied and the animals were examined using a 5.3-10 MHz linear transducer, the maximum depth of field for this transducer was 13 cm. The 2nd transducer used was 2-5 MHz volumetric (4D) transducer, the maximum depth of field for which was 30 cm. Care was taken to record the ultrasonograms at the peak of inspirations. The organ echotexture, motility pattern, wall thickness, optimal topographical locations as well as associated structures were carefully studied. The ultrasonographically determined size and location of various organs were photographically recorded.

All the animals used for standardization went under basic physical, clinical examination and their clinical and hemato-biochemical parameters were noted and recorded and were put under fasting of 12 hours prior to ultrasonography, but water was kept available all the time. The standing animals were restrained in a crate without any sedation.

The topographic regions of each healthy animal, from tuber-coxae to 5th rib space and from dorsal midline of vertebral column to linea alba on right and left sides respectively, were shaved and cleaned with tap water. Regarding clinical cases when a tentative diagnosis was made based on the clinical findings, both sides of the abdomen were shaved as described above for healthy animals.

3.3 Case record

In case of animals presented to TVCC suffering from abdominal disorders the basic parameters like Age, breed, sex, body weight, body condition score, presenting history, ancillary physical examination, clinical examination and hemato-biochemical parameters were noted and recorded as per the performa given below in order to streamline the history taking procedure and ensured the details were not missed. Later on, animals were stabilized and USG was performed to diagnose the underlying cause.

Section 1: Case presentation and history

- Referral agency : ____
- Registration number :____
- Date of examination : ____
- Owner's name : ____
- Breed : ____
- Age (years) : ____
- Gender [M] [F]
- Body condition score [Thin] [Moderate] [Overweight]
- Approximate weight (kg): ______________________________________

Presenting history including nature, severity and duration of clinical signs:

Kicking None ( ) Occasional ( ) Frequent ( )

Pawing None ( ) Occasional ( ) Frequent ( ) [None] [Slight] [Moderate] [Severe]

Sweating

Flank watching None ( ) Occasional ( ) Frequent ( )

Attempts to lie down None ( ) Occasional ( ) Frequent ( )

Rolling None ( ) Occasional ( ) Frequent ( )

(   ) Demeanour

(   ) Standing normally

(   ) Lowered head, no response to auditory stimulus

(   ) Twitching, agitations and continuous movement

Section 2: Physical examination on presentation.

- Heart rate (beats per minute): ____
- Resp. rate (per minute): ____
- Rectal temperature (˚F): ____
- Capillary refill time:/GPT ( )<2.5 seconds ( ) >2.5 seconds
- Mucous membrane colour: [Pink] [Congested] [Cyanotic]
- Auscultation of intestinal sounds: right upper flank ____________________
- Auscultation of intestinal sounds: right lower flank ____________________
- Auscultation of intestinal sounds: left upper flank ____________________
- Auscultation of intestinal sounds: left lower flank ____________________
- Any other observations on physical examination (e.g. abrasions, etc.) ______
- Abdominal distension: [None] [Slight] [Moderate] [Severe]

Section 3: Diagnostic tests

- Rectal examination performed Y/N ______________________________________
- Results of findings ____
- Nasogastric intubation performed Y/N __________________________________
- Results of findings ____
- Blood sample taken Y/N ____
- Results of findings ____
- Abdominocentesis performed Y/N _______________________________________
- Results of findings ____
- Other diagnostic tests: ____

Section 4: Treatment and diagnosis

Please indicate any medication/treatment given to the case prior to presentation

- ( ) NSAIDS
- ( ) Opioids
- ( ) Oral fluids
- ( ) Sedatives
- ( ) Spasmolytics
- ( ) Anthelmintics
- ( ) Laxatives
- ( ) Other

Section 5: Additional case information

- Does this horse have any ongoing or previous health problems? Y/N ___________
- Details of other health problems ____
- If this case has previously been examined for an episode of colic ______________
- Date last Dewormed ____
- Feed
    - ( ) Rice bran/ wheat bran
    - ( ) Hay
    - ( ) Concentrates
- Other ____
- Has there been any recent change in management (e.g. change of feed, Housing etc)
- ____
- Had the horse passed faeces in the previous six hours? Y/N _____________________
- Details of consistency, amount etc ____
- Additional information (e.g. hours stabled, whether turned out at grass) ____ _________

3.3.1Assessment of degree of dehydration was done as per the clinical signs advocated by Barton (2002) which are presented below:

Table 1: Calculation of assessment of degree of dehydration.

Dehydration	% Water loss	Signs
Mild	5-7	Depressed, dry mucous membranes, prolonged CRT
Moderate	8-10	Decreased skin turgor, especially eyelids in horses; tachycardia
Severe	11-12	Cold extremities, recumbent, moribund, skin remains rose when pulled.

3.3.2 Electrocardiogram (ECG)

The animals were restrained in a crate and were kept standing for 15 minutes so that their heart rate becomes normal. Electrocardiogram (ECG) was obtained using base apex bipolar lead system, with the RA and LA electrodes attached proximal to the olecranon on the caudal aspect of the appropriate foreleg; and the RL and LL electrodes were attached over the stifle fold of the appropriate hind leg. The ECG (lead II) was recorded for evaluation of rhythm, time and voltage parameters. Calibration was done at 1 mv = 1 cm and paper speed was 25 mm/sec. Then the ECG was recorded using multi parameter monitor. The skin and electrodes were moistened with an ECG gel before application of ECG electrodes. The time and voltage function components of ECG were recorded from tracings as follows;

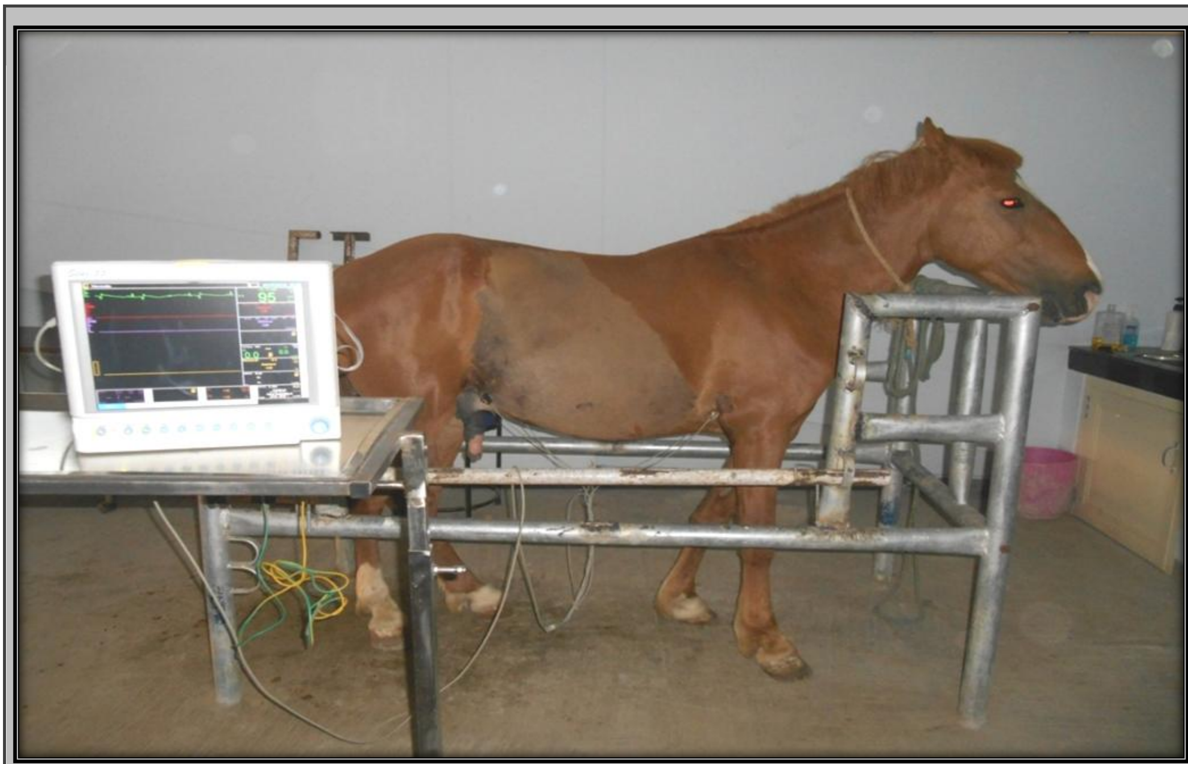


Plate-4. Recording of electrocardiogram in horse.

a. **PR segment,** i.e. end of P wave and start of QRS complex.

b. **QRS interval,** i.e. origin of QRS complex and end of QRS complex.

c. **QT interval,** i.e. origin of QRS complex and end of T wave.

d. **T interval,** i.e. origin of T wave and end of T wave.

e. **ST segment** elevation and depression from base line.

f. **P amplitude,** i.e. amplitude of P wave (origin of P wave to the maximum peak of P wave).

g. **R amplitude,** i.e. amplitude of R wave (origin of R wave to the maximum peak of R wave).

h. **QRS amplitude,** i.e. overall positive amplitude of QRS wave.

i. **T amplitude,** i.e. amplitude of T wave origin of T wave to maximum peak value of T wave).

3.3.3 Hematological and biochemical observations

To evaluate hematological parameters, venous blood (1 ml) from jugular vein of each animal was collected in three percent EDTA rinsed syringes. The hematological parameters estimated were Hemoglobin (Hb), Packed cell volume (PCV), Total leukocyte count (TLC) and Differential leukocyte count (DLC). The samples were analyzed using

Blood cell counter (BC-2800 Vet, Auto Hematology Analyzer, Mindray) and the values obtained were compared with the standard reference range (Jain 1986).

Blood biochemical parameters were estimated by Semi-automatic Chemistry Analyzer (RA-50, Bayer Diagnostics, India) using commercially available kits. The blood glucose was estimated immediately by digital glucometer· (Bayer Contour, Bayer AG) and the values obtained were compared with standard reference range (Kaneko *et al.* 2008).

For this estimation, 3 ml of venous blood was collected in heparinized vials from each animal. The plasma was separated by centrifugation in high speed centrifuge at 3000 rpm for 8 min. This plasma was then used for the estimation of following biochemical parameters.

i. Aspartate aminotransferase (AST).
ii. Alanine aminotransferase (ALT).
iii. Bilirubin (BLU)
iv. Total proteins (TPR).
v. Blood urea nitrogen (BUN).
vi. Creatinine (CRTN).
vii. Alkaline phosphatase (ALKP).
viii. Glucose. (GLU)

3.3.4 Faecal examination

Collection of sample for parasitological examination was done at the time of per rectal examination of the animal and immediately after collection; two direct faecal smears were prepared on clean microscopic glass slides and examined under low power of microscope for presence of ova.

3.3.5 Urine collection

Urine was collected from the bladder using sterile Foleys catheter for culture sensitivity test (CST) in mare.

3.3.6 Statistical analysis

Graphpad Instat software was used to calculate the Mean ± SE of physiological, hematological and biochemical parameters.

3.4 Standardization of the transabdominal ultrasonography

The standard topographic *loci* for the transducer placement to optimally image the various organs have been illustrated in the Plate 5 &6 and listed in Table 2and 3.

3.4.1 Standardization of the transabdominal ultrasonography for imaging of various abdominal organs in different planes as per their topographical anatomy in equines

Table 2. Ultrasonographic examination of the left hemi-abdomen in equines.

S.No.	Organ	Scanning Area
1.	**Liver**	From 6th to 11th intercostal spaces (ICS's) caudal to the diaphragm and cranial to the stomach.
2.	**Stomach**	From 8^{th} to 14^{th}ICS's, caudal to the liver and cranial to the spleen and dorsal to the LDC.
3.	**Spleen**	From 8^{th} to 17^{th} ICS's, and behind the last rib, caudal to the stomach and dorsal to the jejunum.
4.	**Left Dorsal Colon (LDC)**	From 6^{th} to 15^{th} ICS's, and in the lower flank, dorsal to the LVC and ventral to the liver, stomach, spleen and jejunum, respectively.
5.	**Left Ventral Colon (LVC)**	From 9^{th} to 14^{th} ICS's, and in the lower flank, ventral to the LDC up to the linea alba, respectively.
6.	**Jejunum**	From 12^{th} to 17^{th} ICS's, and in the middle flank, caudal to the spleen, and dorsal to the LDC and ventral to the DC, respectively.
7.	**Descending (Small) Colon (DC)**	Left Paralumbar Fossa: Behind the last rib up to the tuber-coxae, caudal to the spleen, and dorsal to the jejunum and LDC and ventral to the lumbar transverse processes
8.	**Left Kidney**	From 16^{th} to 17^{th} ICS's and the 1^{st} to 3^{rd} lumbar vertebrae, medial to the spleen

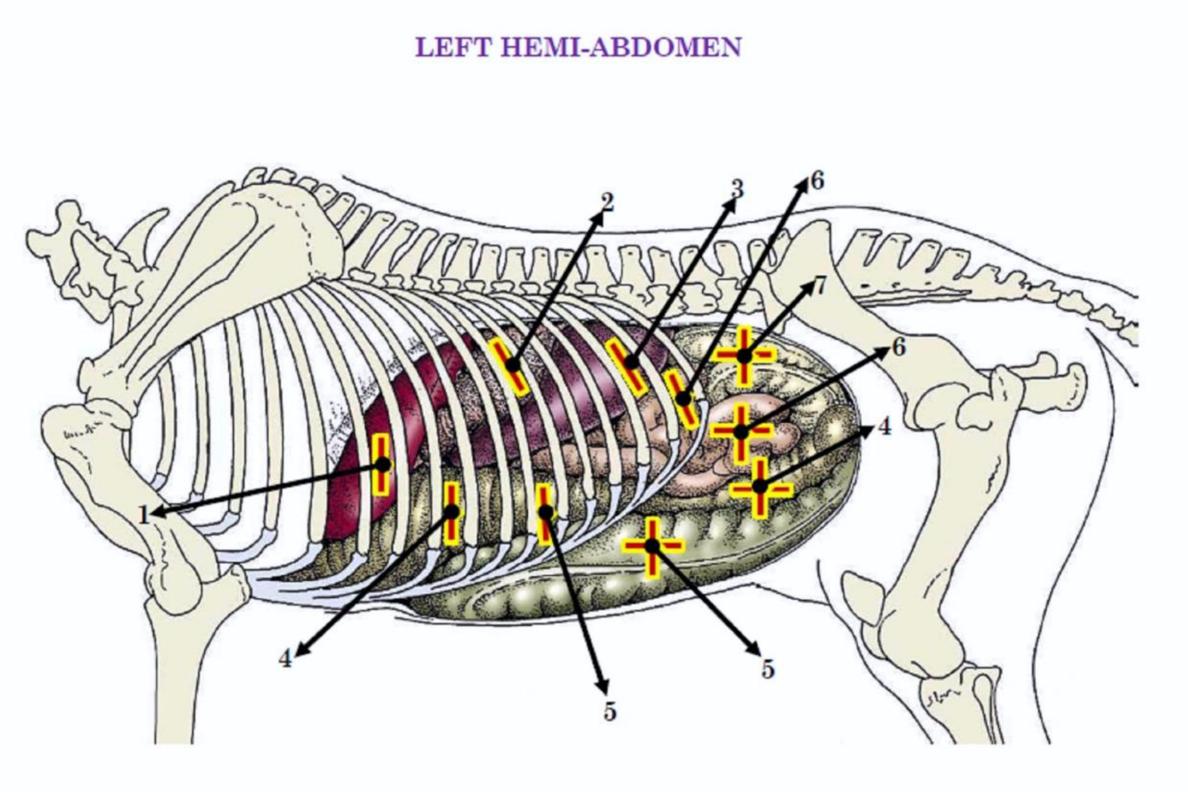


Plate-5: Schematic representation of transducer placement for scanning of different abdominal organs (Left hemi-abdomen).

Table 3. Ultrasonographic examination of the right hemi-abdomen in equines.

S.No.	Organ	Scanning Area
1.	**Caecum**	From 14th to 17th intercostal spaces (ICS's) and the right flank, caudal to the liver and ventral to the RVC up to the linea alba.
2.	**Right Dorsal Colon (RDC)**	From 6th to 14th ICS's, dorsal to the RVC and ventral to the liver, caudal to the diaphragm and cranial to the caecum.
3.	**Right Ventral Colon (RVC)**	From 9th to 17th ICS's, cranial to the caecum, and ventral to the RDC up to the linea alba.
4.	**Right Kidney**	From 14th to 16th ICS's, caudal to the liver, and dorsal to the descending duodenum and ventral to the lumbar transverse processes in the paralumbar fossa.
5.	**Descending Duodenum**	From 14th to 17th ICS's, dorsal to the caecum and ventral to the right kidney.
6.	**Liver**	From 6th to 14th ICS's, caudal to the diaphragm and cranial to the right kidney and descending duodenum, and dorsal to the LDC and caecum, respectively.

- *Each ICS is scanned, beginning dorsally and progressing ventrally with the transducer held parallel to the ribs.*
- *The flank region is scanned, beginning caudally/dorsally and progressing cranially/ventrally with the transducer held parallel/perpendicular to the longitudinal axis of the animal, respectively.*

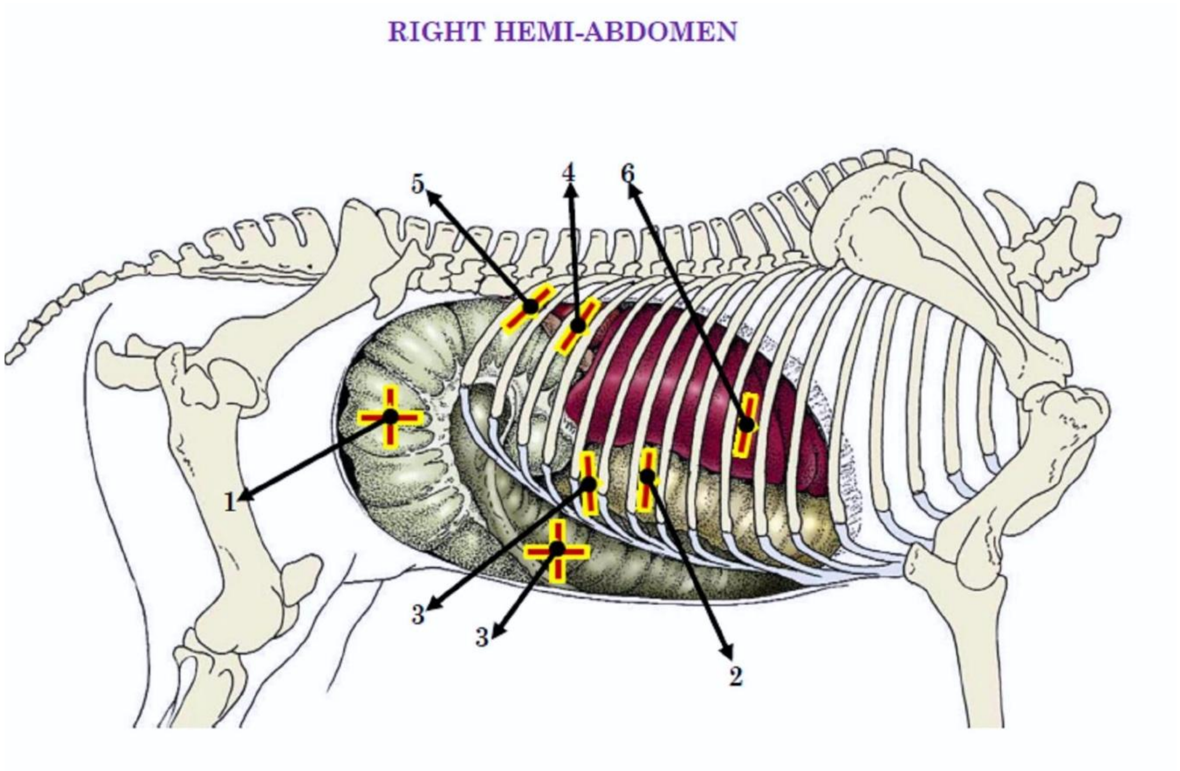


Plate-6: **Schematic representation of transducer placement for scanning of different abdominal organs (Right hemi-abdomen).**

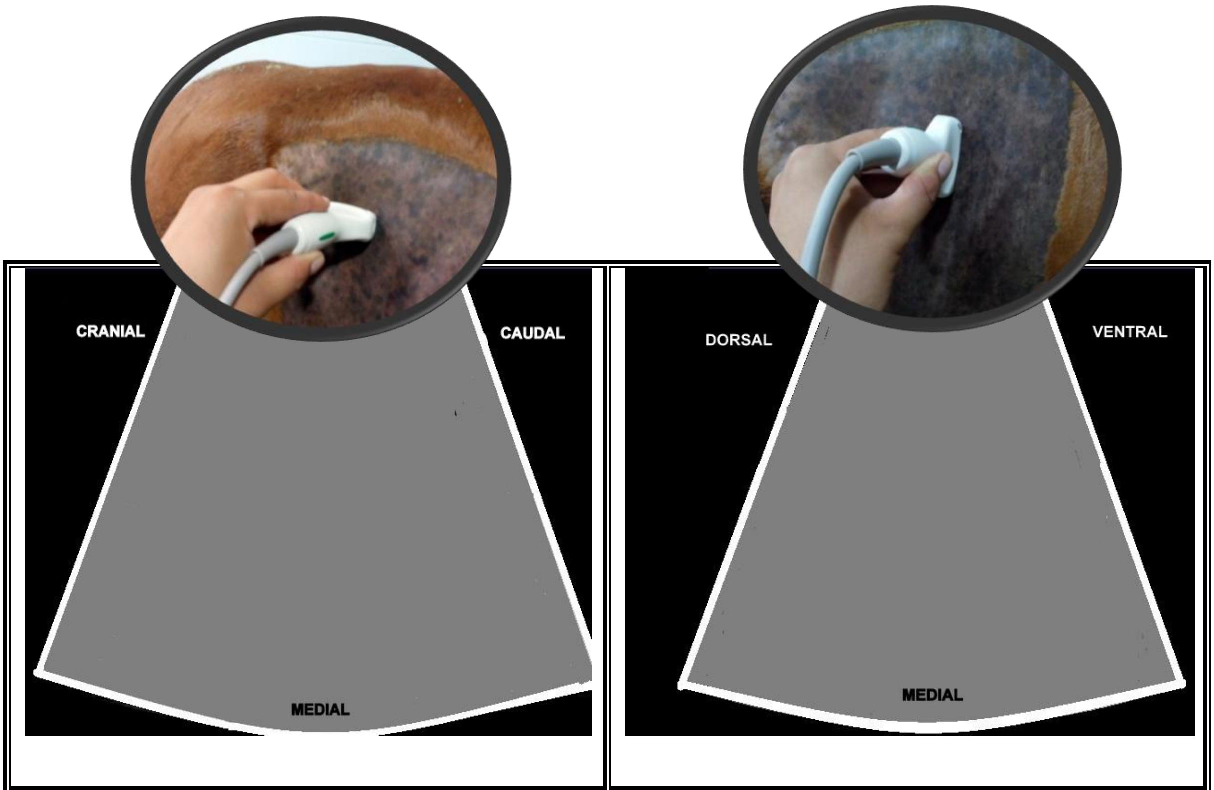


Plate-6a Sonogram as seen on monitor and its directional orientation for interpretation

CHAPTER 4

RESULTS AND DISCUSSION

The present study was undertaken mainly to develop baseline data of ultrasonographic observations of equine abdomen. Initially in standardization phase, the equine abdomen was scanned in a systematic approach (Barton 2011), from top to bottom, rostral to caudal and left to right sides, thereafter that topographic anatomical locations of different abdominal organs and their *in-situ* ultrasonographic features were ascertained by repeated detailed ultrasonography on 10 healthy (5 horses & 5 mules) of either sex. Abdominal ultrasonography was also employed in 14 clinical cases of equines suffering from various diseases for ascertaining diagnostic utility. The results obtained are presented and discussed below.

4.1 STANDARDIZATION PHASE

4.1.1 Liver

In horses, the right lobe of the liver was found from eight to fifteenth intercostal space (ICS) caudal to the diaphragm, cranial to the right kidney and descending duodenum, dorsal to the right dorsal colon and caecum. The left lobe of the liver was found from sixth to eleventh (±1) ICS caudal to the diaphragm, cranial to the stomach and was smaller than the right lobe. While in case of mules the right liver lobe was found between sixth to fifteenth (±1) ICS and left lobe was found between sixth to ninth (±1) ICS. As only a small portion of the liver was imaged from both the sides of the abdomen, therefore it was difficult to estimate the actual size of the organ; hence the estimates of the size rely on its expanse across ICS's. The liver was recognized by its branching vasculature. The vasculature of the liver was visible the portal veins having more connective tissue in their walls appeared more echogenic than the hepatic veins (Plate-7) Rantanen (1986a). The blood in the hepatic veins appeared anechoic or small moving echos were imaged as the ultrasound beam reflects off the moving cells and other blood components. The general echogenicity of the liver was less than the spleen but more echogenic than the adjacent kidney (Plate-8). The common bile duct and its branches within the normal liver were not visible and atrophy of the right lobe of the liver was also observed in some older horses.

The architecture of the liver was found relatively homogenous and the ventral edges of the normal liver were distinctly sharp (Plate-9).

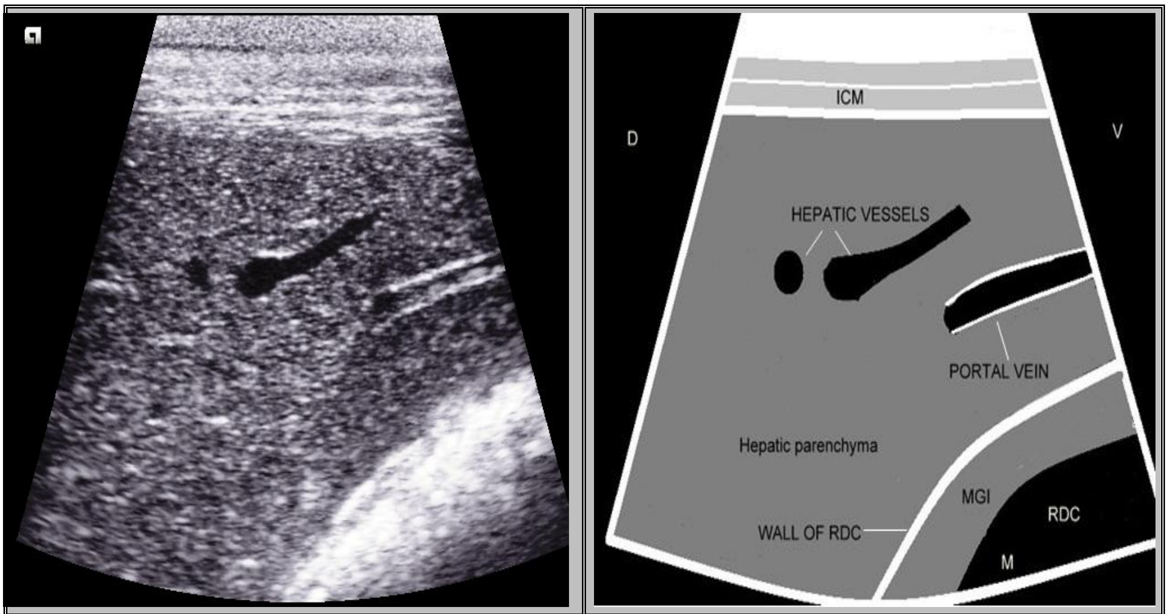


Plate-7. Ultrasonogram of right lobe of liver (Mule) at 13th ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm. (MGI= mucosal gas interface, RDC= right dorsal colon)

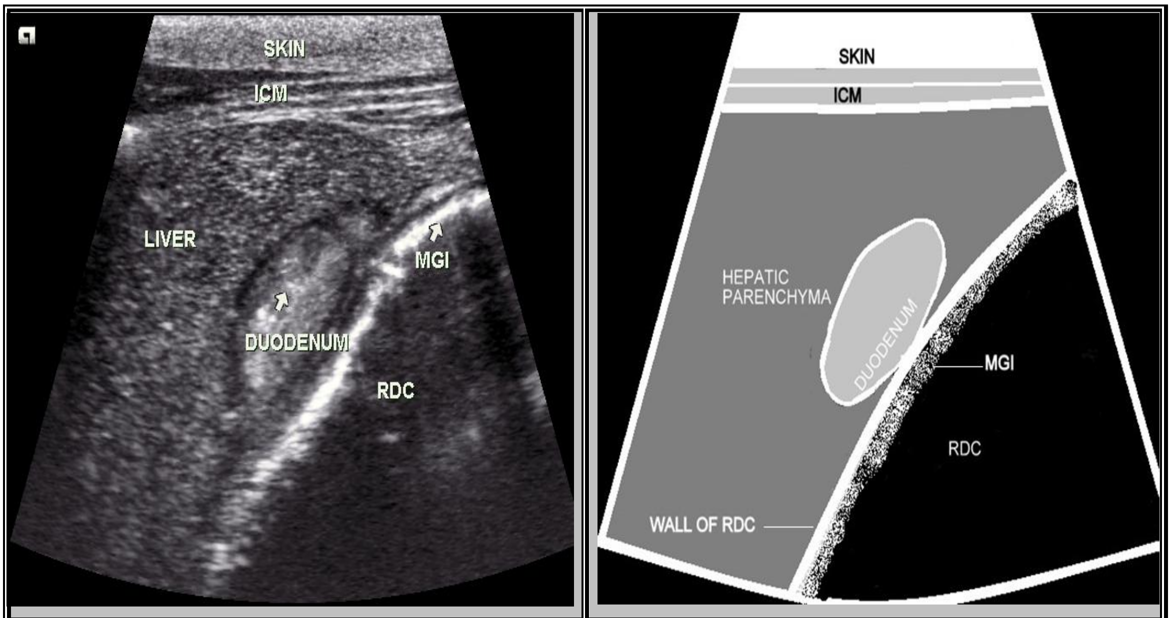


Plate-8. Ultrasonogram of right lobe of liver (Horse) at 11th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. (MGI= mucosal gas interface, RDC= right dorsal colon)

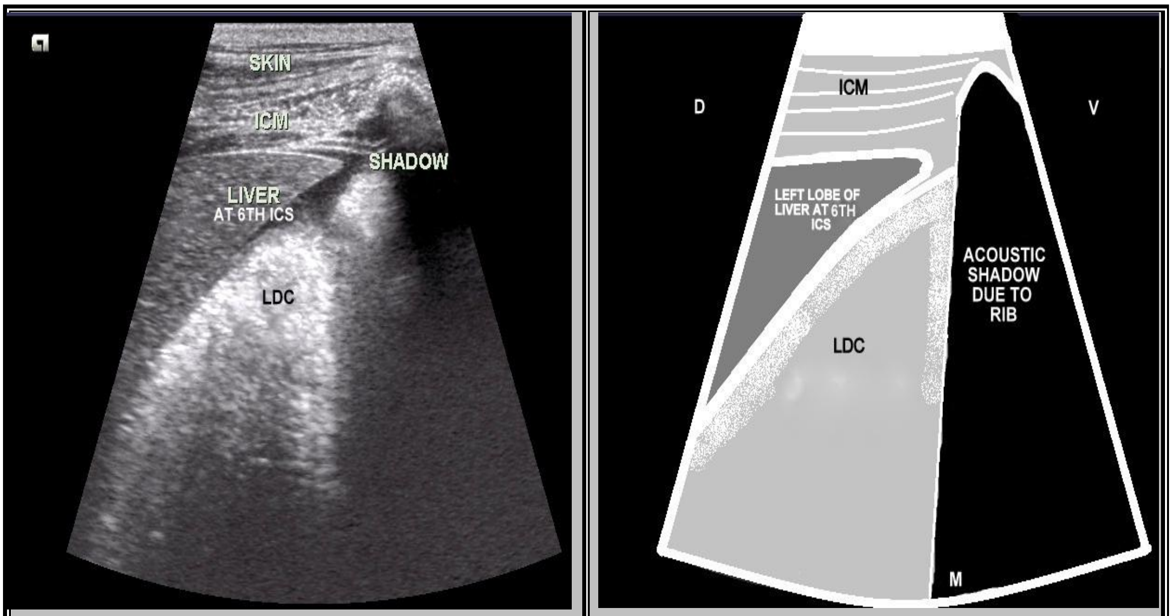


Plate-9. Ultrasonogram of left lobe of liver (Mule) at 6^{th} ICS. The image was obtained with linear transducer at 10 MHz at a depth of 9.5 cm. (ICM= intercostal muscles, LDC= left dorsal colon)

The findings of this study were similar to those of Rantanen (1986a), Aleman *et al.* (2002) and Borton (2011). According to Barton (2011) liver could be located from the 6^{th} to 14^{th} ICSs between the diaphragm and RDC. Reef (1998) reported that liver could be seldom seen beyond the 15^{th} ICS or in the same transverse plane as the kidney, except at the most rostral aspect of the kidney.

4.1.2 Caecum

The caecum was found from 15^{th} to 17^{th} ICS in the right flank caudal to the liver ventral to the right kidney, descending duodenum (Plate-11) and ventral to the RVC upto the linea alba in both horses as well as mules. The contents of the caecum varied from solid, liquid or mixed but usually highly echogenic, causing strong acoustic shadowing and masking the details of the underlying structure. Only the caecal wall and caecal contents upto a few centimeter (cm) depth could be imaged (Plate-12). Sacculations were prominent and motility was assessed from the movement of the wall, underlying hyperechoic shadow and by motion induced changes in the sacculations of the caecum. Freeman (2002b) also reported that ultrasonographically, caecum could be visualized as a sacculated and motile organ extending from the right paralumbar fossa to the ventral midline. In the present study the frequencies of the contractions of the caecum were recorded as 2-6 contractions/ minute in fed animals, 2-4 contractions/ minute when animals were fasted for 12 hrs without holding water, but when animals were fasted upto 24 hrs or more, caecal contraction rate was decreased upto 1-3 contractions/ minute with lot of gas present in the caecum.

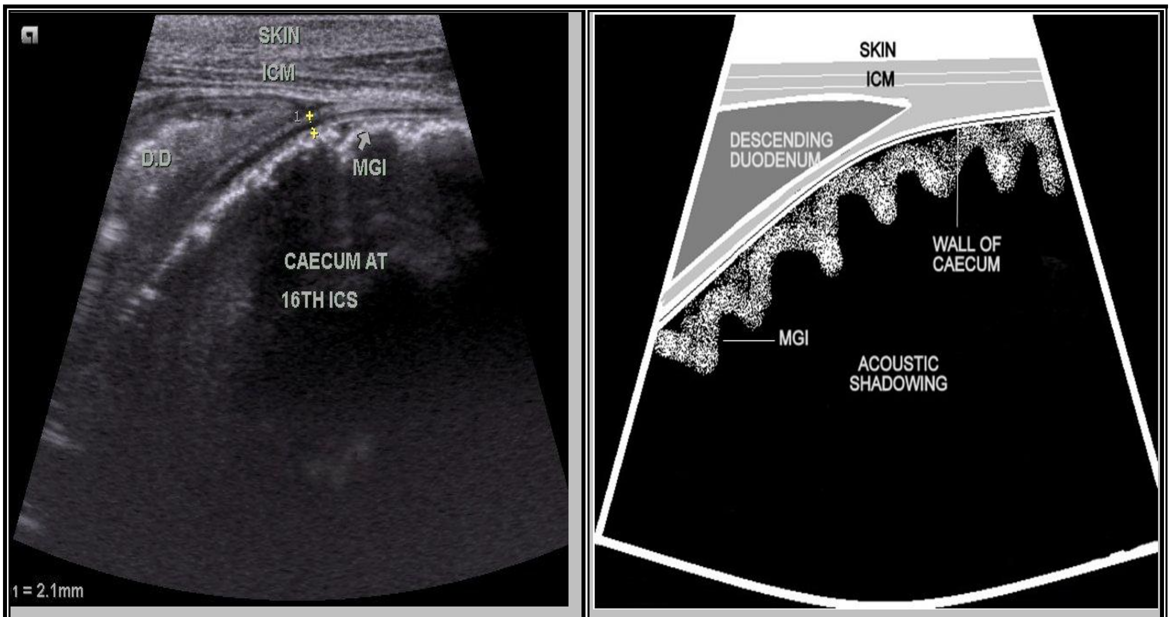


Plate-10. Ultrasonogram of Caecum (Horse) at 16th ICS. The image was obtained with linear transducer at 10 MHz at a depth of 6.5 cm. (MGI= mucosal gas interface, ICM= intercostal muscles)

The caecal wall thickness varied from 2.0 to 2.3 mm with a (Mean ±SE) of 2.1 ±0.05 mm (Plate-10). While in case of mules the caecal wall thickness varied from 1.3 to 1.6 mm with a (Mean ±SE) of 1.4±0.05 mm, which was quite less than the horses. Barton (2011) reported the wall thickness of caecum up to 4mm. Epstein *et al.* (2008) also reported that the caecal wall thickness in mules was 0.179±0.03 cm, which was less than the normal published values for horses. All the muscle layers of the caecal wall were appreciable (Plate-11).

