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Topographic Anatomy of the Abdomen of the Lesser Mousedeer (*Tragulus javanicus*)

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ABSTRAK

*Suatu huraian, disokong dengan kajian radiografi, diberikan ke atas anatomi kasar struktur-struktur dalam abdomen pelanduk (*Tragulus javanicus*). Perut yang besar, kompleks dan berkantung adalah sifat yang paling ketara dalam rongga abdomen haiwan ini. Perut menduduki sebahagian besar sebelah kiri rongga abdomen dan meluas hingga mengisi sebelah kanan bahagian ventral rongga abdomen. Dengan hal yang demikian usus tertolak ke kuadran kauda dorsum, krania kepada apertur pelvis krania. Hati yang multilobus terletak di sebalah kanan rongga abdomen. Ginjal tidak mempunyai lobus; khutub ginjal kanan menusuk lobus kaudat hati sementara kutub ginjal kiri berletak berhampiran, tetapi kauda ginjal kanan. Limpa yang berbentuk segitiga terletak di aspek krania dorsum kantung dorsum rumen.*

ABSTRACT

*A description is given of the gross anatomy supplemented by radiographic studies of the abdominal structures of (*T. javanicus*). The large sacculated stomach complex is the dominant feature of the abdomen, it occupies most of the left side and extends across to fill the ventral right side. The intestine is primarily relegated to the dorsal caudal quadrant immediately cranial to the cranial pelvic aperture. The multilobed liver lies entirely on the right. The kidneys are not lobed, with the cranial pole of the right kidney abutting the caudate lobe of the liver and the left kidney lying adjacent but immediately caudal to its fellow. The small triangular spleen lies on the dorsal cranial aspect of the dorsal sac of the rumen.*

INTRODUCTION

The phylogenetic relationships of the Lesser Mousedeer (*Tragulus javanicus*) have long been the subject of speculation in the scientific literature (Simpson, 1945; Vaughan, 1978). It has a complex stomach as do most of the Artiodactyla but is characterised by having a rumen, reticulum and abomasum but no omasum (Bolk *et al*, 1937; Vidyadaran *et al*, 1982; Langer, 1988). It is this reported unusual anatomy which has stimulated this detailed morphological study of the abdomen of *T. javanicus.*

MATERIALS AND METHODS

Animals

Five adult *T. javanicus* born in captivity were donated by the Institute of Medical Research, Kuala Lumpur. These were housed in individual cages 2' x 2' x 2' at the Animal House Facilities, Faculty of Veterinary Medicine and Animal Sciences, UPM. They were fed on a dietary mix of *Ipomoea* leaves, long beans, sweet potato, bananas and commercial rabbit pellets (Gold coin) and provided water *ad libitum*. The weights of sacrified animals ranged from 1.63 kg to 1.76 kg. Limited data on intestinal lenghts and weights of organs were available from an additional 10 animals used in an earlier study (Vidyadaran *et al*, 1982).

Dissection

Animals were euthanased by an intraperitoneal barbiturate. Three animals were dissected fresh and two following embalming. One embalmed and one freshly killed mousedeer were dissected from a left abdominal flank approach, the other three were dissected from a right abdominal flank approach. Black and white photographs were taken progressively throughout the dissections. Line drawings of the organ positions and their orientation to each other were noted. Dimensions of organs were measured; see Table 1 for measurements actually recorded. The relationships and the varying lengths of the mesenteries were noted.

Radiography

Another four animals were radiographed using a Mobicon III condenser discharge, mobile x-ray apparatus, model MB 101S. Exposure was 4mAs and 44kV for lateral views and 6mAs and 45kV for dorsoventral views. These were all taken at a focal distance of 90 cm.

