ULTRASONOGRAPHIC STUDIES OF FORE-STOMACH IN GOATS (*Capra hircus*)

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ULTRASONOGRAPHIC STUDIES OF 
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ULTRASONOGRAPHIC STUDIES OF FORE-STOMACH IN GOATS (*Capra hircus*)

ABSTRACT

The present study was conducted to establish ultrasonographic features using two dimensional B-mode and real-time scanner (e saote MyLab 40 VET) on (*in vitro*) slaughter house specimens of goat forestomach (n=6) with convex (2.5-7.5 MHz, Group I) and linear (7.5-18 MHz, Group II) probes, and also (*in vivo*) of forestomach in 12 healthy Surti goats. The animals were allotted to two groups, wherein all the twelve goats were scanned using convex (2.5-7.5 MHz, Group I) and linear probes (7.5-18 MHz, Group II).

The *in vitro* study on the slaughter house specimens of goat forestomach was done by placing a water filled balloon over the organs to study the contents, texture and internal mucosa. The walls of rumen, reticulum and omasum appeared thick echogenic. Rumen papillae, honey comb pattern of reticular mucosa and omasal leaves were seen as having mixed hypoechoic to echogenic texture. During *in vivo* study, the 7th -11th left intercostal space, midventral and left paramedian regions were suitable acoustic windows for the rumen. The rumen papillae were typically echogenic and gave a turkish towel appearance. The reticulum was examined from the ventral aspect of the thorax.

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1 M. V. Sc. thesis submitted to Anand Agricultural University, Anand – 388 001 (Gujarat).
on the left and right sides of the sternum as well as to the left and right lateral thorax up to the level of elbow and appeared as a half moon shaped structure with even contour. The honey comb like structure of the mucosa and contents of the reticulum were not often seen clearly due to partly gas composition. Reticular movements were detected through real time scanning in the form of biphasic contractions within nine minutes. The omasum was imaged from the 6th -8th right intercostal spaces using 3.3 MHz convex and 12 MHz linear probes and appeared as a crescent shaped structure with thick echogenic wall and leaves. The right 7th -11th intercostal spaces were the suitable acoustic window for the liver which appeared as numerous weak echoes homogenously distributed with its blood vessels. The musculophrenic vein appeared as a vessel running parallel to the longitudinal axis of the animal within the diaphragmatic musculature. Based on observations of the present study, it can be said that for ultrasonographic imaging in goats, left paramedian region is suitable for rumen, reticulum and rumeno-reticular groove, while right paramedian region for omasum, liver and occasionally reticulum using 7.5 MHz convex and 18 MHz linear probes.
CERTIFICATE – I

Date: 18.06.2010

This is to certify that Ms Aarti H.Pitroda has successfully completed the comprehensive examination of Major and supporting subject on 30.11.2009 as required under the regulation for M.V.Sc in Veterinary.

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CERTIFICATE – II

Date: 18.06.2010

This is to certify that the thesis entitled “Ultrasonography of Fore-stomach in goats (Capra hircus)” submitted for the degree of Master of Veterinary Science in the subject of Veterinary Surgery embodies research work carried out by Aarti H. Pitroda under my guidance and supervision and that no part of this thesis or research work has been submitted for any other degree. The assistance, guidance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 04.01.2010.

(D. B. Patil)                                                        (D. B. Patil)
Head of Department                                                  Major Advisor

(J. V. Solanki)
Principal/Dean
CERTIFICATE – III

Date: 18.06.2010

This is to certify that the thesis entitled “Ultrasonography of Fore-stomach in goats (Capra hircus)” submitted by Aarti H. Pitroda to the Anand Agricultural University, Anand in the partial fulfillment of requirement for the degree of Master of Veterinary Science in the subject of Veterinary Surgery after suggestion and recommendation by external examiner was discussed and defended by the candidate before the following members of the advisory committee. The performance of the candidate in the oral examination on this thesis has been found satisfactory; we therefore recommend that the thesis may be approved.

(D. B. Patil)  (D. B. Patil)
Head of Department  Major Advisor

(Y. L. Vyas)
Minor advisor

(P. V. Parikh)
Committee Member

(D. M. Patel)
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Approved (Seal and Date)
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CERTIFICATE – IV

Date: 18.06.2010

This is to certify that Aarti H. Pitroda, Department of Veterinary Surgery, College of Veterinary Science & Animal husbandry, Anand has made all correction/ modifications in the thesis entitled “Ultrasonography of Fore-stomach in goats (Capra hircus)” which were suggested by the external examiner and the advisory committee in the oral examination held on 15.06.2010. The final copies of the thesis duly bound and corrected were submitted on 18.06.2010 are enclosed here with for approval.

(J. V. Solanki)  (D. B. Patil)
Principal/ Dean       Major Advisor

(D. B. Patil)
Head of Department

APPROVED (Seal and Date)

(                                )

Director of Research and Dean
Faculty of P.G. Studies, AAU, Anand.
DECLARATION

This is to certify that whole of the research work reported in the thesis in partial fulfillment of the requirement for the award of the degree of Master of Veterinary Science in Veterinary in the subject of Veterinary Surgery is the result of investigation done by undersigned under the direct guidance and supervision of Dr. D. B. Patil, Professor and Head of Department, Anand agricultural University, Anand and no part of the research work has been submitted for any other degree so far.

Place: Anand                                                                           (Aarti H. Pitroda)
Date:  18.06.2010

Countersigned by

(D. B. Patil)
Head of Department
CERTIFICATE

This is to certified that the thesis entitled **ULTRASONOGRAPHIC STUDIES OF FORE-STOMACH IN GOATS (Capra hircus)** submitted by **PITRODA AARTI H. (Reg. No. 04-0836-2008)** in the partial fulfilment of the requirements for the award of the degree of **MASTER OF VETERINARY SCIENCE** in the subject of **VETERINARY SURGERY** of the Anand Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

PLACE: ANAND

DATE: 30 / 04 / 2010

MAJOR ADVISOR

(D. B. PATIL)
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Place: Anand (Aarti Pitroda)
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CHAPTER – I

INTRODUCTION

Goats are one of the oldest domesticated species and are said to be the poor man’s cow. The current growth of interest in goat husbandry has been motivated by the particular characteristics in the choice and intake of food, milk composition, mode of its production and the alleged therapeutic effect in some human diseases. Also important is the growing demand for certain goat milk products. Goat population of India is 124.6 million with an overall growth rate of 3.05% (Singh et al., 2008). It was found that goats are multi-purpose ruminants producing 58.4% milk, 35.6% meat, 4.3% hide and 1.7% fibre.

Ultrasound has been an important imaging modality in veterinary medicine since 1980s. Use of diagnostic ultrasound in veterinary surgery is a non invasive method of imaging soft tissues. Two dimensional B-mode and real-time scanning instruments with linear and sector probes can be used successfully for in vitro and in vivo body composition studies in goats. In principle, the depth of penetration of the sound waves and the resolution are inversely related; a low frequency is associated with greater penetration and lower resolution, and vice versa. A transducer sends low intensity, high frequency sound waves into the soft tissues, where the waves interact with the tissue interfaces. Some of the sound waves are reflected back to the transducer, and some are transmitted into deeper tissues. The sound waves that are reflected back to the transducer (echoes) are then analysed by the computer to produce a grey-scale image. The use of ultrasound in conjunction with
radiography gives the veterinarian an excellent diagnostic tool. Radiographs demonstrate the size, shape and position of the organs. The method is well established in human medicine as a well established modality. Moreover, no biological hazard in diagnostic ultrasound has been reported (Baker and Dalrymple, 1978). Ultrasound displays the findings on the radiographs, as well as the soft tissues textures and dynamics of some organs, e.g. motility of the bowel (Siems, 2005).

Ultrasound can provide information about organs architecture independent of its function. It is especially helpful in very young and debilitated patients, in which the contrast agents used in special procedures or exploratory surgery may be contraindicated. Ultrasonographic findings are not necessarily specific for histopathology diagnosis. However, the ability to distinguish solid masses allows the sonographer to focus differential diagnosis and to formulate management plans (Walter, 2003).

Ultrasonography is an ideal method of examining the abdominal organs and gastrointestinal viscera. This sonographic information can be used to decide if surgical intervention is indicated to formulate a prognosis based upon the abnormalities detected and can be used to monitor response to medical treatment. The quality of images produced by most of the ultrasonographic machines has dramatically improved making diagnostic ultrasound still more reliable (Weill, 1989). These facts have led to investigations aimed at the completion of basic morphometric data of the forestomach in the local goat breed.

Ultrasonography is an ideal tool for evaluation of the contour and motility of reticulum and adjacent organs i.e. spleen, diaphragm, abomasum,
Introduction

liver etc. Existing methods of examining the reticulum are not completely satisfactory. Although metal foreign bodies can be observed via radiography, this method does not provide information concerning reticular contour or inflammatory changes. Ultrasonography can be used for visualization of lesions caused by traumatic reticuloperitonitis such as abnormal reticular motility, fibrinous deposits on the reticular wall, between the reticulum and adjacent organs, effusions, reticular abscesses and their percutaneous lancing.

Available literature on ultrasonography in small ruminants is limited and systematic ultrasonographic study of the fore-stomach is lacking. In small ruminants, it is important to know the ultrasound anatomy. Hence this study is envisaged with the following objectives.

Objectives

1. To evaluate rumen, reticulum and omasum in vitro ultrasonographically using convex (2.5-5 MHz) and linear (7.5-18 MHz) probes.
2. To standardize the landmarks for placing the probe to evaluate different parts of fore stomach.
3. To evaluate rumen, reticulum and omasum ultrasonographically using convex (2.5-5 MHz) and linear (7.5-18 MHz) probes in 12 healthy goats.
4. To interpret the ultrasonograms of various compartments of fore-stomach.
REVIEW OF LITERATURE

The pertinent literature has been reviewed under following headings.