Present findings were in agreement with that of Freeman (2002b) and Barton (2011). However, the wall thickness and topographic anatomic variation obtained in the current study was lower. This difference regarding the ultrasonographic imaging of wall thickness in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules.

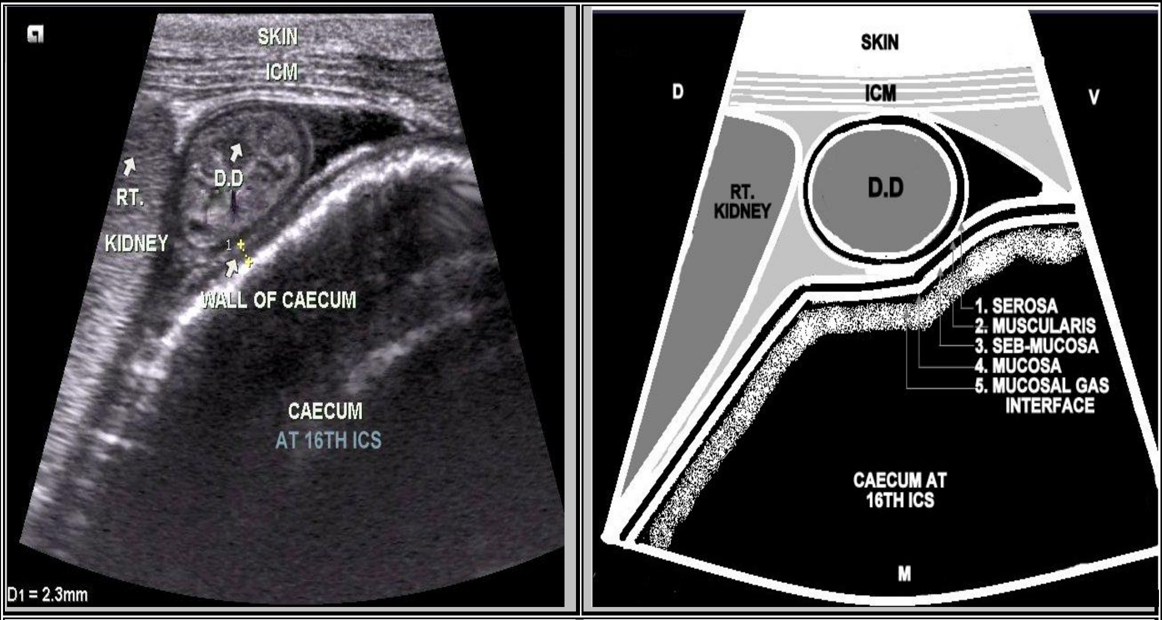


Plate-11. Ultrasonogram of Caecum (Horse) at 16th ICS showing various muscle layers of wall of caecum. The image was obtained with linear transducer at 10 MHz at a depth of 6.5 cm. (DD= descending duodenum, ICM= intercostal muscle)

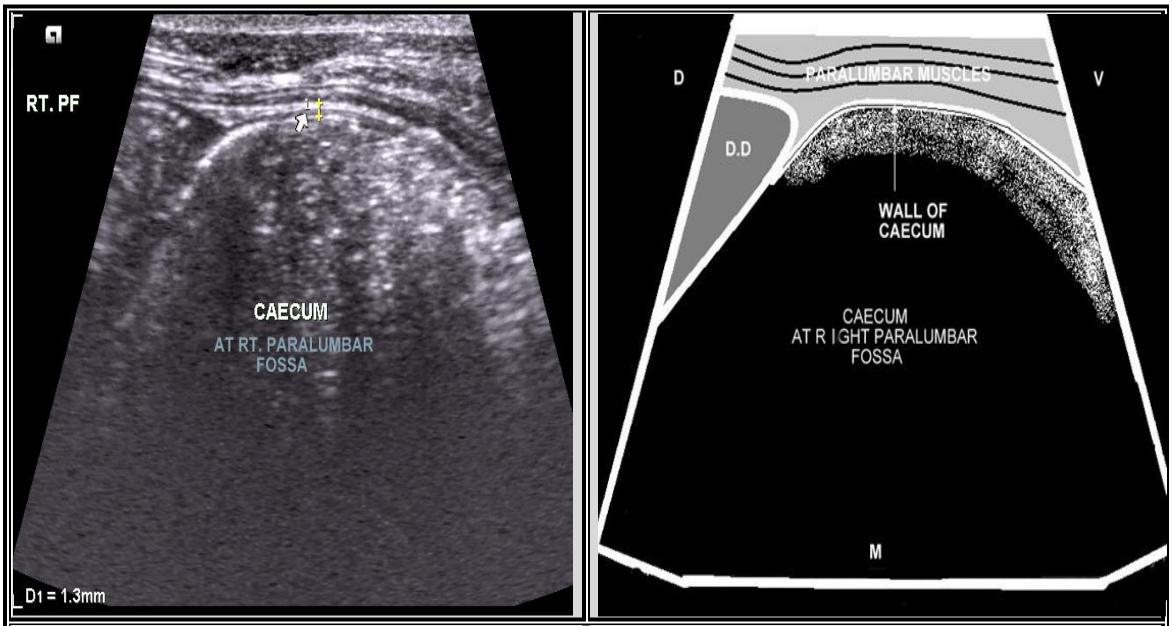


Plate-12. Ultrasonogram of Caecum (Mule) at Rt. Paralumbar fossa. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm. (DD= descending duodenum)

4.1.3 Right Dorsal Colon

The Right dorsal colon (RDC) was found from 6th to 14th ICS's in slightly oblique transverse plane, dorsal to the RVC, ventral to the liver, caudal to the diaphragm and cranial to the caecum both in horses as well as mules. The sacculations in the RDC were absent and consistently appeared as a hyperechoic curved line adjacent to the liver (Plate-13).

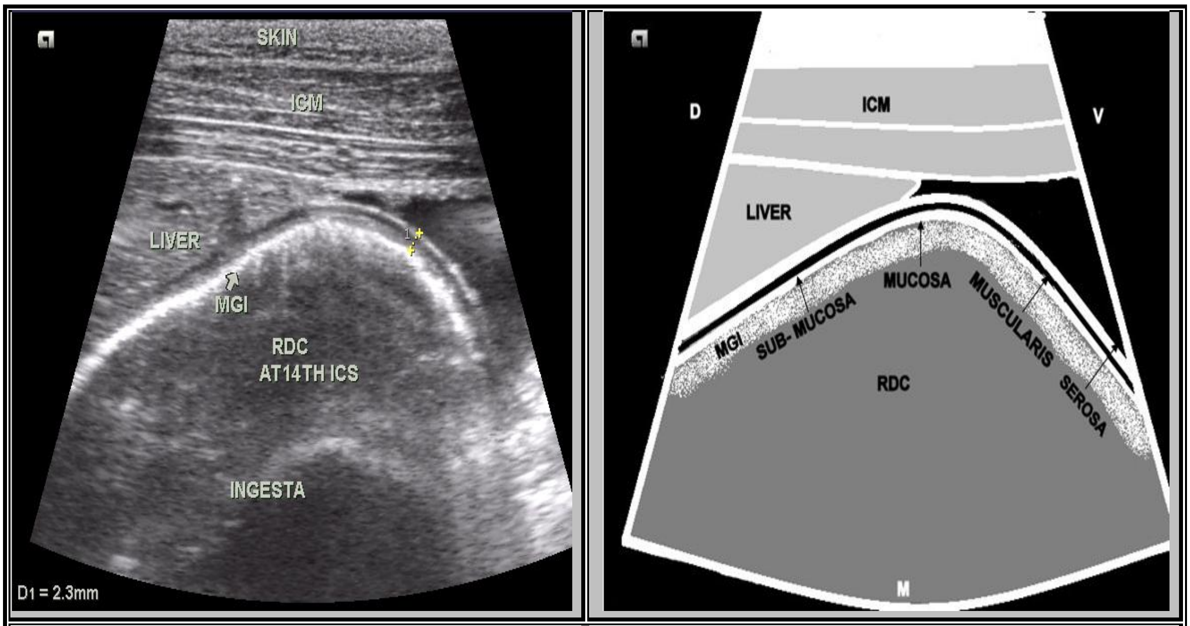


Plate-13. Ultrasonogram of right dorsal colon (Horse) at 7th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (RDC= right dorsal colon, MGI= mucosal gas interface)

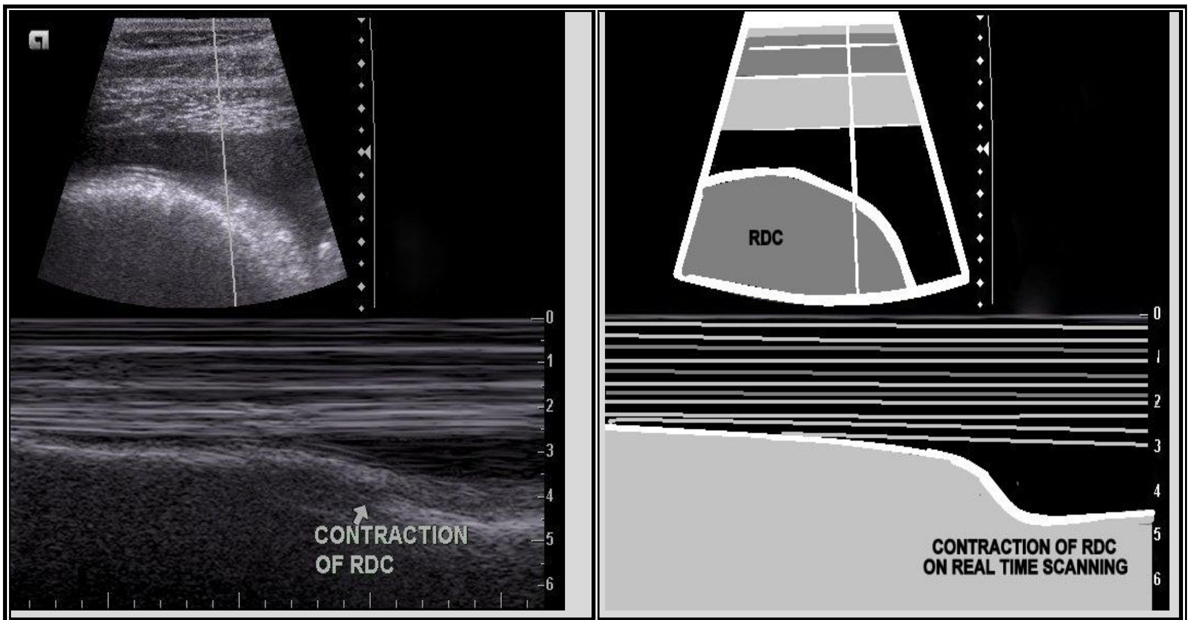


Plate-14. Ultrasonogram of right dorsal colon (Horse) at 6th ICS, showing normal contraction of RDC in real time scanning, The image was obtained with linear transducer at 7.3MHz at a depth of 6.5 cm. (RDC= right dorsal colon)

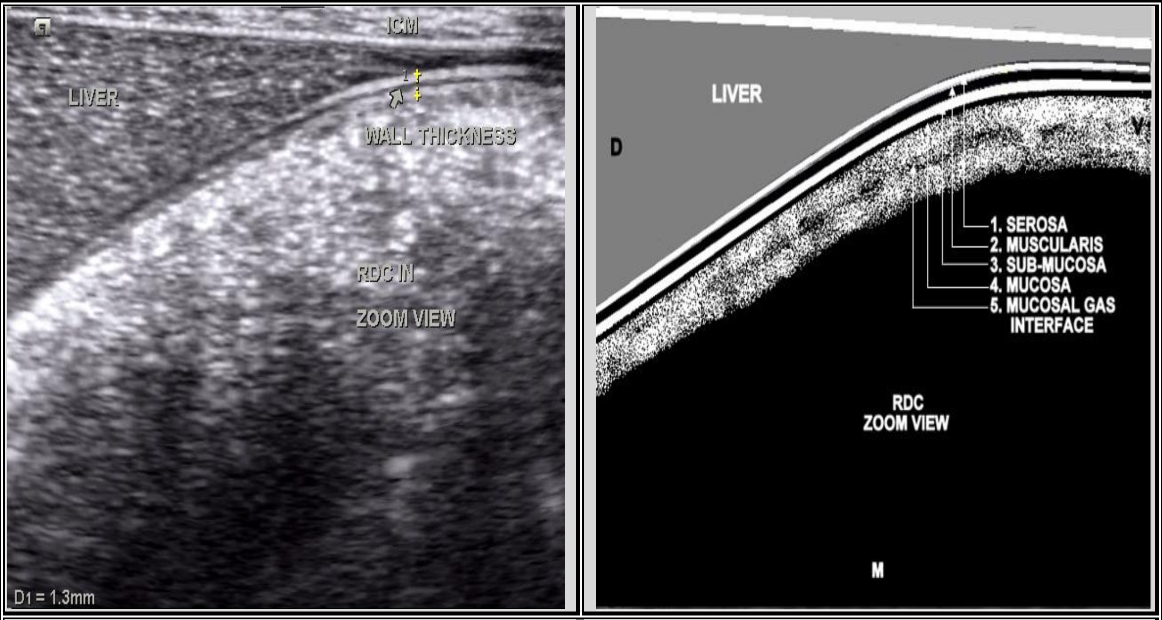


Plate-15. Ultrasonogram of right dorsal colon (Mule) at 9th ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm. (Zoom view)

In fed horses a typical gas pattern was observed which casted a strong acoustic shadowing and masking the details (Plate-13), but in fasted animals a fluid pattern containing multiple echogenic specks and occasional free gas caps were imaged. Only RDC wall and the contents upto few cm depth could be imaged. The motility was assessed from the movement of the wall and separation of the wall from the adjacent liver lobe (Plate-14). The frequencies of the contractions of the RDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more. The RDC wall thickness varied from 2.0 to 2.3 with a (Mean± SE) of 2.16±0.05 mm. however in case of mules the RDC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm and all the muscle layers of the wall were appreciable (Plate-15).

The findings of the present study were in consonant with Kiper *et al.* (1990), Hoffman *et al.* (1995), Kirkberger *et al.* (1995), Freeman (2002b) and Barton (2011). However, Freeman (2002b) reported that the RDC has three taenial bands but in the present study these taenial bands could not be identified on ultrasonography. Keller and Horney (1985) reported that the diameter of the RDC is 30 to 50 cm but in the present study the diameter could not be recorded because only RDC wall and the contents upto few cm depth could be imaged. The wall thickness variation obtained in the current study was lower than that of the Barton (2011) who reported the wall thickness upto 4mm. Jones *et al*. (2003) also reported that the wall thickness of RDC is upto 3mm. These differences regarding the ultrasonographic imaging of wall thickness in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules.

4.1.4 Right Ventral Colon

The right ventral colon (RVC) was found from 9th to 17th ICS's in slightly oblique transverse plane, cranial to the caecum and ventral to the RDC upto the linea alba in both horses as well as mules. The right ventral colon was identified by the presence of sacculations, sluggish motility, inability to identify the entire circumference or diameter of its wall and appeared as a bright hyperechoic line on ultrasonography (Plate-16). As in RDC, RVC also showed a typical gas pattern in fed horses casting a strong acoustic shadowing and masking the details, but in fasted animals a fluid pattern containing multiple echogenic specks, continuous movement of the ingesta and occasional free gas caps were imaged. The motility was assessed from the movement of the wall and separation of the wall from the adjacent abdominal muscles and typical change in pattern of sacculations.

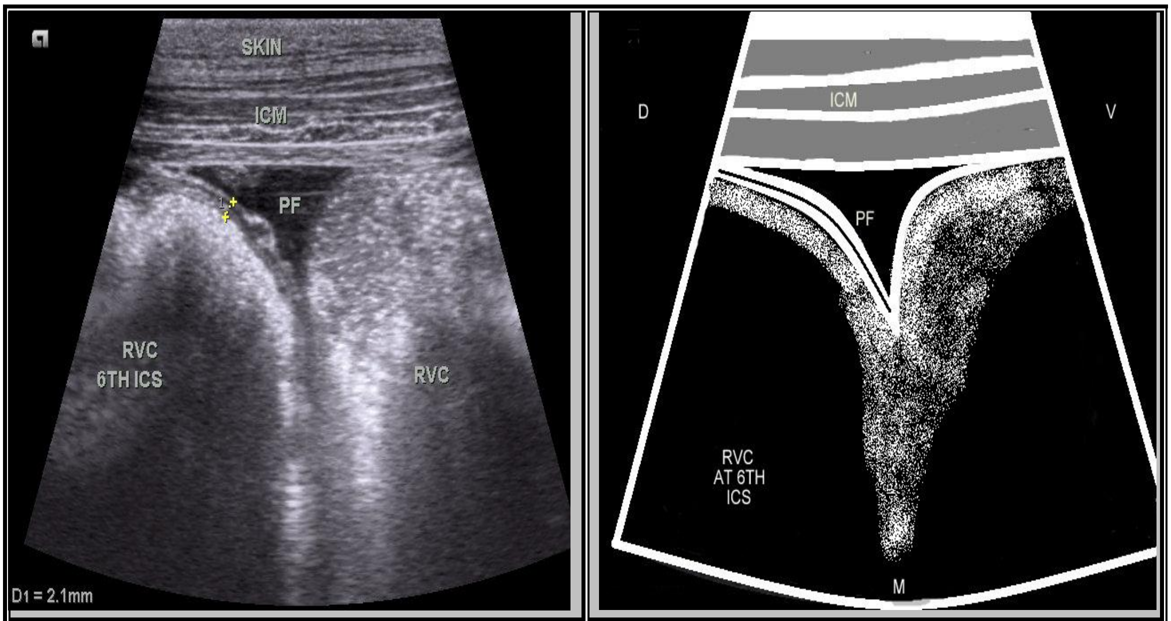


Plate-16. Ultrasonogram of right ventral colon (horse) at 6th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. (RVC= right ventral colon, PF= peritoneal fluid)

No observable difference was noticed between the frequencies of the contractions of the RDC and RVC, for RVC the frequencies of the contraction were same as recorded for RDC i.e. 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for

12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

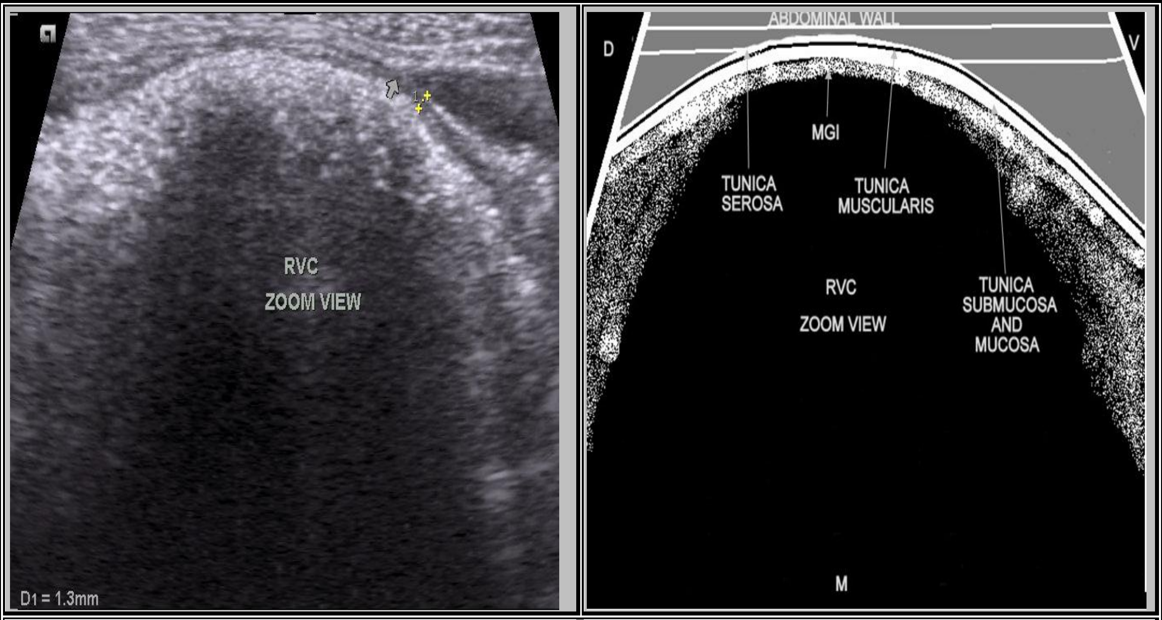


Plate-17. Ultrasonogram of RVC (Mule) at 14th ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm. (Zoom view), (RVC= right ventral colon, MGI= mucosal gas interface)

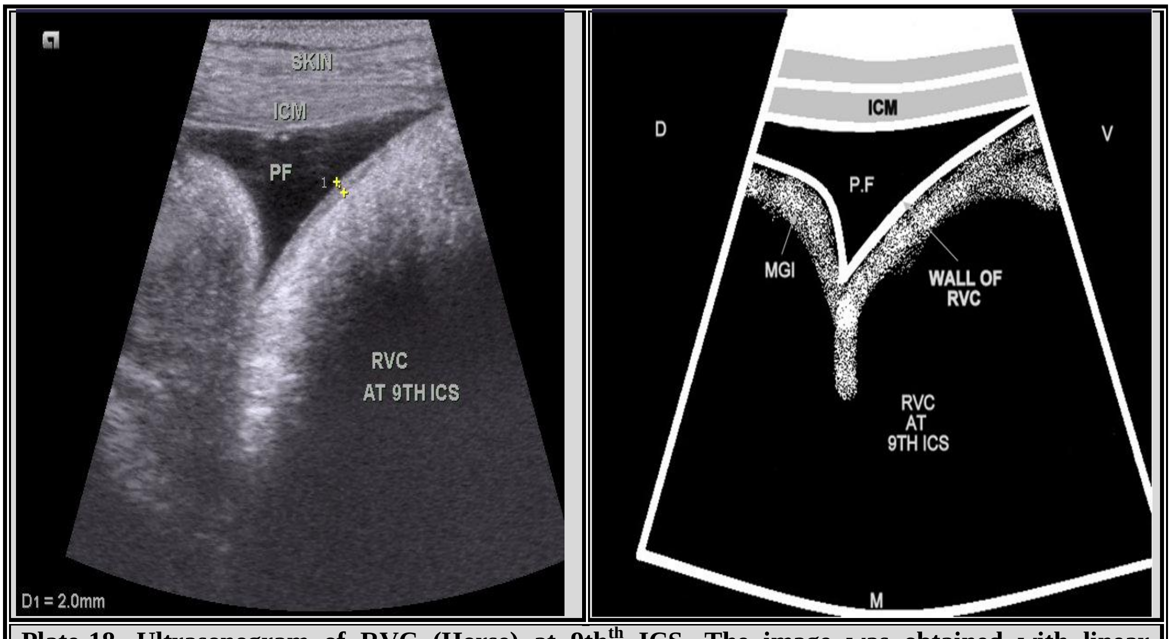


Plate-18. Ultrasonogram of RVC (Horse) at 9th^th ICS. The image was obtained with linear transducer at 10 MHz at a depth of 8.5 cm. (RVC= right ventral colon, PF= peritoneal fluid)

The RVC wall thickness varied from 2.0 to 2.2 with a (Mean± SE) of 2.1±0.03 mm (Plate-18). However in case of mules the RVC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm and all the muscle layers of the RVC wall were appreciable

(Plate-17). The findings of the present study were in agreement with Kirkberger *et al*. (1995), Freeman (2002b) and Barton (2011). However, Freeman (2002b) reported that the RVC has four taenial bands but in the present study these taenial bands could not be identified on ultrasonography. The wall thickness variation obtained in the current study was lower than that of the Barton (2011) who reported the wall thickness upto 4mm. These differences regarding the ultrasonographic imaging of wall thickness in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules.

Colin *et al.* (2005) reported that the frequency of contractions decrease on fasting and diameter of RVC could not be assessed on ultrasonography. Hendrickson *et al.* (2007) also found that the range of the mean values for wall thickness of large colons was 1.6 to 2.7 mm which was less than that reported as normal values i.e. 2.0 to 3.75 mm.

4.1.5 Duodenum

The duodenum was found at two locations in slightly oblique transverse plane in the right hemi abdomen of equines i.e. ascending duodenum from 11th to 13th ICS's in horses, 10th to 13th ICS's in mules, at the level of shoulder located between the liver and the RDC or medial to the liver. where it was imaged transversely in short axis and was again found at the level of the ventral right kidney or around the caudal pole of the right kidney and dorsal to the caecum between 16th to 17th ICS's and sometimes from 16th ICS to just caudal to the last rib at paralumbar fossa as descending duodenum. Whereas in case of mules it was relocated from 15th ICS to just caudal to the last rib at paralumbar fossa.

The duodenum appeared as small circular loop with a hypoechoic to echogenic wall during peristaltic propulsion of ingesta giving the duodenum oval to round shape, otherwise duodenum appeared flattened (Plate-19). A completely round duodenum with a centralized star shape was imaged during circular contraction phases and this sonographic appearance was created by the mucosal invaginations of the duodenum (Plate-20).

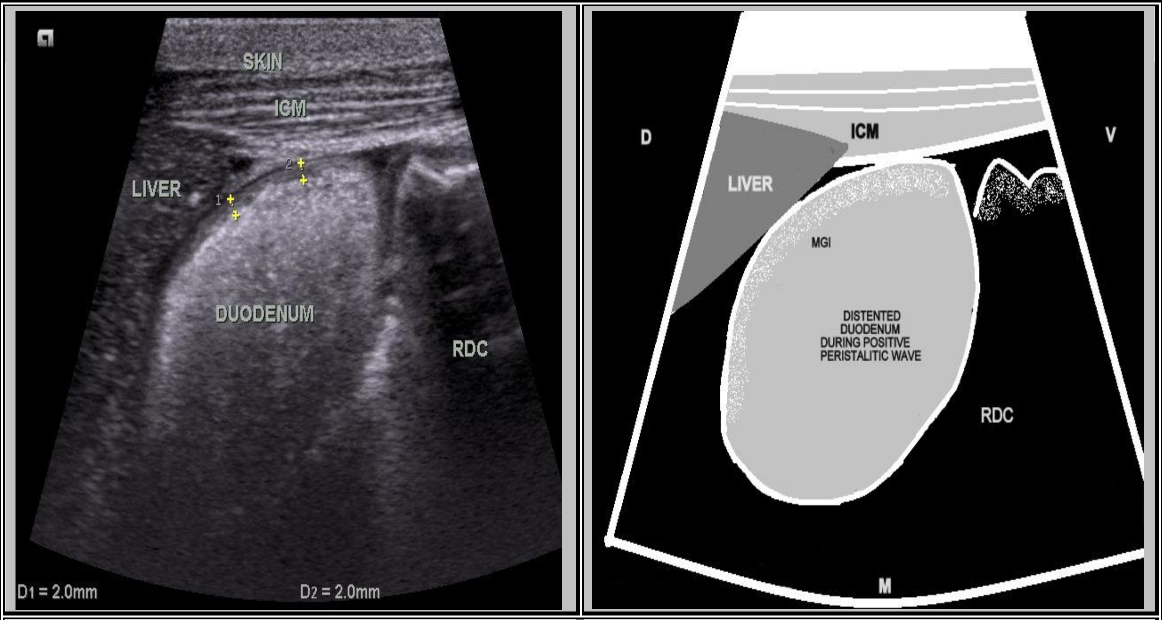


Plate-19. Ultrasonogram of ascending duodenum (Horse) at 12th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. (RDC= right dorsal colon, ICM= intercostal muscle)

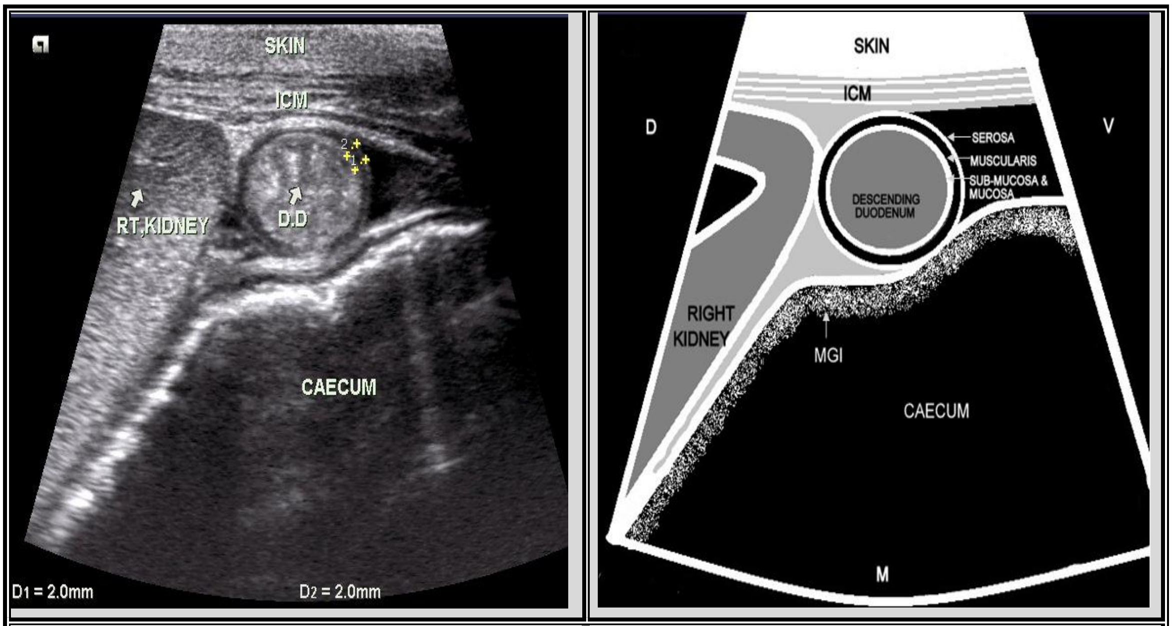


Plate-20. Ultrasonogram of descending duodenum (Horse) at 16th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. Centralized star shape due to mucosal invagination. (MGI= mucosal gas interface, ICM= intercostal muscle)

Kirkberger *et al.* (1995) The contents of the duodenum varied from a hyperechoic gas echo to hypoechoic or hyperechoic fluid, mucus or ingesta and sometimes a fluid pattern containing multiple echogenic specks. The frequencies of the contractions of the duodenum were recorded as 5-6 contractions/ min in fed animals, 2-3 contractions/ minute when fasted for 12 hrs without holding water and 0-1 contractions/ minute when animals were fasted for 24 hrs or more. The duodenal wall thickness was recorded as 2.0 with a

(Mean± SE) of 2.0±0.00 mm in case of horses (Plate-21), however in case of mules the duodenal wall thickness varied from 1.8 to 2.0 with a (Mean± SE) of 1.96±0.04 mm.

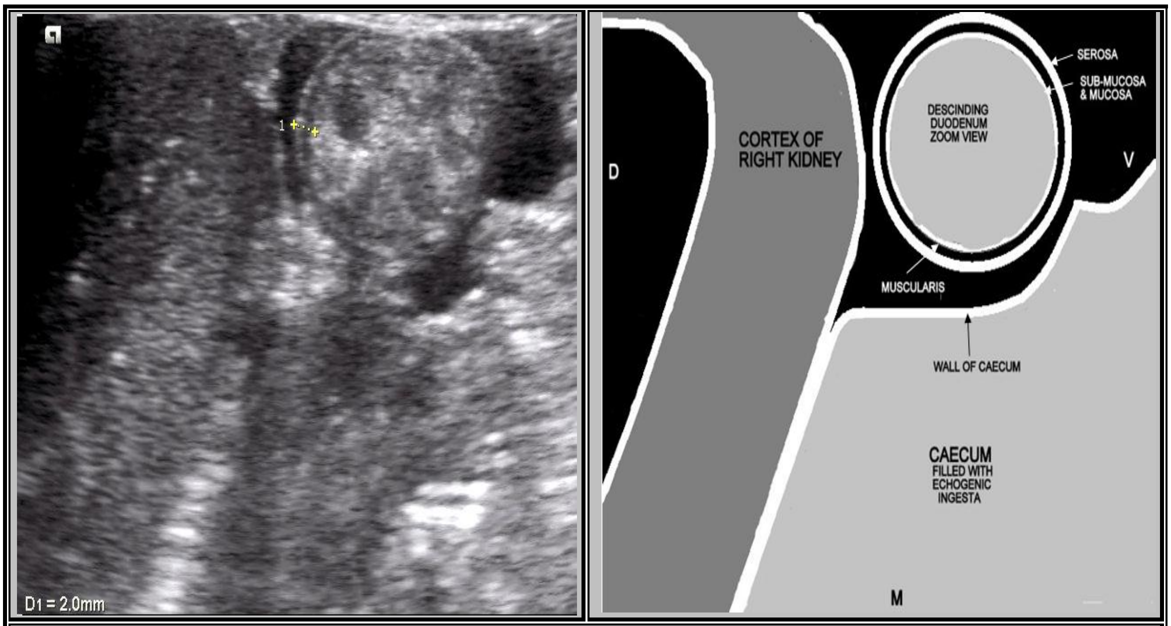


Plate-21. Ultrasonogram of descending duodenum (Mule) at 16th ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm (zoom view).

However, Barton (2011) reported that the wall thickness of the duodenum was less than 4mm. The findings are almost similar to those reported by Kirkberger *et al.* (1995), Reef (1998), Freeman (2002b) and Barton (2011). However these differences regarding the ultrasonographic imaging of wall thickness in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules. But in case of mules our findings regarding the wall thickness of duodenum were in agreement with that of Epstein *et al. (*2008) who reported that the duodenal wall thickness in mules was 0.188±0.033 cm, which was less than the normal published values for horses.

4.1.6 Kidneys

The right kidney was found from 15th (±1) ICS extending upto rostal right paralumbar fossa almost reaching the level of Ist lumbar vertebra, caudal to the liver, dorsal to the descending duodenum and ventral to the lumbar transverse processes, both in horses as well as mules. The renal capsule appeared as echogenic structure surrounding the kidney. The duodenum courses ventrally around the caudal pole of the right kidney and the caecum was imaged ventral and caudal to the right kidney. The right kidney appeared as a triangular curvilinear or heart shaped. The height (in slightly oblique transverse plane) of the right kidney varied from 112.7 to 118.3 with a (Mean± SE) of 115.6±1.01 mm and its thickness varied from 58.4 to 71.2 with a (Mean± SE) of 64.3±2.37 mm.

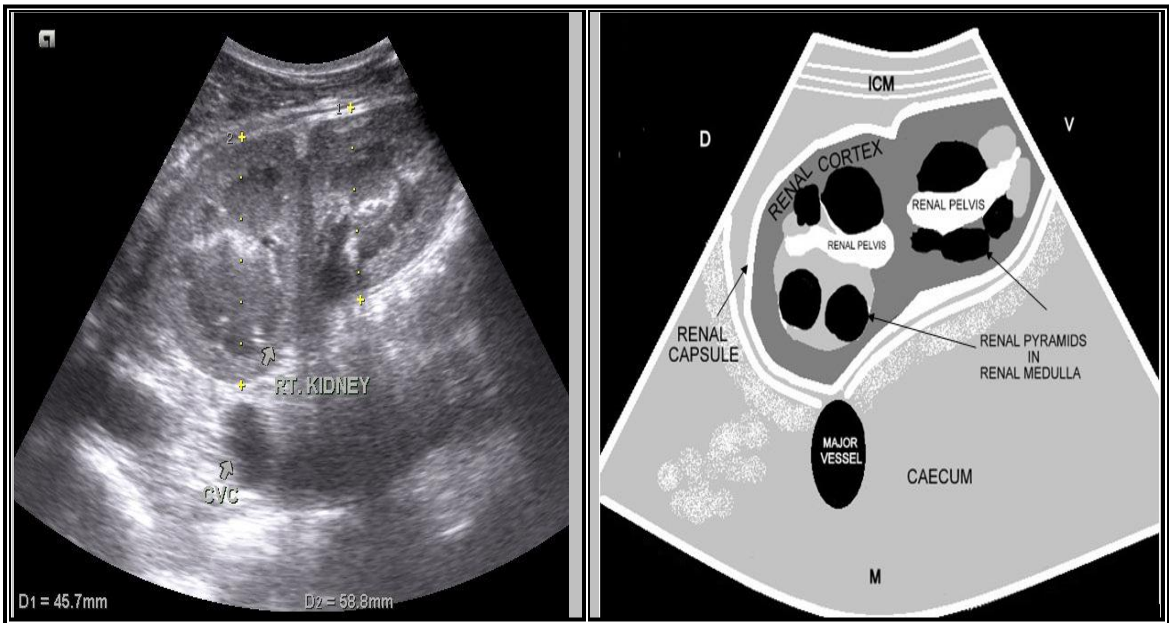


Plate-22. Ultrasonogram of Right kidney (Mule) at 16th ICS. The image was obtained with volumetric (4D) transducer at 5.0 MHz at a depth of 13 cm

However its length was difficult to obtain in its long axis (dorsal plane that is parallel to the spine) because of the interference from the ribs both in horses as well as mules. While in case of mules the height of the right kidney varied from 90.7 to 109.2 with a (Mean± SE) of 101.1±3.14 mm, and its thickness varied from 47.3 to 56.8 with a (Mean± SE) of 52.3±1.57 mm.