High-speed intensifying screens (Kyokko, 250) were used with Curix film (Agfa Gevaert) which were automatically processed (Protec M45) to record the image. A dose of 20 mls of ultrafine suspension of barium sulphate (Barytgen, Fushimi Pharmaceuticals) was given by stomach tube into the distal oesophagus. Animals were positioned by gentle physical restraint on the x-ray table in both left lateral recumbency and in dorsal recumbency with the femora pulled caudally to prevent their superimposition upon the abdomen. No chemical tranquillizers were used. At each session, left lateral and dorsoventral recumbent radiographs were taken at 5 minutes, 2, 7, 24 and 48 hours following the administration of barium sulphate. Between radiographs, the animals were held in their cages.

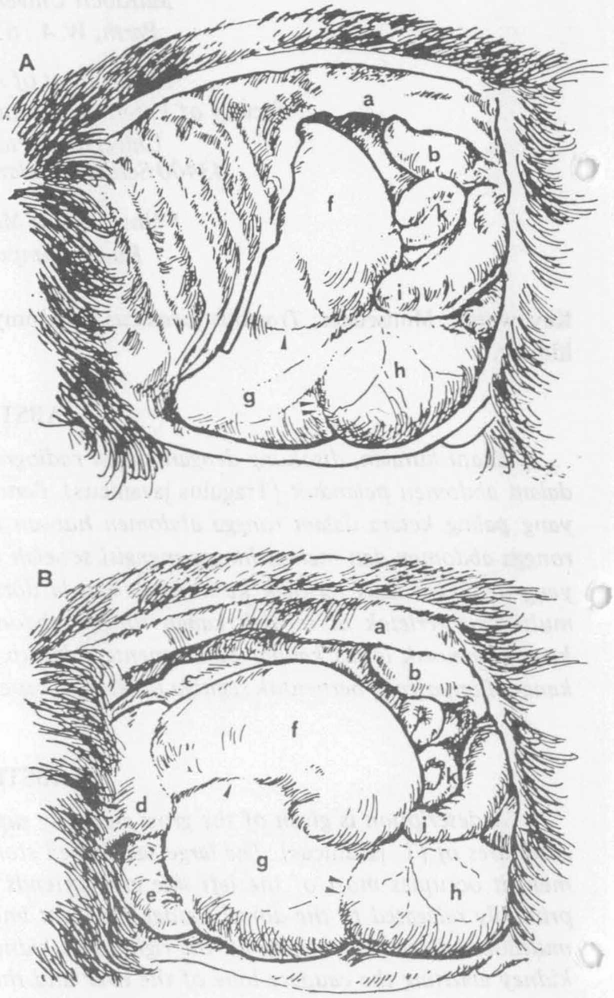


Fig. 1: *A, diagram of left flank of a mousedeer dissected with its thoracic cage intact; B, diagram of left flank of a mousedeer dissected with a thoracic cage removed where; a, lumbar hypaxial musculature; b, left kidney; c, spleen; d, reticulum; e, abomasum; f, dorsal sac of rumen; g, ventral sac of rumen; h, caudoventral blind sac of rumen; i, apex of caecum; k, loops of small intestine, single arrow is left ruminal longitudinal groove; double arrow is ventral coronary groove. Scale line is 30 mm.*

RESULTS

Anatomy: Left Flank

The stomach occupied most of the abdominal cavity immediately beneath the left flank (*Fig. 1*). From this side the three principal compartments of the stomach could be identified with the large rumen dominating most of the abdominal cavity whilst the smaller reticulum and abomasum lay more cranially adjacent the diaphragm (*Fig. 1b*). The reticulum occupied the most cranial position of the stomach compartments with its curved parietal surface abutting the diaphragm over three intercostal spaces, i.e. ventrally in the 6th and dorsally in the 9th space. The reticulum was roughly the size of a golfball (35 mm) and triangular in shape with its ventral border being horizontal (*Fig. 1b*).

Its caudoventral extremity extended into the 9th intercostal space. A ruminoreticular groove distinctly delineated the caudal extremity of the reticulum. Ventral to the reticulum and slightly more caudal to it lay the fundic extremity of the abomasum. This was firmly adherent to the adjacent cranial protion of the ventral sac of the rumen.