2.1 Studies on standardization of probe placement for Forestomach

Ultrasonographic examination of the reticulum in cattle was done when the transducer was applied to the ventral aspect of the thorax on the left and right of the sternum as well as to the left and right lateral thorax up to the level of the elbow with 3.5 MHz linear transducer (Braun, 1997; Braun and Gotz, 1994; Gotz, 1992; Kaske et al., 1994). The reticulum in sheep and goats was examined from the ventral abdominal region just caudal to xiphoid cartilage using a 5 MHz sector transducer. Reticular movements were detected through real time scanning in the form of 4-5 biphasic contractions within 4 minutes (Kandeel et al., 2009).

Assessment of reticular motility in cattle was done by placing 3.5 MHz linear transducer over the left ventral thoracic region. The reticulum was located and observed for three minutes without moving the transducer. The number, amplitude, duration and speed of reticular contractions and the duration of the interval of relaxation between two biphasic reticular contractions were assessed. The reticulum normally contracts once per minute. Thus, in the three minutes observation period, the reticulum has three biphasic contractions (Gotz, 1992).

In the browsing and grazing cattle, rumen was visualized by moving the probe from the left hind limb to the twelfth rib and from the lateral vertebral processes to the subcutaneous abdominal vein with 5 MHz linear
Review of Literature

transducer (Tschuor and Clauss, 2008). Ultrasonographic examination of the rumen in 225 sheep and 275 goats was done by using a 5 MHz sector transducer held on the dorsal aspect of the left flank region (Kandeel et al., 2009).

The omasum was scanned in cows and buffaloes by 3.5 MHz linear transducer by placing it at the eighth to ninth intercostal space. Omasum was seen as a round or oval structure having thick echogenic wall with echogenic leaves (Mohindroo et al., 2008).

Ultrasonography is a valuable technique for the assessment of the size, position and contents of the abomasum in cattle. The abomasum can be visualized with 3.5 MHz linear transducer placing it approximately 10 cm caudal to the xyphoid process from the left and right paramedian regions and from the ventral midline (Braun et al., 1997). Diagnosis of the left displacement of abomasum was done with 3.5 MHz linear transducer from the last three intercostal spaces on the left side by moving the probe ventrally to dorsally with the transducer held parallel to the ribs (Braun et al., 1997). The area immediately caudal to the last rib and the caudal two to three intercostal spaces on the right side were examined ventrodorsally with the transducer held parallel to the ribs for right displacement of abomasum (Braun, 2003).

In goats, liver was scanned on the right side of the abdomen, from the 6th through 12th intercostal space, using a 6-13 MHz linear transducer. In each intercostal space the dimensions of the liver, and if visible, the location and diameter of the portal vein and caudal vena cava were determined (Soroori et al., 2008).
Review of Literature

Braun et al. (2008) performed colour doppler ultrasonography of musculophrenic vein in cattle (n=29) using 5 MHz real time linear transducer. The transducer was placed at the ventral midline, then progressing laterally to the left and then placed parallel to the longitudinal axis of the animal. The vein was visible in both positions.

2.2 Ultrasonographic studies of rumen and reticulum

Fubini et al. (1990) conducted studies to compare radiographic and surgical findings in cattle (n=123) suspected for traumatic reticuloperitonitis. Reticular radiography proved to be a useful diagnostic aid in cattle suspected of having traumatic reticuloperitonitis. Again Parrington and Biller (1991) reported that sensitivity and specificity of radiography in detecting traumatic reticuloperitonitis or pericarditis was 83% and 90% respectively. They suggested, standing lateral abdominal radiographs are valuable in diagnosis of cranial abdominal disorders in bovines. Similar study was conducted by Braun et al. (1993) where they compared radiographs of the reticulum of animals with traumatic reticuloperitonitis to the medical records, surgical, postmortem and radiographic findings of normal animals (n = 151). The sensitivity of the radiographic diagnosis was 76 per cent, the specificity was 93 per cent, the accuracy was 85 per cent, the positive value was 92 per cent and the negative predictive value was 80 per cent.

However, Braun et al. (1993) compared the efficacy of radiography and ultrasonography for the diagnosis of TRP in bovines. They examined the morphological changes in the region of the reticulum ultrasonographically in 26 cows with traumatic reticuloperitonitis (TRP), and were compared with the radiographs. It was concluded that ultrasonography is useful for observing
Review of Literature

reticular motility and for recognizing fibrinous deposits, abscesses and accumulation of fluid even though, metal foreign bodies and magnets cannot be visualized, where radiography remains the best method for this purpose. They opined that ultrasonography of reticulum is useful in diagnosing TRP in cattle and can supplement results of clinical and radiographic examination.

Braun and Gotz (1994) performed ultrasonographic examination of reticulum and its adjacent organs (51 cows) using 3.5 MHz linear transducer, applied to the ventral aspect of the thorax over the sixth and seventh intercostal spaces. Examination included assessment of the contour of the reticulum, reticular contractions and the organs adjacent to the reticulum. The normal reticulum appeared as a half moon shaped structure with a smooth contour; it contracted at regular intervals and was situated immediately adjacent to the diaphragm and ventral portion of the abdominal wall when relaxed. Contents of the reticulum could not normally be imaged because of its partly gaseous composition. The rumeno-reticular groove, cranio-dorsal blind sac and the ventral sac of the rumen were observed caudally. The distal aspect of the spleen and the parts of the omasum, abomasum and the liver could be imaged. Reticular motility was characterized by a biphasic contraction pattern. Four biphasic reticular contractions usually were observed during a 4-minute period.

Braun et al. (1994) compared the radiographic and ultrasonographic findings in cows with traumatic reticuloperitonitis (n= 26). The cows were divided into three groups based on the radiographic findings. In the first group (n =12), the principle radiographic finding was a foreign body penetrating the reticulum; while in the second group (n = 4) there was a gas shadow or a gas-
fluid interface and in the third group (n =10) no reliable radiographic evidence of traumatic reticuloperitonitis was seen. Foreign bodies could not be visualized by ultrasonography in any of the case. In all the cows except one with radiographic evidence of abnormal gas inclusions and gas-filled interfaces, ultrasonography revealed echogenic, partitioned and capsulated structures with central hypoechochogenic cavities. In addition, in some of the cows with no radiographic evidence of the condition, severe changes indicative of inflammatory process were visible by ultrasonography.

Kaske et al. (1994) studied the efficacy of ultrasonography as a useful tool in the investigation of traumatic reticulo-peritonitis (TRP) in ruminants. The sequence of reticular contractions between grass and roughage eaters (cows, sheep) and intermediate feeders (goats) was compared ultrasonographically using 2.5 MHz sector scanner placed on left parachondral region. Duration of contractions was found to be surprisingly uniform between individuals of investigated species, still the velocity of reticular contracts was markedly higher in sheep (5.3 +/- 1.4 cm* s-1) and cows (4.4 +/- 2.0) than in goats (2.1 +/- 0.9), suggesting that in sheep and cattle feed particles are transported with a higher force in the caudo-dorsal direction resulting in longer retention time of particles in the reticulorumen. Sonographic investigations in cows (n=8) with clinical symptoms of acute TRP indicated that sonography is a valuable method for the diagnosis of TRP.

Rehage et al. (1995) evaluated the functional importance of impaired reticular contractions attributable to inflammatory adhesions in the pathogenesis of vagus indigestion in cows with traumatic reticuloperitonitis (TRP).
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Braun et al. (1997) examined 48 cows with left displacement of the abomasum (LDA) and preclinically healthy cows ultrasonographically from 11th and 12th intercostal spaces on the left side. In the controls the rumen was immediately adjacent to the left abdominal wall, whereas in the cows with LDA the rumen was generally immediately adjacent to the left abdominal wall ventrally, but displaced by the abomasum dorsally. The ingesta that were visualized ventrally in the abomasum appeared echogenic to hypoechogenic and in a few cows, the abomasal folds were visible as elongated, echogenic caecal shaped structures.

Braun et al. (1998) conducted ultrasonography in cows (n=5) with signs of TRP. Abdominal radiographs depicted presence of extensive gas-fluid interface in the reticular region and the reticulum was displaced from the peritoneum which gave tentative diagnosis of reticular abscess. Ultrasonography in these cases revealed large reticular abscesses with a well developed capsule. A foreign body penetrating the abscess could be visualised ultrasonographically in one cow. Also in two cows, the abscess could be drained through an ultrasound-guided transcutaneous incision.

Braun et al. (1998) examined Swiss Braunvieh cows (n=3) with peritonitis in the left flank region and performed ultrasonography from the left abdominal wall using 3.5 MHz linear transducer. Changes of varying extent were revealed between rumen and left abdominal wall in all cows. Centesis produced suppurative exudates and a tentative diagnosis of suppurative peritonitis was made. Cows 1 and 3 were killed due to poor prognosis and diagnosis was confirmed on postmortem examination. Cow 3 was treated
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successfully, ultimately concluding that ultrasonography permits a definitive diagnosis of peritonitis which can replace laparotomy.

Braun et al. (2002) conducted ultrasonography to evaluate the pattern of reticular motility in healthy cows premedicated with atropine, scopolamine and xylazine. Reticular motility was assessed for 3 min immediately prior to the administration of a drug and for 21 min after administration, and the later period was divided into seven 3-min intervals. They could successfully document the drug induced inhibition of reticular movements with the aid of ultrasonography.