The left kidney was found between the 16th to 17th ICS and Ist to 2nd lumbar vertebra, while as in case of mules it was found from 16th ICS to 3rd lumbar vertebra medial or deep to the spleen between the level of the tuber coxae and the tuber ischii. The height of the left kidney varied from 87 to 107.8 with a (Mean± SE) of 99.0±3.67 mm, and its thickness varied from 49.5 to 53.8 with a (Mean± SE) of 51.8±0.72 mm. In mules the height of the left kidney varied from 85.5 to 111.4 with a (Mean± SE) of 95.3±2.36 mm, and its thickness varied from 43.4 to 55.7 with a (Mean± SE) of 50.6±2.53 mm.

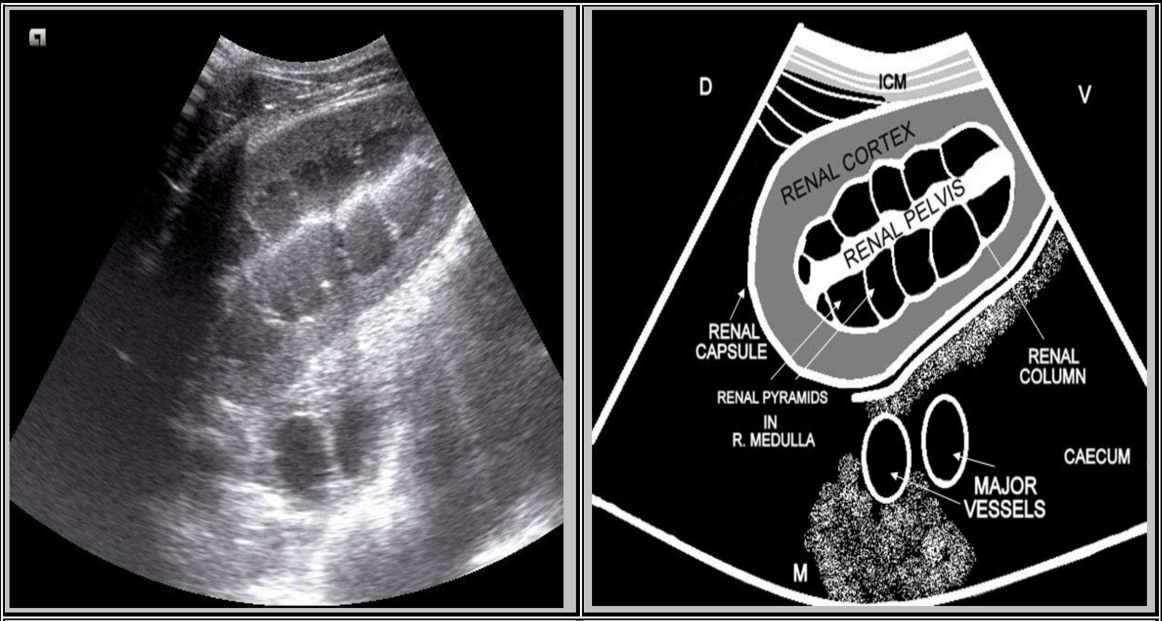


Plate-23. Ultrasonogram of Right kidney (Mule) at 16th ICS. The image was obtained with volumetric (4D) transducer at 5.0 MHz at a depth of 13 cm. (ICM= intercostal muscle)

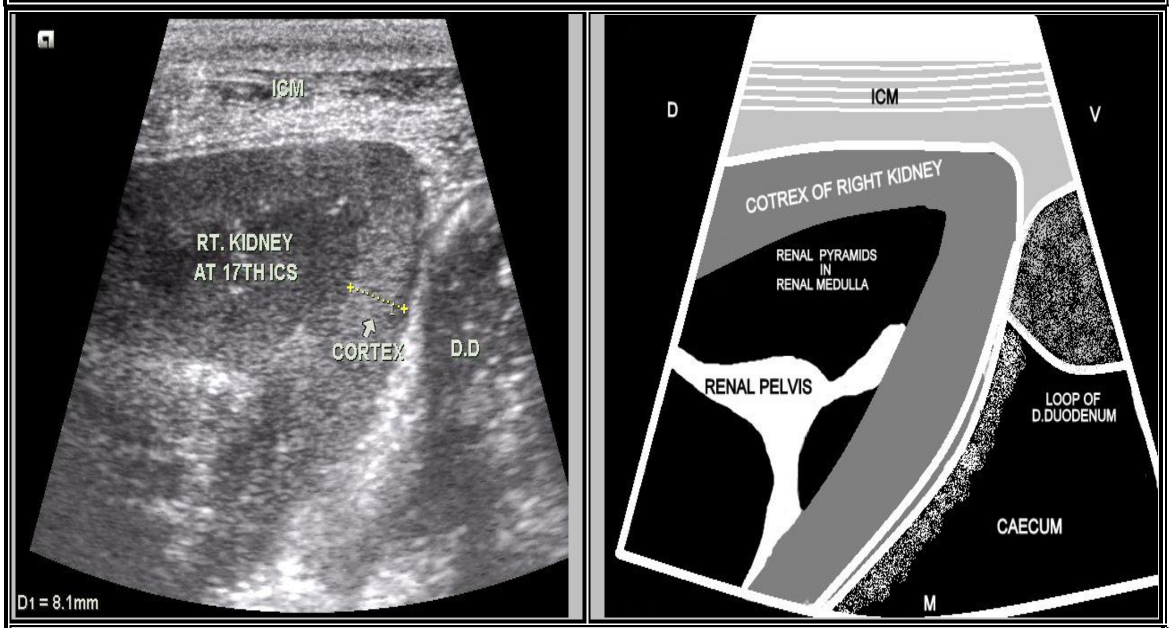


Plate-24. Ultrasonogram of Right kidney (Horse) at 17th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. (ICM= intercostal muscle)

The thickness of the cortex varied from 8.1 to 8.6 mm in horses whereas in case of mules it varied from 8.0 to 8.1 mm (Plate-24). The renal cortex was found hypoechoic compared with the surrounding tissues but more echogenic than the adjacent medulla. Renal pyramids appeared as distinct hypoechoic circles separated from each other by renal column. Renal pelvis was found in the centre and most echogenic structure in each kidney (Plate-22 &23). The observations of the present study were in agreement with those of the Kiper *et al.* (1990), Hoffman *et al.* (1995) and Reef (1998), except for that in their study the left kidney was found upto 3rd lumbar vertebra in case of horses and thickness of cortex was reported to be 1 to 2 cm thick, which was higher than the findings of the present study. Similarly the height and thickness of both the kidneys in the present study varied from that of Hoffman *et al.* (1995) who reported that the height of the right kidney varies from 13 to 18 cm, with a length of 13 to 15 cm and thickness of 5 cm, while as height of left kidney varies from 11 to 15 cm, length 15 to 18 cm and thickness of 5 to 6 cm. Freeman (2002b) suggested that transrectal ultrasonography produced higher quality images, allowing visualization of the renal vasculature and ureters, however the transrectal technique is limited by the size of the horse, but in the present study none of the kidneys could be imaged through transrectal ultrasonography due to the small size of the animals. The different measurement of both the kidneys and topographic anatomic variation obtained in the current study was lower as in local horses and mules may have variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules.

4.1.7 Stomach

The stomach was found from 8th to 13th ICS's while in fed horses, upto 15th ICS (Plate-26). In case of mules it was found from 8th to 14th ICS's caudal to the liver, cranial to the spleen and dorsal to the RDC at the level of shoulder. At this location the only part of the stomach that was visible was the wall of the greater curvature, which was identified as semicircular, curvilinear hyperechoic line with proximity to the adjacent spleen at the level of splenic vein. In fasted horses the stomach was not found in its usual position, instead it was found ventral to the costochondral junction (Plate-25).

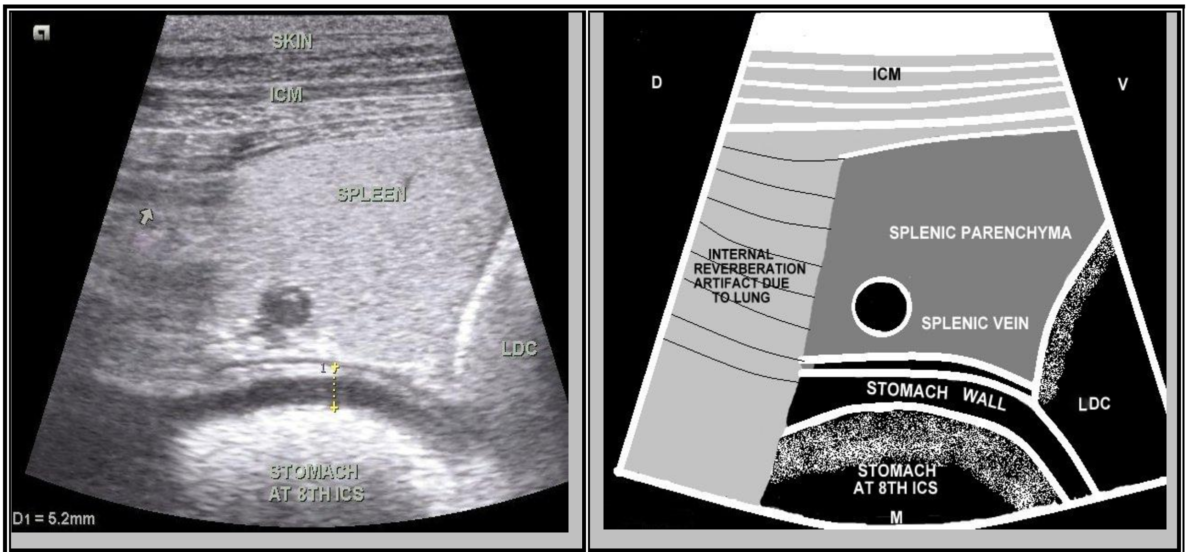


Plate-25. Ultrasonogram of Stomach (Horse) at 8th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (LDC= left dorsal colon)

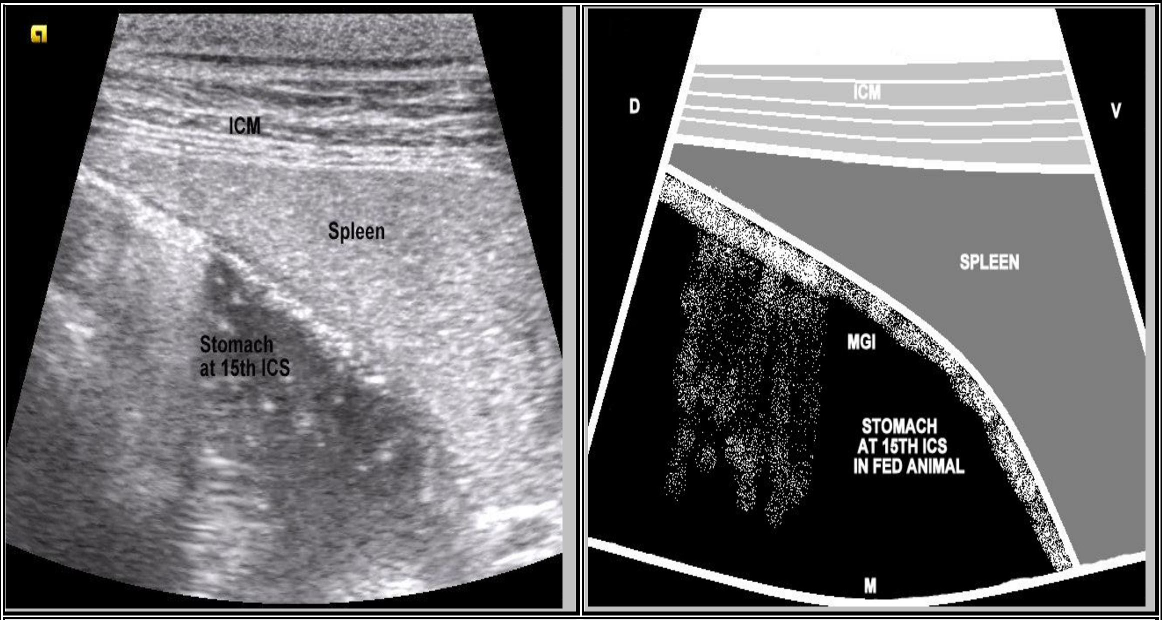


Plate-26. Ultrasonogram of Stomach (Horse) at 15th ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 5 cm. (MGI= mucosal gas interface, ICM= intercostal muscle)

It was found that the lumen generally contained gas, casting strong acoustic shadowing and often the contents of the stomach were not visible (Plate-28), but when the stomach contained fluid a distinct gas fluid interface was observed and in addition to this sometimes specks of feed were seen floating within the fluid of the stomach (Plate-26).

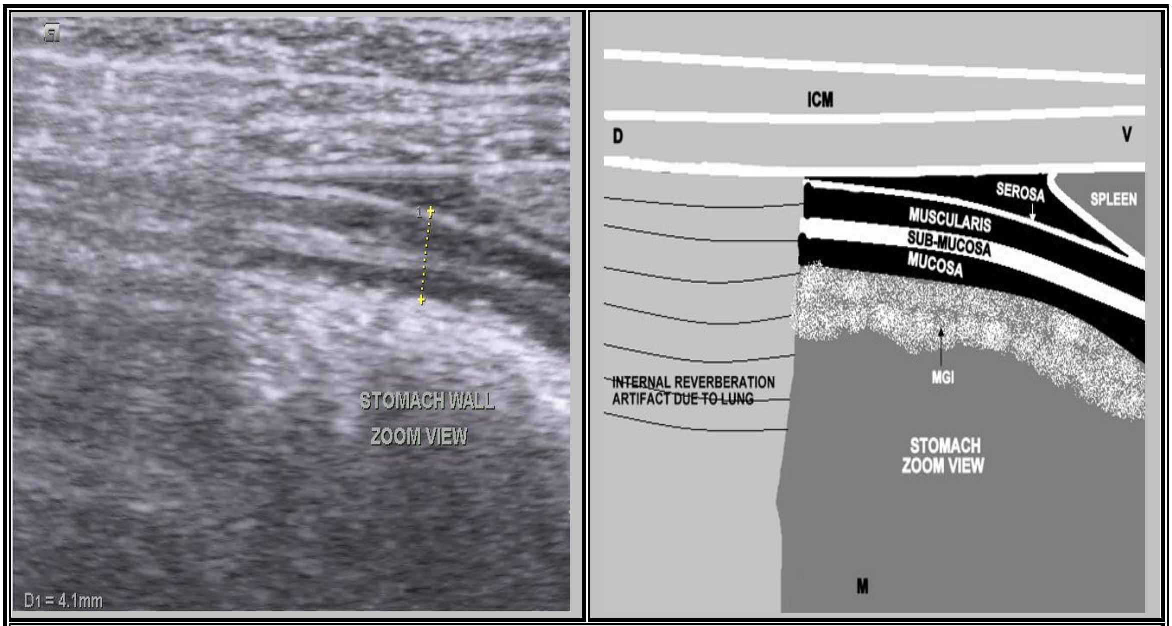


Plate-27. Ultrasonogram of Stomach (Mule) at 12th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm (zoom view), (MGI= mucosal gas interface, ICM= intercostal muscle)

The stomach wall thickness varied from 4 to 5.2 with a (Mean± SE) of 4.92±0.23 mm and in case of mules it varied from 4.1 to 4.4 with a (Mean± SE) of 4.24±0.06 mm.

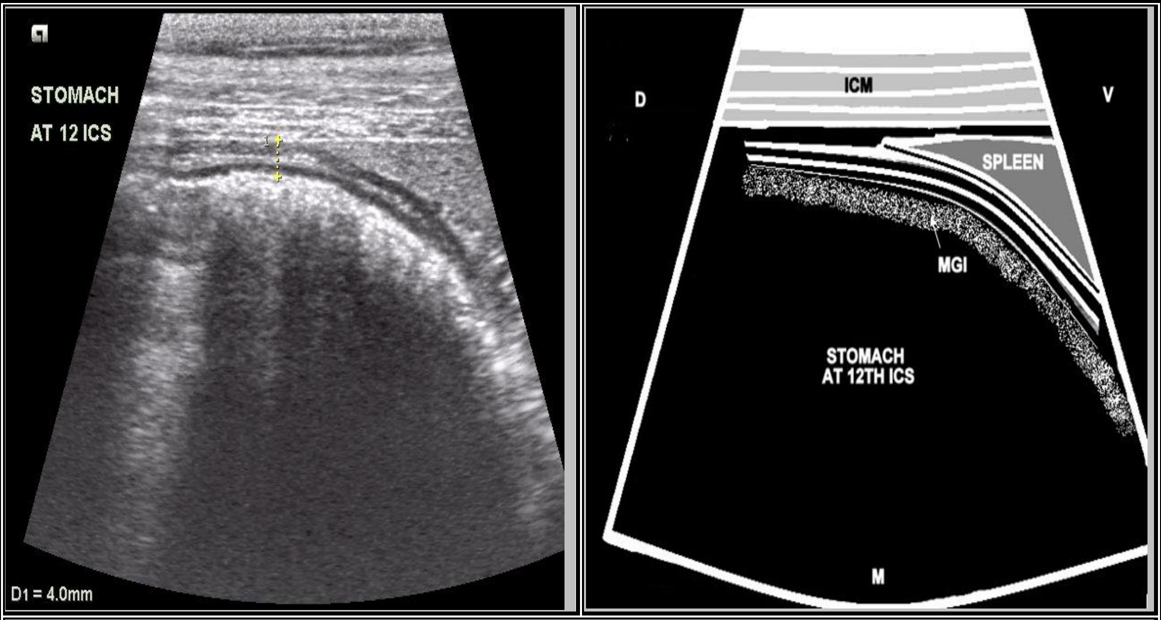


Plate-28. Ultrasonogram of Stomach (Mule) at 12th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (MGI= mucosal gas interface, ICM= intercostal muscle)

It was observed that stomach has the thickest wall of the gastrointestinal tract and all the muscle layers of the stomach wall were distinctly appreciable (Plate-27). The findings of the present study were similar to those of Canon *et al.* (1995), Reef (1998), Freeman (2003), Colin *et al.* (2005) and Barton (2011).

However the wall thickness variation obtained in the current study was lower than that of the Freeman (2003) who reported that the wall thickness varies with the degree of gastric distention but is usually less than 0.75 cm and Barton (2011) who reported that it would be an indication of gastric distention or displacement by other viscera if the stomach extends beyond the 14 ICS in a horse that has not eaten recently and stomach has the thickest wall measuring roughly 7 mm and if the stomach is empty, the wall may be upto 1 cm thick. The difference regarding the ultrasonographic imaging of wall thickness in local horses may be possibly attributed to the variations in the body weight/size or breed type.

But in case of mules our findings regarding the wall thickness of stomach were in agreement with that of Epstein *et al. (*2008) who reported that the stomach wall thickness in mules was 0.431±0.06 cm, which was less than the normal published values for horses.

4.1.8 Spleen

The spleen was found from 8^{th} to 17^{th} ICS's and just caudal to the last rib in left paralumbar fossa, in slightly oblique transverse plane, anteriorly caudal to the stomach dorsal to the jejunum, laterally caudal and medial to the left kidney both in horses as well as mules.

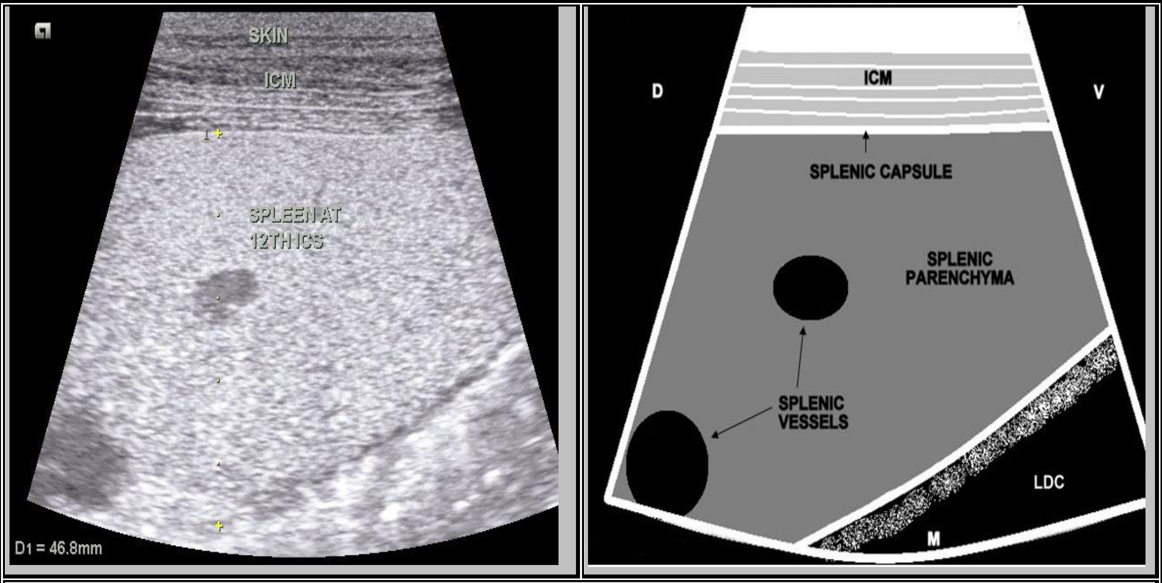


Plate-29. Ultrasonogram of spleen (Horse) at 12^{th} ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm. (LDC= left dorsal colon)

The splenic parenchyma appeared as granular, homogenous in appearance with few blood vessels and is a most echogenic organ in the abdominal cavity of equines (Plate-29). Spleen was found encapsulated with an echogenic capsule and splenic vein was easily located as an anechoic tubular structure medial to the spleen around 10^{th} ICS (Plate-30).

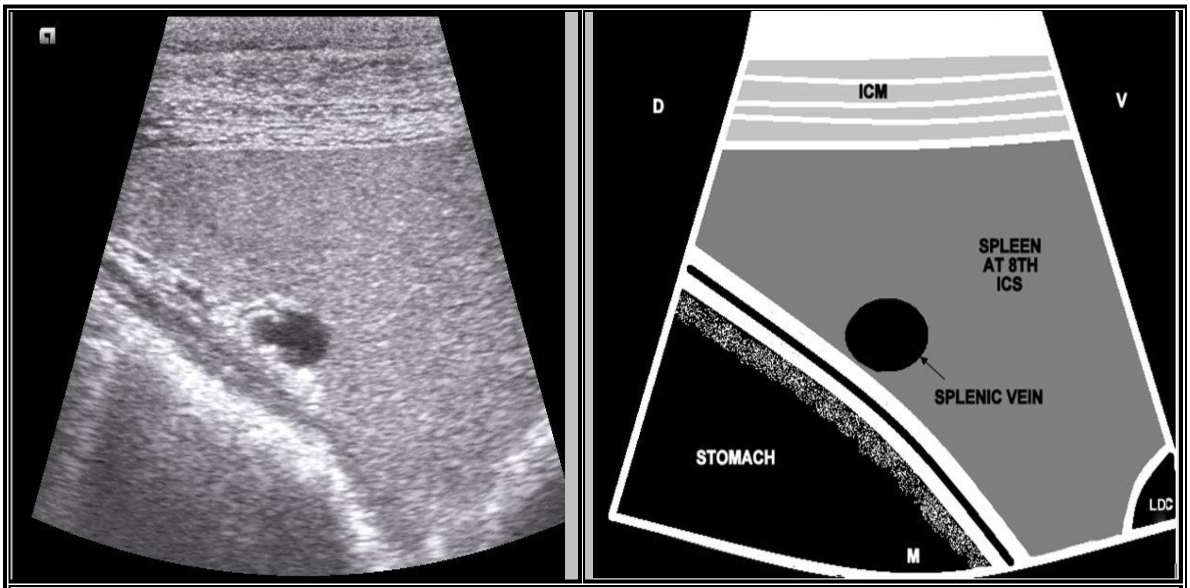


Plate-30. Ultrasonogram of spleen (Mule) at 8^{th} ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (ICM= intercostal muscles)

The spleen was found variable in location depending on gastric distention and the size of the adjacent organs like liver and in one animal (mule) spleen was found extended beyond the ventral midline towards the right hemi abdomen. Rantanen (1986a) also reported that the size and the location of the spleen is highly variable and should be identifiable immediately adjacent to the body wall, from the left ventral 8th ICS extending upto paralumbar fossa and it may remain to the left of the midline, or extend slightly beyond the right of the ventral midline. In the present study the only measurement that was reliably obtained was the central thickness or depth of the spleen, which varied from 41.4 to 68.4 with a (Mean± SE) of 50.84±4.61 mm and in case of mules it varied from 37.9 to 51.6 with a (Mean± SE) of 42.76±2.34 mm.

The finding of the present study were more consistent with that of Rantanen (1986a), Reef (1991), Reef (1998), Freeman (2002b) and Barton (2011), except for the central thickness of the spleen which highly varied from the published values of the Rantanen (1986a) who reported that the central thickness of the spleen is usually less than 15 cm. Therefore these differences regarding the central thickness of the spleen in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules.

4.1.9 Left dorsal colon

The left dorsal colon (LDC) was found from 6th to 15th ICS's ventromedial to the spleen, in the lower flank, dorsal to the LVC, ventral to the stomach, liver and jejunum in both horses as well as mules (Plate-31).

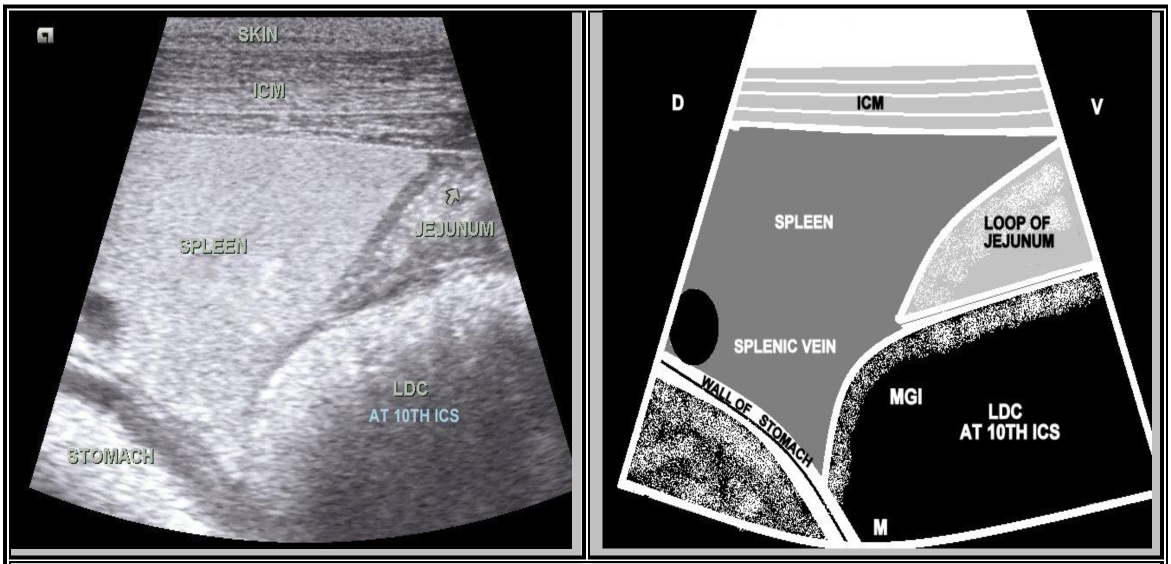


Plate-31. Ultrasonogram of LDC (Horse) at 10th ICS. The image was obtained with linear transducer at 5.3 MHz at a depth of 6.5 cm. (LDC= left dorsal colon, ICM= intercostal muscles)

The sacculations in the LDC were absent and appeared as a hyperechoic line adjacent to the spleen and jejunum. Freeman (2002b) also reported that the LDC lacks sacculations and this allows the distinction between the dorsal and the ventral colon. In fed animals a peculiar gas pattern was observed which typically generated a hyperechoic appearing wall with an indistinct luminal border and intraluminal acoustic shadowing that precluded the identification of the contents and the medial wall (Plate-32), but in fasted animals a fluid pattern containing multiple echogenic specks and occasional free gas caps were imaged. Only LDC wall and the contents upto few cm depth could be imaged. The motility was assessed from the movement of the wall and separation of the wall from the adjacent organs.

The frequencies of the contractions of the LDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

All the five layers of the LDC i.e. (Serosa, Muscularis, Submucosa, Mucosa and Mucosal gas interface) were identified (Plate-33) using 7.3 MHz linear transducer at a depth of 6.5 cm.

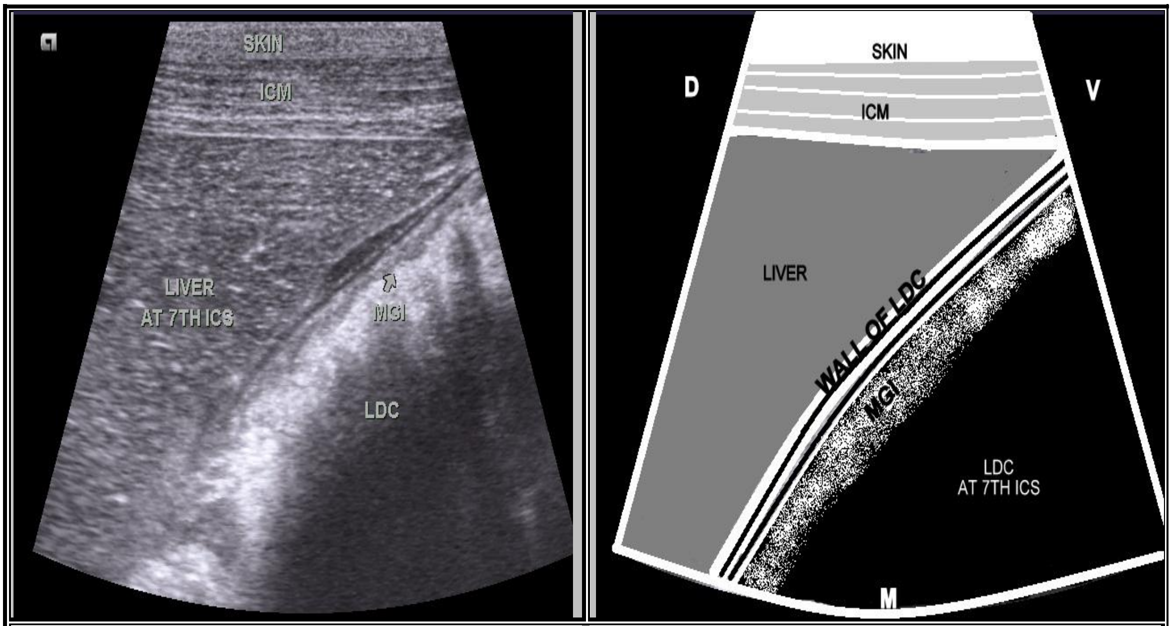


Plate-32. Ultrasonogram of LDC (Horse) at 7th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. (LDC= left dorsal colon, ICM= intercostal muscles)

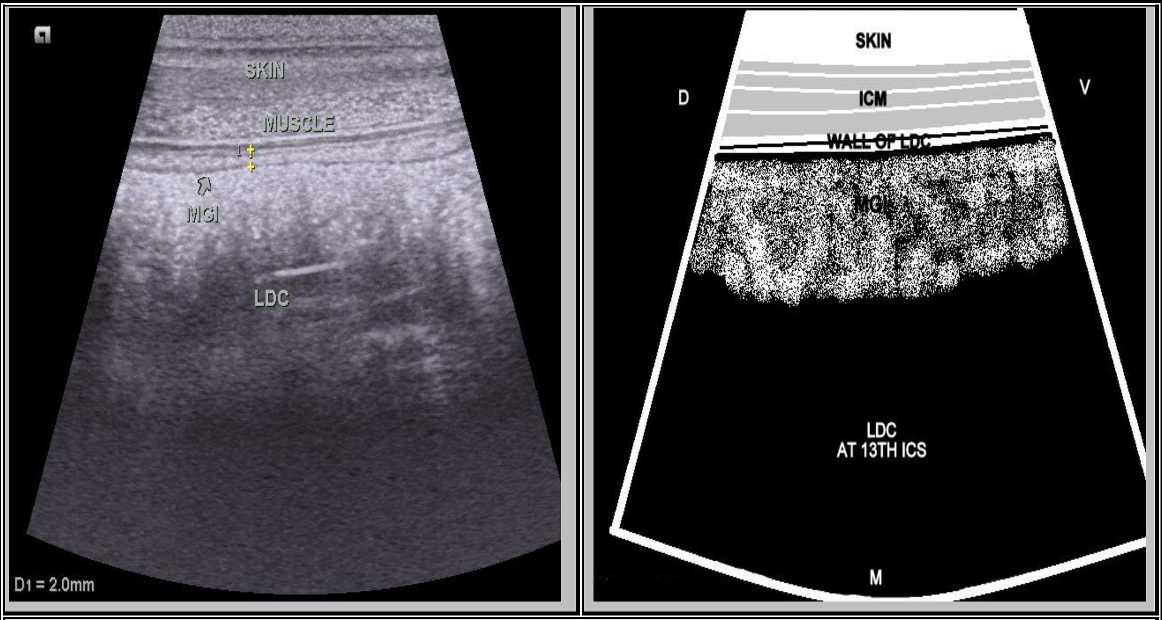


Plate-33. Ultrasonogram of LDC (Horse) at 13th ICS. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm. (LDC= left dorsal colon, ICM= intercostal muscles)

The LDC wall thickness varied from 2.0 to 2.2 with a (Mean± SE) of 2.12±0.03 mm. however in case of mules the LDC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm.

Our findings of the present study were in consonant with findings of Freeman (2002), Freeman (2003), Colin *et al.* (2005), Hendrickson *et al.* (2007) and Barton (2011), except for the wall thickness which varied than the normal published values of Barton (2011) and in case of mules the wall thickness of the LDC was less than the horses which could be possibly due to the variations in body weight/size, breed type, and/or hybrid (interspecies variation) nature of mules.

4.1.10 Left ventral colon

The left ventral colon (LVC) was found from 9th to 14th ICS's in the lower flank and ventral to the LDC upto the linea alba both in horses as well as mules. The LVC was identified by the presence of sacculations, sluggish motility, inability to identify the entire circumference of its wall and appeared as a bright hyperechoic line on ultrasonography.

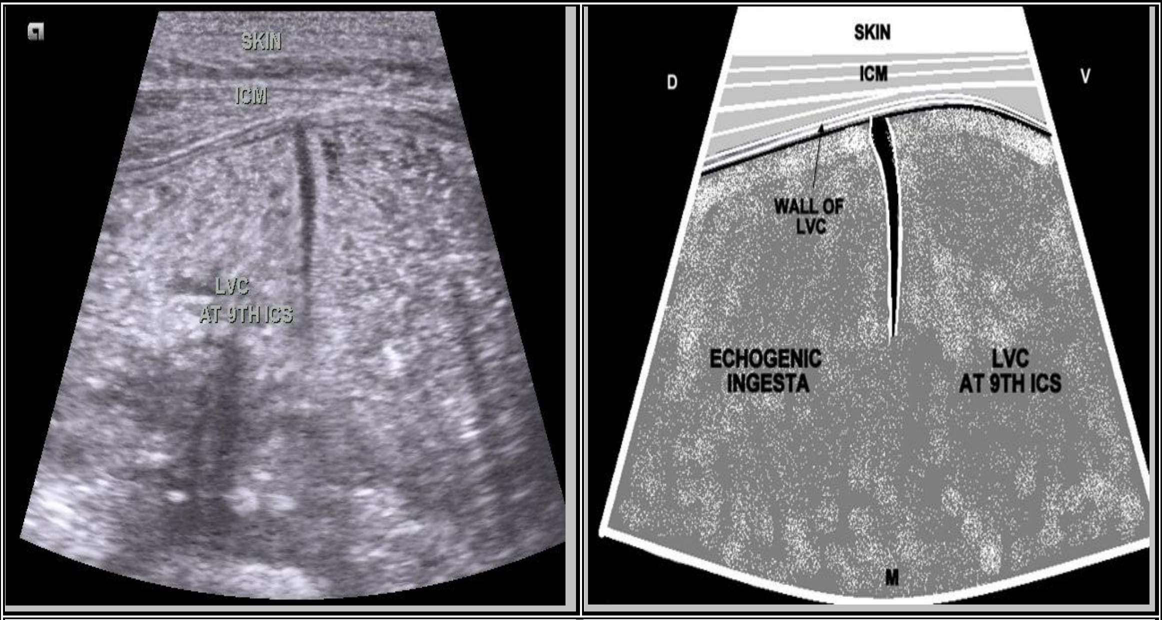


Plate-34. Ultrasonogram of LVC (Horse) at 9th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (LVC= left ventral colon, ICM= intercostal muscles)

As in LDC, LVC also showed a typical gas pattern in fed animals casting a strong acoustic shadowing and masking the details (Plate-35&36), but in fasted animals a fluid pattern containing multiple echogenic specks, continuous movement of the ingesta and occasional free gas caps were imaged (Plate-34).