The rumen consisted of a distinct dorsal sac directly overlying the ventral sac which led further caudally to a large caudoventral blind sac (*Figs. 1a and b*). No caudodorsal blind sac could be found. The rumen ran from the 9th intercostal space caudally to the level of the last lumbar vertebra (L7) or the first sacral vertebra. Its dorsal sac while sometimes extending towards the last lumbar vertebral levels more often terminated in the midlumbar region.

The dorsal sac lay primarily on the left side with a little extending past the midline onto the right side. A small triangular spleen lay dorsally at the junction of the reticulum and dorsal sac of the rumen. It was held in place by a short gastrosplenic ligament. The spleen had a central hilus. The most cranial portion of the ventral sac usually lay in the 9th intercostal space. Its ventral border lay on the floor of the abdomen and ran caudally to virtually enter the pelvic cavity. Surprisingly little fat occupied the left longitudinal groove between the dorsal and ventral ruminal sacs or in the ventral coronary groove between the caudoventral blind sac and the ventral rumen sac. Depending on the level of stomach fill and the extent of gas in the stomach, the ventral sac and the caudoventral blind sac usually lay contiguously in a straight line. However, sometimes, the caudoventral blind sac lay above the ventral sac.

Taking origin from the left longitudinal groove and extending ventrally and caudally was the greater omentum which covered the ventral sac and caudoventral blind sac before running over

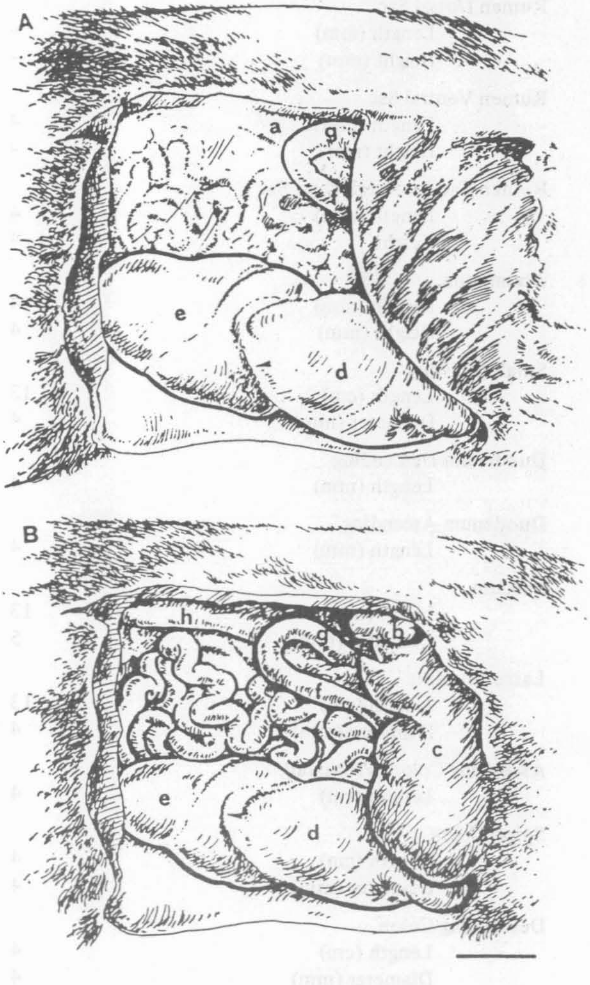


Fig. 2: A, diagram of right flank of a mousedeer with its thoracic cage intact. B, diagram of right flank of a mousedeer dissected with the thoracic cage removed where a, lumbar hypaxial musculature; b, right kidney; c, liver; d; ventral sac of rumen; e, caudoventral blind sac; f, descending duodenum; g, ascending duodenum; h, descending colon, single arrow is ventral coronary groove. Scale line is 30 mm.