Braun et al. (2002) examined three Swiss Braunvieh cows, of age varying from 3 to 8 years, presented with anorexia, tympany and regurgitation. Radiography and ultrasonography of the reticulum was performed in all the cases. In cows 1 and 2, an ill defined mass, which almost filled the reticulum and extended into the cranial dorsal sac of the rumen in cow 1. Radiograph of cow 3 showed a magnet and small amount of sediment in the ventral reticulum. Ultrasonography revealed cow 2 with normal pattern of reticular contractions with three biphasic contractions per three minutes. The other 2 cows had hyper motility of the reticulum. Post mortem examination of cows 1 and 3 revealed a piece of rope, weighing 3.0 and 3.3 kg, respectively and completely filling the reticulum. A left flank laparotomy was performed in cow 2, during which a bunched piece of rope, approximately 1 m in length was recovered from reticulum. It was concluded that the diagnosis of a foreign body (rope) in the reticulum of two of three cows was made via radiography. In obscure cases, such as cow 3, with regurgitation and hyper motility, as
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assessed by ultrasonography, a rumenotomy is indicated to complete the diagnosis.

Ramaprabhu et al. (2002) reported reticular abscess to be a frequent complication of traumatic reticuloperitonitis and is often associated only with vagus signs of chronic indigestion, and therefore difficult to diagnose. Formerly reticular abscesses were commonly diagnosed on exploratory laparotomy or occasionally by laparoscopy, while many cases were diagnosed only at slaughter. They opined that introduction of radiography and ultrasonography led to an improvement in diagnosis of reticular abscess in cattle.

Braun (2003) evaluated the use of ultrasonography for the diagnosis of various gastrointestinal disorders in cattle. He performed scanning in standing non-sedated cattle using a 3.5 MHz linear transducer. In animals with traumatic reticuloperitonitis, inflammatory fibrinous changes, and abscesses could be imaged; however magnets and foreign bodies were difficult to visualize because of the gas content of the reticulum. His studies revealed that ultrasonography can be used to assess the size, position and contents of the abomasums and percutaneous ultrasound-guided abomasocentesis could be performed to evaluate the nature and chemical composition of its contents. In left displacement of the abomasum, it is seen between the left abdominal wall and the rumen. It contains fluid ingesta ventrally and a gas cap of varying size dorsally. Occasionally, the abomasal folds are seen in the ingesta. Again right displacement of the abomasum will have an ultrasonographic appearance similar to that described for left displacement. Motility and diameter of the intestine are the most important criteria for ultrasonographic assessment of
ileus. However the cause of the ileus is rarely determined using ultrasonography. In case of ileus of small intestine, there is dilatation of the intestine and motility will be reduced or absent. In caecal dilatation, the caecum can always be imaged from the right lateral abdominal wall. The wall of the caecum closest to the transducer appears as a thick, echogenic and semi-circular line. He concluded that ultrasonography is an ideal diagnostic tool for the investigation of bovine gastrointestinal disorders, the most common of which include traumatic reticuloperitonitis, left and right displacement of the abomasum, ileus of the small intestine and dilatation and displacement of the caecum.

Ramaprabhu *et al.* (2003) studied comparative efficacy of various diagnostic tests for diagnosis of traumatic reticuloperitonitis and allied syndromes in cattle. A total of 67 animals (51 cows and 16 buffaloes) affected with the clinical symptoms of traumatic reticuloperitonitis were subjected to clinical/haematological/biochemical evaluation, radiography, ultrasonography and exploratory laparotomy. Ultrasonography was performed using a 3.5 MHz linear array transducer of 40mm radius placed on the left and right sides of the thorax. They opined radiography to be the best method for visualizing metallic foreign bodies and for obtaining accurate information about their position and nature whereas ultrasonography helped to reveal the presence of fibrinous changes or abscesses that could not be visualized by radiography. The major advantage of ultrasonography is it overcomes the problem of locating the lesion but also its size and extent. However they could find that ultrasonography, radiography and metal detector failed to detect the presence of non-metallic foreign bodies like polythene bags which are a major
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environmental pollutant. They concluded that although radiography or ultrasonography alone provides a limited amount of information, the two techniques complement one another well. Thus when radiographic examination of the animal provided information regarding visualization of the foreign body, ultrasonography provided excellent data about reticular motility, fibrinous deposits and abscesses. Hence, both ultrasonography and radiography should be used judiciously in diagnosing problems causing the foreign body syndrome in cattle.

Senna et al. (2003) evaluated ultrasonography and pericardiocentesis as diagnostic tools for cattle and buffaloes (n=30) with traumatic reticuloperitonitis and pericarditis. They concluded that ultrasonography is the safest and most non-invasive confirmatory aid in diagnosing traumatic reticuloperitonitis and pericarditis in cows and buffaloes.

Braun (2004) opined that ultrasonography is an integral part of contemporary bovine medicine. He suggested that for diagnostic work, a 3.5 MHz transducer provides adequate depth and good resolution, whereas a 2.5 MHz transducer can be used to examine structures that are more than 20 cm from the abdominal wall; however, the resolution is poorer. Structures close to the surface of the body can be examined with 5.0, 7.5 or even 10.0 MHz transducer.

Kumar et al. (2007a) conducted ultrasonography on buffaloes suffering from reticulophrenic adhesions using a 3.5 MHz microconvex transducer. The sonographic findings were then confirmed on exploratory laparo-rumenotomy. The ultrasonographic findings were correlated with history, symptoms, clinical
findings haemato-biochemical parameters and radiography. They found ultrasonography to be a reliable tool for diagnosis of reticular adhesions.

Rathore (2007) conducted ultrasonography in non-sedated, six male buffalo calves aged between 1 to 2 years. The animals were studied in two groups. Group I comprised of 3 male buffalo calves aged 1 year and the ultrasonographic evaluation of rumen, reticulum and omasum was done. Ultrasonographic examination of reticulum collected from slaughter house showed tunica serosa as thin echogenic line, the tunica muscularis appeared as hypoechogenic line of almost similar thickness and tunica mucosa with the tela submucosa which appeared as 3 to 4 times thicker echogenic band when viewed by linear probe in animals of group II. A characteristic biphasic contraction cycle showing reticular motility was seen in all animals of groups I and II. Four to five biphasic reticular contractions were seen during 4-minute period. The wall of cranio-dorsal blind sac of rumen and rumino-reticular groove were seen as echogenic lines caudal to reticulum in animals of groups I and II.

Mohindroo et al. (2008) reported ultrasonographic features of normal omasum in 15 adult buffaloes suffering from rumino-reticular disorders. Ultrasonography of the omasum was performed with 3.5 MHz microconvex transducer and the sonographic findings were then confirmed upon exploratory laparo-rumenotomy.

Braun and Rauch (2008) assessed reticular motility in 30 healthy, standing, non-sedated cows while they were at rest, eating, ruminating and under stress using 3.5 MHz linear transducer. The ultrasonographic examinations were made over periods of nine minutes and video was recorded
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for analysis. The reticulum contracted in a biphasic pattern while the cows were resting, eating or stressed. The first contraction was incomplete and was followed by a period of incomplete relaxation. A complete second contraction occurred immediately afterwards, followed by an interval of complete relaxation and the return of the organ to its original position. When the cows were ruminating, a regurgitation contraction, which was incomplete, occurred immediately before the biphasic contraction. The number of reticular contractions in a nine-minute period was largest when the cows were eating (13.9 contractions or approximately 1.5 per minute) and smallest when they were stressed (9.3 contractions, or approximately 1 per minute). The duration of the first reticular contraction was shortest during rumination (2.4 seconds) and longest when the cows were eating (3.0 seconds). The interval between two biphasic contractions was shortest when the cows were eating (31.6 seconds) and longest when they were stressed (53.8 seconds).

Soroori et al. (2008) obtained detailed information about the normal size and texture of goat liver by means of ultrasonography. The structure, location and size of the liver, portal vein and caudal vena cava were examined ultrasonographically in six goats. The angle of the liver and the thickness of the gall bladder wall were also determined. Examinations were performed on the right side of the abdomen, from the 6th intercostal space through 12th intercostal space, using 6-13 MHz linear transducer. In each intercostal space the dimensions of the liver, and if visible, the location and diameter of the portal vein and caudal vena cava were determined. They concluded that ultrasonographic measurement of liver size and location in healthy goats can be used as a reference for changes in the liver attributable to illness.
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Tschour and Clauss (2008) studied degree of stratification in the reticulorumen contents for morphological and physiological differences between ruminant feeding types. They hypothesized that the contents of the gastrointestinal tract cannot be usually evaluated by ultrasonography, but the three typical layers of stratified reticulorumen contents (gas dome, fibre mat, fluid) can be demonstrated. In three domesticated cows, the gas dome in rumen could be demonstrated by reverberation lines running in parallel to the line demarcating the rumen mucosa, as is typical for the sonographic image of large, gas-filled spaces. More ventrally, the area behind the rumen mucosa showed typical pattern indicating gaseous inclusions, corresponding to the fibre mat inside the rumen. Further ventrally, in two of the animals, the area behind the demarcation line appeared dark without reverberation lines, as is typical for large fluid-filled spaces. When the technique was applied to a captive, habituated, browse-fed moose, no gas dome could be demonstrated, supporting the hypothesis that the reticulorumen contents of browsers are less stratified. The results of the study indicated that sonography represents a useful tool for the demonstration of reticulorumen content stratification in live animals.

Abdelaal et al. (2009) performed study to document the clinical and ultrasonographic differences between cattle and buffaloes with various sequelae of traumatic reticuloperitonitis (TRP) and the importance of ultrasonography in detection of such sequelae. Twentynine cows and thirtythree buffaloes with TRP were investigated by using ultrasonography and confirmatory techniques such as paracentesis, laparotomy and necropsy. Ultrasonography was performed using 3.5- and 5 MHz convex transducer
placed on the ventral abdomen and on both sides of the thorax. The results of the study indicated that the classical symptom of pain and systemic reactions were common in most sequelae of TRP in cattle and less common in buffaloes. Brisket oedema and distended jugular veins have been shown in both cattle and buffaloes with pericarditis and also in four buffaloes with thoracic abscesses. Whereas ultrasonography provided exact information concerning the various sequelae of TRP in both species. Moreover, ultrasonography made it possible to determine the location and extent of the lesions accurately, and the site best suited for abdomino- and thoraco-centesis. Thus it was concluded that ultrasonography is important for early detection of TRP especially in buffaloes and to discriminate between different sequelae which have the same clinical findings.