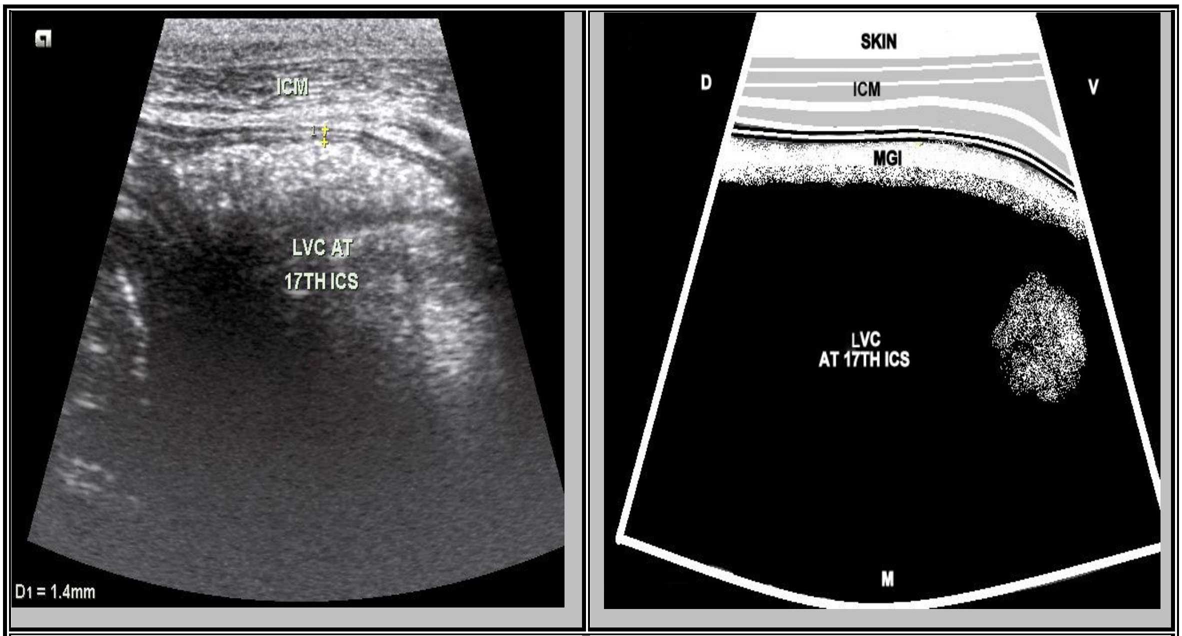


Plate-35. Ultrasonogram of LVC (Horse) at 17th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (LVC= left ventral colon, ICM= intercostal muscles)

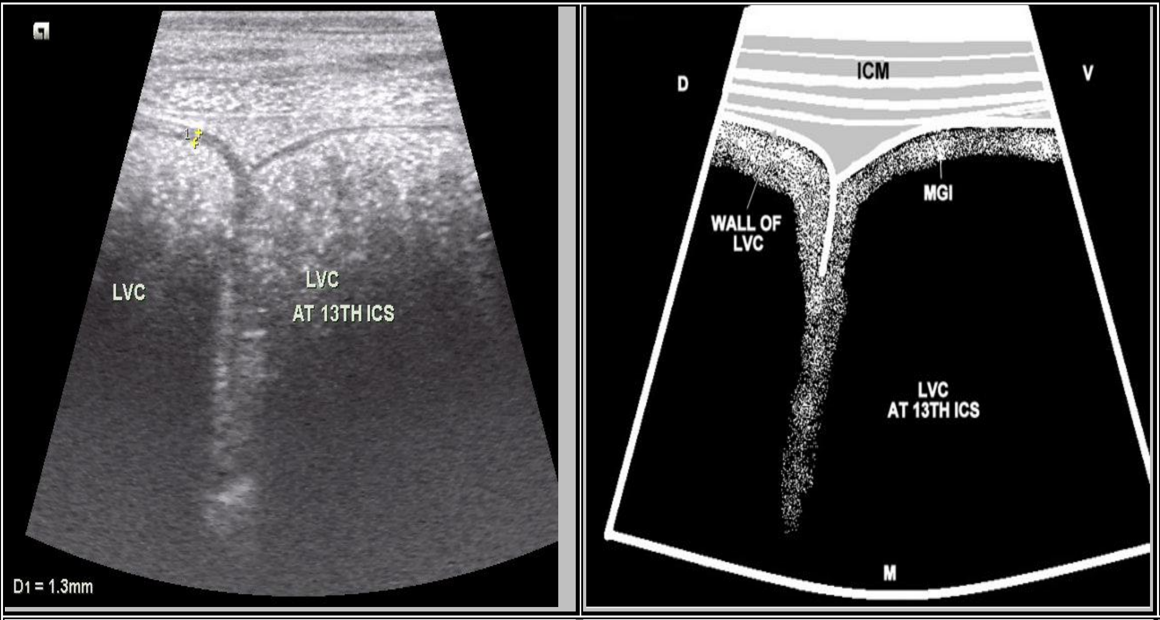


Plate-36. Ultrasonogram of LVC (Mule) at 13th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm

Barton (2011) also reported that gas in the colons typically generates a hyperechoic appearing wall with an indistinct luminal border and intraluminal acoustic shadowing that precludes identification of the contents and the medial walls (Plate-37).

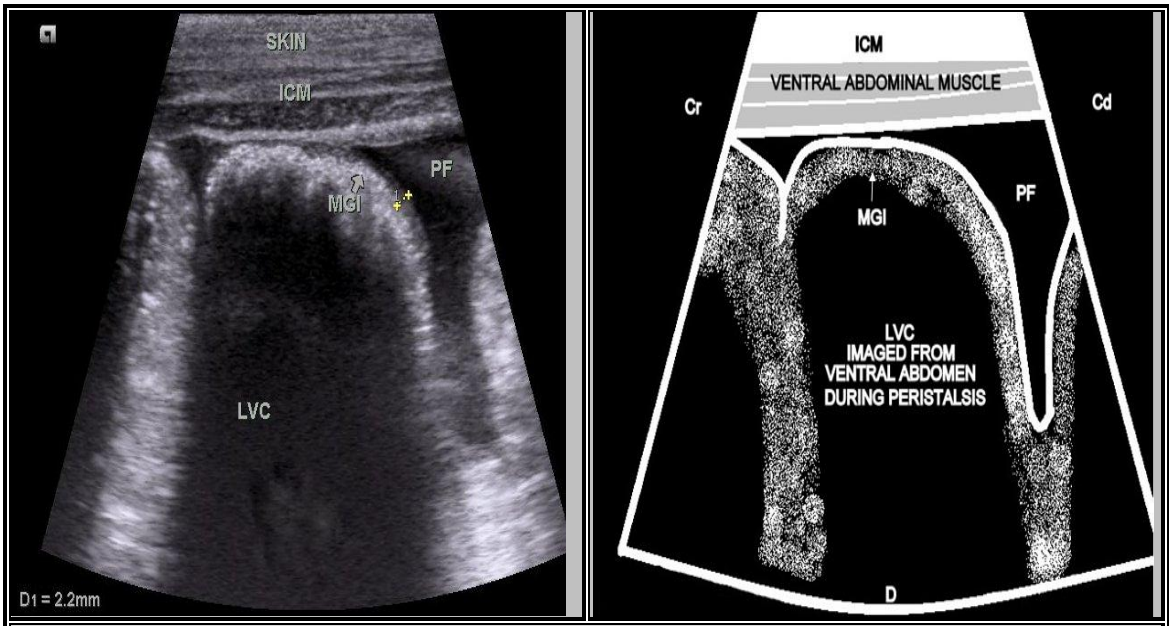


Plate-37. Ultrasonogram of LVC (Horse) at lower ventral abdomen. The image was obtained with linear transducer at 10.0 MHz at a depth of 7 cm

He also reported that the LVC is sacculated with sluggish motility and wall thickness measures less than 4 mm. In the present study the motility was assessed from the movement of the wall and separation of the wall from the adjacent abdominal muscles and typical change in pattern of sacculations. For LVC the frequencies of the contraction were same as recorded for LDC i.e. 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

The LVC wall thickness varied from 2.0 to 2.2 with a (Mean± SE) of 2.1±0.03 mm. however in case of mules the LVC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm.

The findings of the present study were in agreement with Freeman (2002b) and Reef *et al.* (2004). The wall thickness variation obtained in the current study was lower than that of the Barton (2011) who reported the wall thickness of less than 4mm.These differences regarding the ultrasonographic imaging of wall thickness in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules. Colin *et al.* (2005) reported that the frequency of contractions decrease on fasting and diameter of LVC could not be assessed on ultrasonography due to the acoustic shadowing. Hendrickson *et al.* (2007) also found that the range of the mean values for wall thickness of large colons was 1.6 to 2.7 mm which was less than that reported as normal values i.e. 2.0 to 3.75 mm.

4.1.11 Jejunum

The jejunum was found from 12^{th} (±1) to 17^{th} ICS's caudal to the spleen (Plate-38), dorsal to the LDC, ventral to the descending colon, in the mid flank and left inguinal area in both horses as well as mules.

In some animals it was found that the interposed gas filled large colon made it hard to visualize jejunum unless a peristaltic wave generates transient expansion of the lumen from the movement of the fluid contents but in most of the animals used in the standardization phase the jejunum was always found in the left mid flank ventral to the descending colon. Barton (2011) also reported that it is difficult to visualize the small intestine in normal horses unless a peristaltic wave causes moderate expansion of the lumen.

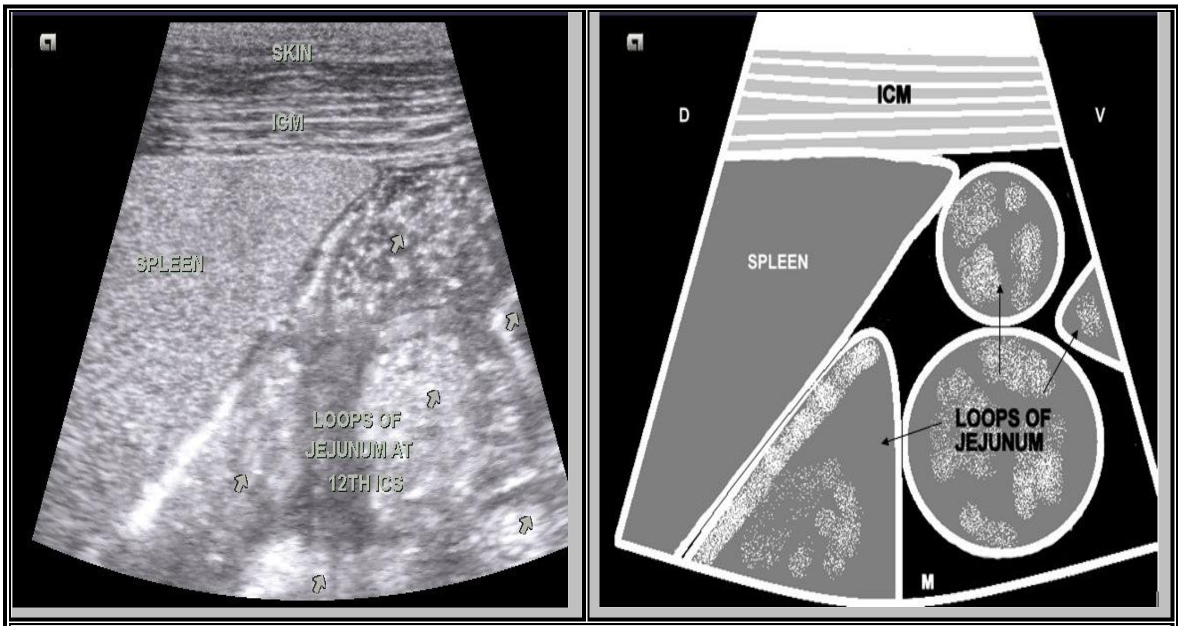


Plate-38. Ultrasonogram of jejunal loops (Horse) at 12th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (ICM= intercostal muscles)

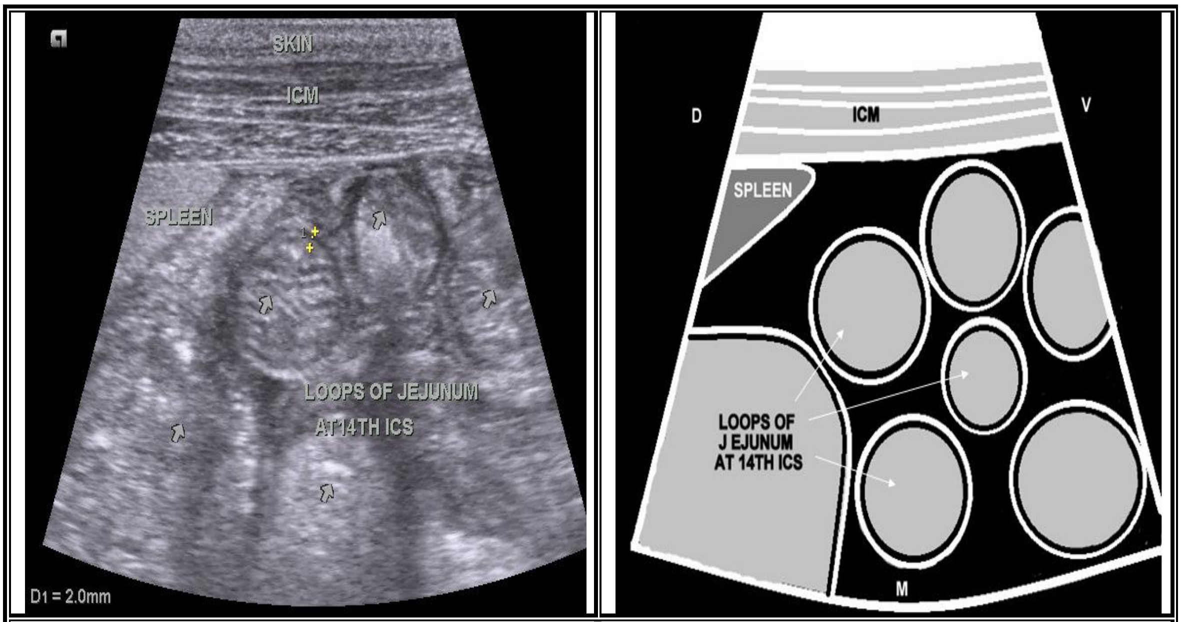


Plate-39. Ultrasonogram of jejunal loops (Horse) at 14th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 6.5 cm. (ICM= intercostal muscles)

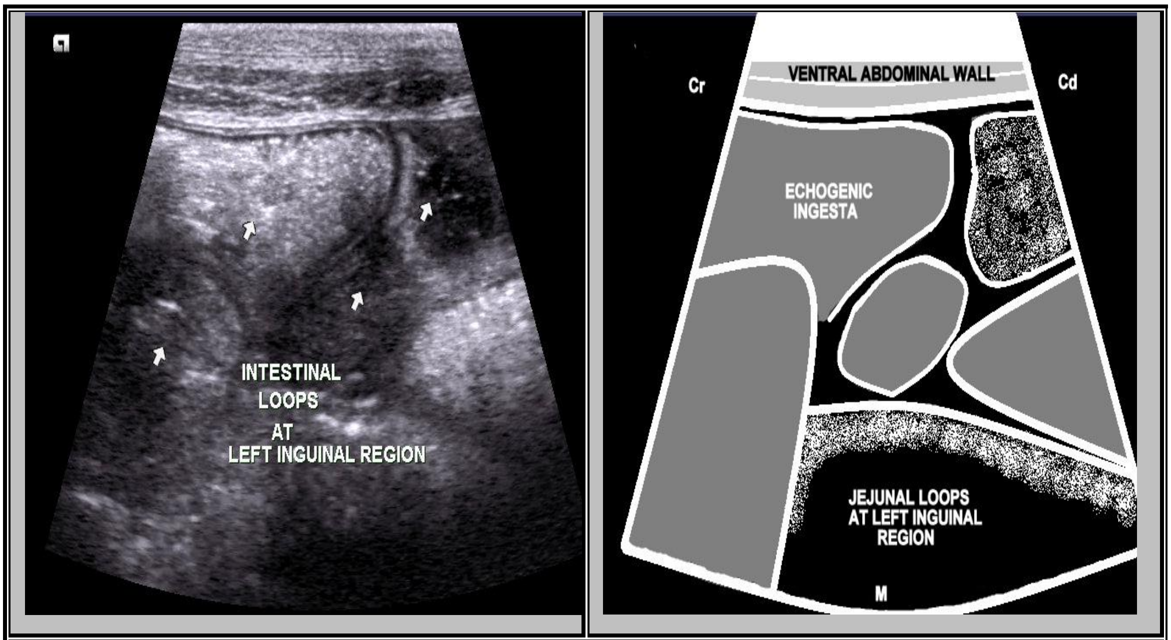


Plate-40. Ultrasonogram of jejunal loops (Mule) at left inguinal region. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm

Jejunum was more visible in fasted horses but with decreased activity, this increase in visibility may have occurred due to emptying of the colons, same findings were reported by Colon *et al.* (2005). On ultrasonography, jejunum appeared as small circular to triangular loops with no sacculations and contents were predominantly fluidy but varied in echogenicity depending upon the amount of fluid, ingesta and gas (Plate-39). Desrochers (2005) also reported that small intestine appears as small tubular or circular loops, which lack sacculations, having frequent contractions and wall thickness measures less than 0.3 cm. In the present study fluid was seen as hypoechoic, ingesta as echogenic producing a heterogeneous pattern with mixed fluid and particulate matter often visible without acoustic shadowing (Plate-40) and gas as hyperechoic with acoustic shadowing.

Freeman (2002b) reported that the intestinal wall comprises of five layers, the serosa, muscularis, submucosa, mucosa and mucosal gas interface and this five layered ultrasonographic appearance is present throughout the small and large intestine of the horse, except for the ileum which has seven layered appearance due to additional muscle layer, but these findings are evident only during in vitro (water bath) studies and concluded that in vivo, these features are difficult to identify. In the present study, this five layered ultrasonographic appearance was appreciated in large intestine, however in small intestine it was difficult to differentiate between submucosa and mucosa but rest of the layers were appreciable (Plate-41).

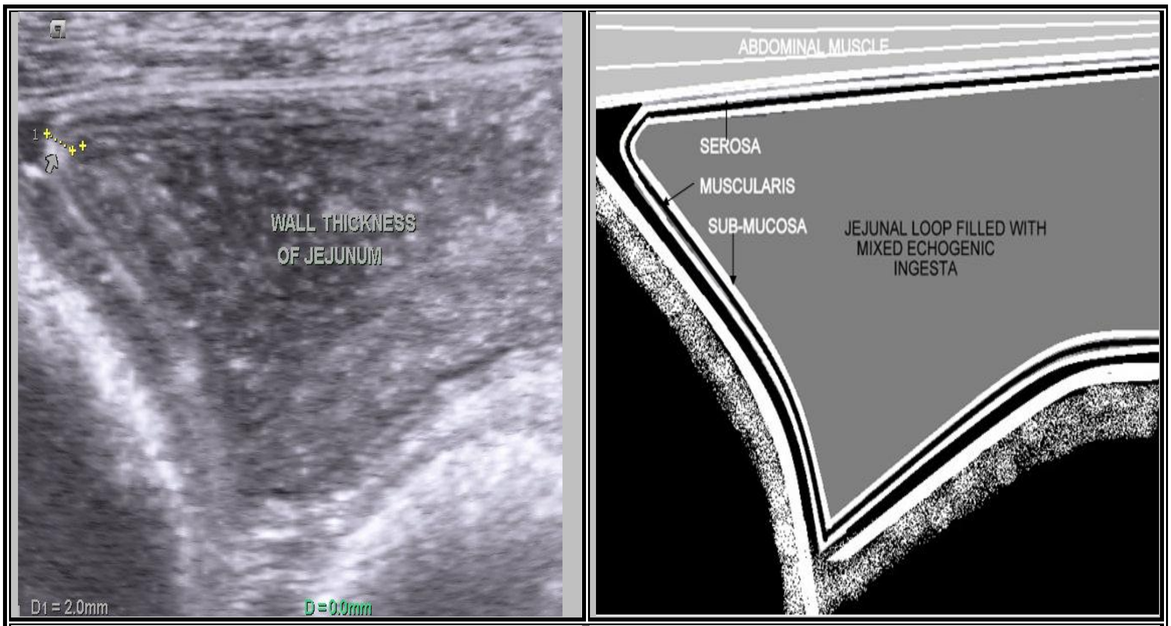


Plate-41. Ultrasonogram of jejunal loop (Mule) at left mid flank region showing the various muscle layers of wall of jejunum. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm.

It was also observed that small intestine (Jejunum) was having the most visible motility of any part of the gastrointestinal tract, with peristaltic waves producing rhythmic contractions of about 5 to 15 contractions per minute. It was also found that fasting adversely decreases the motility of the intestine upto 4 contractions per minute. The fluidy contents of the lumen enabled distinction of the wall thickness and visualization of the distal wall in either it's long or short axis.

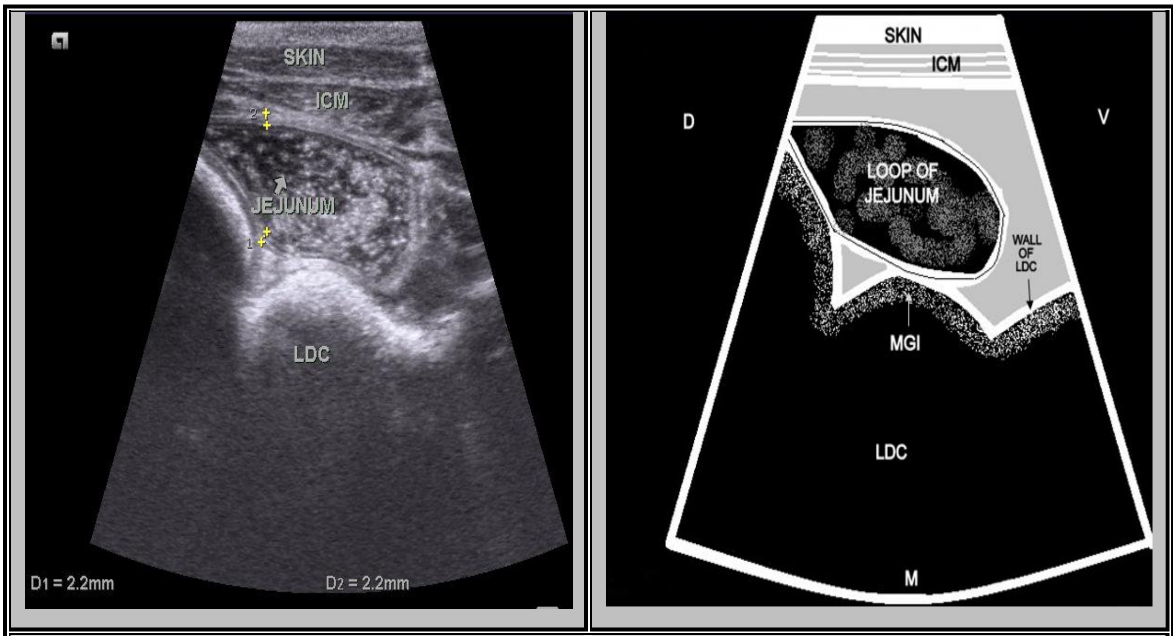


Plate-42. Ultrasonogram of jejunal loop (Horse) at 9th ICS. The image was obtained with linear transducer at 10.0 MHz at a depth of 10 cm. (LDC= left dorsal colon)

The wall thickness of the jejunum varied from 2 to 2.2 with a (Mean± SE) of 2.04±0.04 mm, whereas in case of mules it varied from 2 to 2.1 with a (Mean± SE) of 2.02±0.02 mm. Epstein *et al.* (2008) reported that the mean wall thickness of jejunum in mules as 0.195±0.03 cm. Our findings were in agreement with those of the Reef (1998), Freeman (2002b) and Barton (2011), except for the wall thickness which varied from the normal published values of Barton (2011) and Freeman (2002b), however Freeman (2002b) also reported that size of the horse could potentially alter the wall thickness of the intestines. So this could be the reason for the variation in the wall thickness of jejunum.

4.1.12 Descending colon

Descending colon (DC) was found in the left paralumbar fossa, behind the last rib upto tuber-coxae, caudal to the spleen, dorsal to the jejunum and LDC and ventral to the lumbar transverse processes. It was identified by its small diameter, sacculations and packed serpentine loops. It was observed that small sections of the surface of the loops were visible as short sharply curving hyperechoic lines and when faecal balls were present in the DC these hyperechoic lines casted a strong acoustic shadowing (Plate-43).

Like the large colons the motility was sluggish with 1 to 3 contractions per minute and luminal gas prevented visualization of the contents and the distal wall of the DC. The wall thickness of DC was observed same in case of horses as well as mules and varied from 2 to 2.1 with (Mean± SE) of 2.04±0.02 mm (Plate-44).

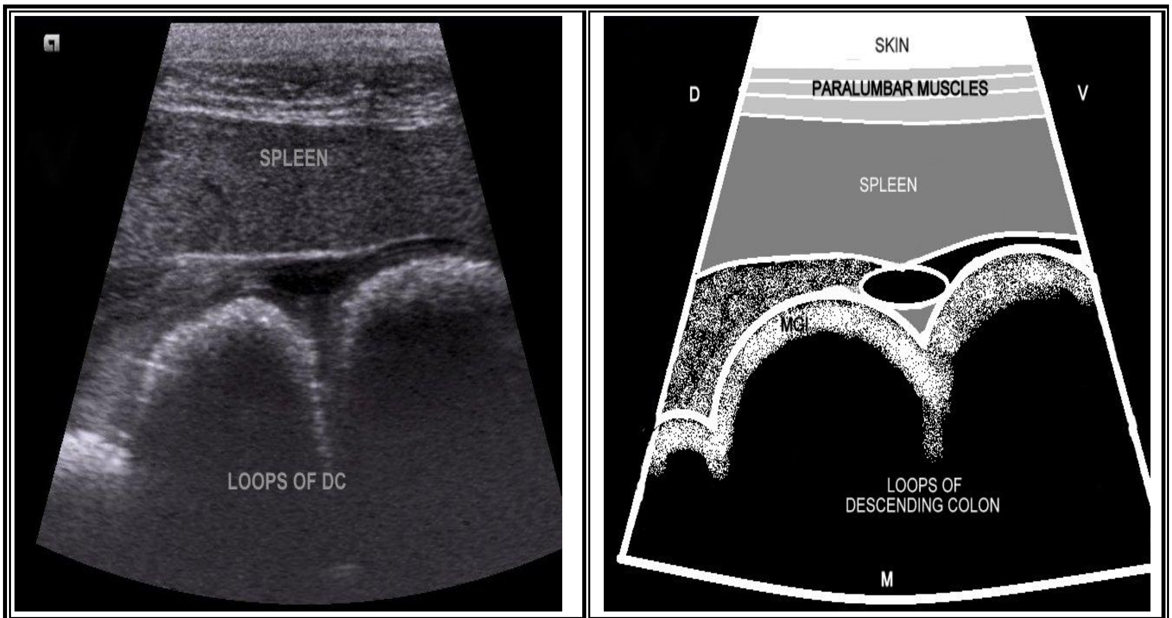


Plate-43. Ultrasonogram of loops of descending colon (Mule) at left paralumbar fossa. The image was obtained with linear transducer at 7.3 MHz at a depth of 6.5 cm.

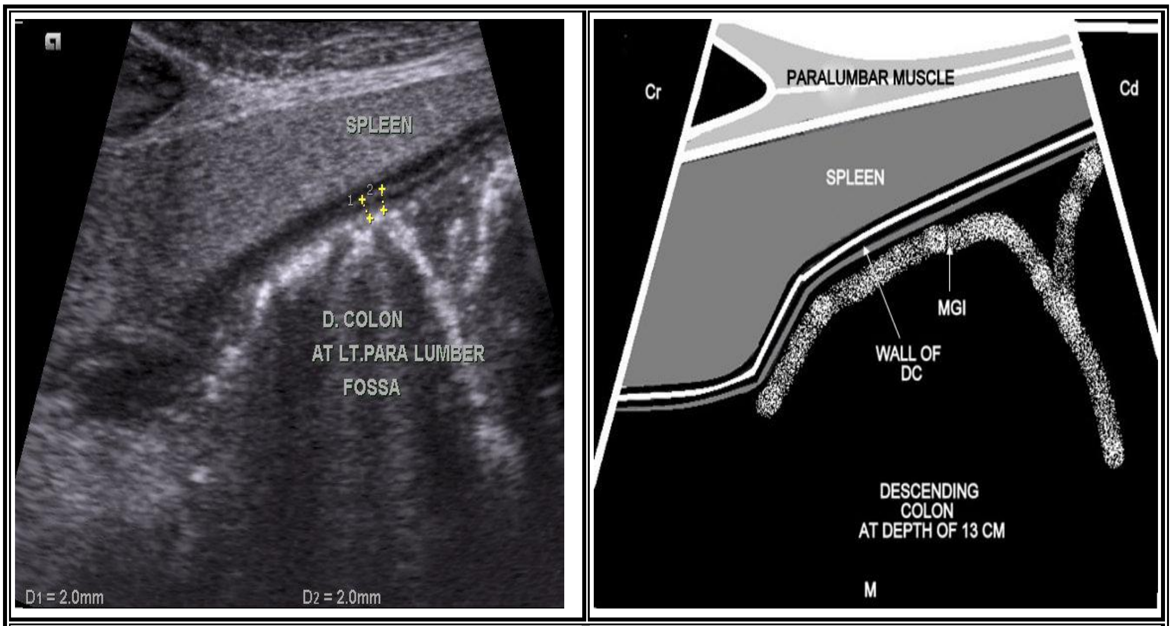


Plate-44. Ultrasonogram of loop of descending colon (Horse) at left paralumbar fossa. The image was obtained with linear transducer at 7.3 MHz at a depth of 13 cm. (MGI= mucosal gas interface, DC= descending colon)

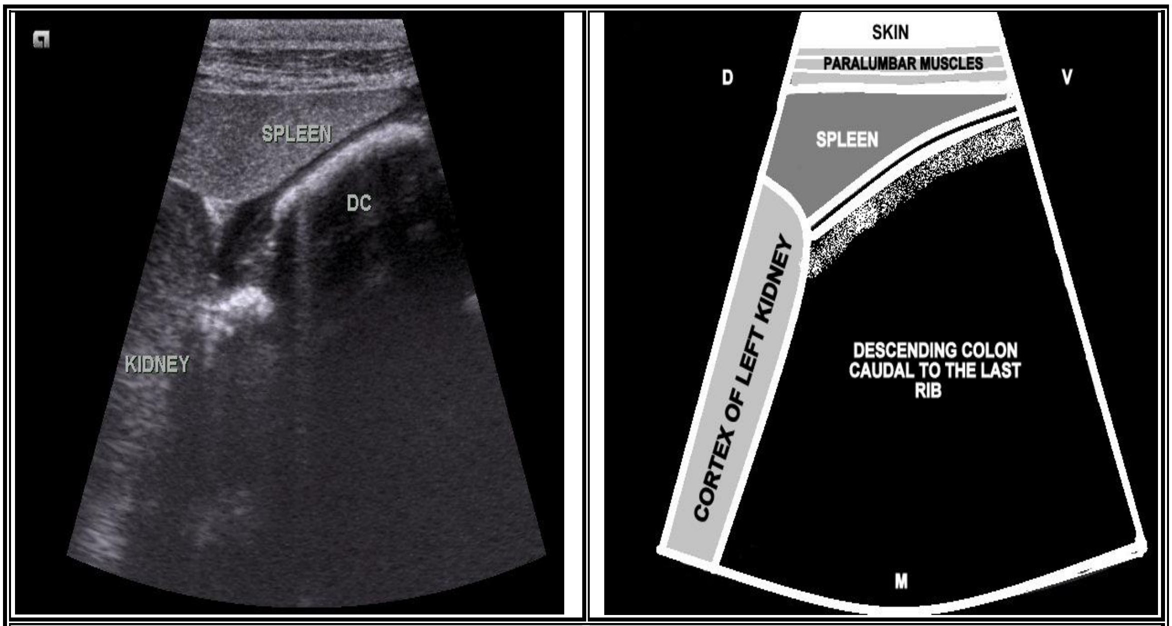


Plate-45. Ultrasonogram of descending colon (Horse) at left paralumbar fossa. The image was obtained with linear transducer at 10.0 MHz at a depth of 9.5 cm.

Reef (1998) reported that the small colon can be imaged from the ventral abdomen only through a distended urinary bladder which is used as an acoustic window. However in the present study urinary bladder could not be found through the ventral abdomen and it may be due to the gas present in the ventral colons or bladder might not be fully distended at the time of sonography, therefore small colon was not visualized through ventral abdomen in the present study. Freeman (2002b) reported that small colon can be located more easily using transrectal ultrasonography, however in the present study only transcutaneous ultrasonography was used to visualize the DC. Keller and Horney (1985) reported that the small colon is small in size with diameter of 7 to 10 cm, whereas the diameter of the small colon could not be recorded due to the strong acoustic shadowing by faecal balls present in the small colon which masked the details of the medial wall (Plate-45). Rest of the findings of the present study were in agreement with those of Keller and Horney (1985), Reef (1998), Freeman (2002b) and Barton (2011).

4.1.13 Urinary Bladder

The urinary bladder was located on transrectal ultrasonography as an oval to round structure in the caudal ventral abdomen (Plate-46). The urinary bladder appeared as anechoic with hyperechoic particles swirling inside the urine and sometimes these particles settled at the ventral portion of bladder forming sludge and caused strong acoustic shadowing.