TABLE 1
Measurement taken of the mousedeer *T. javanicus*

		n	Mean	±	S.E.
Weight (g)		15	1585.13		53.04
Kidney	Length (mm)	8	34.38		0.42
,,	Height (mm)	8	11.00		0.33
,,	Width (mm)	8	12.88		0.30
,,	Weight (g)	4	4.00		0.41
Reticulum	Length (mm)	4	35.50		2.47
,,	Height (mm)	4	42.75		3.30
Rumen Dorsal Sac					
	Length (mm)	4	96.25		6.88
	Height (mm)	4	44.00		2.94
Rumen Ventral Sac					
	Length (mm)	4	83.75		2.39
	Height (mm)	4	52.00		4.32
Rumen Caudoventral Blind Sac					
	Length (mm)	4	60.00		0.82
	Height	4	53.75		4.27
Abomasum					
	Length (mm)	4	66.25		1.75
	Height (mm)	4	23.75		2.39
Small Intestine					
	Length (cm)	13	176.38		7.48
	Diameter (mm)	4	5.75		0.25
Duodenum Descending					
	Length (mm)	4	65.00		2.04
Duodenum Ascending					
	Length (mm)	4	47.50		1.44
Caecum					
	Lenth (mm)	13	77.62		3.75
	Diameter (mm)	5	20.00		1.70
Large Intestine					
	Length (cm)	13	69.69		3.73
	Diameter (mm)	4	8.75		1.11
Ascending Colon (Proximal)					
	Length (cm)	4	9.25		0.48
Spiral Colon					
	Length (cm)	4	27.50		0.9574
	Diameter (mm)	4	5.50		0.29
Descending Colon					
	Length (cm)	4	16.75		0.75
	Diameter (mm)	4	4.50		0.29

the ventral abdominal floor and up the right flank separating the duodenum from the remainder of the intestine (*Figs. 1b and 2b*). The caecum was elongate, cylindrical and without any longitudinal muscle bands (taenia) or sacculations (haustra). Its base was on the right side but the body extended across to the left side so the bulk of the caecum could be seen usually from the left (*Figs. 1a, b*). Also occupying the dorsal left were many coils of small intestine. Abutting the hypaxial lumbar muscles in the same quadrant was the left kidney. This was oval shape with no indication of lobulation. It measured about 35mm long, 10.5 mm high and 13 mm wide. See Table 1.

Little or no perirenal fat was visible.

Anatomy: Right Flank

From this approach the ventral rumen and the liver were the most obvious features. The liver lay completely on the right side and could be seen lying with its parietal surface closely following the concavity of the diaphragm. The visceral surface was distinctly fissured thus delineating its various lobes. The caudodorsal portion of the caudate lobe had a definite concavity in which lay the cranial pole of the right kidney. As in other mammals, the bile duct, hepatic portal vein and hepatic artery all traversed the hepatic porta.

The ventral half of the abdomen was occupied mostly by the extensions of the ventral sac and caudoventral blind sacs of the rumen (*Fig. 2*). The abomasum lay across the axis of the body with its body lying against the ventral diaphragm and below the right lateral lobes of the liver.

The pylorus was directed caudodorsally to the descending duodenum. A short hepatoduodenal ligament anchored this portion to the hepatic porta. Running from the porta was a short bile duct which passed into the descending duodenum 3–4 cm from the pylorus. The descending duodenum ran dorsally and obliquely to the midlumbar region where it turned at the cranial duodenal flexure (*Fig. 2*) to become the ascending duodenum. This ran forwards adjacent to the hypaxial muscles then ventral to and obliquely across the right kidney to become the jejunum. The ascending duodenum was tightly bound to the proximal descending colon by a 1–2 mm long duodenocolic ligament.

Both arms of the duodenum were linked by a loose mesoduodenum in which lay the distinctly lobulated pancreas. Jejunal coils could be seen through the greater omental sheet lying haphazardly medial to the duodenum (*Fig. 2a*). This right lateral sheet of greater omentum ran dorsally to insert into the hypaxial muscle tendon origins medial to the right kidney. Once the greater omentum had been removed, the long tangle of jejunal coils could be seen (*Fig. 2b*). These were highly mobile and were held by an elongate mesojejunoileum.

The terminal element of these coils, the ileum, was conspicuous where it entered the colon. A short triangular mesentery, the ileocaecal mesentery, joined the lesser curvature of the caecum to the ileum.