2.3 Ultrasonographic studies on omasum, abomasum and liver

Yamaga et al. (1983) examined the abdominal organs and fetus of normal cows, horses, goats and dogs by use of ultrasonography. In cows and goats, the liver was imaged on the right side between the 8th and 12th intercostal spaces. In horses however, only the parenchymal margin was visualized. In cows, goats and dogs, the parenchyma, portal vein, hepatic vein and gall bladder showed characteristic echo patterns, respectively, but the appearance of the bile ducts was obscure. In each animal, the ultrasound images of the spleen were obtained on the left side in the lower intercostal spaces.

Braun (1990) determined the size of the liver, as well as the situation and diameter of vessels in cattle by use of ultrasonography in 10 cows, using 3.5 MHz linear transducer placed on the right 10th, 11th and 12th intercostal
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spaces. Dorsal and ventral margins of the liver, localization and diameter of the caudal vena cava and the portal vein were determined in each intercostal space, also the circumference of the gall bladder was determined. It was concluded from the study that ultrasonographic values of the liver size and localization in healthy cows could be used as reference values for the diagnosis of changes in liver size attributable to illness.

Braun and Hausammann (1992) used diagnostic ultrasound as a mass screening technique for detection of hydatid cysts in the liver and lungs of sheep and goats and reported that the sensitivity and specificity of this method was 54.36% and 97.64%, respectively. Acorda et al. (1994) performed ultrasonography of the liver in 200 Holstein Friesian dairy cattle using 3.5 MHz transducer with a linear array electronic scanner. The hepatic ultrasonograms were evaluated according to the presence of bright pattern, dark pattern, deep attenuation, vascular blurring and blurring of edges. Results suggested that different ultrasonographic patterns can be observed in various diffuse hepatocellular disorders in dairy cattle.

Braun et al. (1994) performed ultrasonography in a 6 year old Holstein Friesian cow with extrahepatic cholestasis. Ultrasonographic examination of liver and gall bladder revealed severe bile stasis and the intrahepatic bile ducts, the cystic duct and the gall bladder were severely dilated. These findings were confirmed upon postmortem examination.

Braun et al. (1997) examined ultrasonographically abdomen ventral to the xiphoid process with a 3.5 MHz linear transducer in 50 healthy cows. The abomasum could be visualized from both sides and from the ventral midline of 47 cows. The abomasum could be clearly differentiated from adjacent organs.
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because of its contents, which appeared as heterogenous, moderately echogenic structure with echogenic stippling. Slow movements of the feed in the abomasum were also visualized.

Kumar et al. (2006b) diagnosed ultrasonographically peritonitis with increased peritoneal fluid in 12 buffaloes and confirmed by ultrasound guided abdominocentesis. The ultrasonographic findings were correlated with clinical, haemato-biochemical and radiographic findings. Ultrasonographic examination was found to be reliable in diagnosis of diffused peritonitis with increased peritoneal fluid in buffaloes.

Scott (2007) performed transabdominal ultrasonographic examination to investigate the peritoneal cavity (ascites, uroperitoneum, peritonitis) liver, spleen, rumen, reticulum, abomasum, intestines and right kidney. Transrectal examination was also carried out to examine the uterus and foetus(es), bladder and kidneys. Transabdominal ultrasonographic examination is most useful in the diagnosis of focal peritonitis.

Mohindroo et al. (2008) studied the ultrasonographic features of the healthy and impacted omasum in cows and buffaloes, using 3.5MHz microconvex transducer. The omasum appeared as a round or oval structure having thick echogenic wall with echogenic leaves in healthy buffaloes, while in healthy cows the omasum was seen as a crescent-shaped structure with an echogenic wall. The contents of the omasum or omasal leaves could not be visualized. Omasal contractility was not as prominent as in buffaloes. In buffaloes, the impacted omasum appeared amotile, the omasal leaves were not visible, and the omasum as a whole gave a prominent distal acoustic shadow. In cows, the impaction could be diagnosed based on a motile omasum.
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covering a large area on the right side. It was concluded that ultrasonography
was found to be helpful in subjective assessment of omasal impaction but
could not aid in diagnosing the severity of impaction.

Braun et al. (2009) performed ultrasonography in a goat with
mesothelioma having marked bilateral distension of the abdomen due to
ascites. Ultrasonographic examination revealed accumulation of massive
amount of hypoechoic fluid in the abdominal cavity and nodular lesions on the
peritoneum, omentum and wall of the omasum.

Kandeel et al. (2009) studied ultrasonographically five goats for
normal anatomical positions of the abdominal organs through serial cross and
sagittal sections. The aim of performing anatomical study was to determine the
acoustic window for different abdominal organs in sheep and goats. The liver
of sheep and goats was examined in standing position or with the animal on
left lateral recumbency using 3.5/5 MHz sector transducer. The right 7th
to12th intercostal spaces were the suitable acoustic window for liver which
appeared as numerous weak echoes homogenously distributed with its blood
vessels. The portal vein appeared with an echogenic wall, while the hepatic
vein had a less echogenic wall. The gall bladder was examined in standing or
lateral recumbency from the right side at 9th and/or 10th intercostals spaces
using 6/8 MHz linear transducer and appeared as elongated oval or circular
shape with anechoic content "bile" with smooth and thin echogenic wall. The
omasum was examined using a 3.5-5 MHz sector transducer on the right side
at 10th intercostal space, while the abomasum was imaged using a 3.5-5 MHz
sector transducer on both ventral midline and right paramedian areas.
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MATERIALS AND METHODS

The present study entitled “Ultrasonographic studies of Forestomach in Goats (Capra hircus)” was conducted at Instructional Farm, College of Veterinary Science and Animal Husbandry, Anand, Gujarat. The animals were allotted to two groups, viz., Group I and Group II.

**Group I** – *In vitro* ultrasonography of the wall of rumen, reticulum and omasum brought from slaughter house was performed using a convex (2.5-7.5 MHz) probe through a water filled balloon placed on these organs (n=6). *In vivo* ultrasonography was performed in 12 goats for evaluation of rumen, reticulum and omasum using convex (2.5-7.5 MHz) probe.

**Group II** – *In vitro* ultrasonography of the wall of rumen, reticulum and omasum brought from slaughter house was performed using a linear (7.5-18 MHz) probe through a water filled balloon placed on these organs (n=6). *In vivo* ultrasonography was done in 12 goats for evaluation of rumen, reticulum and omasum by linear (7.5-18 MHz) probe.

The convex probe presents variable frequencies of 2.5, 3.3, 5 and 7.5 MHz and linear probe posses of 7.5, 10, 12, 15 and 18 MHz.

**3.1 Preparation of site and positioning of animal**

The area over the ventral thoraco-abdominal region and left and right sides of thorax up to the level of cubital joints was clipped and shaved and ultrasonography was carried out in standing, non sedated animals (Plate 3.1).
Materials and Methods

3.2 Placement of probe (Adopted from Braun 2003)

The probe was placed longitudinally on the ventral aspect of abdomen, on left side at the 7th to 11th intercostal spaces and on the left paramedian region to visualize rumen. Reticulum was visualized from 6th to 7th intercostal spaces of left and right side of abdomen, midventral region and left paramedian region and then for reticular contractions at the left lateral and occasionally on the right side of abdomen up to the level of elbow. Omasum was scanned by placing the probe at 6th - 8th intercostal space on the right side of abdomen, right paramedian region and midventral region (Plate 3.3, 3.5).

3.3 B – Mode Ultrasonography of Forestomach

Two dimensional B-mode and real-time scanning instruments with convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes were used for in vitro and in vivo body imaging studies in goats.

3.3.1 In Vitro B-mode Ultrasonography of Forestomach obtained from slaughter house

In the present study, apparently normal rumen, reticulum and omasum of 6 goats were collected from slaughter house. The ultrasonographic features of the normal rumen, reticulum and omasum were recorded by placing a water filled balloon on these organs. Scanning was done with e saote MyLab40 VET1 ultrasound scanner (Plate 3.2) in real time B-mode with convex (2.5-7.5 MHz) and linear probes (7.5-18 MHz) (Plate 3.4).

3.3.2 In Vivo B-mode Ultrasonography of Forestomach in Goats

After securing the animal in standing position, ultrasonography in 12 healthy goats was performed by placing the probe directly over the skin

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1 e saote MyLab40 VET: Esaote Europe B.V., Philipsweg 1, 6227 AJ Maastricht, The Netherlands.
Materials and Methods

liberally covered with acoustic coupling gel. Ultrasonography was performed with the help of convex (2.5-7.5 MHz) and linear probes (7.5-18 MHz) by placing it on the ventral and lateral aspects of thoraco abdomen region.

Ultrasonographic visualization of rumen and reticulum was done from the 6th and 7th intercostal space on left side of abdomen. Liver, omasum and abomasum were visualized from 6th to 8th intercostal space on right side of abdomen. Reticulum was also examined over the ventral abdominal area to the right of midline, over the midline and left of midline.

3.4. Assessment of Rumen by Ultrasonography

Ultrasonographic visualization of rumen was done from the 7th - 11th intercostal space on left side of abdomen, ventral aspect of abdomen and on the left paramedian region.

3.5 Assessment of Reticulum by Ultrasonography

Reticulum was visualized by placing the transducer over the ventral aspect of thorax on the left and right sides of the sternum as well as on the left and right lateral thorax up to the level of elbow.

3.6 Assessment of the Reticular Motility by Ultrasonography

In the present study, the transducer was placed on the left side of abdomen from 6th to 7th intercostal space and on the midventral region for assessing the reticular motility.