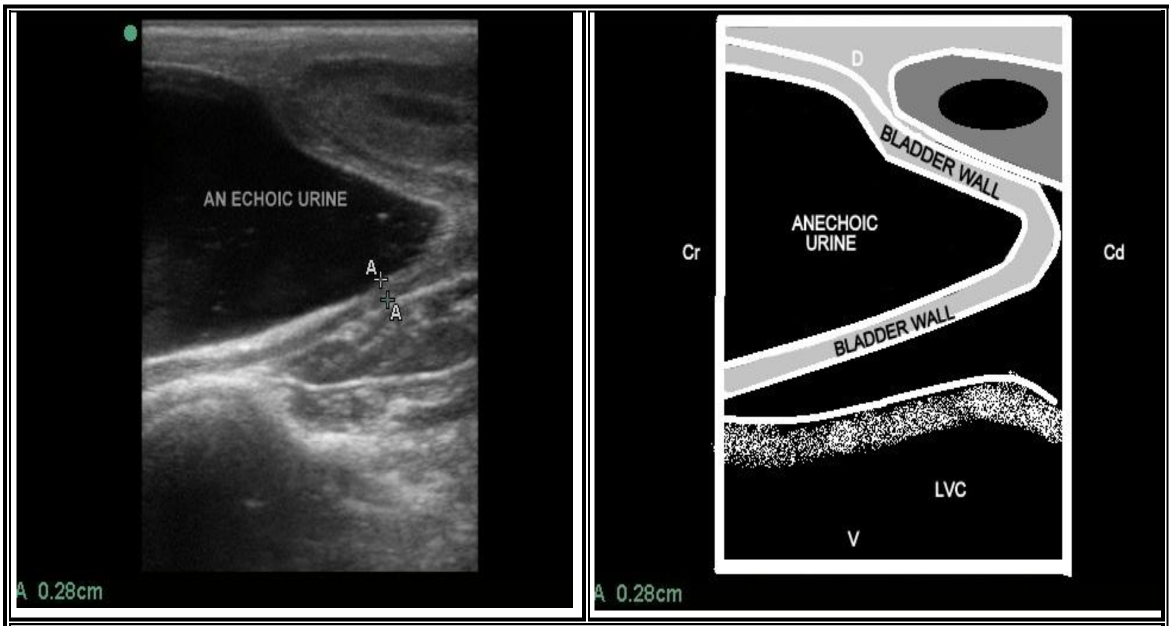


Plate-46. Ultrasonogram of urinary bladder (Horse). The image was obtained with linear transrectal transducer at a depth of 7 cm. (LVC= left ventral colon, A-A' 0.28cm= wall thickness of urinary bladder)

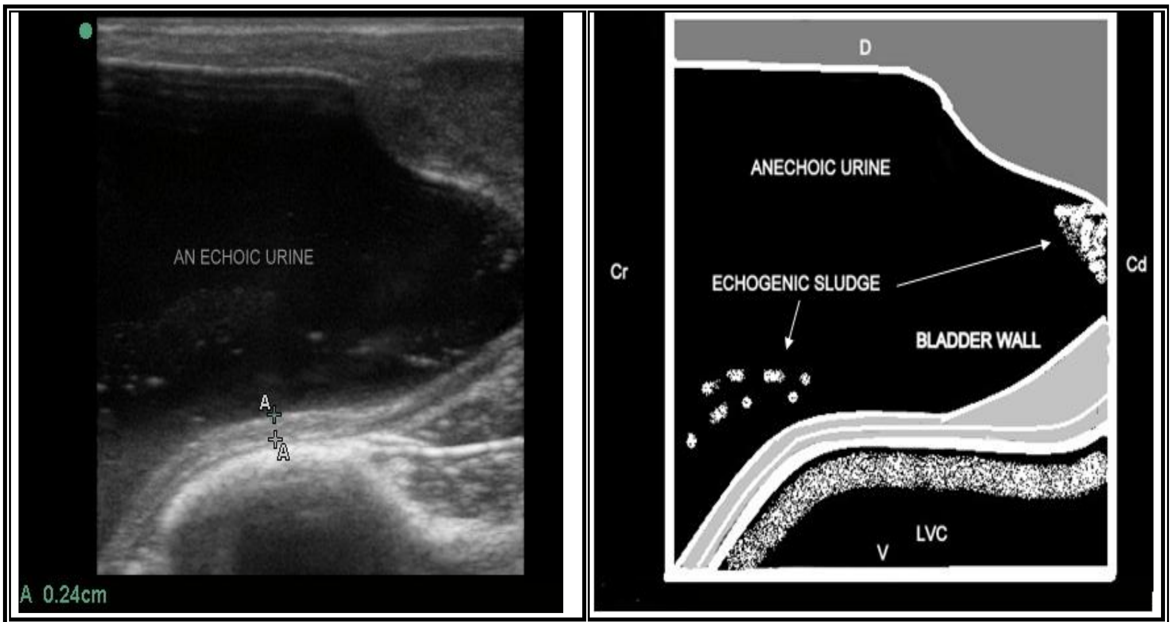


Plate-47. Ultrasonogram of urinary bladder (Mule). The image was obtained with linear transrectal transducer at a depth of 5.4 cm. (LVC= left ventral colon, A-A¯ 0.24cm= wall thickness of urinary bladder)

Due to the presence of mucous and calcium, urine appeared very echogenic (Plate-48). Schmidt (1989) reported that hyperechogenicity of urine depends on the degree of urine, mucus and crystals present.

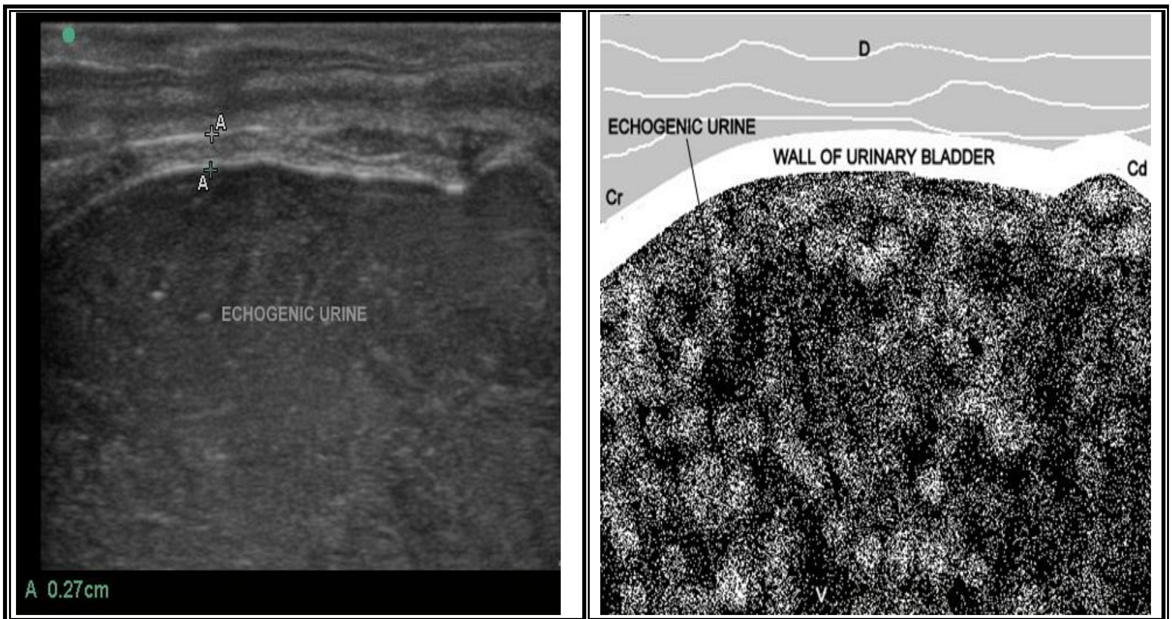


Plate-48. Ultrasonogram of urinary bladder (Horse) showing echogenic urine inside bladder. The image was obtained with linear transrectal transducer at a depth of 4.2 cm. (A-A¯ 0.27cm= wall thickness of urinary bladder)

Barton (2011) also reported this hyperechogenicity of urine is due to mucous and calcium in urine in adult horses. The urinary bladder was not imaged from transcutaneous ventral window, due to the presence of gas within the large intestine. The ureters and urethra could not be visualized in the present study. However urethra was seen only when the catheter was passed through the urethra.

Reef (1998) also reported that urethra and ureters cannot be imaged unless abnormally distended. Diaz *et al.* (2005) reported that the opening of the ureters into the urinary bladder can be imaged transrectally in the adult horse, and normal urine flow into the bladder can be imaged. The ureters appear as small echoic collapsed tubular structures with pluses of anechoic urine entering the dorsal aspect of the bladder.

However none of these features could be appreciated in the present study and the reason possibly may be the continuous straining of the animal on transrectal ultrasonography and highly echogenic urine which masked the details of the urinary bladder. In the present study the wall thickness of urinary bladder in horses varied from 2.7 to 2.8 mm with (Mean± SE) of 2.74±0.02 mm (Plate-48), while as in case of mules it varied from 2.4 to 2.7 mm with (Mean± SE) of 2.62±0.05 mm (Plate-47). However Reef (1998) reported that the normal wall thickness of bladder should measure between 0.3 to 0.6 cm. Therefore these differences regarding the wall thickness of the urinary bladder in local horses and mules may be possibly attributed to the variations in the body weight/size, breed type and/or hybrid (interspecies variation) nature of mules.

The concised information pertaining to clinical, hematological, biochemical parameters, wall thickness of different organs, peristaltic motility pattern of different organs and topographic scanning areas of different abdominal organs for ready reference are being tabulated in Annexure (Table no. 13 to 21).

Clinical Case Studies

4.2 Clinical phase

Abdominal ultrasonography was performed in 14 clinical cases of equines suffering from various diseases for ascertaining the diagnostic utility of ultrasonography. The disease classification of the cases studied is presented in the tabulated form below:

Table 4. Abdominal diseases of equids subjected to ultrasonography

Disease		Number of cases
Colonic Impactions occurring with ingesta and sand	LVC (n=4)	4
Enteroliths of Descending Colon/Small Colon		4
Jejunal Intussusception along with enterolith and LVC impaction		1
Urinary Bladder Rupture		1
Peritonitis		1
Stercoral Fistula of RVC		1
Renal Abscessation along with Cystitis		1
Enteritis along with LVC impaction		1

Colonic Impactions

4.2.1 Left ventral colon impactions

Four mules (age 10-13 years) with history of cessation of defecation ranging from 2-4 days were presented. The initial signs of colic were manifested by kicking at belly, stamping at the ground, frequent rolling, sweating, muscle tremors especially of hind quarters and repeated attempts to void faeces but could only pass scanty mucus. Other associated symptoms were anorexia and reduced urine output. All the affected animals were treated with analgesics, diuretics and liver tonics before referral.

On physical examination all the animals were dull, depressed and dehydrated (status of dehydration was calculated as per Barton 2002, Table-1) with mild congestion of conjunctival mucus membranes and gum perfusion time (GPT) of 2 seconds. Heart rate and respiration rate were slightly increased (Table-5). Mild distention of the left side abdomen was seen along with hypothermia in two animals. In 3 cases, abdominal auscultation revealed mild tinkling and fluid splashing sounds of borborygmi whereas no audible sound was heard in one animal. After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In the mean time electrocardiography was performed and animals were stabilized by administering intravenous fluids. Once the animals were stabilized, lubrication of the rectum with liquid paraffin was done and transrectal examination was performed, which revealed absence of faecal material with dryness of rectal mucosa and distended intestinal loops. But impaction could not be ascertained due to animal's violent straining, frequent attempts to lie down and apprehension of rectal tear. In all the animals whatever the faecal material present in the rectum was collected for parasitological examination. Following physical examination, the animals were prepared for ultrasonography.

Table 5. Clinical parameters in case of left ventral colon impactions in 4 animals.

Parameters	Mean±SE	Reference range	Parameters	Mean±SE	Reference range
Rectal temperature (˚F)	100.3±0.53	99.5-101.5	ALT (u/L)	25.75±5.97	3-23
Respiration rate/min	16.5±1.25	10-15	AST (u/L)	307.75±46.90	226-366
Heart rate/min	56.5±8.08	25-45	ALKP (u/L)	156±19.90	143-395
Hemoglobin (g/dL)	16.65±0.34	11-19	BUN (mg/dL)	19.82±4.15	10-24
PCV (%)	46.2±1.19	32-53	Creatinine (mg/dL)	1.37±0.24	0.9-1.9
TLC(×10^9/L)	11.65±1.14	5.4-14.3	Glucose (mg/dL)	111.75±22.35	75-115
Lymphocytes (%)	35.22±5.12	17-68	Bilirubin (mg/dL)	3.22±0.78	1-2
Monocytes (%)	2.15±0.23	0-14	Protein (g/dL)	7.6±0.35	5.5-8
Granulocytes (%)	62.62±5.14	22-72			

I. Ultrasonographic observations of left ventral colon impactions

On ultrasonography the left ventral colon wall was found flattened against the ventral body wall with loss of normal sacculations and peristaltic movement in three animals, while in one animal the sacculations were present but the wall of LVC was seen edematous with increased wall thickness (Plate-49), but absence of peristaltic activity. Similar findings were reported by Freeman (2002a). In one animal the investigation of the more cranio-dorsal portion of the LVC revealed normal wall thickness with presence of mixed echogenic ingesta (Plate-50).

Inflamed wall of the LVC without loss of sacculations and strong acoustic shadowing due to impacted ingesta

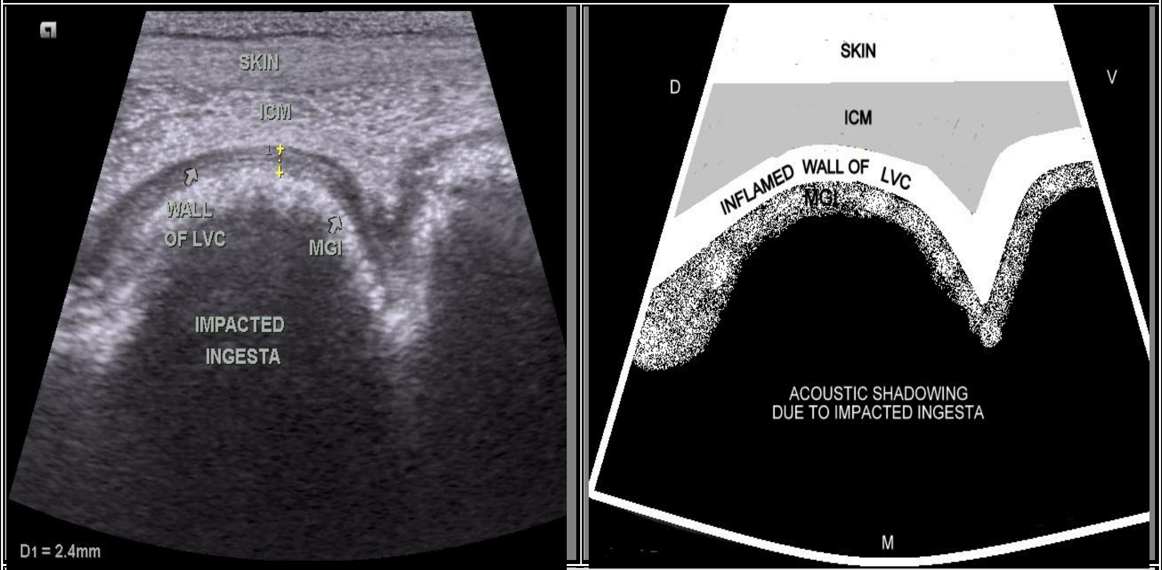


Plate-49. Ultrasonogram of impacted LVC (Mule) at lower flank. The image was obtained with 5.3 MHz linear transducer at a depth of 5.5 cm. (LVC= left ventral colon, MGI= mucosal gas interface)

Reef *et al.* (2004) stated that the bowel wall may be of normal thickness or may be thicker than the normal and there is a large acoustic shadow cast from the impacted ingesta adjacent to the colonic mucosa. The impaction of LVC in all animals was imaged as hyperechoic intraluminal structure casting a strong acoustic shadow (Plate-51).

Cranio-dorsal portion of the same LVC at 10th ICS with normal wall thickness and echogenic ingesta

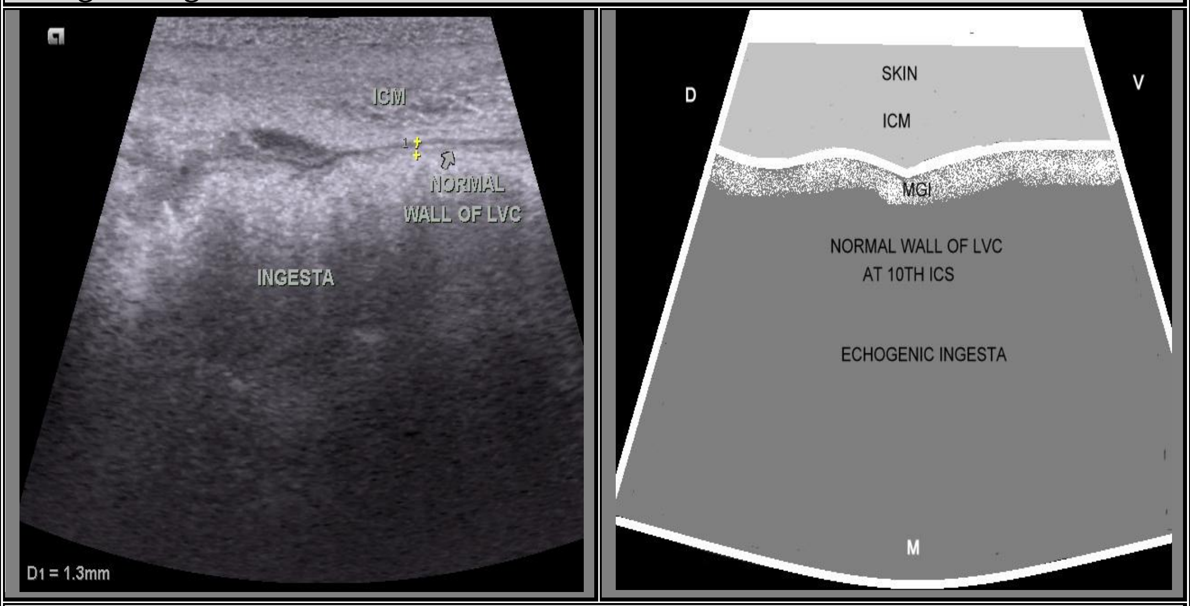


Plate-50. Ultrasonogram of LVC (Mule). The image was obtained at 5.3 MHz with linear transducer at a depth of 5.5 cm. (ICM= intercostal muscles, MGI= mucosal gas interface)

Compression of ventral abdominal muscles, inability to identify the LVC wall due to severe distention of LVC.

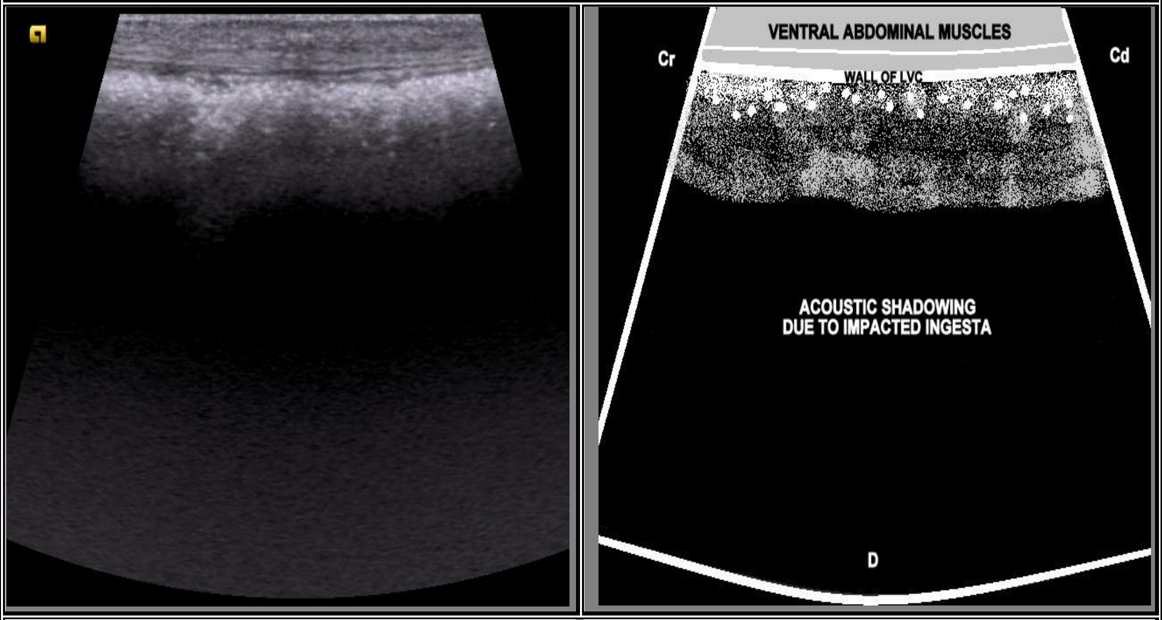


Plate-51. Ultrasonogram of impacted LVC. The image was obtained at 5.3 MHz with linear transducer at a depth of 6.5 cm. (LVC= left ventral colon)

In two animals, towards ventral abdomen small pinpoint hyperechoic structures on the mucosal surface were seen casting small acoustic shadows in different directions depending upon the fanning of the beam which were highly suggestive of sand impaction.

Korolainen and Ruohoniemi (2002) also found that impactions appear as hyperechoic line casting an acoustic shadow from the mucosal surface, whereas small hyperechoic particles causing reverberation artifacts are consistent with sand impaction.

Reef (1998) reported similar findings and in addition to this he also found fluid distention of the more proximal small intestine in horses with large colon or caecal impactions. In all the animals the loops of small intestine were observed in transverse as well as longitudinal sections as hypermotile distended with fluidy ingesta and hyperechoic feed particles swirling inside that fluidly ingesta (Plate-52).

Dilated loops of jejunum filled with echogenic ingesta. Consistent feature of LVC impaction

Plate-52. Ultrasonogram of dilated loops of jejunum (longitudinal section). The image was obtained at 3.3 MHz with volumetric (4D) transducer at a depth of 15 cm.

Presence of dilated multiple loops of intestine in a single scanning area

Plate-53. Ultrasonogram of dilated multiple loops of jejunum (cross section). The image was obtained at 5.3 MHz with linear transrectal transducer at a depth of 6.5 cm.

The presence of dilated multiple loops of intestine in a single scanning area was also observed in two animals. This happens due to excessive entrapment of gases as well as ingesta in the lumen of the intestinal segments proximal to the obstruction (Plate-53).

Impacted LVC with internal reverberation due to large amount of gas in the LVC

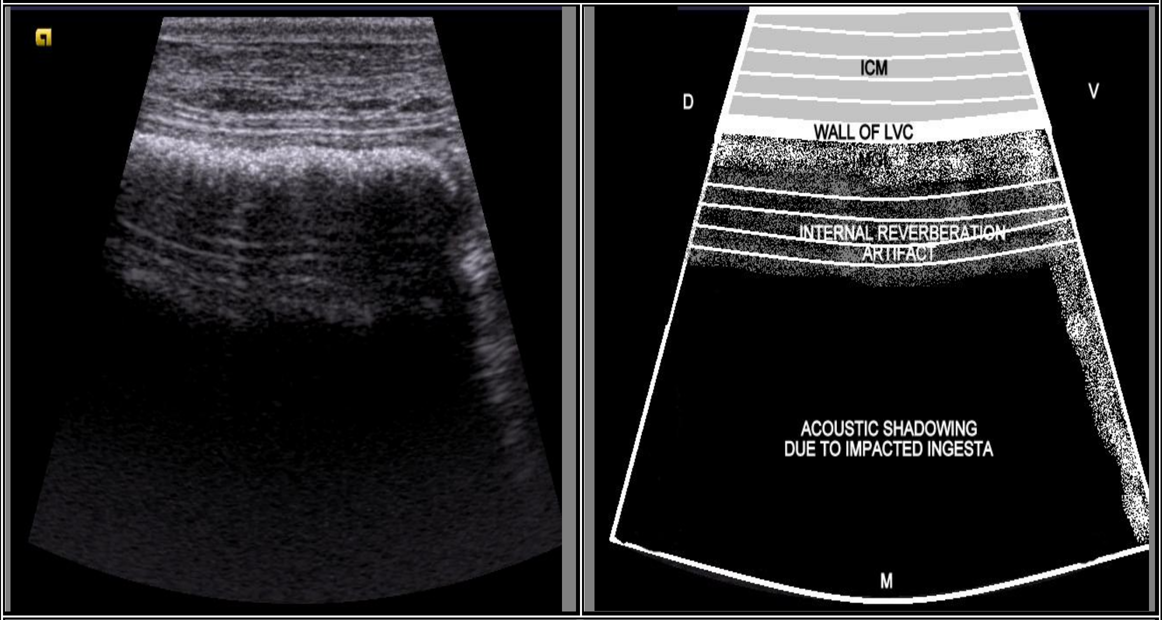


Plate-54. Ultrasonogram of LVC (Mule) at 12th ICS The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm. (LVC= left ventral colon, ICM= intercostal muscles)

Thus ultrasonography proved to be a useful tool in diagnosis of LVC impactions. After proper diagnosis all the animals were treated conservatively as mentioned below:

a. Analgesics
b. Anti-inflammatory drugs
c. Antibiotics
d. Tetanus toxiod (5ml)
e. Intravenous fluid therapy (NS, DNS and RL)
f. Oral fluids (Luke warm water 4 to 5 ltr, simethicone 200 ml, liquid paraffin 1ltr, linseed oil 1ltr) through Nasogastric tube (Smiths medical International Ltd. UK) only after ruling out the presence of nasogastric reflux. The satisfactory restoration of frequency of defecation and consistency of stools was ascertained and subsequently the patients were discharged.

4.2.2 Jejunal-Jejunal intussusception with impaction of LVC, RVC and obstruction of descending colon

One female mule of (18 years age) was presented with history of cessation of defecation with severe abdominal pain from last four days. The initial signs of colic were manifested by stamping at the ground, paddling of the limbs, frequent rolling, sweating, muscle tremors especially of hind quarters and repeated attempts to void faeces. Other associated symptoms were anorexia and reduced urine output. The animal was earlier treated with liquid paraffin, analgesics, antibiotics, anti inflammatory drugs and liver tonics but due to persistent abdominal pain despite regular administration of analgesics the animal was referred for further evaluation by local attending Veterinarian.

Abnormal findings during physical examination of the animal included dullness, depression with moderate dehydration and mild congestion of conjunctival mucus membrane, elevated heart and respiration rate (Table-6) and absence of intestinal motility on auscultation and GPT of 3 seconds.

After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In this animal electrocardiography could not be done as the animal was making frequent attempts to lie down. Animal was stabilized by administering intravenous fluids. Once the animals was stabilized, lubrication of the rectum with liquid paraffin was done and transrectal examination was performed, which revealed absence of faecal material with dryness of rectal mucosa, distended intestinal loops and presence of a firm mass at the pelvic flexure cranial to the pelvic brim. The fecal matter collected during this procedure was kept for parasitological examination. Following physical examination, the animals was prepared for ultrasonography.

Table 6. Clinical parameters in case of intestinal intussusception of mule.

Parameters	Values	Reference range	Parameters	Values	Reference range
Rectal temperature (˚F)	100.4	99.5-101.5	ALT (u/L)	40	3-23
Respiration rate/min	52	10-15	AST (u/L)	429	226-366
Heart rate/min	96	25-45	ALKP (u/L)	830	143-395
Hemoglobin (g/dL)	19.5	11-19	BUN (mg/dL)	26.2	10-24
PCV (%)	54.2	32-53	Creatinine (mg/dL)	1.6	0.9-1.9
TLC($\times 10^9$/L)	15.2	5.4-14.3	Glucose (mg/dL)	68	75-115
Lymphocytes (%)	40.4	17-68	Bilirubin (mg/dL)	0.9	1-2
Monocytes (%)	2.4	0-14	Protein (g/dL)	9	5.5-8
Granulocytes (%)	57.2	22-72			

I. Ultrasonographic observation

On abdominal ultrasonography, the left ventral colon and right ventral colonic walls was found flattened against the ventral body wall with loss of normal sacculations and peristaltic movement suggestive of LVC and RVC impactions. The impactions were imaged as hyperechoic intraluminal structures casting a strong acoustic shadow masking the details of the inner organs. Korolainen and Ruohoniemi (2002) and Reef *et al.* (2004) also stated the same ultrasonographic findings for colonic impactions. As the transducer was moved towards the left mid abdomen i.e. ventral to the left flank region to scan jejunum a multilayered mass of elliptical or circular rings with typical onion peeling pattern of varying echogenicities was seen and was highly suggestive of jejunal intussusception (Plate-55).

Scharner *et al.* (2002) also reported the similar ultrasonographic features i.e. multiple concentric rings of varying thickness and echogenicity for intestinal intussusceptions The intussuscipiens (enveloping segment) was seen as echogenic layers with hypoechogenic segment indicative of edema; whereas, the intussusceptum (invaginated segment) was seen echogenic to hypoechoic with a hypoechoic core giving it a characteristic " Bulls eye" or target lesion appearance when imaged across the short axis of the jejunum.

Bernard *et al.* (1989) reported that the diagnosis of intussusception of small intestine is made by identifying a "Bulls eye" sign or target like lesion and this is obtained by scanning through the apex of the intussusception and this appearance is created by the difference in acoustic impedance between the thick walled, congested, edematous inner intussusceptum and the outer intussuscipiens and the interposed fluid layer and intussusception appear as two concentric rings with a central area of echogenic core representing the inner lumen of the intussusceptum and this appearance occurs where the walls of the intussusceptum and intussuscipiens are less edematous.

Typical onion peeling pattern of varying echogenicities, or “Bulls eye” sign or target like lesion of jejunal intussusception

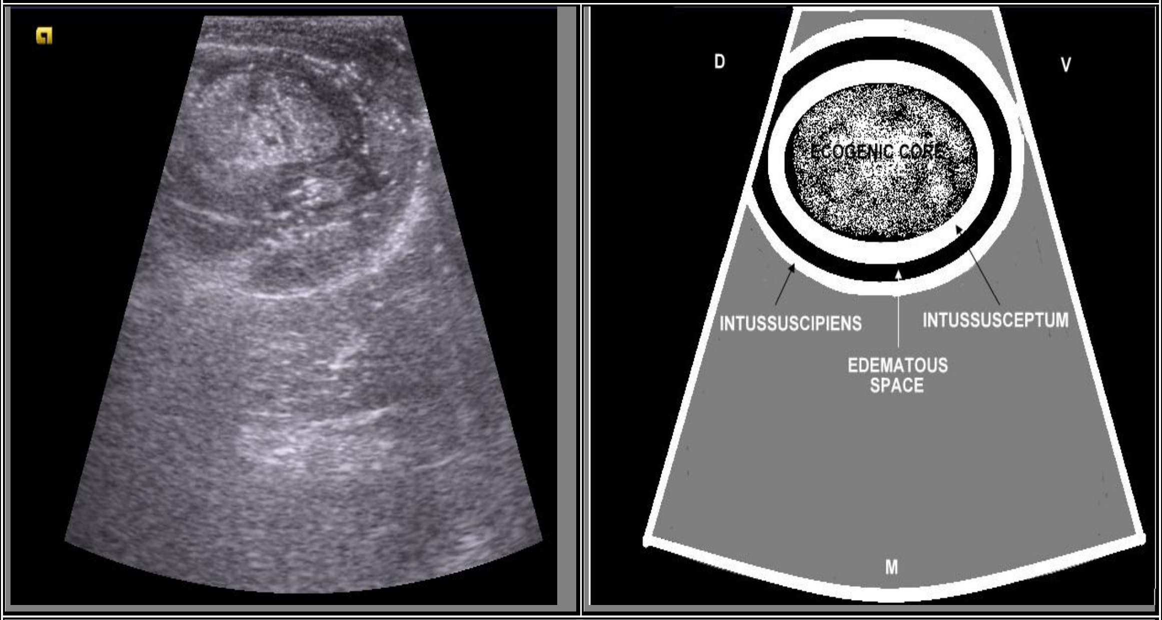


Plate-55. Ultrasonogram of jejunal-jejunal intussusception in (Mule) left mid flank area cross section. The image was obtained at 7.3 MHz with linear transducer at a depth of 9.0 cm.

In the present study the intussuscipien and the intussusceptum were separated by an anechoic space (Plate-55). McGaddery (1996) reported that the intussusceptions appear as symmetric and multiple concentric rings representing wall layers of the intussusceptum and intussuscipiens. The intussusceptum usually appears as a central echogenic core representing normal bowel layering. Occasionally, invaginated mesenteric fat, fluid or fibrin may be present between the intussusceptum and intussuscipien and if the walls are compromised, they may appear hypoechoic because of edema.

Rodgerson and Rodgerson (2001) in their study of 2 cases of intestinal intussusception also stated the same finding as in the present study. McAuliffe (2004) stated that on ultrasonography intussusceptions give a characteristic “Bulls eye” or “Target” appearance, where the intussusceptum is surrounded by fluid and the intussuscipien Longitudinal scanning in the present study comprised of echogenic parallel lines separated by hypoechoic lines with a hypoechoic core giving it a “Sandwich” appearance when imaged across the long axis of the jejunum (Plate-56). Karapinar and Kon (2007) also stated that the longitudinal imaging of intussusception gives “Sand wich” configuration in case of jejunoileal intussusception in a cow.

"Sandwich" appearance of jejunal-jejunal intussusception across the long axis of the jejunum

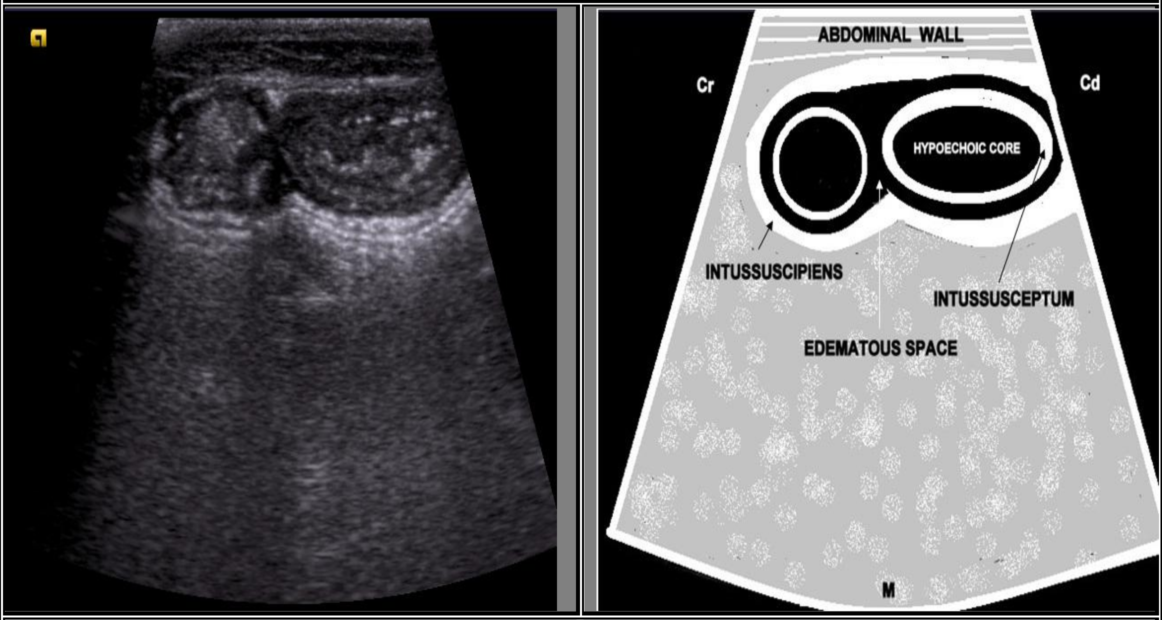


Plate-56. Ultrasonogram of jejunal-jejunal intussusception longitudinal section. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm.

On further scanning towards flank region a large hyperechoic mass casting a strong acoustic shadow was imaged in the lumen of the descending colon suggestive of obstruction of the descending colon (feacolith) with loss of normal sacculations and peristaltic movement of descending colon.

Reef (1998) reported that the impaction or obstruction of the small colon is usually imaged as a hyperechoic intraluminal structure casting an acoustic shadow with loss of normal sacculations and peristaltic activity. Reef *et al*. (2004) also stated that enteroliths appear as a large hyperechoic masses casting a strong acoustic shadow within the lumen of the intestine (Plate-57). Stomach was found distended upto 16th ICS which might be secondary to the obstruction.

The greater curvature of the stomach appeared less semicircular and spleen was displaced caudally and contents of the stomach appeared hypoechoic with small hyperechoic feed particles floating inside the fluid. Scharner (2002) also stated the same findings in horses suffering from gastric distension secondary to the small intestinal obstruction. Therefore a diagnosis of three conditions i.e. intussusception, impaction of LVC, RVC and obstruction of small colon was made and obstruction of small colon may have lead to the secondary impactions of large colons and intussusception may have occurred due to continuous straining and repeated attempts by animal to void the faeces. This animal collapsed within 15 minutes during a period of stabilization

Loss of sacculations and strong acoustic shadowing due to obstructed mass in DC

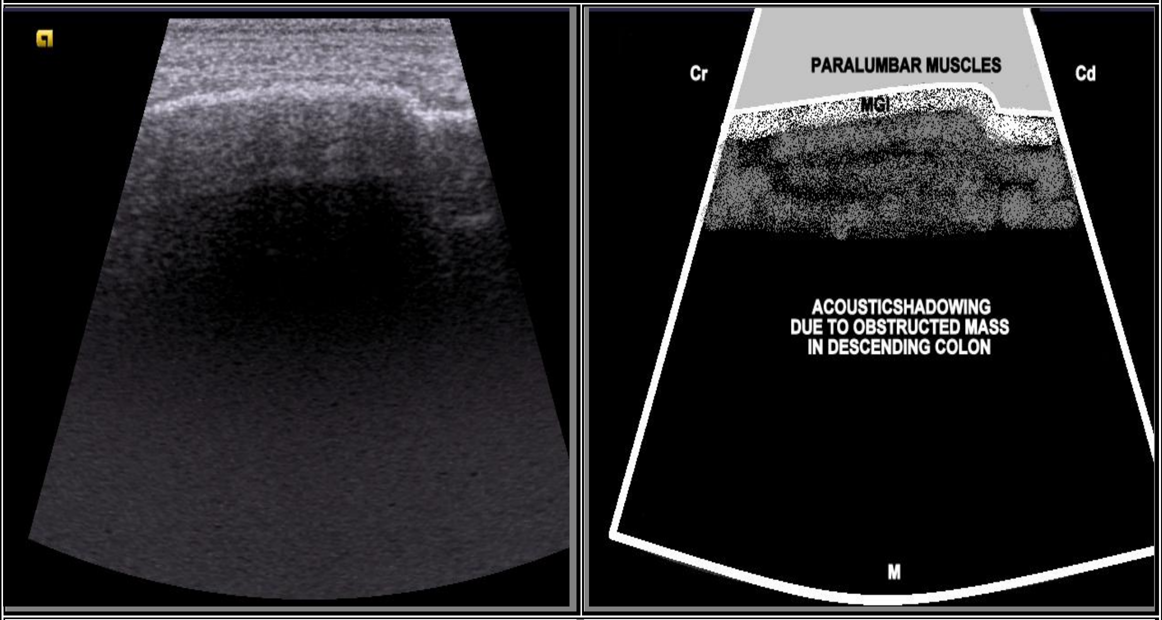


Plate-57. Ultrasonogram of obstructed descending colon (Mule) at left Paralumbar fossa. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm. (MGI= mucosal gas interface)

On post mortem examination (PME) the ultrasonographic findings were found in consistent with the PM findings. Jejunal-jejunal intussusception of about one meter was observed, the affected part of jejunum was edematous with cyanotic changes.