Anatomy: Mid Abdomen

The proximal portion of the large intestine was not readily observable from either flank. The caecum, which ran from right to left, had most of its bulk on the left, and was contiguous with the ascending colon. The proximal portion of the ascending colon was simple, non-taeniated, non-haustrated, short and wide. After 4–5 cm it was twisted into a loose spiral which had 2.5 centrifugal and 2.5 centripetal coils. These were constant in diameter.

The caecum, ascending colon and spiral colon were all loosely held by mesenteries which allowed them much freedom of movement. These elements normally lay in the dorsal caudal quadrant of the abdomen but occasionally strayed forwards to lie beneath the thoracic cage. The last centrifugal coil of the spiral colon ran into a few simple loops then became the transverse colon and ultimately the proximal descending colon. The descending colon was held in place by mesocolon which was 3 cm long proximally and tapered down to 3 mm within the pelvic canal. The descending colon could be seen from the right side, medial to the cranial duodenal flexure (*Fig. 2b*).

Radiography

The radiographic studies confirmed and clarified the general topographic anatomy of the gastrointestinal tract. In the normal mousedeer, without the administration of radiographic contrast media, the stomach and intestine could not be distinguished readily (*Fig. 3*). Occasionally gas in the

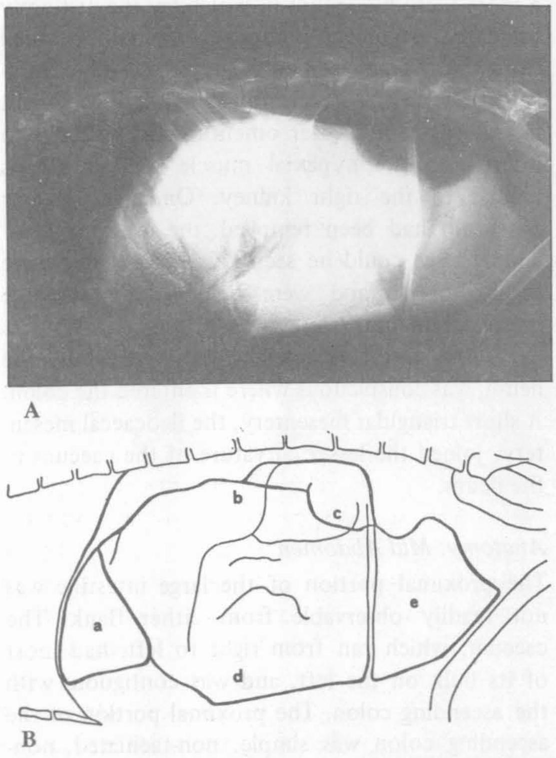


Fig. 3: *A, plain radiograph of the mousedeer abdomen, left lateral view; B, line drawing of 'A' where; a, diaphramatic silhouette; b, lumbar vertebra; c, gas in rumen; d, sacrum; e, pelvis; f, femur; g, abdominal floor; h, craniodorsal quadrant; i, cranioventral quadrant; k, caudodorsal quadrant; 1, caudoventral quadrant.*