3.6.1 Video recording of Ultrasonographic Examination

The ultrasonographic examination was video-filmed and analysed as described by Braun and Rauch 2008. In each, nine minute recording, the number of reticular contractions and the duration of the interval between each biphasic contraction were determined. A stop watch was used to measure the later and the duration of the first and second reticular contractions.

3.7 Assessment of Omasum by Ultrasonography
Materials and Methods

The structure, omasum wall and pattern of omasal leaves were examined ultrasonographically in 12 goats. Examinations were performed on the right side of the abdomen from 6th to 8th intercostal space, using a 2.5-7.5 MHz convex and 7.5-18 MHz linear transducers.

3.8 Assessment of Liver by Ultrasonography

The structure, location, size and texture of the liver, portal vein, and caudal vena cava were examined ultrasonographically in 12 goats. Examinations were performed on the right side of the abdomen from the 6th to 7th intercostal space using a 2.5-7.5 MHz convex and 7.5-18 MHz linear transducers. In each intercostal space the dimensions of the liver, and if visible, the location and diameter of the portal vein and caudal vena cava were determined.

3.9 Assessment of Musculophrenic Vein by Ultrasonography

A 7.5-18 MHz real-time linear transducer was used to examine the musculophrenic vein twice, starting at the ventral midline and progressing laterally to the left. The transducer was held parallel to the longitudinal axis of the animal. The abdominal wall was scanned first, and then the left musculophrenic vein was identified and viewed longitudinally with B-mode.

3.9.1 Doppler Observation

The colour-Doppler gate was directed parallel to the wall of the vein to visualise the blood flow and then positioned at a 60° angle in the centre of the vein. Optimal colour flow was frozen on the screen to determine the distance between the Doppler measurement point and the body surface and the diameter of the vein.
Materials and Methods

The reproducibility and reliability of results were evaluated by repeated examination of 12 goats in both the groups.
Results

CHAPTER – IV

Diverse ultrasonographic observations recorded in animals of both the Groups (I & II) were in accordance with the objectives of the study.

4.1 Preparation of site and positioning of animal

The ultrasonographic study was done in standing, non-sedated twelve surti goats. For ultrasonographic examination of forestomach, the left side of the abdomen from 6th to 11th intercostal space on the ventral abdominal region at the left and right sides of the sternum were scrubbed and shaved for examination of rumen, reticulum and rumeno-reticular groove. For liver, omasum and abomasum area from the 6th to 8th intercostal space and right paramedian region were shaved and the site was prepared for scanning. The position of the animals and sites prepared were appropriate for conducting the ultrasonographic studies.

4.2 Standardization of landmarks for probe placement to evaluate different parts of forestomach in goats

B- Mode ultrasonography was performed with convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes to standardize the landmarks for probe placement and to evaluate different parts of forestomach. Rumen, reticulum and rumeno-reticular groove could be visualized from the left side of the abdomen at the level of left paramedian and midventral regions. Also, rumen was seen by placing the probe at the level of 7th -11th intercostal space.
Results

Reticulum was visualized at 6\textsuperscript{th} - 7\textsuperscript{th} intercostal spaces and rumeno-reticular groove was seen through 7\textsuperscript{th} intercostal space. Omasum was clearly visible through right side of the abdomen at the level of 6\textsuperscript{th} - 8\textsuperscript{th} intercostal space, right paramedian and midventral regions. However, adjoining organs such as liver and spleen were visible through 7\textsuperscript{th} intercostal and 6\textsuperscript{th} – 7\textsuperscript{th} intercostal space, respectively (Table 4.1).

4.3 B-mode Ultrasonography of Forestomach

Two dimensional B-mode and real-time scanning with convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes were done for \textit{in vitro} and \textit{in vivo} body imaging studies in goats.

4.3.1 Ultrasonographic examination of rumen, reticulum and omasum collected from slaughter house

The specimens of forestomach of six goats collected from slaughter house were subjected to ultrasonographic studies using convex (2.5-7.5 MHz, Group I) and linear probes (7.5-18 MHz, Group II). The contents and the texture of the internal mucosa of rumen, reticulum and omasum were studied ultrasonographically by placing a water filled balloon over the specimens.

The rumen wall had a thick echogenic texture and the rumen papillae were seen clearly echogenic (Plate 4.1, 4.2). Reticulum wall had a thick echogenic layer but different layers of the wall were not visible. The honey comb pattern of the reticular mucosa was clear in all the 6 specimens and had a thick echogenic pattern evenly distributed (Plate 4.4, 4.5). The caudo dorsal (Plate 4.3) and caudo ventral blind sacs of rumen (Plate 4.3), rumeno-reticular groove (Plate 4.6, 4.7); coronary (Plate 4.10), longitudinal (Plate 4.11) and
Results

transverse grooves of rumen (Plate 4.12); reticulo-omasal (Plate 4.13) and omaso-abomasal grooves (Plate 4.14) were also visible as a distinct echogenic lines. The distinctly echogenic wall of omasum and less echogenic omasal leaves were visible with both convex (Plate 4.8) and linear probes (Plate 4.9).

4.4 Assessment of Rumen by Ultrasonography in goats

The degree of stratification in the reticulorumen contents is considered as a major explanatory factor for morphological and physiological differences. The rumen was visualized from 7th -11th intercostal space on the left side of abdomen. The thick echogenic rumen wall with rumen papillae and the structures between the rumen wall and the outer skin were clearly visible in all the twelve goats of Groups I (Plate 4.15) and II (Plate 4.16), but it was not possible to differentiate the layers of the rumen wall. The rumen content was not clearly visible in 12 goats. Whereas, in a clinical case of goat with suspected rumen impaction, the rumen was filled with distinctly echogenic foreign material (plastic), which was confirmed on rumenotomy.

4.5 Assessment of Reticulum by Ultrasonography

Reticulum was visualized by placing the transducer over the ventral aspect of thorax on the left and right sides of the sternum as well as on the left and right lateral thorax up to the level of elbow.

Reticulum appeared as a half moon shaped structure with even contour which contracted at regular intervals and was situated immediately adjacent to the peritoneum. The different layers of the reticular wall was not imaged and the honey comb like structure of the mucosa and contents of the reticulum
Results

were not often seen clearly due to partially gas filled composition (Plate 4.17, 4.18). The rumeno-recticular groove appeared thick distinctly homogenous echogenic structure with both convex (Plate 4.21) and linear probes (Plate 4.22). However, when the transducer was moved caudally towards the left paramedian region, rumeno-recticular groove, cranio dorsal blind sac of the rumen along with ventral sac were seen (Plate 4.20). The distal aspect of the spleen could also be seen.

4.6 Assessment of Reticular Motility by Ultrasonography

Reticular motility was characterized by typical biphasic contraction patterns in all animals of Groups I and II (Plate 4.19, 4.20). Biphasic contractions were visualized for 9 minutes and the time interval between two biphasic contractions was 3.36 minutes. However, the first contraction was completed in 1.2 minute, i.e. commencement of movement of reticular wall away from abdominal wall on monitor view and regaining the previous position close to the abdominal wall. The first reticular contraction was incomplete followed by a period of incomplete relaxation (Plate 4.19). A complete second contraction occurred immediately afterwards followed by an interval of complete relaxation and return of organ to its original position (Plate 4.20). Parts of cranio-dorsal blind sac of rumen, spleen and the abomasum were often seen during reticular contractions.

4.6.1 Video Recording of Ultrasonographic Examination

A serial video imaging of nine minutes of the reticular contractions was successfully done in order to study the pattern of contraction.

4.7 Assessment of Omasum by Ultrasonography
Results

The omasum was seen with the convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes at 6th-8th intercostal space as a crescent shaped structure with 0.26-0.27 mm thick echogenic wall and echogenic leaves ranging from 0.28-0.31 mm in thickness without distal acoustic shadowing in animals of both the Groups (I -Plate 4.23 ; II Plate - 4.24 ). The medial wall of the omasum was not clearly defined in majority of the animals. Gradual slow movements of omasal leaves could be seen in a real-time B-mode in all the goats. The omasum appeared to be distinct, large and closer to the transducer. Omasal contractions could be recorded, but was not marked. The omasum never retracted away from the transducer, however, the size of the omasum reduced to a certain extent with each contraction.

4.8 Assessment of Liver by Ultrasonography

The liver was well visualized in the dorsal part of 6th-7th intercostal space two-third down the right chest wall and sometimes immediately caudal to the costal arch with convex (2.5-7.5 MHz) (Plate 4.25) and linear (7.5 – 18 MHz) probes in all the animals (Plate 4.25). The caudal vena cava was visualized in the dorsal part and the portal vein could be scanned in the ventral part. The hepatic vasculature could be recognized as anechoic tubular structure within the parenchyma. The liver parenchyma appeared hypoechoic, as numerous weak echoes were homogenously distributed over the entire liver. The portal vein and caudal vena cava could be seen within the normal texture in all goats (Plate 4.25). The caudal vena cava usually had an oval or triangular shape in cross section, except in 1 goat which had dilated inferior vena cava, but the portal vein always had a circular diameter. The visceral surface was sometimes difficult to assess when adjacent to the intestine. The
Results

gall bladder was visualized in the hypochondrium with an oval or sometimes pear-like shape and appeared as a fluid-filled vesicle. The bile ducts were not visible in the normal liver structure.

4.9 Assessment of Musculophrenic vein by Ultrasonography

The musculophrenic vein could be visualized in all the goats and appeared as a vessel running parallel to the longitudinal axis of the animal within the diaphragmatic musculature. The vein was located a few centimeters from the body surface and this distance increased slightly from caudal to cranial because of the anatomical position of the diaphragm. The diameter of the vein varied from 0.25-0.27 mm in thickness (Plate 4.25).

4.9.1 Doppler observation

The spectral display appeared as a broad band with a wave-like course. The maximum blood flow was noted and video recording was done (Plate 4.25).