The large colons were found impacted with dry ingesta with mixed sand and a feacolith of about 20 cm was found in DC which has led to the hemorrhagic and necrotic changes in the wall of the DC. The proximal and distal part of the DC was found empty and corrugated.

4.2.3 Obstruction of Descending Colon

Out of four patients three animals (2 horses and 1 mule) age ranging from 10-14 years were presented with history of abdominal pain and cessation of defecation ranging from 2-3 days. The initial signs of colic were manifested by kicking at belly, pawing at the ground, frequent rolling, sweating, muscle tremors especially of hind quarters and repeated attempts to void faeces but could pass only scanty mucous. It was found that all the animals had lost their appetite since the start of abdominal pain. All the affected animals were earlier treated with analgesics, diuretics and liver tonics, but due to persistent abdominal pain despite regular administration of analgesics the animal was referred for further evaluation by local attending paravets. While the fourth animal (mule) was presented with a history of mass protruding from the rectum from last one day. According to the history feed and water intake of animal was reduced, but urination was normal.

On physical examination all the animals were dull, depressed and dehydrated with mild to severe congestion of conjunctival mucus membranes and GPT of 3 seconds. Heart rate and respiration rate were elevated in all the four animals (Table-7). Distention of the abdomen was seen in three animals at the time of presentation while as in the fourth animal suffering from rectal prolapse the distention was seen after 48 hrs of presentation. In 2 cases, abdominal auscultation revealed mild tinkling and fluid splashing sounds of borborygmi whereas no audible sound was heard in other 2 animals.

After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In the mean time electrocardiography could be done in two animals only and animals were stabilized by administering intravenous fluids. Once the animals were stabilized, lubrication of the rectum with liquid paraffin was done in three animals and transrectal examination was performed, which revealed absence of faecal material with dryness of rectal mucosa and distended intestinal loops. As the animals were of smaller size, therefore due to animal's violent straining, frequent attempts to lie down and apprehension of rectal tear, thorough per-rectal examination could not be done. In all the animals whatever the faecal material present in the rectum was collected for parasitological examination. All the three animals showed severe bilateral abdominal distention which was relieved by caecum puncture with 16 gauge needle from right flank taking all aseptic measures. Following physical examination, the animals were prepared for ultrasonography.

While in fourth animal (mule with rectal prolapse) the prolapsed mass was washed with normal saline and after liberal application of ointment lignocaine jelly and ointment soframycin, the prolapsed mass was reposed. The animal didn't showed improvement and the signs of colic were persistent. This animal was maintained and treated conservatively and then subjected to ultrasonography.

Table 7. Clinical parameters in case of small colon obstruction in 4 animals.

Parameters	Mean±SE	Reference range	Parameters	Mean±SE	Reference range
Rectal temperature(°F)	101.8±0.76	99.5-101.5	ALT (u/L)	57.15±14.74	3-23
Respiration rate/min	33.5±4.11	10-15	AST (u/L)	375.25±45.57	226-366
Heart rate/min	96.5±3.50	25-45	ALKP (u/L)	834.75±114.27	143-395
Hemoglobin (g/dL)	18.12±0.77	11-19	BUN (mg/dL)	31.9±7.81	10-24
PCV (%)	49±3.32	32-53	Creatinine (mg/dL)	1.52±0.16	0.9-1.9
TLC($\times 10^9$/L)	10.77±2.28	5.4-14.3	Glucose (mg/dL)	94±22.43	75-115
Lymphocytes (%)	28.72±4.29	17-68	Bilirubin (mg/dL)	1.5±0.44	1-2
Monocytes (%)	3.42±0.88	0-14	Protein(g/dL)	8.75±0.48	5.5-8
Granulocytes (%)	67.82±3.62	22-72			

I. Ultrasonographic findings:

On ultrasonography in one animal the left ventral colon wall was found flattened against the ventral body wall with loss of normal sacculations and peristaltic movement suggestive of LVC impaction. The impaction was imaged as hyperechoic intraluminal structures casting strong acoustic shadows and masking the details of the medial side (Plate-58). The findings were in agreement with that of Korolainen and Ruohoniemi (2002) and Reef (1998), but in RVC the hypermotile strong churning movements of the ingesta were observed. The stomach was not distended and caecum was found hypermotile, but small intestine could not be appreciated. On scanning the left paralumbar fossa a large hyperechoic mass casting a strong acoustic shadow was imaged in the lumen of the descending colon suggestive of obstruction of the descending colon (feacolith) with loss of normal sacculations and peristaltic movement of descending colon (Plate-59, 60 and 61). The findings were in agreement with that of Reef *et al.* (2004) and Reef (1998) but no literature was found about the finding i.e. (strong churning movements of the ingesta in ventral colons) which according to our study is a very significant and typical finding in descending colon obstructions.

Typical loss of sacculations of LVC with strong acoustic shadowing.

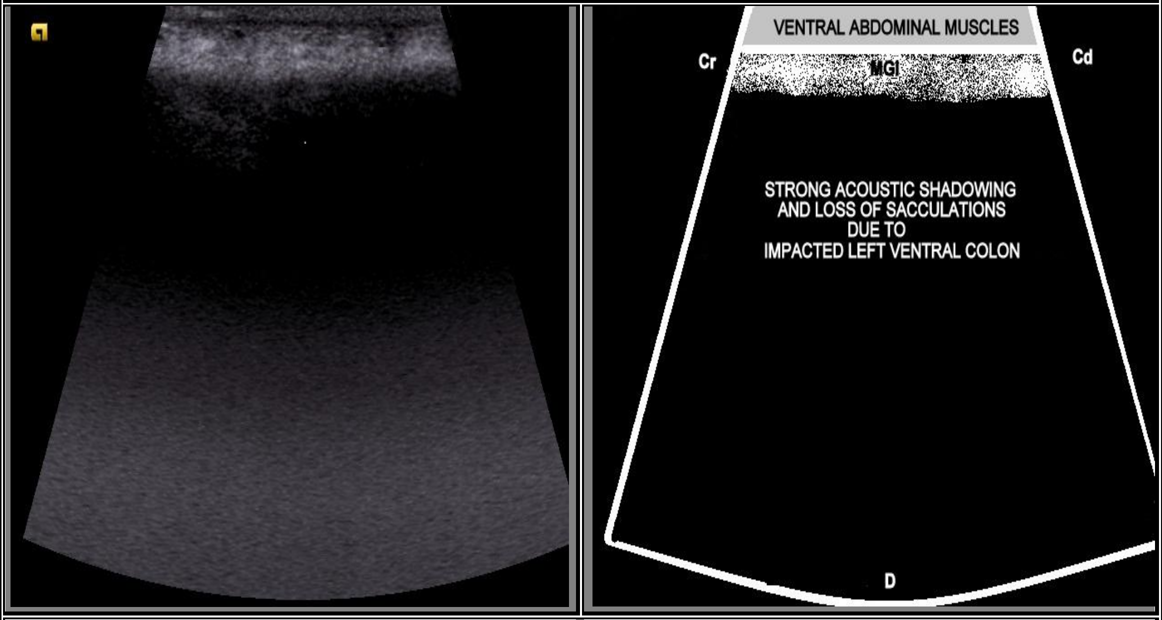


Plate-58. Ultrasonogram of impacted LVC. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm.

Obstructed DC casting acoustic shadow and accumulation of gas and ingesta proximal to the obstruction at left paralumbar fossa.

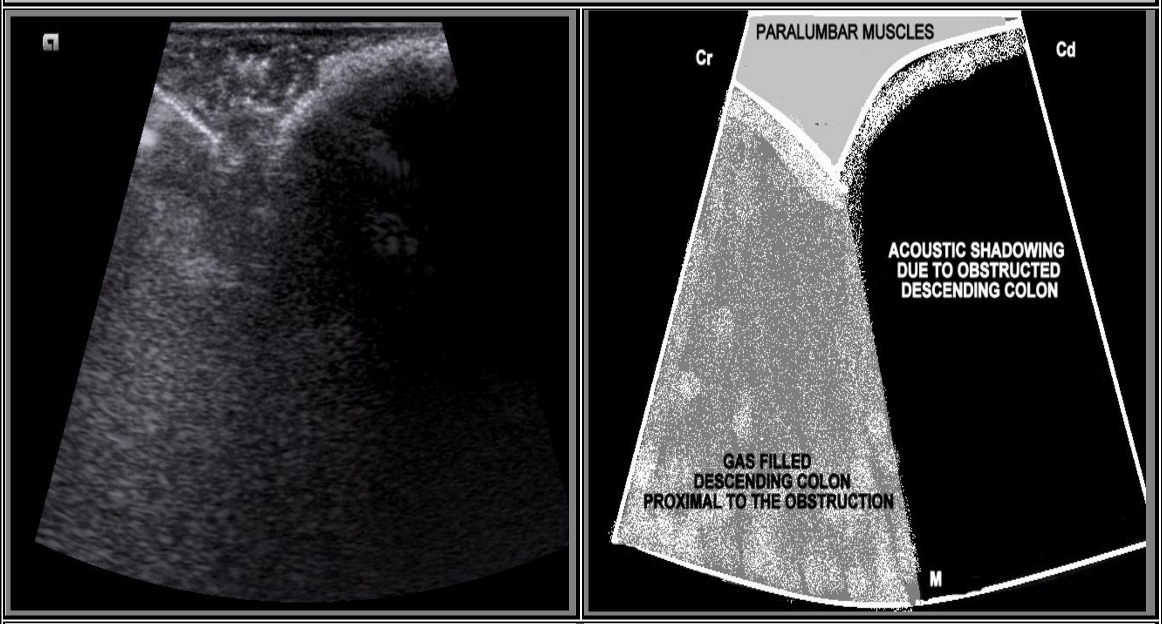


Plate-59. Ultrasonogram of Descending colon. The image was obtained at 10.0 MHz with linear transducer at a depth of 6.5 cm.

Accumulation of gas and ingesta proximal to the obstructed DC (In dual image mode).

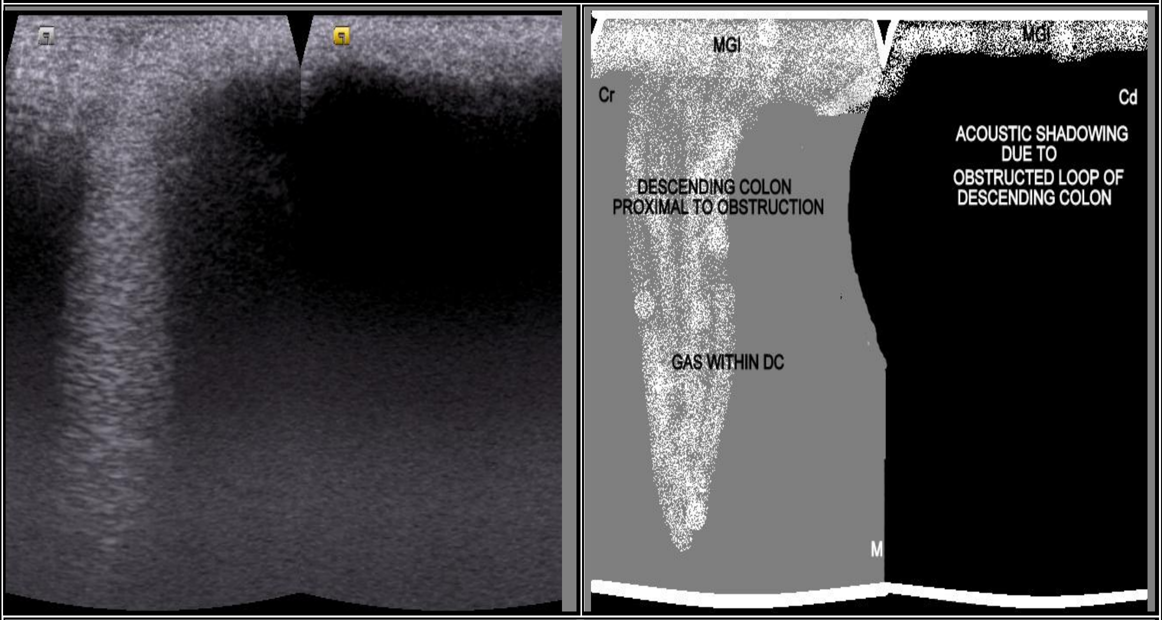


Plate-60. Ultrasonogram of DC. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm. (DC= descending colon)

In other two animals the same hypermotile strong churning movements of the ingesta were observed in both ventral colons and again on scanning the left paralumbar fossa a large hyperechoic mass casting a strong acoustic shadow was imaged in the lumen of the descending colon with loss of normal sacculations and peristaltic movement of descending colon (Plate-61, 62 & 63).

The intestines were found distended and filled with echogenic ingesta. In fourth animal the large ventral colons (LVC and RVC) were found impacted and on ultrasonography appeared as flattened against the ventral body wall with loss of normal sacculations and peristaltic movement.

The impactions were imaged as hyperechoic intraluminal structures casting strong acoustic shadows and masking the details of the medial side. The small intestines were having sluggish motility and filled with anechoic fluidly ingesta. No distention of stomach was observed.

Loss of sacculations of DC due to obstructed mass and reverberation due to presence of gas

Plate-61. Ultrasonogram of obstructed DC. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm.

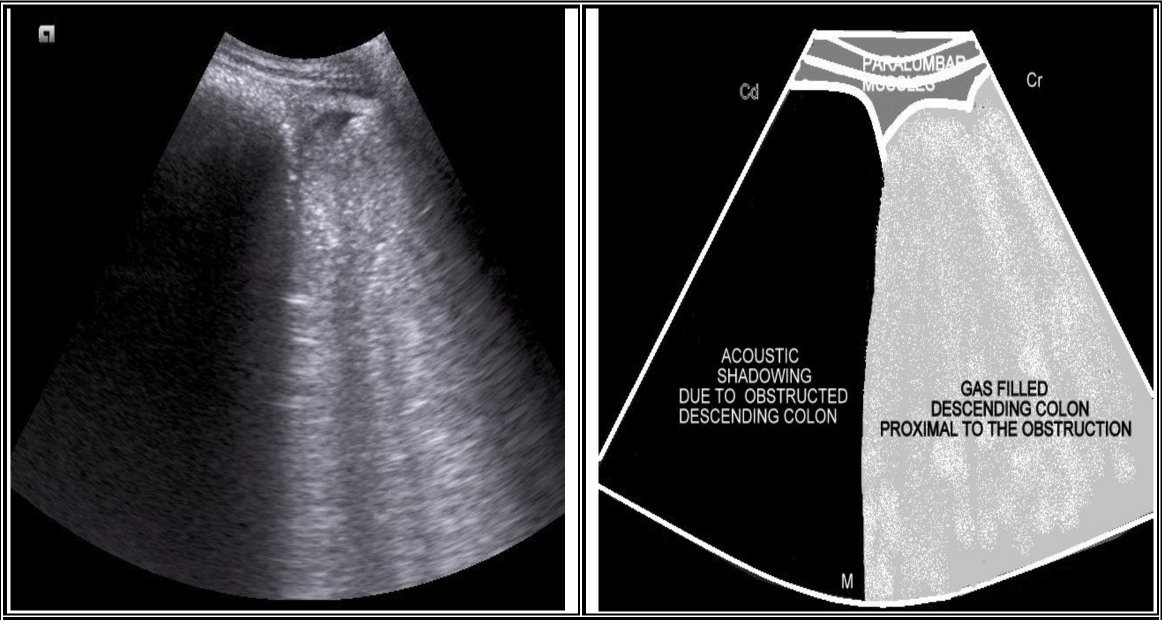


Plate62. Ultrasonogram of obstructed DC at left Paralumbar fossa. The image was obtained at 3.3 MHz with volumetric (4D) transducer at a depth of 13 cm.

Heavy acoustic shadowing due to obstructed mass

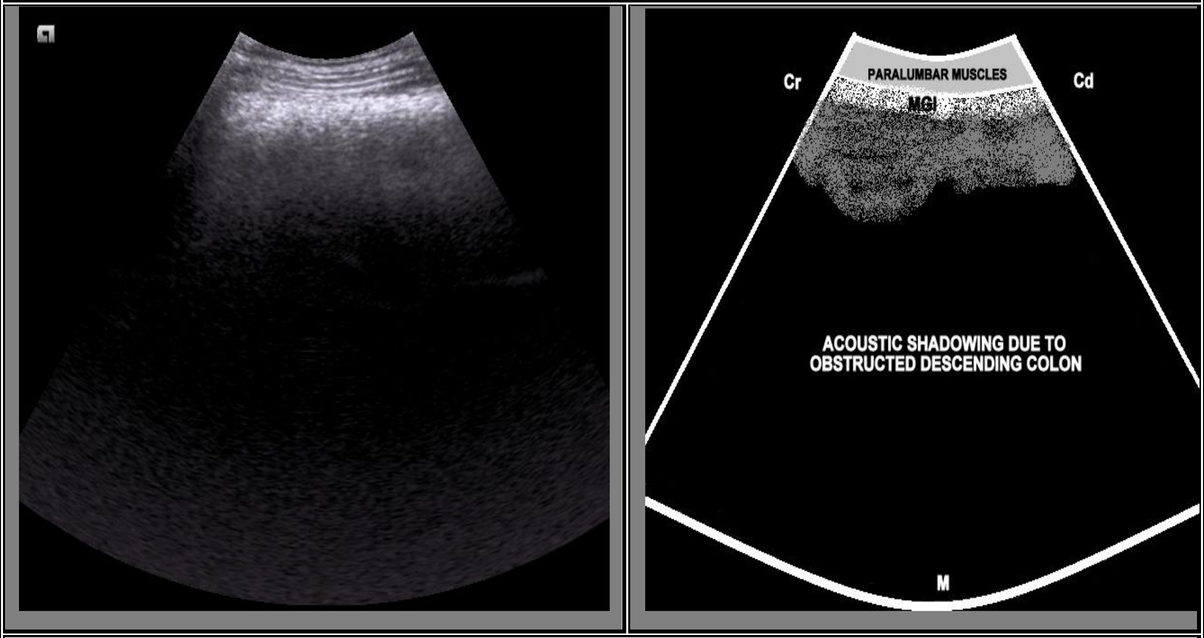


Plate-63. Ultrasonogram of obstructed DC at left Paralumbar fossa. The image was obtained at 3.3 MHz with volumetric (4D)transducer at a depth of 13 cm.

Thus ultrasonography proved to be a useful tool in diagnosis of impactions and obstructions of large and small colon. After proper diagnosis all the animals were provided conservative treatment mentioned below:

a. Analgesics
b. Anti-inflammatory drugs
c. Antibiotics
d. Tetanus toxiod (5ml)
e. Intravenous fluid therapy (NS, DNS and RL)
f. Oral fluids (Luke warm water 4 to 5 ltr, simethicone 200 ml, liquid paraffin 1ltr, linseed oil 1ltr) all of them were give through Nasogastric tube only, if no nasogastric reflux was found.

Out of these four animals 2 animals were not found fit for the immediate surgery therefore it was decided to operate them the next morning after stabilizing them but both the animals died during the intervening night due to severe distention of the abdomen. While the third animal was operated immediately after the ultrasonography and when the feacolith of the DC was being removed animal collapsed during surgery (Plate-63a and 63b).

The fourth animal was put on above mentioned treatment but abdominal distention was consistent due to which animal showed severe signs of pain as this animal was suffering from rectal prolapse therefore transrectal examination was not done due to the fear of reoccurrence of rectal prolapse.

As mentioned earlier, abdominal distention was found to be a prominent feature of DC obstruction, therefore it was decided to repeat the scanning once again. After 12 hrs ultrasonography was repeated and it was observed that RVC impaction was dislodging and regaining its motility but LVC impaction was persistent, but obstruction of small intestine or DC could not be appreciated, hence it was decided to operate the animal but owner compliance was not there.

After 2 hours, due to severe distention of abdomen, the animal collapsed. Post mortem of all the four animals was performed and the findings were in consonant with the findings of the ultrasonography. Feacoliths were found in DC at the level of ventral paralumbar fossa in two animals (Plate-63c and 63d). In the third animal LVC impaction and feacolith was found at left paralumbar fossa, whereas in the fourth animal, ultrasonographic findings could not ascertain the presence of feacolith but at PM, LVC impaction was observed along with feacolith of DC which was medial to the jejunum (Plate-63e, 63f and 63g), that is why it could not be ascertained on ultrasonography.

Plate-63a. Obstruction of Descending Colon: Obstructed DC with ischemic and necrotic changes at the site of obstruction.

Plate-63b. Feacolith Removed from lumen of descending colon.

Plate63c. Obstructed DC with ischemic and necrotic changes. The feacolith consisted of sand, gravel, dried faecal matter, shreds of plastic rope and polythene.

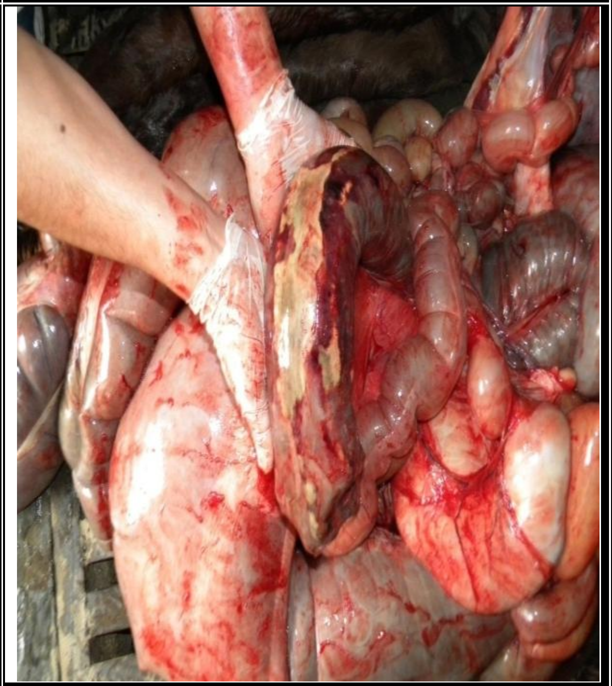


Plate-63d. Obstructed descending colon.

Plate-63e.obstruction of descending colon: Impacted LVC due to stricture (narrowing of diameter) at pelvic flexure.

Plate-63f. Obstructed descending colon.

Plate-63g. Impacted left ventral colon.

4.2.4 Peritonitis due to rectal tear

One female mule (age 6 years) was presented with history of abdominal pain and cessation of defecation and frequent urination in small amounts from last 48 hrs. The only sign of pain manifested by animal was rolling on ground. Animal was off fed since the start of abdominal pain. The animal was treated with analgesics and diuretics and after that per-rectal examination was done by local attending paravet, but due to persistent abdominal pain despite regular administration of analgesics the animal was referred for further investigation. Abnormal findings during physical examination of the animal included dullness, depression, dehydration, congestion of conjunctival mucus membrane, elevated heart rate (Table-8) and absence of intestinal motility on auscultation and GPT of 3 seconds. After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In the mean time electrocardiography was done and the animal was stabilized by administering intravenous fluids. Once the animals was satisfactorily stabilized, lubrication of the rectum with liquid paraffin was done and transrectal examination was performed, which revealed presence of polythene bag mixed with fluidy faecal material and it was removed from the rectum. Further examination revealed a long rectal tear communicating directly with the abdominal cavity. Following physical examination, the animals was prepared for ultrasonography.

Table 8. Clinical parameters in case of peritonitis due to rectal tear in mule.

Parameters	Values	Reference range	Parameters	Values	Reference range
Rectal temperature(˚F)	99.6	99.5-101.5	ALT (u/L)	99	3-23
Respiration rate/min	15	10-15	AST (u/L)	120	226-366
Heart rate/min	68	25-45	ALKP (u/L)	89	143-395
Hemoglobin (g/dL)	18.8	11-19	BUN (mg/dL)	25.2	10-24
PCV (%)	57	32-53	Creatinine (mg/dL)	1.3	0.9-1.9
TLC(×10⁹/L)	17.2	5.4-14.3	Glucose (mg/dL)	164	75-115
Lymphocytes (%)	31.7	17-68	Bilirubin (mg/dL)	0.5	1-2
Monocytes (%)	3.1	0-14	Protein (g/dL)	6.9	5.5-8
Granulocytes (%)	65.2	22-72			

I. Ultrasonographic findings

On ultrasonography stomach was found distended upto 16th ICS and contents producing strong acoustic shadowing. The spleen was found displaced and jejunal loops were imaged distended, medial to the spleen with anechoic ingesta, sluggish motility. Wall of jejunum was markedly thickened with thickness of 6.9 mm (Normal range: 2-2.2 mm). Freeman (2002a) and Scharner *et al.* (2002) reported that peritonitis is characterized by changes in the abdominal fluid and by prominent appearance of the jejunum (Plate-64 & 65). The jejunal wall can be thickened and peristalsis can be normal or decreased.

Marked thickening of jejunal wall in case of peritonitis

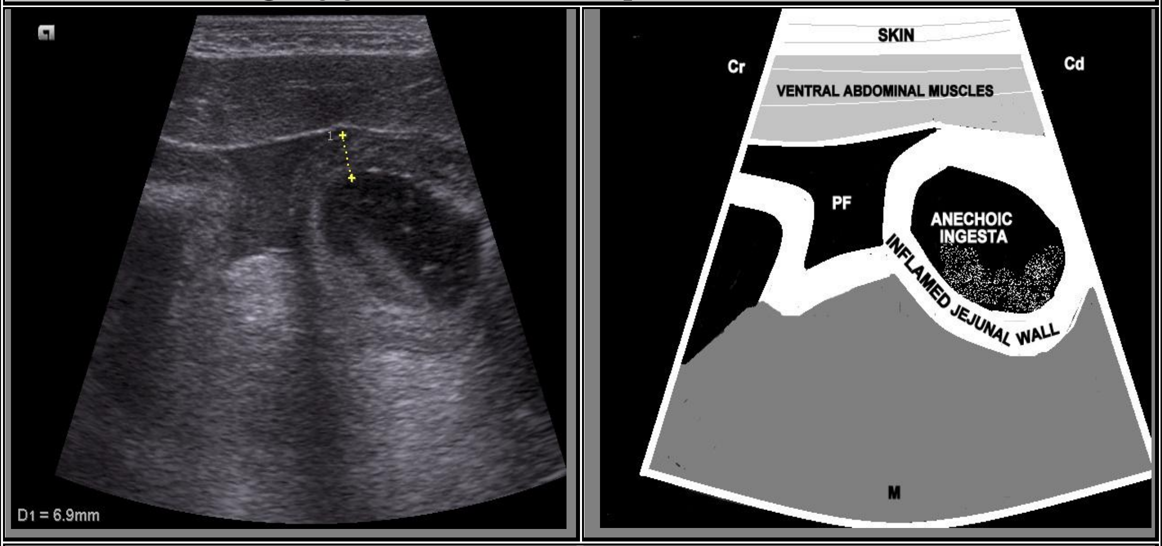


Plate-64. Ultrasonogram of jejunum at ventral abdomen. The image was obtained at 5.3 MHz with linear transducer at a depth of 8.0 cm. (PF= peritoneal fluid)

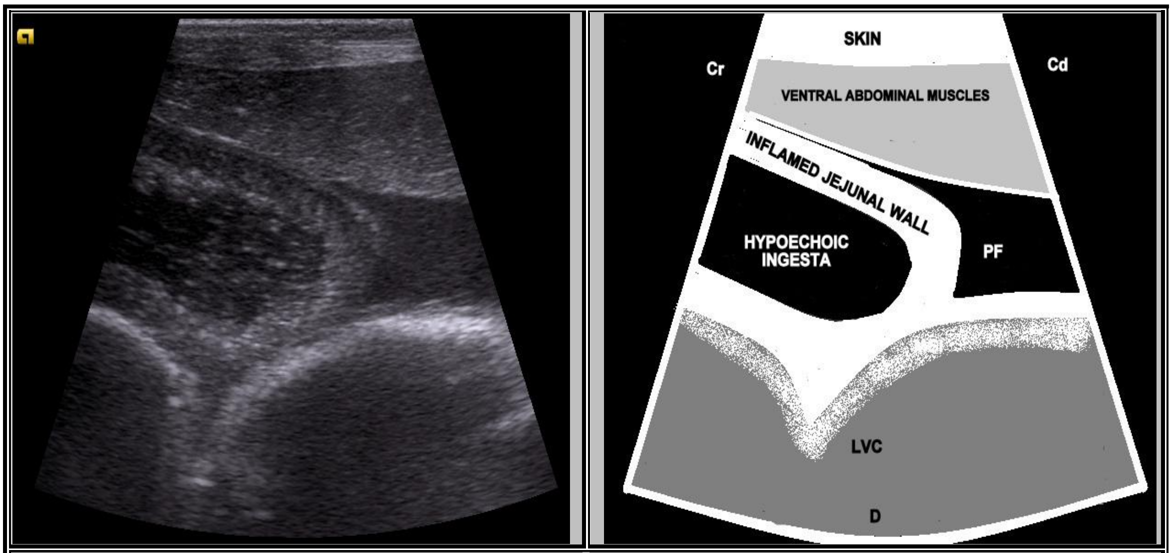


Plate-65. Ultrasonogram of inflamed jejunum at ventral abdomen. The image was obtained at 5.3 MHz with linear transducer at a depth of 8.0 cm.(PF= peritoneal fluid, LVC= left ventral colon)

While scanning the ventral abdomen a free floating anechoic layer of about 30 mm was imaged between the abdominal muscles and the ventral colons (Plate-66). The anechoic fluid was clear without any fibrous tags; In addition to this hypoechoic fluid was seen between the serosal surfaces of the intestine.

Reef *et al.* (2004) stated that the detection of hypoechoic or echogenic, flocculent, composite fluid between the serosal surfaces of the intestine and the abdominal wall is compatible with peritonitis. Barton (2011) stated that peritonitis should be suspected if there is increased volume of peritoneal fluid and in some cases free floating or adherent fibrin may be visible. So these findings were highly suggestive of peritonitis.

Abdominocentesis was performed which revealed dark coloured blood mixed fluid which might have been due to the rectal tear bleeding and caused peritonitis. The animal was put on conservative treatment but in the intervening night animal again showed severe signs of pain and died.

Inflamed peritoneum with lot of peritoneal fluid highly characteristic of peritonitis

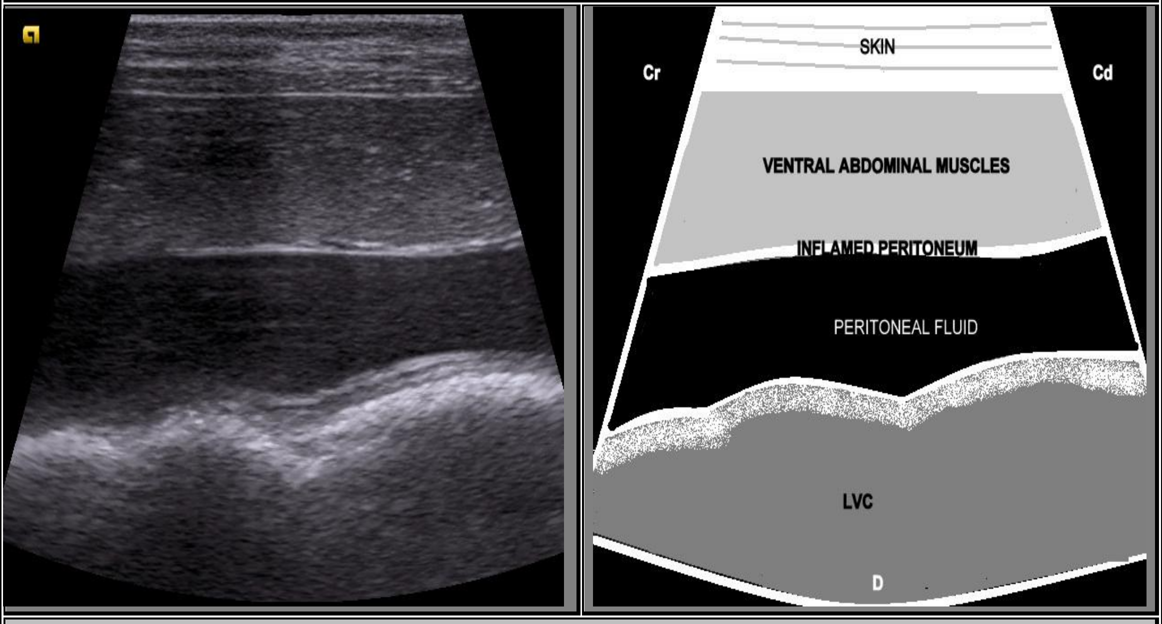


Plate-66. Ultrasonogram of ventral abdomen. The image was obtained at 5.3 MHz with linear transducer at a depth of 8.0 cm. (LVC= left ventral colon)

On post mortem examination it was found that the abdominal cavity contained approximately 1000 to 1500 ml of frank dark coloured blood mixed fluid and faecal matter (Plate-66e). Approximately 80% of the surfaces of the large colon, omentum, caecum and serosal surfaces of intestine showed congestion and petechial hemorrhages.

The serosal surfaces of the intestine had a roughened appearance consistent with acute inflammation (Plate-66a, b, c and d). The findings of the post mortem were consonant with Lohmann *et al.* (2010) who also reported the same findings in 3 cases of peritonitis caused by penetrating metallic foreign bodies. In Addition to this a 19 cm long rectal tear was found at the rectum. Whole of the GIT was examined for presence of any kind of impaction or obstruction but only semisolid ingesta was found.

Plate-66a. Peritonitis due to rectal tear: Piece of polythene removed from rectum.

Plate-66b. Surfaces of the large colon, omentum, caecum and serosal surfaces of intestine showing congestion and petechial hemorrhages

Plate-66c. A 19 cm long rectal tear of rectum communicating directly with the abdominal cavity.

Plate-66d. Roughened appearance of small intestine with thickening and petechial hemorrhages

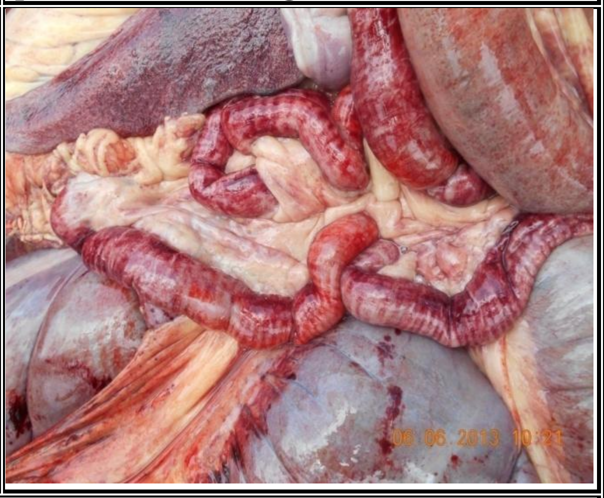
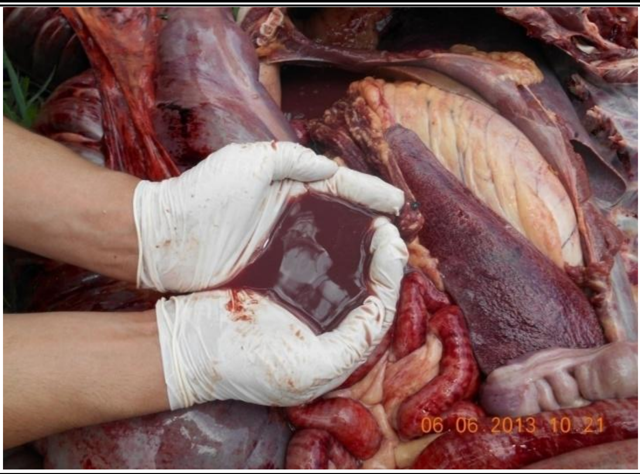


Plate-66e. Dark coloured blood mixed fluid found inside the abdominal cavity in peritonitis



4.2.5 Stercoral Fistula of RVC

One male horse (age 12 years) was presented with history of horn thrust by a stray bull on the cranial ventral right abdomen that resulted into a deep wound and showed leakage of faecal matter through the wound, but defecation and urination was normal. On physical examination it was found that animal was dull, depressed, hypothermic and with mild dehydration. Heart and respiration rate were normal (Table-9). It was observed that with each intestinal contraction the faecal matter was coming out through the wound .After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In the mean time electrocardiography was done. Animal was stabilized by providing suitable treatment. The fecal matter was collected per rectum for parasitological examination. Following physical examination and initial treatment the animal was prepared for ultrasonography.