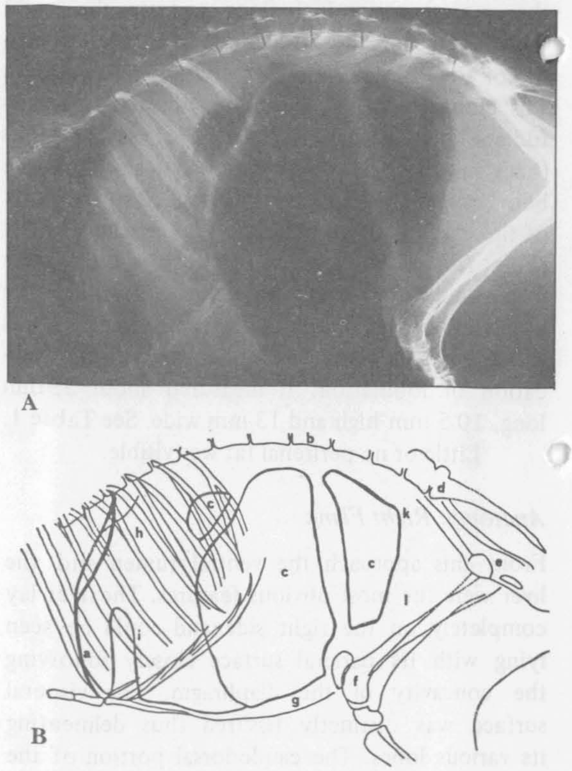


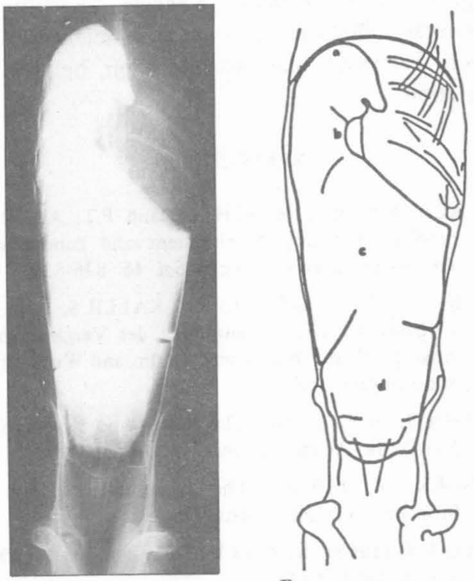
Fig. 4: *A, radiograph of the mousedeer abdomen, left lateral view, 5 minutes after the administration of the contrast agent; B, line drawing of 'A' where; a, reticulum; b, dorsal sac of the rumen; c, left kidney; d, ventral sac of the rumen; e, caudoventral blind sac.*

stomach allowed the ruminal pillars to be seen but overall this was of little use to interpreting structure. However the contrast media studies allowed an overall picture of the form of the alimentary tract to be gradually built up from the timed radiographic series (*Figs. 4, 5 and 6*).

The reticulum appeared triangular on lateral view and rhomboid or oval in the dorsoventral view. A generalised mottling with islands of contrast media up to 2 mm in diameter, was seen in some very early radiographs of some series. Usually the reticulum was flooded with contrast agent which precluded a detailed analysis of its internal architecture.

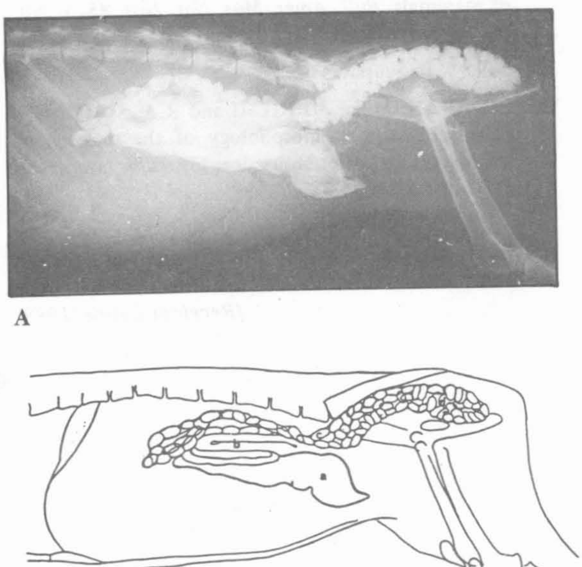
The rumen occupied most of the abdominal cavity, it being responsible for the displacement of the liver to the right and of the intestine to the right craniodorsal and to both the left and the right caudodorsal portions of the abdominal cavity. The dorsal sac of the rumen was principally on the left side (*Fig. 5*) and ran from the 8th–10th intercostal spaces, caudally to the level of the 5th or 6th lumbar vertebrae (*Fig. 4*). The dorsal sac lay above the much larger ventral compartment which ran, in its extreme cases, from the 11th intercostal space through to the 3rd sacral vertebral level. The ventral sac usually extended from T13 to L6 and the caudoventral blind sac from L5 to S3 (*Figs. 4, 5*). The distinct outline of the longitudinal and caudoventral pillars mirroring the ruminal and caudoventral coronary grooves respectively were noted (*Figs. 4, 5*). These varied a little in their position and were at times difficult to identify.