4.10 Comparison of frequencies of convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes for evaluation of fore stomach collected from slaughter house

Rumen

The rumen wall was clearly visible in all the six samples brought from the slaughter house after placing a water filled balloon over the specimens. The rumen papillae had a typical turkish towel appearance and the details of rumen wall and rumen papillae were seen excellent with 7.5 MHz convex (Plate 4.1) and 7.5,15 MHz linear probes (Plate 4.2). The coronary (Plate
Results

4.10), longitudinal (Plate 4.11), transverse (Plate 4.12), reticulo-omasal (Plate 4.13) and omaso-abomasal grooves (Plate 4.14) showed marked echogenic layer and was seen excellent with 18 MHz linear probe.

Reticulum

The wall of the reticulum was clearly visible with all convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes, but 18 MHz linear probe was excellent (Plate 4.5). The honey comb pattern of the mucosa was often seen clearly after placing a water filled balloon over the organ. A 3.3 MHz convex (Plate 4.4) and 7.5 and 12 MHz linear (Plate 4.5) probes showed distinct echogenic pattern of reticular mucosa.

Rumeno-reticular groove showed marked echogenic layer and had good details with 7.5 MHz convex (Plate 4.6) and 18 MHz linear probes (Plate 4.7).

Omasum

Omasum had a thick echogenic wall in all the 6 samples of fore stomach collected from slaughter house. The details of the omasal wall were similar with all the frequencies of convex (Plate 4.8) and linear probes (Plate 4.9). The omasal leaves were also seen clearly with all the frequencies of convex probe. However, 15 and 18 MHz linear probe gave excellent quality and detail (Plate 4.9).

4.11 Comparison of frequencies of convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes for evaluation of fore stomach in goats.

Rumen
Results

The rumen content was not clearly visible with both convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes because of the gas filled composition of the rumen. The rumen wall was seen clearly with 7.5 MHz convex (Plate 4.15) and linear probes (Plate 4.16). The rumen papillae were most distinct with 7.5 MHz convex (Plate 4.15) and 15 and 18 MHz linear probes (Plate 4.16) and the muscle layer between the skin and the rumen were seen with 10, 12, 15 and 18 MHz frequencies of linear probe (Plate 4.16).

Reticulum

Reticulum could be visualized with both convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes. The details of the reticulum wall were clear with 5 and 7.5 MHz convex (Plate 4.17) and 18 MHz linear probes (Plate 4.18), but the different layers of the wall of reticulum were not seen. The reticular mucosa was seen almost similar with no difference in echogenicity using different frequencies of convex (Plate 4.17) and linear probes (Plate 4.18), but the typical honey comb pattern of reticulum mucosa could not be clearly imaged with any of the frequencies of the convex and linear probes. The rumeno-recticular groove was seen clearly with 2.5 and 7.5 MHz convex (Plate 4.21) and 10 and 18 MHz linear probes (Plate 4.22) and the details of the abdominal muscle between the skin and reticulum were similar with all the frequencies of the convex and linear probes. The muscle layer between the skin and rumeno-recticular groove were seen more pronounced with 2.5 MHz convex (Plate 4.21) and 15, 18 MHz linear probes than with other frequencies. (Plate 4.22)

Omasum
**Results**

Omasum was seen with convex probe at 2.2, 3.3, 5.0, 7.5 MHz frequencies and with linear probe at 7.5, 10, 12, 15 and 18 MHz frequencies. Omasum appeared as a crescent shaped structure with a thick echogenic wall, but the different layers of the wall of omasum were not clear. The details of the omasal leaves were best seen with 3.3 MHz convex probe (Plate 4.23). Amongst the various frequencies of linear probe, 10 and 12 MHz gave excellent quality and detail for omasal wall and omasal leaves (Plate 4.24). The muscle layer between the skin and omasum was distinct with 7.5 MHz convex (Plate 4.23) and 18 MHz linear probes (Plate 4.24).

**Liver**

The details of the liver parenchyma, gall bladder, portal vein and caudal vena cava were much clearer with 7.5 MHz convex and 18 MHz linear probes. The liver parenchyma was seen along with reticulum and omasum with clear omasal leaves using 18 MHz linear probe as compared with lower frequencies of convex and linear probes (Plate 4.25, Fig. 3).

**Musculophrenic vein**

The musculature between the skin and the musculophrenic vein was much clear when 7.5 MHz linear frequency probe as compared with the other frequencies (Plate 4.25, Fig 5).
Discussion

CHAPTER – V

DISCUSSION

The current chapter on the comparative ultrasonographic study of the forestomach in healthy goats and the specimens collected from slaughter house were indicated to focus light on the ultrasonographic anatomy and ultrasonographic diagnosis of gastrointestinal diseases in goats. B-mode and real time ultrasound scanning was done with e saote MyLab40 VET ultrasound scanner.

5.1 Preparation of site and positioning of animal

During the study, B-mode ultrasonography of forestomach was performed both in vitro and in vivo in slaughter specimens (n=6) and healthy surti goats (n=12), respectively using convex (2.5-7.5 MHz) and linear probes (7.5-18 MHz). In vivo study was performed in non-sedated goats in standing position. Ultrasonography in non-sedated cattle and buffalo calves in standing position was also reported earlier (Braun 2003 and Rathore 2007).

The rumen, reticulum and omasum were easily accessible to ultrasonography because these organs were situated immediately adjacent to the ventral abdominal wall. Additionally liver, gall bladder, abomasum, spleen and musculophrenic vein were also seen. The use of linear and microconvex transducers for diagnostic ultrasonography of forestomach was reported earlier in buffalo calves (Rathore, 2007) and in adult ruminants (Kaske et al., 1994; Kumar 2006a and b, Mohindroo et al., 2006 and Mohindroo et al., 2008). Majority of workers used only linear probe (Braun and Gotz, 1994; Braun, 2003 and Braun, 2004). However, convex probe was easy to maneuver in the
Discussion

narrow intercostal spaces while examining the omasum in the cows and buffaloes (Mohindroo et al., 2008).

Ultrasoundography is an integral part of contemporary bovine medicine. For diagnostic ultrasoundography, a 3.5 MHz transducer provides adequate depth and good resolution, whereas a 2.5 MHz transducer can be used to examine structures that are more than 20 cm from the abdominal wall; however, the resolution is poorer. Structures close to the surface of the body can be examined with 5.0, 7.5 or even 10.0 MHz transducer (Braun, 2004).

5.2 Assessment of Rumen by Ultrasonography

The ultrasonographic study of rumen is important in relation to the diagnosis of fore-stomach disorders (Braun et al., 1993) and reticular hernias (Singh et al., 1997; Singh et al., 1980) in cattle and buffaloes. The present study will provide a landmark for the normal ultrasonographic structure and location of different parts of fore-stomach, thus helping in the diagnosis of diseases of forestomach in goats.

The anterior dorsal blind sac and ventral sac of rumen were visualized predominantly from the ventral midline, left paramedian region and from the level of 7th to 11th intercostal spaces. Similar findings were also observed in goats (Kandeel et al., 2009).

In the present study, the ultrasonogram of rumen wall in all the twelve goats of Groups I and II appeared as thick echogenic structure, while the contents of the rumen were not visualized because of gas filled composition of the rumen. These findings were in correlation with earlier studies (Kandeel et al., 2009; Abu-Seida 2002 and Braun, 2003). Contents of the gastrointestinal tract cannot be usually evaluated by ultrasonography, but the three typical
Discussion

layers of stratified reticulorumen contents (gas dome, fibre mat, fluid) can be demonstrated (Tschour and Clauss, 2008)

5.3 Assessment of Reticulum by Ultrasonography

The reticulum was visualized through 6th and 7th left intercostal spaces, midventral and left and right paramedian approach. Similar observations were also made in cattle (Braun and Gotz, 1994) and buffalo calves (Rathore 2007). The reticulum appeared as a half moon shaped structure with an even contour in all the goats of Groups I & II. Similar findings on examining reticulum in cattle (Braun, 2003 and Braun and Gotz, 1994) and buffalo calves (Rathore 2007) were recorded. Contents of the reticulum, foreign bodies and magnets could not imaged because of the partially filled gas composition of reticulum (Braun, 2003), which is in accordance with our findings. It was suggested that in such conditions radiography is the method of choice (Braun et al., 1993, Braun et al., 1994).

Braun et al., (1993) advocated ultrasonography to visualize the contour of reticulum, reticular contractions, fibrinous adhesions, abscess and involvement of organ adjacent to the reticulum. Contour of the reticulum and reticular contractions were seen in all twelve goats of the present study. Similar findings were also reported in buffalo calves (Rathore 2007), but honey comb pattern was not seen. However, Braun (2003) and Braun and Gotz (1994) reported honey comb pattern visibility during ultrasononographic examination in cattle. In the present study, honey comb pattern was visible in reticulum of the forestomach specimens brought from slaughter house, but was not seen in 12 healthy goats of Groups I and II.
Discussion

Rumeno-reticular groove was easily discernible with convex and linear probes in goats of Groups I and II. Similar findings were observed in cattle using linear probe (Braun and Gotz 1994) and with convex probe in buffalo calves (Rathore 2007).

The wedge shaped spleen was visible through 7th intercostal space of left abdomen in the animals. Braun and Gotz (1994) and Rathore (2007) also observed distal parts of spleen through this region, close to the reticulum while examining cattle and buffalo calves, respectively.

5.4 Assessment of Reticular motility by Ultrasonography.

The frequency, duration, velocity and amplitude of reticular contractions can be determined and lesions such as fibrinous deposits and abscesses in the reticulum or adjacent organs can be detected using ultrasonography (Braun, 2003). In contrast to other methods, ultrasonography provides direct visualization of reticular motility and can be carried out on a large number of patients as it is straightforward and non-invasive. Reticular motility has been evaluated using ultrasonography in healthy cows at rest and in cows with traumatic reticuloperitonitis, reticular abscesses and reticulomasal stenosis (Braun et al. 2002, Braun and Gotz 1994, Kaske et al., 1994).