Table 9. Clinical parameters in case of Stercoral fistula in horse.

Parameters	Values	Reference range	Parameters	Values	Reference range
Rectal temperature(˚F)	97.2	99.5-101.5	ALT (u/L)	10	3-23
Respiration rate/min	10	10-15	AST (u/L)	290	226-366
Heart rate/min	40	25-45	ALKP (u/L)	300	143-395
Hemoglobin (g/dL)	14.6	11-19	BUN (mg/dL)	15.8	10-24
PCV (%)	39.7	32-53	Creatinine (mg/dL)	0.9	0.9-1.9
TLC(×10⁹/L)	13.2	5.4-14.3	Glucose (mg/dL)	87	75-115
Lymphocytes (%)	51.2	17-68	Bilirubin (mg/dL)	0.40	1-2
Monocytes (%)	3.5	0-14	Protein (g/dL)	7	5.5-8
Granulocytes (%)	45.3	22-72			

Ultrasonographic findings:

On ultrasonography at 10^{th} ICS, it was found that the injured part involved was RVC and there were adhesions between the RVC and the abdominal wall which formed a natural seal and prevented the fecal matter to come in direct contact with the abdominal cavity which could have caused peritonitis. The adhesions were imaged as hyperechoic strands causing acoustic shadow (Plate-67). Lot of anechoic fluid was present at the site of injury which may be due to seroma formation (Plate-68). The whole abdominal cavity was scanned to ascertain whether peritonitis was there or not, but no signs of peritonitis were imaged as normal amount of peritoneal fluid was found and no fibrinous reaction was visible. Colons and intestines were imaged with normal echogenic ingesta and motility.

Fibrinous adhesion formation between ruptured RVC and intercostal muscles

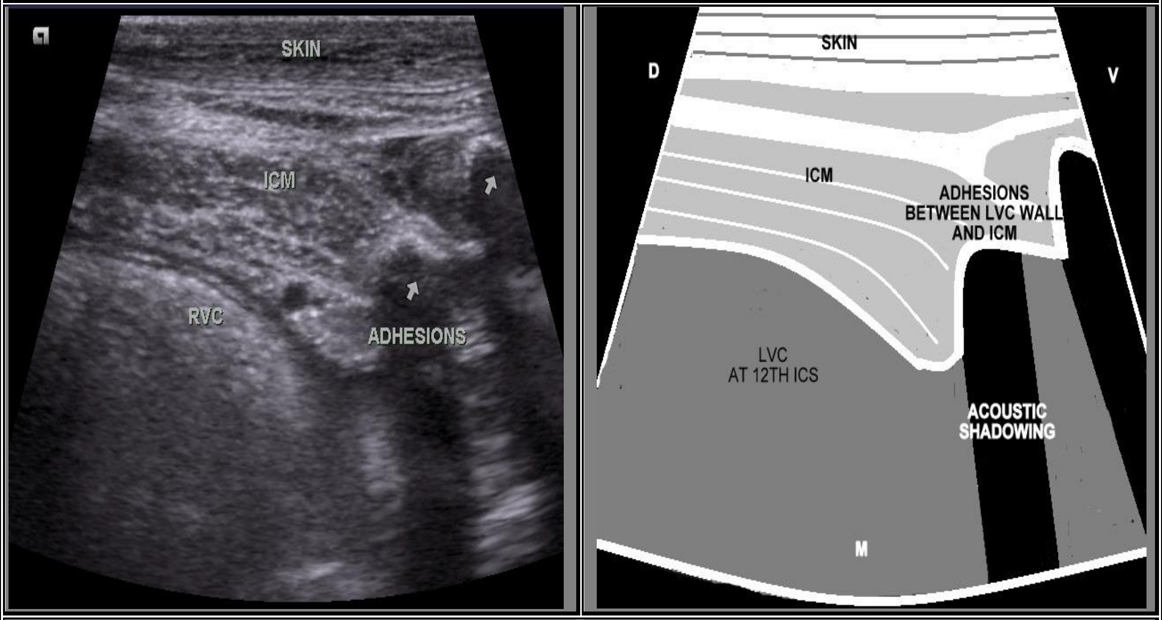


Plate-67. Ultrasonogram of right lateral abdomen at 12th ICS. The image was obtained at 7.3 MHz with linear transducer at a depth of 5.0 cm. (ICM= intercostal muscles, LVC= left ventral colon)

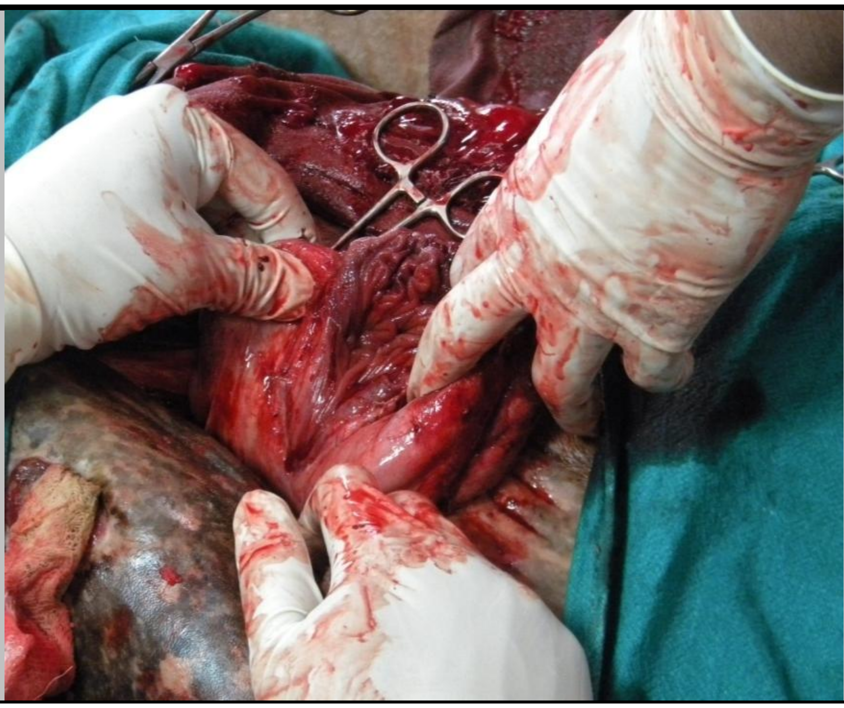
Severe adhesion reaction and seroma formation at the site of injury.

Plate-68. Ultrasonogram of right lateral abdomen at 12th ICS. The image was obtained at 7.3 MHz with linear transducer at a depth of 7.5 cm.

After proper diagnosis the animal was stabilized conservatively. Stabilization period of four days was observed and on 5th day corrective surgery was done (Plate-68a and 68b). The animal was kept in observation for few more days till animal recovered after which animal was discharged.

Plate-68a. Stercoral fistula due to horn thrust at 10th ICS towards right lower abdomen.

Plate68b. Intra-operative picture of ruptured right ventral colon.



4.2.6 Urinary bladder rupture and Uroperitoneum

One female mule (age 8 years) was presented with history of abdominal pain, passing very scanty faeces and dribbling of urine from last 3 days. The signs of pain manifested by animal were rolling on ground, kicking at belly. Animal was off fed since the start of abdominal pain. The animal was earlier treated with analgesics and diuretics but animal could not pass urine freely, due to persistent abdominal pain despite regular administration of analgesics the animal was referred for further investigation by local attending paravet. On physical examination animal was found to be dull, depressed, dehydrated, mild abdominal distention and mild congestion of conjunctival mucus membranes was also observed. Heart rate was slightly increased (Table-10). On per rectal examination nothing abnormal could be detected. After physical examination blood was collected from jugular vein for hematological and biochemical analysis.

The biochemical analysis revealed marked increase in blood urea nitrogen (BUN) and creatinine highly suggestive of azotemia (Table-10). Animal was stabilized by administering intravenous fluids and after one hour animal passed urine normally. After that animal was prepared for ultrasonography.

Table10. Clinical parameters in case of urinary bladder rupture and uroperitoneum in mule.

Parameters	Values	Reference range	Parameters	Values	Reference range
Rectal temperature(˚F)	99.6	99.5-101.5	ALT (u/L)	24	3-23
Respiration rate/min	15	10-15	AST (u/L)	254	226-366
Heart rate/min	68	25-45	ALKP (u/L)	300	143-395
Hemoglobin (g/dL)	12.2	11-19	BUN (mg/dL)	34	10-24
PCV (%)	40.3	32-53	Creatinine (mg/dL)	3.2	0.9-1.9
TLC($\times 10^9$/L)	9.3	5.4-14.3	Glucose (mg/dL)	70	75-115
Lymphocytes (%)	31.4	17-68	Bilirubin (mg/dL)	1.3	1-2
Monocytes (%)	2.2	0-14	Protein (g/dL)	6.8	5.5-8
Granulocytes (%)	66.4	22-72			

Ultrasonographic findings

On ultrasonography, lot of anechoic fluid was found at the ventral abdomen masking the details of the other organs.

Partial tear of cranio-dorsal aspect of urinary bladder.

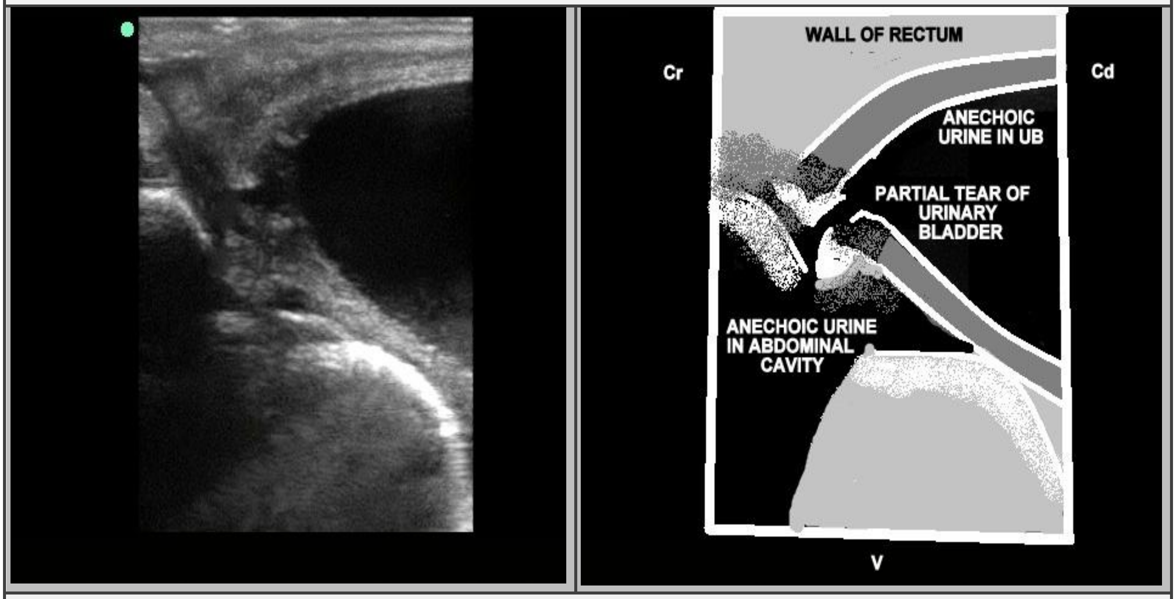


Plate-69. Ultrasonogram of ruptured urinary bladder. The image was obtained with linear transrectal transducer at a depth of 7.0 cm. (UB= urinary bladder)

So there was a suspicion of urinary bladder rupture. Therefore it was decided to go for transrectal ultrasonography and on ultrasonography a small rent at cranio-dorsal portion of the bladder was image (Plate-69). The bladder was found full and turgid and on real time ultrasound urine was found seeping through the tear into the abdominal cavity (Plate-70). Porter and Ramirez (2005) also reported that urinary bladders with small tears can appear full and turgid however the tear commonly occurs in the dorsal urinary bladder wall. The defect may not always be imaged during the sonographic examination because of infolding of the bladder wall. The infolding wall should not be mistaken for recently voided small and contracted urinary bladder. They also reported that urine may be seen passing through the rent into the peritoneum on real time sonography. Abdominocentesis was performed and urine was collected and sent for further investigation, where it was confirmed as urine. The condition was explained to the owner and was advised for reappraisal next morning but owner never came back. Behr *et al*. (1981), Trotter *et al*. (1981), Pankowski and Fubini (1987), Vacek *et al.* (1992), Reef (1995) and Jones *et al.* (1996) and also reported that the horses with uroperitoneum are usually depressed and lethargic with a progressively distending abdomen. Affected horses typically have pollakiuria with decreased fecal production and abdominal pain. All these findings were in agreement with the findings of the present study.

Anechoic urine present in abdominal cavity.

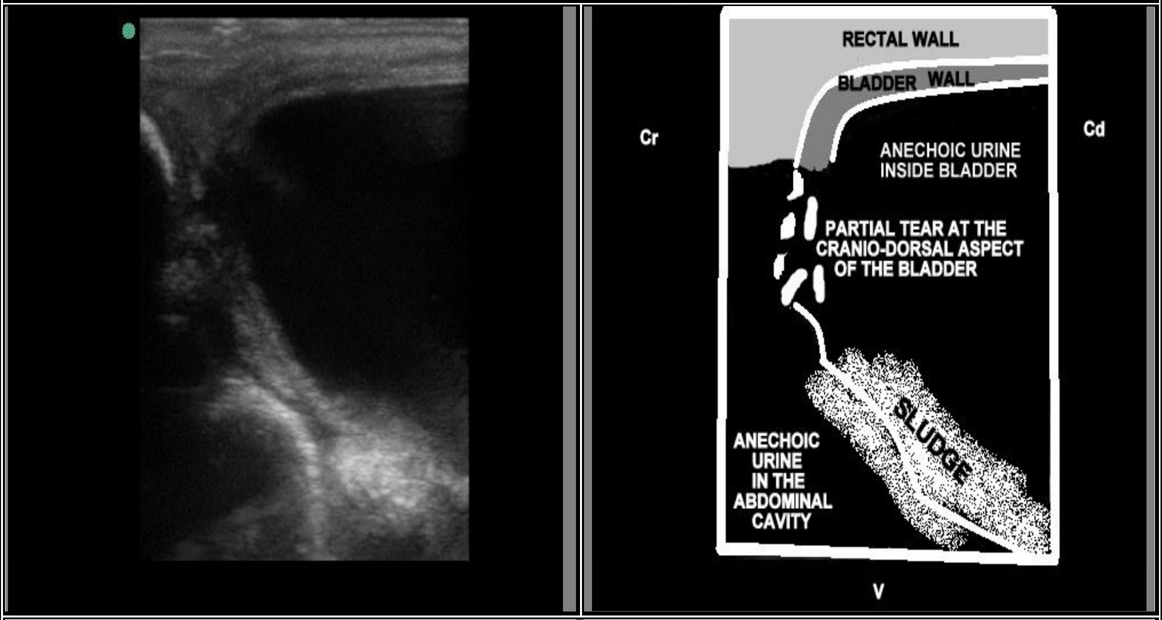


Plate-70. Ultrasonogram of ruptured urinary bladder. The image was obtained with linear transrectal transducer at a depth of 7.0 cm.

4.2.7 Renal abscess with cystitis

One mule (age 6 years) with history of cessation of defecation from last 2 days was presented. The history of initial signs of colic exhibited by kicking at belly, stretching (Plate-74a) and frequent rolling; other associated symptoms were anorexia and severely reduced urine output. Owner complained that the colour of the urine has changed to brown. On physical examination the animal was dull, depressed, and dehydrated with mild congestion of conjunctival mucus membranes and GPT of 2 seconds. Heart rate and respiration rate were normal (Table-11). Mild distention of the abdomen was seen along with hypothermia. Abdominal auscultation revealed audible sounds of borborygmi. After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In the mean time electrocardiography was performed and animal was stabilized by administering intravenous fluids. Once the animals were stabilized, lubrication of the rectum with liquid paraffin was done and transrectal examination was performed, which revealed presence of scanty faecal material inside the rectum, the urinary bladder was found distended and on pressing it coffee coloured urine dribbled out and animal showed signs of pain. The urine sample was collected and sent for culture sensitivity test (CST) and it was found highly positive for staphylococcus infection. No other abnormality was ruled out and after rectal examination was completed animal passed normal faeces. The faecal material was collected for parasitological examination. Following physical examination, the animal was prepared for ultrasonography.

Table 11. Clinical parameters in case of Renal abscess with cystitis in mule.

Parameters	Values	Reference range	Parameters	Values	Reference range
Rectal temperature(˚F)	96.2	99.5-101.5	ALT (u/L)	30	3-23
Respiration rate/min	18	10-15	AST (u/L)	160	226-366
Heart rate/min	48	25-45	ALKP (u/L)	94	143-395
Hemoglobin (g/dL)	10.8	11-19	BUN (mg/dL)	33.2	10-24
PCV (%)	25.5	32-53	Creatinine (mg/dL)	3.4	0.9-1.9
TLC(×10⁹/L)	19.2	5.4-14.3	Glucose (mg/dL)	127	75-115
Lymphocytes (%)	54.4	17-68	Bilirubin (mg/dL)	0.8	1-2
Monocytes (%)	2.2	0-14	Protein (g/dL)	6.2	5.5-8
Granulocytes (%)	43.4	22-72			

I. Ultrasonographic findings

On ultrasonography the accessible GIT was found normal with echogenic ingesta present inside the colons and intestines. The motility was also found normal. While on scanning the left kidney an echogenic thick fluid filled round cavity casting an acoustic shadow was imaged primarily in the renal cortico-medullary junction towards the cranial pole of the kidney. This was highly suggestive of renal abscess. Reef (1998) also stated that the sonographic appearance of the renal abscess is that of a hypoechoic to echogenic fluid filled cavity within the kidney and hyperechoic structures casting acoustic shadows may also be detected in horses with renal abscesses.

Renal abscess of the left kidney. Abscess appears as circular echogenic area with little acoustic shadowing.

Plate-71. Ultrasonogram of left kidney. The image was obtained with linear transrectal transducer at a depth of 7.0 cm. (DC= descending colon)

In the present study the echotexture of that area was abnormal with increased parenchymal echogenicity and this increase in parenchymal echogenicity is associated with fibrosis. There was poor differentiation of the internal architecture and one could not differentiate between the cortex and the medulla (Plate-71). Rantanen (1986b), Penninck *et al.* (1986), Schmidt (1989) and Reef (1991) also reported the same findings which were in agreement with the present study.

Hyperechoic organized blood clots inside urinary bladder in case of cystitis

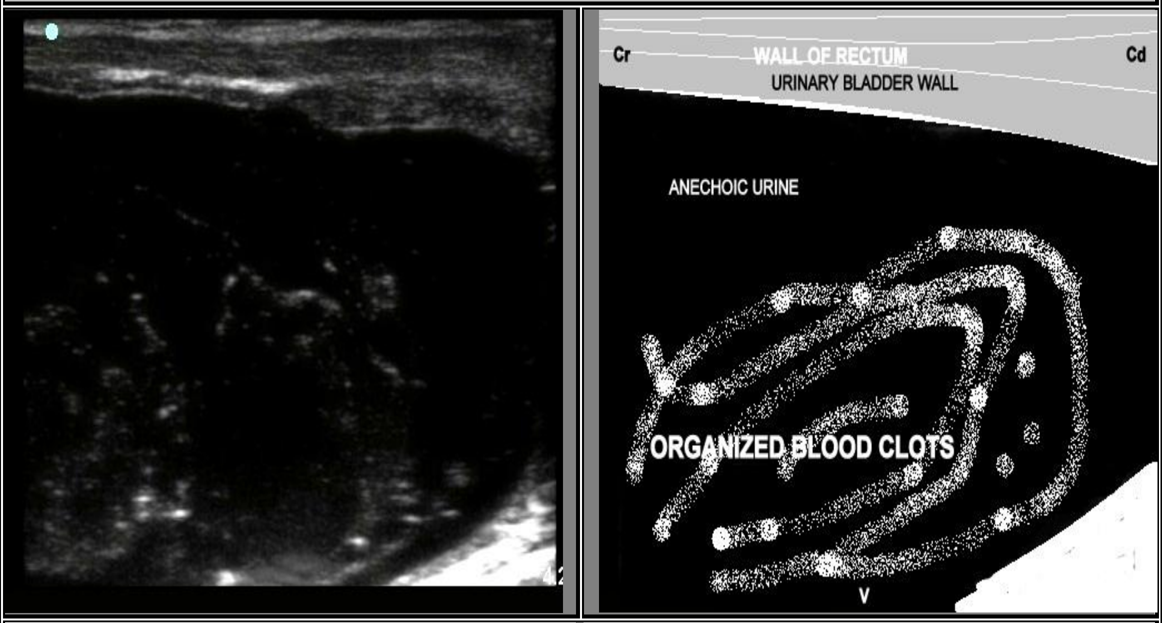


Plate-72. Ultrasonogram of urinary bladder. The image was obtained with linear transrectal transducer at a depth of 4.2 cm.

On transrectal scanning the bladder wall was found thickened and echogenic with double wall appearance which is characteristic of cystitis. Inside the bladder an anechoic to hyperechoic urine was imaged and echogenic loculated masses were found inside the anechoic urine representing clot formation inside the bladder (Plate-72, 73&74). Reef (1998) reported the same ultrasonographic findings for clot formation in case of splenic hematomas. Towards the ventral wall of the bladder, hyperechoic sludge was imaged. After ultrasonography animal was put on conservative treatment but for few days animals passed frank clots with urine (Plate-74b). Owner was advised to repeat the treatment for one more week and was discharged.

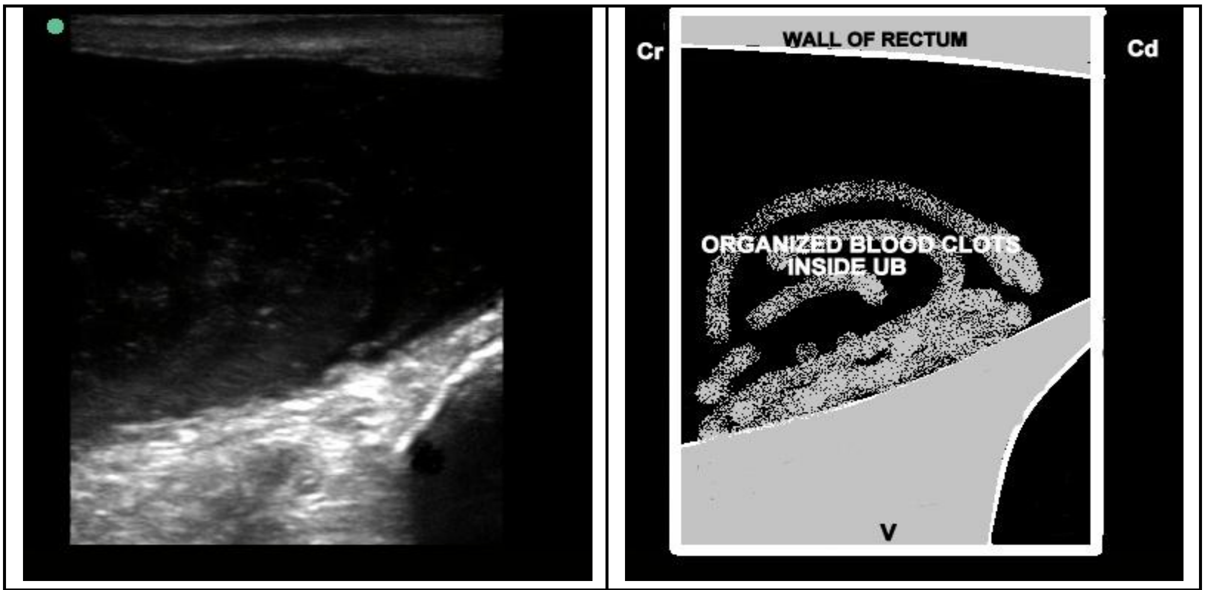


Plate-73. Ultrasonogram of urinary bladder. The image was obtained with linear transrectal transducer at a depth of 4.2 cm.

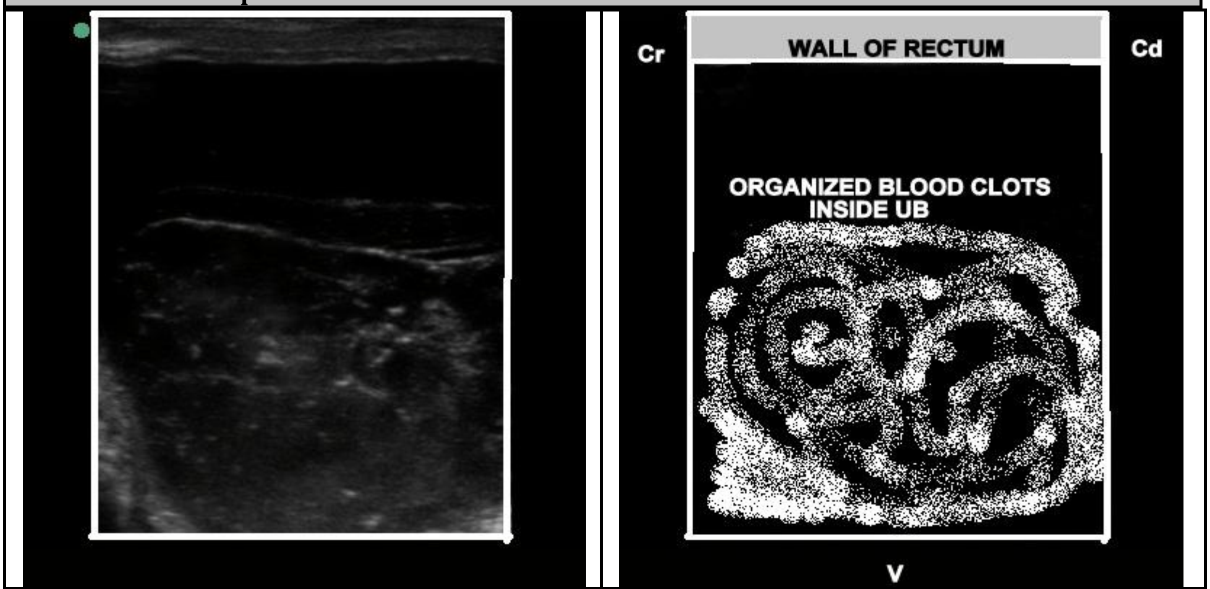


Plate-74. Ultrasonogram of urinary bladder. The image was obtained with linear transrectal transducer at a depth of 7.0 cm.

Plate-74a. Renal abscess with cystitis: Typical straining by animal showing signs of pain	Plate-74b. Intact blood clots in urine voided by the affected animal.
	

4.2.8 Anterior enteritis with left ventral colon impaction:

One animal mule (age 3 years) was presented with history of anorexia, cessation of defecation and urination from last 3 days. The initial signs of colic were manifested by kicking at belly, stamping at the ground, frequent rolling, sweating and repeated attempts to void faeces but could only pass scanty mucus. The affected animal was earlier treated with analgesics, antibiotics and liver tonics by local paravet.

On physical examination the animals was dull, depressed and dehydrated with congestion of conjunctival mucus membranes and GPT of 2 seconds. Heart rate and respiration rate was elevated (Table-12). Abdominal auscultation revealed mild tinkling and fluid splashing sounds of borborygmi.

After physical examination blood was collected from jugular vein for hematological and biochemical analysis. In the mean time electrocardiography was performed and animal was stabilized by administering intravenous fluids. Once the animals were stabilized, lubrication of the rectum with liquid paraffin was done and transrectal examination was performed, which revealed absence of faecal material with dryness of rectal mucosa and distended intestinal loops and firm pelvic flexure. Following physical examination, the animals was prepared for ultrasonography.

Table 12. Clinical parameters in case of Anterior enteritis with LVC impaction in mule.					
Parameters	Values	Reference range	Parameters	Values	Reference Range
Rectal temperature(°F)	100	99.5-101.5	ALT (u/L)	69	3-23
Respiration rate/min	24	10-15	AST (u/L)	236	226-366
Heart rate/min	84	25-45	ALKP (u/L)	367	143-395
Hemoglobin (g/dL)	16.4	11-19	BUN (mg/dL)	26.5	10-24
PCV (%)	48.2	32-53	Creatinine (mg/dL)	2.1	0.9-1.9
TLC(×10^9/L)	15.1	5.4-14.3	Glucose (mg/dL)	322	75-115
Lymphocytes (%)	15.4	17-68	Bilirubin (mg/dL)	0.5	1-2
Monocytes (%)	2.9	0-14	Protein (g/dL)	8.4	5.5-8
Granulocytes (%)	81.7	22-72			

I. Ultrasonographic findings:

On ultrasonography stomach was found distended upto 16th ICS due to which spleen was found displaced towards vertebral column and left paralumbar fossa (Plate-75). The left ventral colon wall was found flattened against the ventral body wall with loss of normal sacculations and peristaltic movements were absent.

Displacement of spleen due to distension of stomach upto 16th ICS.

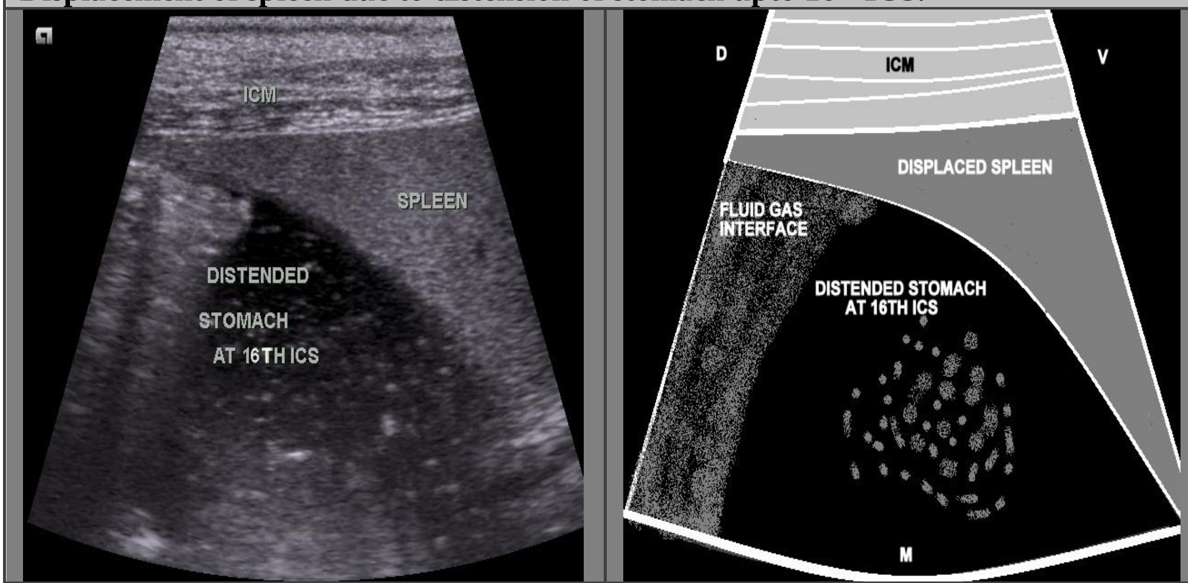


Plate-75. Ultrasonogram of distended stomach. The image was obtained at 10.0 MHz with linear transducer at a depth of 6.5 cm. (ICM= intercostal muscles)

Strong acoustic shadowing due to impacted mass/ingesta.

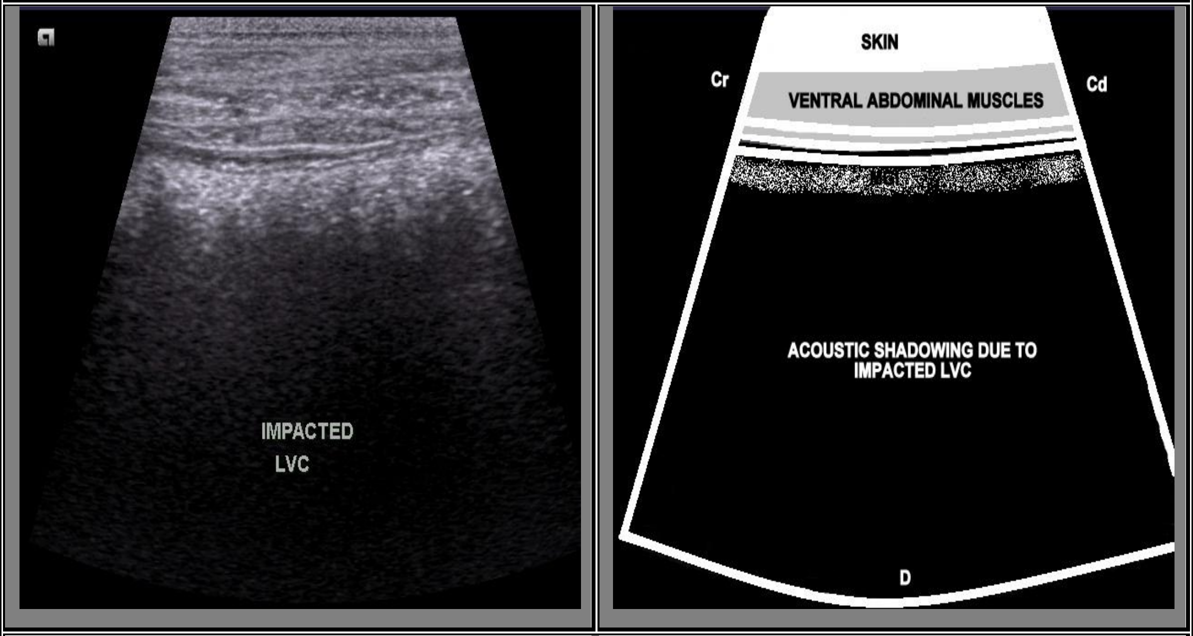


Plate-76. Ultrasonogram of impacted LVC. The image was obtained at 5.3 MHz with linear transducer at a depth of 6.5 cm. (LVC= left ventral colon)

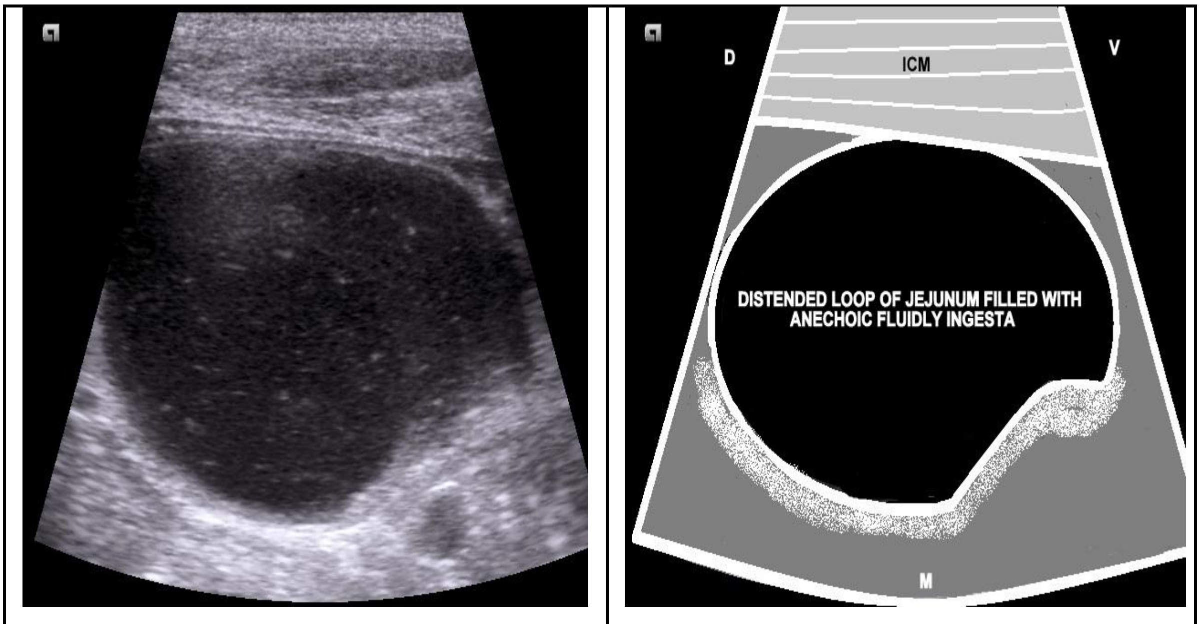


Plate-77. Ultrasonogram of distended loop of jejunum. The image was obtained at 10.0 MHz with linear transducer at a depth of 6.5 cm. (ICM= intercostal muscles)

Reef *et al.* (2004) stated that the bowel wall may be of normal thickness or may be thicker than the normal and there is a large acoustic shadow cast from the impacted ingesta adjacent to the colonic mucosa. The impaction of LVC was imaged as hyperechoic intraluminal structure casting a strong acoustic shadow (Plate-76). Jejunal loops were found filled with fluid, anechoic in nature and were hypermotile (Plate-77). Reef (1991) stated that fluid filled hypermotile intestine is most frequently imaged in horses with enteritis involving the small or large intestine.