The contrast agent in the rumen usually prevented a clear view of the pylorus. However occasionally it could be seen immediately caudal and medial to the right lateral lobe of the liver.



A B

Fig. 5: A, radiograph of the mousedeer abdomen, dorsoventral view, 5 minutes after the administration of the contrast agent; B, line drawing of 'A' where; a, reticulum; b, dorsal sac of the rumen; c, ventral sac of the rumen; d, caudoventral blind sac.



A

B

Fig. 6: A, radiograph of the mousedeer abdomen, left lateral view, 21 hours after the administration of the contrast agent; B, line drawing of 'A' where; a, caecum; b, spiral colon; c, descending colon; d, rectum.

Small intestine loops were seen lying usually in the caudodorsal quadrant of the abdomen. These were highly coiled and often extended caudally into the entrance to the pelvis. The caecum was readily seen having its base to the right of the abdomen and its apex across to the left side. Its cylindrical nature was obvious (*Fig. 6*). The spiral colon was usually difficult to see because it was masked by contrast agent elsewhere in the intestine. The descending colon was an obvious dorsal feature to the right midline of the abdomen. Masses of faecal pellets could be seen in the distal descending colon and even more in the rectum.

DISCUSSION

In the true ruminant both the reticulum and omasum are responsible for particle separation (Hungate 1966; Becker *et al*, 1963). Yet the absence of a functional omasum in the mousedeer, as reported by Vidyadaran (1982), was confirmed by this study thus posing the question of which structures are critical for the sorting of digesta particulate matter. If, as has been suggested by Simpson (1945) and Langer (1988) the Tragulidae are truly a primitive Artiodactyl, then what is the significance of an omasum? It is well developed in the Giraffidae and Bovinae but not so in the Cervidae and Antilopinae (Moir, 1968). The importance of the presence and absence of the omasum in the order Artiodactyla is still a puzzle.

The absence of an omasum results in the cardia and reticuloabomasal orifices being close to one another. This in turn has resulted in the abomasum being permanently held close to the reticulum with the abomasal fundus lying to the left of the midline. The reticulum is constant in its position, it being held against the left dorsal region of the diaphragm. The abomasal fundus lies fixed ventral to the reticulum and the abomasal body is twisted to the right so that ultimately the pylorus lies medial and caudal to the right lateral lobes of the liver. The topographic relationships and mobility of the small intestine segments are similar to those found in domesticated small ruminants (Nickel *et al*, 1973).

The caecum is large without taenia or haustra. Together with the distal small intestine, ascending colon and spiral colon, the caecum is extremely mobile. This complex, which is held closely together by many mesenteric attachments, usually lies in the caudodorsal abdomen but may occasionally swing forward to lie close to the diaphragm.

Of the other abdominal organs, the kidneys and liver are noteworthy. The liver is displaced to the right presumably by the large stomach complex on the left. However it is still multilobed and has not been simplified in form as is seen in the domestic ruminants (Nickel *et al,* 1973). On the other hand the kidneys are simple bean-shaped and not lobed as stated by Simpson (1984) which is the normal situation for small ruminants (Nickel *et al,* 1973). The left kidney has long loose mesenteric attachments which allow it to be displaced probably to allow extensive distension of the rumen.

However, of all the differing and unusual morphological features possessed by the Tragulidae, it is the absence of the oamsum which most readily leads to important ongoing studies. The use of either radioisotopes or radiopaque makers are needed to determine the fluid and particulate matter dynamics of the mousedeer's alimentary tract. These techniques could determine where and how particulate matter is sorted in these animals. It is possible that the absence of an omasum may simplify digesta transport and could lead to the efficient conversion of food into body tissue. Consequently nutritional studies of the semi-domesticated Lesser Mousedeer would be extremely important in assessing whether or not these may be a potential source for meat production.

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