Reticular motility can readily be observed in the cranial abdomen immediately caudal to the left arch in sheep (Scott, 2007), whereas Kaske et al., 1994 investigated from the left ventral parachondriac region using 2.5 MHz sector scanner in cattle. In the present study, reticular motility was observed from 6th to 8th intercostal space and on the left paramedian region using convex probe (2.5-7.5 MHz).
Discussion

A characteristic biphasic contraction were observed and recorded for 9 minutes. The time interval between 2 biphasic contractions was 3.36 minutes, i.e the first biphasic contraction started at 1.2 minutes and 2nd contraction started at 4.56 minutes. However, Braun and Gotz (1994) recorded four biphasic contractions during four minute period in cows. Braun (2003) studied the reticular motility for 3 minutes and opined that reticulum contracted once per minute i.e. reticulum had three biphasic contractions, the first of which was incomplete. Whereas, Braun and Rauch (2008) observed reticular motility for nine minutes and recorded the same findings, i.e the reticulum contracted in a biphasic pattern nevertheless the cows were in rest, stressed or eating. In sheep and goats, Kandeel et al. (2009) also observed reticular movements through real time scanning in the form of 4-5 biphasic contractions within 4 minutes.

Kaske et al., (1994) compared the sequence of reticular contractions sonographically between grass and roughage eaters (cow, sheep) and intermediate eaters (goats) and checked whether sonography may be useful for the investigation of cattle with a history of traumatic reticulo-peritonitis (TRP). Duration of contractions was found to be surprisingly uniform between individuals of the investigated species. However, in cattle and sheep the reticular floor moves over longer distance during both contractions in cranio-dorsal direction as compared to goats, i.e. the velocity with which the reticulum contracts was markedly higher in sheep (5.5 +/- 1.4 cm s-1) and cows (4.4 +/- 2.0) than in goats (2.1 +/- 0.9). Thus, in sheep and cattle, feed particles are transported with a higher force in caudo-dorsal direction resulting in a longer retention time of particles in reticulorumen than in goats. Parts of
Discussion

cranio-dorsal blind sac of rumen, spleen and the abomasum were often seen during reticular contractions in goats of the present study.

5.5 Assessment of Omasum by Ultrasonography

The omasum was imaged from the right paramedian, midventral regions and at the level of 6th to 8th right intercostal spaces, but it could not be imaged from the left paramedian region. Mohindroo et al., 2008 observed omasum from 6th to 8th intercostal space from right side of abdomen with 3.5 MHz microconvex probe in cows and buffaloes. The different layers of omasum wall were not visible, whereas thin echogenic tunica serosa and muscularis layer were hypoechoic separating the thick echogenic mucosa in cows and buffaloes (Mohindroo et al., 2008) and in buffalo calves (Rathore 2007). Omasum in goats and sheep appeared bean shaped upon ultrasonography (Dyce et al., 2002), but such observations were not recorded in the present study.

Mohindroo et al., (2008) observed gradual slow movements of omasal leaves while studying the real time B-mode ultrasonographic features of healthy and impacted omasum in cows and buffaloes. The omasum appeared to be very clear, large, and close to the transducer at the start of the omasal contraction, and as the contraction progressed, the omasum retracted away from the transducer and became very small. However, in the present study omasal leaves were visualized in all the animals of Groups I and II, but the omasum contents and omasal contractibility could not be imaged.

5.6 Assessment of Liver by Ultrasonography

Liver was visible from 6th to 7th intercostal space and right paramedian region. Soroori et al., (2008) used linear (6-13 MHz) transducer to examine


discussion

the liver of goat from last rib to the 6th intercostal space of the right abdomen. Scott (2007) reported that the liver can also be visualized from half way down the right costal arch with the probe head angled towards the left shoulder in sheep. Alternatively, the liver can be imaged half way down the 8th to 10th intercostal spaces with the probe head held at a right angle to the chest wall.

Liver was visible as a structure of mixed echogenicity through right 6th and 7th intercostal space between the reticulum and omasum in all the twelve goats of Groups I and II. Gall bladder was also visualized as an anechoic structure within the liver parenchyma. Ultrasonographic measurement of liver size and location in healthy goats can be used as a reference for changes in the liver attributable to illness (Braun and Hausammann, 1992). Ultrasonography can be used to provide better characterization of abdominal distension, internal and external abdominal masses, and gross lesions of the liver in sheep and goats (Navarre and Pugh, 2002)

5.7 Assessment of Musculophrenic Vein by Ultrasonography

The musculophrenic vein is a reference structure while performing ultrasonography of reticulum in ruminants (Braun and Rauch, 2008). During examination of the reticulum in 12 goats of Groups I and II, the vein could be imaged with linear (7.5 - 18MHz) probe and was seen distinctly by Doppler sonography because of its size and location in the diaphragmatic musculature. The vein was visible and easily accessible in longitudinal section and the diameter of the vein varied from 0.25-0.27 mm and thus it fulfilled all the requirements necessary for colour Doppler sonography of a vein. Widder and Goertler (2004) stated that the vein is accessible in longitudinal section using a beam angle of 60°, while Braun and Rauch (2008) recorded the diameter of the
Discussion

vein varied from 0.5 to 1.1 cm and 0.4 to 1.2 cm, before and after sedation in healthy cows.

The results of present study have shown that the ultrasonography is a valuable supplementary technique for the assessment of the forestomach in goats. The ultrasonographic examination of rumen may prove strategic to the diagnosis of many diseases in adjoining parts of the stomach or organ.
SUMMARY AND CONCLUSIONS

The present study entitled “Ultrasonographic Studies of Fore-stomach in Goats (Capra hircus)” was carried at the Instructional Farm, College of Veterinary Science and Animal Husbandry, Anand, Gujarat. Two dimensional B-mode and real-time scanning was done with e saote MyLab 40 VET ultrasound scanner on (in vitro) slaughter house specimens of goat forestomach (n=6) with convex (2.5-7.5 MHz, Group I) and linear (7.5-18 MHz, Group II) probes, and also (in vivo) of forestomach in 12 healthy Surti goats. The animals were allotted to two groups, wherein all the twelve goats were scanned using convex (2.5-7.5 MHz, Group I) and linear probes (7.5-18 MHz, Group II).

In vitro ultrasonographic study on the slaughter house specimens of forestomach was done by placing a water filled balloon over the organs to study the wall, contents and texture of the mucosa of rumen, reticulum and omasum. Rumen wall had a typical echogenicity and the rumen papillae had distinct echogenic turkish towel appearance. The reticulum had an echogenic wall and distinctly echogenic honey comb pattern of reticular mucosa was seen. Rumeno-reticular groove had a thin echogenic line. The details of the rumen papillae, reticular mucosa and rumeno-reticular groove were similar with all the frequencies of linear and convex probes. Omasum had a crescent shaped structure showing echogenic omasal leaves.
Summary & Conclusions

During in vivo study, rumen was visualized from 7th-11th left intercostal space, midventral and left paramedian region. The rumen wall and the structures between the rumen wall and the outer skin were clearly visible in all the twelve goats, but it was not possible to differentiate the layers of the rumen wall and contents of the rumen. Whereas, the turkish towel appearance of rumen papillae appeared echogenic.

In one clinical case of goat ruminal impaction was noticed while scanning the rumen. The rumen was filled with distinctly echogenic ruminal foreign material (plastic). The findings were confirmed on rumenotomy.

Reticulum was visualized by placing the transducer over the ventral aspect of thorax on the left and right sides of the sternum as well as to the left and right lateral thorax up to the level of elbow. The reticulum appeared as a half moon shaped structure with even contour, which contracted at regular intervals. The different layers of the reticular wall were not imaged and the honey comb like structure of the mucosa and contents of the reticulum were not often seen clearly due to partly gas composition. The details of the rumen papillae, reticular mucosa and rumeno-reticular groove were similar with all the frequencies of linear and convex probes used in this study.

Biphasic reticular contractions were visualized for 9 minutes. The first reticular contraction was incomplete followed by an interval of incomplete relaxation. Then the second reticular contraction occurred which was immediately followed by a second complete contraction and an interval of complete relaxation in which reticulum returned to its initial position. Parts of
cranio dorsal blind sac of rumen, spleen and the abomasum were often seen during reticular contraction.

However, when the transducer was moved caudally on the left side, rumeno-recticular groove, cranio dorsal blind sac of the rumen and ventral sac of rumen were seen. The distal aspect of the spleen was also visualized occasionally.

The omasum was seen at the 6\textsuperscript{th}-8\textsuperscript{th} intercostal space as a crescent shaped structure with 0.28-0.31mm thick echogenic leaves without distal acoustic shadowing. The details of the omasal wall were similar with all the frequencies of linear and convex probes, but the omasal leaves was seen excellent with 3.3 MHz convex and 10 and 12 MHz linear probes.

The liver was well visualized in the dorsal part of the 7\textsuperscript{th}-11\textsuperscript{th} intercostal space, two-thirds down the right chest wall and sometimes immediately caudal to the costal arch. The caudal vena cava was visualized in the dorsal part, and portal vein could be scanned in the ventral part. The hepatic vasculature could be recognized as an anechoic tubular structure within the hepatic parenchyma which appeared hypoechoic, as numerous weak echoes were homogenously distributed over the entire liver. The inferior vena cava had an oval or triangular shape in cross section, except in one goat which has dilated inferior vena cava, but the portal vein always had a circular diameter.

The musculophrenic vein could be visualized in all the goats and appeared as a vessel running parallel to the longitudinal axis of the animal within the diaphragmatic musculature. The diameter of the vein varied from
Summary & Conclusions

0.25-0.27 mm. The Doppler observation appeared as a broad band with a wave-like course. The maximum blood flow was noted during video recording.