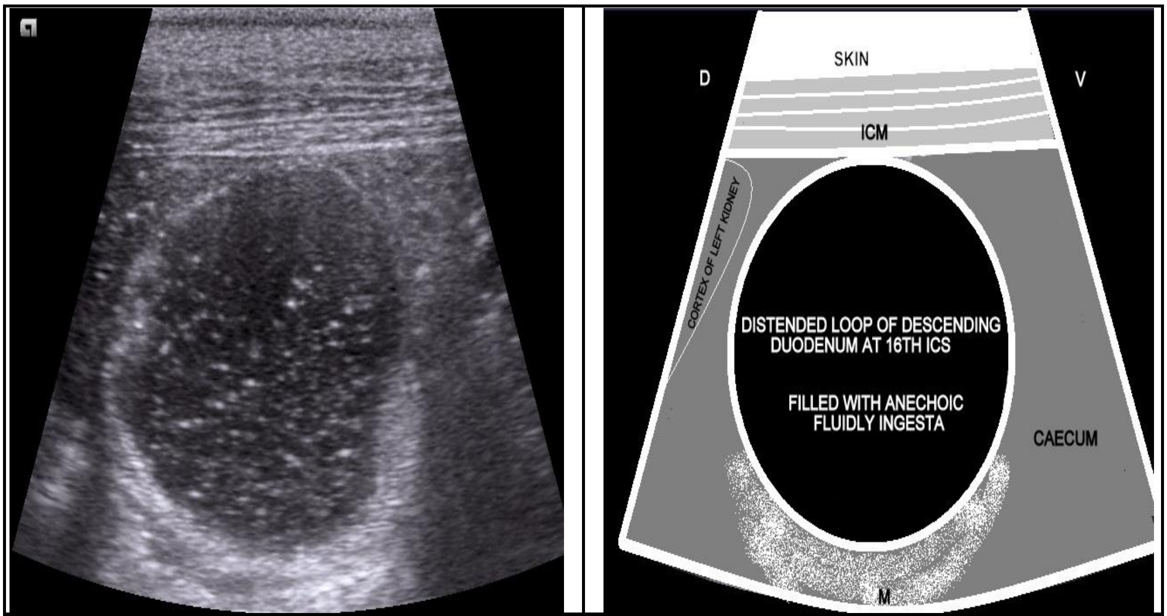


Plate-78. Ultrasonogram of dilated descending duodenum at 16th ICS. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm. (ICM= intercostal muscles)

In contrast to the hypomotile fluid filled intestine usually detected in horses with anterior enteritis. Towards the right abdomen, the duodenum was found highly distended filled with anechoic fluid and no motility was observed and diameter was 47.6 mm (Plate-78).

Kirkberger *et al.* (1995) reported that it would unusual for the entire duodenal diameter to exceed approximately 4 cm in normal horses. The duodenum was found distended at both sites i.e. medial to the liver (Plate-79) and at the caudal pole of kidney. Reef (1991) stated that duodenitis or anterior enteritis is usually characterized by fluid filled hypomotile bowel and wall of the duodenum may have normal thickness with a large fluid lumen. The RDC, LDC and RVC were found normal. In this case hepatic calcification was also imaged which an accidental was finding and calcified tissue showed acoustic shadow.

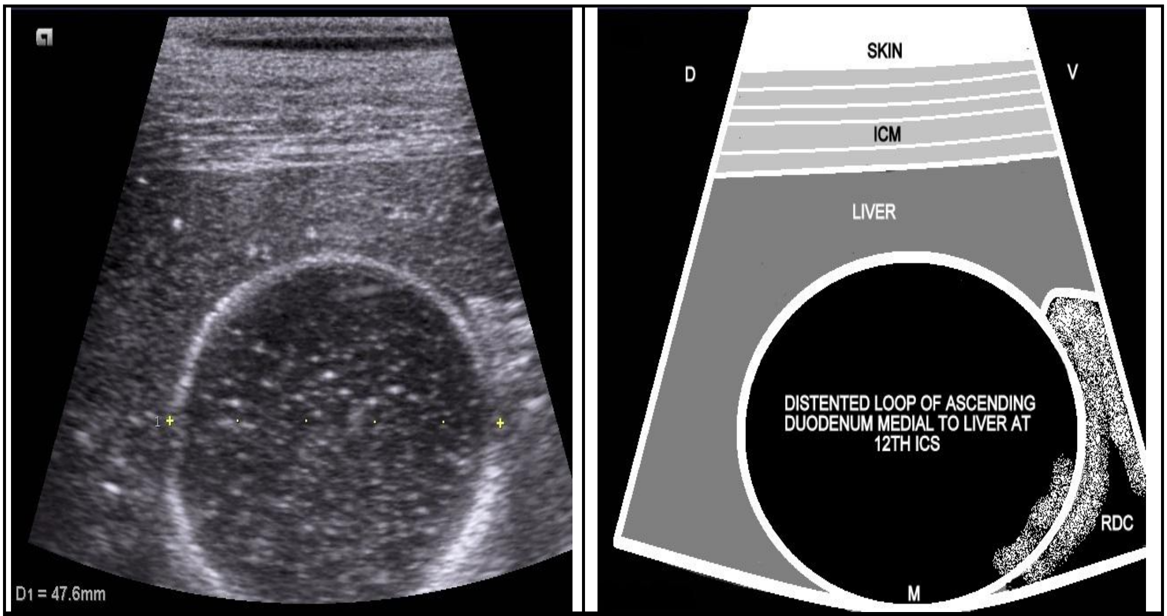


Plate-79. Ultrasonogram of dilated ascending duodenum at 12th ICS. The image was obtained at 7.3 MHz with linear transducer at a depth of 6.5 cm. (RDC= right dorsal colon, ICM= intercostal muscles)

4.2.9 Physiological and Hematological changes:

In the present study, the physiological parameters like respiration and heart rate showed slight increase in cases of LVC impactions, peritonitis, urinary bladder rupture, and renal abscess where as there was marked increase in cases of small colon obstructions, intussusception and anterior enteritis. The heart rate of survivors ranged from 32 to 74 beats/ min. whereas in case of non survivors the heart ranged from 82 to 100 beats / min. Radostits *et al.* (2000) advocated that respiration rate is of minor importance except as an indicator of severity of pain, or in terminal stages of endotoxic shock or dehydration when it becomes gasping, where as increasing heart rate is associated with diminished chances of survival, a horse with a heart rate of 80 beats/ min has a 50% chance of survival whereas one with a heart rate of 50 beats / min has a 90% chance of survival. Hypovolemic shock occurs due to decrease in circulating blood volume that occurs when extracellular fluid is sequestered in a third space. In an effort to provide proper tissue perfusion the heart rate increases.

Ihler *et al*. (2004) found that increased heart rate, not PCV to be a significant predictor for poor outcome. Vander Linden *et al. (*2003) also found no correlation between PCV and outcome, but reported that heart rate was a significant prognostic indicator. The hematological changes in cases of left ventral colon impactions, and anterior enteritis with LVC impaction, were not pronounced but were on higher limit of the prescribed range.

In cases of small colon obstructions, intussusception and peritonitis the haemoconcentration and hypovolemia can be because of dehydration, as all animals were off water since the start of abdominal pain and increase in PCV might be attributed to dehydration or splenic contraction, as splenic contraction is epinephrine mediated and may occur with excitement or pain. Radostits *et al.* (2002) advocated that hematocrit increases as a consequence of splenic contraction or dehydration, making the use of this variable as a sole indicator of hydration status unreliable, however increase in both hematocrit and total protein concentration indicate dehydration and plasma protein concentrations may decline if there is significant loss of protein into the gut lumen or peritoneal space. Whereas in case of urinary bladder rupture, renal abscess with cystitis and stercoral fistula, the Hb and PCV values were found within the normal range. Leukocytosis was observed in case of peritonitis, renal abscess with cystitis and in intussusception, where as in rest of the patients it was within normal range and this increase, can be attributed to acute, progressive, or chronic inflammation of the intestinal tract and urinary tract.

4.2.10 Biochemical changes

The significant increase in total bilirubin was seen in cases of left ventral colon impaction where it ranged from 1.6-4.9 mg/dl (3.22±0.78), whereas it was towards the upper limit in case of small colon impactions where it ranged from 1.3 to 1.9 mg/dl and in case of intussusception the level of bilirubin was increased (2.6 mg/dl). However in rest of the cases it was found within normal limits. The normal range for bilirubin is considerably higher in the horse than other species due to the lack of gall bladder. Most of the serum bilirubin is indirect and elevations may be observed secondarily to many conditions. Anorexia, haemolytic anaemias, hepatic disease, endotoxemia and colic are commonly associated with high total and indirect bilirubin values in the horses. Axiom (2005) advocated that large animals are least efficient at excreting bilirubin in the urine and in horses most of the serum bilirubin is indirect and elevations occur due to anorexia, endotoxemia and colic.

The serum protein concentrations were found markedly increased in cases of intussusception and small colon obstructions and it was towards higher limit of the prescribed range in cases of LVC impaction, this increase in total protein concentration can be attributed to the haemoconcentration and dehydration (Jain 1986). In rest of the cases the protein concentration was found within normal limits.

In present study blood glucose levels were also found towards the higher limit of the prescribed range and this increase may be related to the over activity of the cortisones or it may be secondary to increased hepatic glycogenolyis occurring in early stages of shock or sepsis and hypoglycemia at later stages can occur because of decreased gluconeogenesis and increased peripheral glucose utilization (Kuesis and Spier 1999).

In all the cases of the present study (except for stercoral fistula and urinary bladder rupture) ALT was found increased and it can be due to altered membrane permeability and the causes for this rise can be metabolic disturbances, inflammation and toxemia. Whereas AST was found markedly increased in, descending colon obstructions and in case of intussusception and in rest of the cases the values were in normal range and this elevation in the present study could have been due to muscle injury during ischemia of bowel wall Axiom (2005).

In the present study ALKP was found markedly increased in descending colon obstructions and in case of jejunal intussusception, whereas in rest of the cases the values were in normal range. Horses with anterior enteritis and small intestinal obstruction showed higher serum AST and ALKP concentrations, which Davis *et al*. (2003) attributed to hepatic injury due to ascending infection from the common bile duct and absorption of endotoxin or inflammatory mediators from the portal circulation, or hepatic hypoxia resulting from systemic inflammation and endotoxic shock. Alkaline phosphatase is found in the brush border of the intestinal wall. In cases of increased intestinal wall damage, this enzyme leaks into the blood and increases in concentration. Damage to the intestinal mucosa releases the ‘ischemic ALKP’ into the circulation, which migrates faster than the known liver ALKP standard and exhibited elevated plasma levels Williams and Wilson (1981), as it was obtained in our study, which is marked by the elevated ALKP levels.

The majority of the blood urea is synthesized in the liver from ammonia. Once formed, urea diffuses freely throughout all body fluids. The kidney is the most important route of urea excretion and as a result, urea appears in the glomerular filtrate in the same concentration as is found in the blood. This filtration process does not require energy. Decreased glomerular filtration increases urea. Some urea is passively resorbed from the tubules back into the blood. The amount resorbed is inversely related to the rate of urine flow through the tubules the lower the urine flow rate the greater the tubular urea resorption resulting in an increased urea. Increase in BUN has also been attributed to prerenal diseases like infection, tissue necrosis, fever and decreased glomerular filtration rate due to hypovolemia.

All these factors might have contributed to increase levels of BUN in the present study. However in case of (urinary bladder rupture and renal abscess with cystitis) marked increase was found in BUN and creatinine levels denoting azotemia.

In case of bladder rupture as the urine present in the peritoneal cavity is high in urea, creatinine, low in sodium and chloride and with high osmolarity, so during extensive shift of fluids the urea and creatinine migrate into the interstitial fluids, raising the blood levels of BUN and creatinine, whereas vice versa shift of sodium, chloride and water is observed, which results in hyponatremia, hypocloremia and severe dehydration Donecker and Bellamy (1982).

Whereas in case of renal abscess with cystitis prerenal (infection, tissue necrosis) and renal (direct damage to the nephrons reducing the GFR) causes can be attributed for azotemia.

4.2.11 Electrocardiographic parameters

In standardization phase all the animals were subjected to electrocardiography, all the recorded parameters were found within normal range depicting that there was not any kind of cardiac abnormality in the said animals, however in few animal bifid P waves were noticed which occurs at slow heart rate and first peak represents the depolarization of the right atrium and second peak represents depolarization of the left atrium.

Electrocardiogram of only 8 clinical patients were recorded, which showed significant decrease in P interval, QRS complex, QT segment, T interval and PR interval , which can be attributed to the increased heart rate because as the heart rate increases the conduction time decreases.

Tilly (1992) in dogs also reported that the higher the heart rate, the shorter the conduction time and shorter the PR interval and QT segment. In most of the animals the T waves were found tall and peaked and this occurs due to the excitation or increased heart rate which is common in colicky patients.

Steel (1963), Bergsten and Persson (1966), Fregin (1975) and Holmes and Rezakhani (1975) also reported that number of physiological factors influence the polarity and amplitude of the equine T waves and exercise and excitation with increased heart rate rapidly give rise to T wave changes.

Likewise Patteson (1996) mentioned that T wave is variable in size and orientation and particularly dependent upon the heart rate but T waves are not helpful in the diagnosis of cardiac diseases. He also reported that Purkinje fibre system is much more extended in horses than man and small animals, therefore, the equine QRS complex provides little or no information about the heart size or ectopic beat, but provides information regarding the heart rate only.

4.2.12 Parasitological examination

The faecal examination of all the animals revealed moderate endoparasitic infestation, the common parasites found were Strongyles, Amphistomes and in one case Gastrophlius larvae were found attached to the stomach wall.

CHAPTER 5

SUMMARY AND CONCLUSION

Equine diagnostic abdominal ultrasonography has largely remained limited to developed countries. The present study was undertaken mainly to develop baseline data of ultrasonographic observations of equine abdomen and its clinical applications.

This study was carried out in two phases using 5.3-10.0 MHz linear transducer, the maximum depth of field for this transducer was 13 cm and the other transducer used was 2-5 MHz volumetric (4D) transducer, the maximum depth of field for which was 30 cm. In first phase, 10 native adult (5 horses and 5 mules), clinically healthy animals were subjected to detailed abdominal ultrasonography a number of times to develop baseline topographical data of various organs. The standard topographic *loci* for the transducer placement in order to optimally image the various abdominal organs in live healthy animals were studied in detail. In second phase, 14 clinical equine cases presented to Teaching Veterinary Clinical Complex, DGCN COVAS, Palampur suspected of abdominal involvement were subjected to ultrasonography for assisting the diagnosis.

In standardization phase *in-vivo* organ studies revealed that the right lobe of liver was found from 8^{th} to 15^{th} (±1) ICS and left lobe of liver was found from $6^{th}$to 11^{th} (±) ICS, while in case of mules right lobe of liver was found from 6^{th} to 15^{th} (±1) ICS and left lobe of liver was found from 6^{th} to 9^{th} (±1) ICS. As only a small portion of the liver was imaged from both the sides of the abdomen, therefore it was difficult to estimate the actual size of the organ; hence the estimates of the size rely on its expanse across ICSs. The liver parenchyma was seen isoechogenic with lesser echogenicity as compared to the spleen. The vasculature of the liver was visible but portal veins having more connective tissue in their walls appeared more echogenic than the hepatic veins.

The right kidney was found from 15^{th} (±1) ICS extending upto rostral right paralumbar fossa almost reaching the level of Ist lumbar vertebra, caudal to the liver, dorsal to the descending duodenum and ventral to the lumbar transverse processes, both in horses as well as mules. The height (in slightly oblique transverse plane) of the right kidney varied from 112.7 to 118.3 with a (Mean± SE) of 115.6±1.01 mm and its thickness varied from 58.4 to 71.2 with a (Mean± SE) of 64.3±2.37 mm. While in case of mules the height of the right kidney varied from 90.7 to 109.2 with a (Mean± SE) of 101.1±3.14 mm and its thickness varied from 47.3 to 56.8 with a (Mean± SE) of 52.3±1.57 mm.

The left kidney was found between the 16th to 17th ICSs and Ist to 2nd lumbar vertebra, while as in case of mules it was found from 16th ICS to 3rd lumbar vertebra medial or deep to the spleen between the level of the tuber coxae and the tuber ischii. The height of the left kidney varied from 87 to 107.8 with a (Mean± SE) of 99.0±3.67 mm and its thickness varied from 49.5 to 53.8 with a (Mean± SE) of 51.8±0.72 mm. while in case of mules the height of the left kidney varied from 85.5 to 111.4 with a (Mean± SE) of 95.3±2.36 mm and its thickness varied from 43.4 to 55.7 with a (Mean± SE) of 50.6±2.53 mm. The thickness of the cortex varied from 8.1 to 8.6 mm in horses whereas in case of mules it varied from 8.0 to 8.1 mm. Both the kidneys could be easily observed transcutaneously, the renal cortex was found hypoechoic compared with the surrounding tissues but more echogenic than the adjacent medulla. Renal pyramids appeared as distinct hypoechoic circles separated from each other by renal column. Renal pelvis was found in the centre and most echogenic structure in each kidney.

The spleen was found from 8th to 17th ICS's and just caudal to the last rib in left paralumbar fossa, in slightly oblique transverse plane, anteriorly caudal to the stomach dorsal to the jejunum, laterally caudal and medial to the left kidney both in horses as well as mules. The splenic parenchyma was found granular, homogenous in appearance with few blood vessels and most echogenic organ in the abdominal cavity of equines. Spleen was found encapsulated with an echogenic capsule and splenic vein was easily located as an anechoic tubular structure medial to the spleen around 10th ICS. The only measurement that was reliably obtained was the central thickness or depth of the spleen which varied from 41.4 to 68.4 with a (Mean± SE) of 50.84±4.61 mm and in case of mules it varied from 37.9 to 51.6 with a (Mean± SE) of 42.76±2.34 mm.

The stomach was found from 8th to 13th ICS's and in fed horses, upto 15th ICS where as in case of mules it was found from 8th to 14th ICS's caudal to the liver, cranial to the spleen and dorsal to the RDC at the level of shoulder. The stomach wall thickness varied from 4 to 5.2 with a (Mean± SE) of 4.92±0.23 mm and in case of mules it varied from 4.1 to 4.4 with a (Mean± SE) of 4.24±0.06 mm.

The RDC was found from 6th to 14th ICS in slightly oblique transverse plane, dorsal to the RVC, ventral to the liver, caudal to the diaphragm and cranial to the caecum. The RDC wall thickness varied from 2.0 to 2.3 with a (Mean± SE) of 2.16±0.05 mm, however in case of mules the RDC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm. The frequencies of the contractions of the RDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

The right ventral colon (RVC) was found from 9th to 17th ICS's in slightly oblique transverse plane, cranial to the caecum and ventral to the RDC upto the linea alba in both horses as well as mules. The RVC wall thickness varied from 2.0 to 2.2 with a (Mean± SE) of 2.1±0.03 mm. However in case of mules the RVC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm. For RVC the frequencies of the contraction were same as recorded for RDC i.e. 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

The left dorsal colon (LDC) was found from 6thto 15th ICS's ventro-medial to the spleen, in the lower flank, dorsal to the LVC, ventral to the stomach, liver and jejunum in both horses as well as mules. The LDC wall thickness varied from 2.0 to 2.2 with a (Mean± SE) of 2.12±0.03 mm, however in case of mules the LDC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm. The frequencies of the contractions of the LDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

The left ventral colon (LVC) was found from 9th to 14th ICS's in the lower flank and ventral to the LDC upto the linea-alba both in horses as well as mules. The LVC wall thickness varied from 2.0 to 2.2 with a (Mean± SE) of 2.1±0.03 mm, however in case of mules the LVC wall thickness varied from 1.3 to 1.4 with a (Mean± SE) of 1.32±0.02 mm. For LVC the frequencies of the contractionwere same as recorded for LDC i.e. 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.

The caecum was found from 15^{th} to 17^{th} ICS in the right flank caudal to the liver ventral to the right kidney, descending duodenum andventral to the RVC upto the linea alba in both horses as well as mules. The contents of the caecum varied from solid, liquid or mixed but usually highly echogenic, causing strong acoustic shadowing and masking the details of the underlying structure. Only the caecal wall and caecal contents upto a few centimeter (cm) depth could be imaged. The caecal wall thickness varied from 2.0 to 2.3 mm with a (Mean ±SE) of 2.1 ±0.05 mm. While in case of mules the caecal wall thickness varied from 1.3 to 1.6 mm with a (Mean ±SE) of 1.4±0.05 mm, which was quite less than the horses. Sacculations were prominent and motility was assessed from the movement of the wall, underlying hyperechoic shadow and by motion induced changes in the sacculations of the caecum. In the present study the frequencies of the contractions of the caecum were recorded as 2-6 contractions/ minute in fed animals, 2-4 contractions/ minute when animals were fasted for 12 hrs without holding water, but when animals were fasted upto 24 hrs or more, caecal contraction rate was decreased upto 1-3 contractions/ minute with lot of gas present in the caecum. Wall layering of the right dorsal colon, right ventral colon, left dorsal colon, left ventral colon, caecum and stomach from outside to inside as outer thin echogenic tunica serosa, thick hypoechoic tunica muscularis, thin echogenic tunica sub-mucosa, thin hypoechoic tunica mucosa and lastly echogenic mucosal gas interface.

The wall layering of the small intestines was observed in the same fashion except for tunica mucosa which was not clearly appreciable. The jejunum could be differentiated from the duodenum by their topographic anatomical location.

The duodenum was found at two locations in slightly oblique transverse plane in the right hemi abdomen of equines i.e. ascending duodenum from 11^{th} to 13^{th} ICS's in horses, 10^{th} to 13^{th} ICS's in mules, at the level of shoulder located between the liver and the RDC or medial to the liver, where it was imaged transversely in short axis and was again found at the level of the ventral right kidney or around the caudal pole of the right kidney and dorsal to the caecum between 16^{th} to 17^{th} ICS's and sometimes from 16^{th} ICS to just caudal to the last rib at paralumbar fossa as descending duodenum. Whereas in case of mules it was found from 15^{th} ICS to just caudal to the last rib at right paralumbar fossa. The duodenal wall thickness was recorded as 2.0 with a (Mean± SE) of 2.0±0.0 mm in case of horses, however in case of mules the duodenal wall thickness varied from 1.8 to 2.0

with a (Mean± SE) of 1.96±0.04 mm. The frequencies of the contractions of the duodenum were recorded as 5-6 contractions/ min in fed animals, 2-3 contractions/ minute when fasted for 12 hrs without holding water and 0-1 contractions/ minute when animals were fasted for 24 hrs or more.

The jejunum was found from 12^{th} (±1) to 17^{th} ICS's caudal to the spleen, dorsal to the LDC, ventral to the descending colon, in the mid flank and in the left inguinal area. The wall thickness of the jejunum varied from 2 to 2.2 with a (Mean± SE) of 2.04±0.04 mm, whereas in case of mules it varied from 2 to 2.1 with a (Mean± SE) of 2.02±0.02 mm. It was also observed that small intestine was having the most visible motility of any part of the gastrointestinal tract, with peristaltic waves producing rhythmic contractions of about 5 to 15 contractions per minute. It was also found that fasting adversely decreases the motility of the intestine upto 4 contractions per minute.

Descending colon (DC) was found in the left paralumbar fossa, behind the last rib upto tuber-coxae, caudal to the spleen, dorsal to the jejunum and LDC and ventral to the lumbar transverse processes. Like the large colons the motility was sluggish with 1 to 3 contractions per minute. The wall thickness of DC was observed same in case of horses as well as mules and varied from 2 to 2.1 with (Mean± SE) of 2.04±0.02 mm.

In second phase, ultrasonography was employed for diagnosis of clinical cases of intestinal intussusceptions, colonic impactions, descending colon obstructions urinary bladder ruptures, cases of peritonitis and enteritis. Bull's eye or sandwich like appearances of intestinal loops was seen in cases of intestinal intussusceptions transabdominally.

In colonic impactions wall was found flattened against the ventral body wall with loss of normal sacculations and peristaltic movement. Impaction itself in all animals was imaged as hyperechoic intraluminal structure casting a strong acoustic shadow. Descending colon obstructions were imaged as a large hyperechoic intraluminal masses casting a strong acoustic shadow with loss of normal sacculations and peristaltic movement of descending colon. In case of normal animals peritoneum could not be appreciated on ultrasonography, but in case of peritonitis the peritoneum could be imaged as thin echogenic layer with lot of peritoneal fluid present inside the abdominal cavity with marked thickening of jejunal wall. In case of bladder rupture abdominal cavity was found filled with anechoic fluid masking the details of the other organs, the contour of the wall of the urinary bladder was found lost with invagination of the wall and seeping of urine into the abdominal cavity could be appreciated on real time ultrasonography.In case of enteritis intestines were found markedly distended with transient ileus, filled with anechoic fluid and free gas caps were found swirling inside that anechoic fluid.

Based on this study following salient conclusions were drawn-

i. In the standardization phase detailed systematic ultrasonographic baseline data of native Spiti horse and mule abdomen was compiled, which will help in future to delineate the normal and abnormal conditions of an equine abdomen.

ii. Imaging of some static and dynamic variables of Intestines like wall thickness and frequency of contractions provides an important diagnostic lead in management of intestinal affections.

iii. In the clinical application phase ultrasonography was found to be an important imaging diagnostic aid for diagnosing different abdominal disorders in equines like colonic impaction, intestinal obstruction, intussusception, peritonitis, urinary bladder rupture, renal disorder, various hepatic and splenic disorders, hernias, enteritis and gastric distension.

iv. The sonographic evaluation of the abdomen equips the surgeon/clinician to differentiate between true and false colic, which helps reach at an accurate diagnosis and formulate a precise and efficient therapeutic plan.

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APPENDIX

Some of the concised information derived from standardization phase studies for ready reference are being tabulated in Table no.13 to 21. These include studies pertaining to (physical, hematological, biochemical parameters, wall thickness of different organs, and scanning areas of different organs.

Table-13. Physical and hematological parameters of animals used in standardization phase

Parameters	Values(MEAN±SE)	Reference range
Rectal temperature(°F)	100.69±0.14	99.5-101.5
Respiration rate/min	13±0.68	10-15
Heart rate/min	40.4±0.95	25-45
Hemoglobin (g/dL)	12.6±0.89	11-19
PCV (%)	35.83±2.66	32-53
TLC($\times 10^9$/L)	8.58±0.66	5.4-14.3
Lymphocytes (%)	32.21±3.42	17-68
Monocytes (%)	2.83±0.23	0-14
Granulocytes (%)	65.76±3.13	22-72

Table-14. Biochemical values of normal animals used in standardization phase

Parameters	Values(MEAN±SE)	Reference range
ALT (u/L)	13.3±1.23	3-23
AST (u/L)	309±11.78	226-366
ALKP (u/L)	161.7±8.94	143-395
BUN (mg/dL)	15.09±1.20	10-24
CREATININE (mg/dL)	1.15±0.09	0.9-1.9
GLUCOSE (mg/dL)	111.6±4.96	75-115
BILIRUBIN (mg/dL)	0.82±0.11	1-2
PROTEIN(g/dL)	6.71±0.23	5.5-8

Table-15. Wall thickness measurements of different organs of normal horses used in standardization phase

Organ (right hemi-abdomen)	Values (MEAN±SE)
Right dorsal colon	2.16±0.15
Right ventral colon	2.1±0.03
Caecum	2.1±0.05
Duodenum	2.0±0.00
Right kidney (height and thickness)	115.64±1.01 64.3±2.37
Organ (left hemi-abdomen)	
Stomach	4.92±0.23
Spleen (central thickness)	50.84±4.61
Left dorsal colon	2.12±0.03
Left ventral colon	2.1±0.03
Descending colon	2.04±0.02
Jejunum	2.04±0.04
Left kidney (height and thickness)	99.08±3.67 51.8±0.72
Urinary bladder	2.74±0.02

Table 16. Wall thickness measurements of different organs of normal mules used in standardization phase

Organ (right hemi-abdomen)	Values (MEAN ± SE)
Right dorsal colon	1.32±0.02
Right ventral colon	1.32±0.02
Caecum	1.4±0.05
Duodenum	1.96±0.04
Right kidney (height and thickness)	101.14±3.14 52.34±1.57
Organ (left hemi-abdomen)	
Stomach	4.24±0.06
Spleen (central thickness)	42.76±2.34
Left dorsal colon	1.32±0.02
Left ventral colon	1.32±0.02
Descending colon	2.02±0.02
Jejunum	2.02±0.02
Left kidney (height and thickness)	95.34±4.39 50.64±2.53
Urinary bladder	2.62±0.05

Table 17. Scanning areas for ultrasonographic examination of the left hemi-abdomen in native (Spiti) horses.		
S.No.	**Organ**	**Scanning Area**
1.	**Liver**	From 6th to 11th (±1) intercostal spaces (ICSs), caudal to the diaphragm and cranial to the stomach.
2.	**Stomach**	From 8th to 13thICSs and upto 15th ICS in fed horses caudal to the liver and cranial to the spleen and dorsal to the LDC.
3.	**Spleen**	From 8th to 17th ICSs, and behind the last rib, caudal to the stomach and dorsal to the jejunum.
4.	**Left Dorsal Colon (LDC)**	From 6th to 15th ICSs, and in the lower flank, dorsal to the LVC and ventral to the liver, stomach, spleen and jejunum, respectively.
5.	**Left Ventral Colon (LVC)**	From 9th to 14th ICSs, and in the lower flank, ventral to the LDC up to the linea alba, respectively.
6.	**Jejunum**	From 12th (±1) to 17th ICSs, and in the middle flank, caudal to the spleen, and dorsal to the LDC and ventral to the DC, respectively.
7.	**Descending (Small) Colon (DC)**	Left Paralumbar Fossa: Behind the last rib up to the tuber-coxae, caudal to the spleen, and dorsal to the jejunum and LDC and ventral to the lumbar transverse processes,
8.	**Left Kidney**	From 16th to 17th ICSs and 1st to 2nd lumbar vertebrae, medial to the spleen and ventral to the lumbar transverse processes,

Table 18. Scanning areas for ultrasonographic examination of the right hemi-abdomen in native (Spiti) horses.		
S.No.	**Organ**	**Scanning Area**
1.	**Caecum**	From 15^{th} to 17^{th} intercostal spaces (ICSs), and the right flank, caudal to the liver and ventral to the RVC up to the linea alba.
2.	**Right Dorsal Colon (RDC)**	From 6^{th} to 14^{th} ICSs, dorsal to the RVC and ventral to the liver, caudal to the diaphragm and cranial to the caecum.
3.	**Right Ventral Colon (RVC)**	From 9^{th} to 17^{th} ICSs, cranial to the caecum, and ventral to the RDC up to the linea alba.
4.	**Right Kidney**	From 15^{th} (±1) ICS to rostal right paralumbar fossa upto Ist lumbar vertebra, caudal to the liver, dorsal to the descending duodenum and ventral to the lumbar transverse processes,
5.	**Ascending Duodenum**	From11^{th} to 13^{th} ICSs in horses, at the level of shoulder located between the liver and the RDC or medial to the liver.
6.	**Descending Duodenum**	From 16^{th} to 17^{th} ICS dorsal to the caecum and ventral to the right kidney.
7.	**Liver**	From 6^{th} to 15^{th} (±1) ICSs, caudal to the diaphragm and cranial to the right kidney and descending duodenum, and dorsal to the LDC and caecum, respectively.

Table 19. Scanning area for ultrasonographic examination of the left hemi-abdomen in (Native) mules.

S.No.	Organ	Scanning Area
1.	**Liver**	From 6th to 9th (±1) intercostal spaces (ICSs), caudal to the diaphragm and cranial to the stomach.
2.	**Stomach**	From 8th to 14thICSs caudal to the liver and cranial to the spleen and dorsal to the LDC.
3.	**Spleen**	From 8th to 17th ICSs, and behind the last rib, caudal to the stomach and dorsal to the jejunum.
4.	**Left Dorsal Colon (LDC)**	From 6th to 15th ICSs, and in the lower flank, dorsal to the LVC and ventral to the liver, stomach, spleen and jejunum, respectively.
5.	**Left Ventral Colon (LVC)**	From 9th to 14th ICSs, and in the lower flank, ventral to the LDC up to the linea alba, respectively.
6.	**Jejunum**	From 12th (±1) to 17th ICSs, and in the middle flank, caudal to the spleen, and dorsal to the LDC and ventral to the DC, respectively.
7.	**Descending (Small) Colon (DC)**	Left Paralumbar Fossa: Behind the last rib up to the tuber-coxae, caudal to the spleen, and dorsal to the jejunum and LDC and ventral to the lumbar transverse processes,
8.	**Left Kidney**	From 16th to 17th ICSs and 1st to 3rd lumbar vertebrae, medial to the spleen and ventral to the lumbar transverse processes,

Table 20. Scanning areas for ultrasonographic examination of the right hemi-abdomen in (Native) mules.		
S.No.	**Organ**	**Scanning Area**
1.	**Caecum**	From 15th to 17th intercostal spaces (ICSs), and the right flank, caudal to the liver and ventral to the RVC up to the linea alba.
2.	**Right Dorsal Colon (RDC)**	From 6th to 14th ICSs, dorsal to the RVC and ventral to the liver, caudal to the diaphragm and cranial to the caecum.
3.	**Right Ventral Colon (RVC)**	From 9th to 17th ICSs, cranial to the caecum, and ventral to the RDC up to the linea alba.
4.	**Right Kidney**	From 15th (±1) ICS to rostal right paralumbar fossa upto Ist lumbar vertebra, caudal to the liver, dorsal to the descending duodenum and ventral to the lumbar transverse processes,
5.	**Ascending Duodenum**	From10th to 13th ICSs in mules, at the level of shoulder located between the liver and the RDC or medial to the liver.
6.	**Descending Duodenum**	From 15th ICS to just caudal to the last rib at paralumbar fossa dorsal to the caecum and ventral to the right kidney.
7.	**Liver**	From 6th to 15th (±1) ICSs, caudal to the diaphragm and cranial to the right kidney and descending duodenum, and dorsal to the LDC and caecum, respectively.

Table 21. Frequency of peristaltic activity of different abdominal organs in native horses and mules.		
S.No.	**Organ**	**Scanning Area**
1.	**Right Dorsal Colon**	The frequencies of the contractions of the RDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.
2.	**Right Ventral Colon**	The frequencies of the contractions of the RDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more.
3.	**Caecum**	The frequencies of the contractions of the caecum were recorded as 2-6 contractions/ minute in fed animals, 2-4 contractions/ minute when animals were fasted for 12 hrs without holding water, 1-3 contractions/ minute when fasted for 24 hrs. or more.
4.	**Duodenum**	The frequencies of the contractions of the duodenum were recorded as 5-6 contractions/ min in fed animals, 2-3 contractions/ minute when fasted for 12 hrs without holding water and 0-1 contractions/ minute when animals were fasted for 24 hrs or more.
5.	**Left Dorsal Colon)**	The frequencies of the contractions of the LDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more
6.	**Left Ventral Colon**	The frequencies of the contractions of the LDC were recorded as 2-6 contractions/ min in fed animals, 2-4 contractions/ minute when fasted for 12 hrs without holding water and 1-2 contractions/ minute when animals were fasted for 24 hrs or more
7.	**Jejunum**	It was observed that Jejunum was having the most visible motility of any part of the gastrointestinal tract, with peristaltic waves producing rhythmic contractions of about 5 to 15 contractions per minute. And fasting adversely decreases the motility of the intestine upto 4 contractions per minute
8.	**Descending (Small) Colon**	The motility of DC was sluggish with 1 to 3 contractions per minute

Table 22: Summary of clinical cases of equine abdominal emergencies with respect to signalment and outcome

S. No	Species	Age (years)	Sex	Diagnosis	Outcome
1	Mule	12	F	Left ventral colon impaction	Survived
2	Mule	10	F	Left ventral colon impaction	Survived
3	Mule	13	M	Left ventral colon impaction	Survived
4	Mule	12	F	Left ventral colon impaction	Survived
5	Horse	10	F	Obstruction of Descending colon and left ventral colon impaction	Died
6	Horse	14	M	Obstruction of Descending colon	Died
7	Mule	6	F	Obstruction of Descending colon	Died
8	Mule	10	M	Obstruction of Descending colon and Right and Left ventral colon impaction.	Died
9	Mule	18	F	Jejunal- Jejunal intussusception with impaction of LVC and obstruction of descending colon.	Died
10	Mule	6	F	Anterior enteritis with left ventral colon impaction	Survived
11	Mule	6	F	Peritonitis	Died
12	Mule	6	F	Renal abscess with cystitis	Survived
13	Horse	12	M	Stercoral fistula	Survived
14	Mule	8	F	Urinary bladder rupture	Not known

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12th Class	2005	J&K BOSE	55.66	2nd
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M.V.Sc.	2014	DGCN COVAS, CSK HPKVV, Palampur, India	80.02	1st