Based on the results of this study following conclusions were drawn:

- *In vitro* ultrasonographic studies on six slaughter house specimens of forestomach of goats with variable frequencies convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes revealed that 7.5 MHz convex and 15, 18 MHz linear probes provided excellent quality and details of rumen, reticulum wall, rumeno-reticular groove and omasum. Whereas longitudinal, transverse, coronary, omaso-abomasal and reticulo-omasal grooves were best seen with 18 MHz linear probe.

- *In vivo* ultrasonography of forestomach in twelve goats with variable frequencies of convex (2.5-7.5 MHz) and linear (7.5-18 MHz) probes revealed that rumen wall was best seen with 7.5 MHz convex and 7.5 MHz linear probes. Ruminal papillae were best seen with 7.5 MHz convex and 15, 18 MHz linear probes.

- Reticular wall was seen excellent with 5, 7.5 MHz convex and 18 MHz linear probes and honey comb pattern of reticular mucosa had clear details with 15 MHz linear probe.

- Rumeno-reticular groove was best imaged with 2.5, 7.5 MHz convex and 10, 18 MHz linear probes.
Summary & Conclusions

- Omasal wall appeared similar with all the frequencies of convex and linear probes whereas, omasal leaves were best seen with 3.3 MHz convex and 10, 12 MHz linear probes.

- During *in vitro* study, thick echogenic walls of rumen, reticulum and omasum were seen. Rumen papillae, honey comb pattern of reticular mucosa and omasal leaves were seen as having mixed hypoechoic to echogenic texture.

- In goats, left paramedian region was best for observing rumen, reticulum and rumeno-reticular groove, whereas, right paramedian region was best suited for examining omasum, liver, abomasum and occasionally reticulum.

- During *in vivo* study in goats
  
  ✓ Rumen and reticular wall were seen as having thick echogenicity with hypoechoic rumen papillae and honey comb pattern structure of reticular mucosa.

  ✓ Reticular movements were detected through real time scanning in the form of biphasic contractions within nine minutes.

  ✓ Distinctly echogenic omasal wall with leaves of variable sizes ranging from 0.26-0.27 mm thickness were seen.

  ✓ Musculophrenic vein was seen within the diaphragmatic musculature and its diameter varied from 0.25-0.27mm.


References


References


References


References


References


Table 4.1: Ultrasonographic interpretation of forestomach and abdominal organs visualized on placement of probes at different positions in goats.

<table>
<thead>
<tr>
<th>Type of probe</th>
<th>6th intercostal space</th>
<th>7th intercostal space</th>
<th>8th intercostal space</th>
<th>Midventral</th>
<th>Paramedian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td>Convex (2.5-7.5 MHz) (Group I)</td>
<td>Reticulum</td>
<td>Liver</td>
<td>Omasum</td>
<td>Reticulum</td>
<td>Reticulum</td>
</tr>
<tr>
<td>Linear (7.5-18 MHz) (Group II)</td>
<td>Reticulum</td>
<td>Liver</td>
<td>Omasum</td>
<td>Reticulum</td>
<td>Reticulum</td>
</tr>
</tbody>
</table>


Plate 3.5  Schematic representations for ultrasonographic examination of forestomach in goats

Fig 5. Ultrasonographic examination of Left paramedian view (Adopted from Braun et al., 1997 and Braun, 2003)
1- Reticulum 2- Cranio dorsal blind sac of rumen 3-Ventral sac of rumen 4- Diaphragm

Fig 6. Ultrasonographic examination of Left paramedian view (Adopted from Braun and Goz, 1994)
1- Liver 2- Reticulum 3- Spleen 4- Sternal part of diaphragm 5- Musculophreniv vein 6- Abdominal wall 7- Linear probe
Plate 3.1 e saote MyLab40 VET ultrasound scanner
Plate 3.2 Different sites for ultrasonographic visualization of forestomach in goats

Fig. 1 Left side - 6th to 11th intercostal space to visualize rumen, reticulum and rumeno-reticular groove

Fig. 2 Right side - 6th to 8th intercostal space to visualize liver, omasum and abomasum
Plate 3.3 Probe placement for ultrasonographic examination of forestomach in goats

Fig. 3 Convex probe placement
A. Left side B. Right side

Fig. 4 Linear probe placement
A. Left side B. Right side
Plate 3.4 Ultrasonography using different probes placed on the forestomach collected from slaughter house

A- Convex probe (2.5-7.5 MHz)

B- Linear probe (7.5-18 MHz)
Plate 4.1 *In vitro* ultrasonograms of rumen using convex probe (Group I)

2.5 MHz

3.3 MHz

5.0 MHz

7.5 MHz

A - Thick echogenic rumen wall
B - Rumen papillae
Plate 4.2 *In vitro* ultrasonograms of rumen using linear probe (Group II)

- **7.5 MHz**
- **10 MHz**
- **12 MHz**
- **15 MHz**
- **18 MHz**

**A** - Thick echogenic rumen wall
**B** - Rumen papillae
Plate 4.3 *In vitro* ultrasonograms of caudo dorsal & caudo ventral blind sac of rumen using linear probe (Group II)

**Caudo dorsal blind sac**

![Image of caudo dorsal blind sac at 7.5 MHz](image1)

![Image of caudo dorsal blind sac at 10 MHz](image2)

![Image of caudo dorsal blind sac at 12 MHz](image3)

**Caudo ventral blind sac**

![Image of caudo ventral blind sac at 7.5 MHz](image4)

![Image of caudo ventral blind sac at 10 MHz](image5)

![Image of caudo ventral blind sac at 12 MHz](image6)
Plate 4.4 *In vitro* ultrasonograms of reticulum using convex probe (Group I)

A - Thick echogenic reticular wall
B - Honey comb pattern of reticular mucosa
Plate 4.5 *In vitro* ultrasonograms of reticulum using linear probe (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

**A** - Thick echogenic reticular wall

**B** - Honey comb pattern of reticular mucosa
Plate 4.6 *In vitro* ultrasonograms of rumeno-reticular groove using convex probe (Group I)

A - Thick distinctly homogenous rumeno-reticular groove
Plate 4.7 *In vitro* ultrasonograms of rumeno-reticular groove using linear probe (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

A - Thick distinctly homogenous rumeno-reticular groove
Plate 4.8 *In vitro* ultrasonograms of omasum using convex probe (Group I)

A- Thick echogenic omasal wall
B- Echogenic omasal leaves
Plate 4.10 *In vitro* ultrasonograms of coronary groove using linear probe (Group II)

A- Thick distinctly echogenic coronary groove
Plate 4.11 *In vitro* ultrasonograms of longitudinal groove with linear probe (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

A- Thick distinctly echogenic longitudinal groove
Plate 4.12 *In vitro* ultrasonograms of transverse groove using linear probe (Group II)

A - Thick distinctly echogenic transverse groove
B - Dorsal sac of rumen showing echogenic rumen papillae
C - Ventral sac of rumen showing echogenic rumen papillae
Plate 4.13 *In vitro* ultrasonograms of reticulo-omasal groove using linear probe (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

A- Thick distinctly echogenic reticulo-omasal groove
B- Reticulum C- Omasum
Plate 4.14 *In vitro* ultrasonograms of omaso-abomasal groove using linear probe (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

A- Thick distinctly echogenic omaso-abomasal groove  
B- Omasum  C- Abomasum
Plate 4.15 Ultrasonograms of rumen using convex probe in goats (Group I)

2.5 MHz

3.3 MHz

5.0 MHz

7.5 MHz

A - Thick echogenic rumen wall
B - Rumen papillae
Plate 4.16 Ultrasonograms of rumen using linear probe in goats (Group II)

7.5 MHz  
10 MHz  
12 MHz  
15 MHz

Fig 7.  
a- echogenic impacted rumen material  
b- rumen wall

A- Thick echogenic rumen wall  B- rumen papillae
Plate 4.17 Ultrasonograms of reticulum using convex probe in goats (Group I)

A - Thick echogenic reticular wall
Plate 4.18 Ultrasonograms of reticulum using linear probe in goats (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

A- Thick echogenic reticular wall  B- Reticular mucosa

a- Reticulum viewed from 6-7th right intercostal space
b- Liver
Plate 4.19 Ultrasonograms showing reticular contractions when viewed from 6 - 7th left intercostal space with convex probe (Group I)

First phase of biphasic reticular contraction

Second phase of biphasic reticular contraction
Plate 4.20 Ultrasonogram of reticulum viewed from 6 - 7th left intercostal space in goats

Completion of biphasic reticular contraction

A- Rumeno-reticular groove  
B- Cranio dorsal blind sac of rumen  
C- Ventral sac of rumen

A- Wedge shaped spleen seen through 7th- 8th intercostal spaces
Plate 4.21 Ultrasonograms of rumeno-recticular groove using convex probe (Group I)

2.5 MHz

3.3 MHz

5.0 MHz

7.5 MHz

A- Thick echogenic rumeno-recticular groove
Fig. 4.22 Ultrasonograms of rumeno-recticular groove using linear probe (Group II)

A- Thick echogenic rumeno-recticular groove
Plate 4.23 Ultrasonograms of omasum using convex probe (Group I)

2.5 MHz
3.3 MHz

5.0 MHz
7.5 MHz

A- Thick echogenic omasal wall
B- Echogenic omasal leaves
Plate 4.24 Ultrasonograms of omasum using linear probe (Group II)

7.5 MHz

10 MHz

12 MHz

15 MHz

18 MHz

A - Thick echogenic omasal wall
B - Echogenic omasal leaves
Plate 4.25 Ultrasonograms of liver and musculophrenic vein

A - Liver with 7.5 MHz convex probe
B - Reticulum
C - Omasum

Measurement of portal vein

A - Dilated inferior vena cava

Doppler ultrasonograms showing musculophrenic vein (L) and its diameter (R)
Plate 4.9 *In vitro* ultrasonograms of omasum using linear probe (Group II)

A - Thick echogenic omasal wall
B - Echogenic omasal leaves