Pertanika 11(3), 427-435 (1988)

The Radiographic Anatomy of the Gastrointestinal Tract of the Lesser Mousedeer *(Tragulus javanicus)*

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Key words: Mousedeer; Tragulus javanicus; anatomy; gastrointestinal tract; rumen; reticulum; intestine; passage rate; barium sulphate; radiopaque markers; contrast agent.

ABSTRAK

Anatomi radiografi pelanduk (Tragulus javanicus) *adalah dihuraikan. Pelanduk mempunyai perut yang sangat besar dan kompleks yang mengisi sebelah kiri dan ventral kanan abdomen. Omasum dan pundi tuli kaudodorsum tidak wujud. Retikulum biasanya terletak kranio-ventral di sebelah kiri menyusuk diafragma. Fundus abomasum terletak kaudal dan ventral kepada retikulum. Kadar pergerakan bahan radio legap di sepanjang salur alimentari juga dihuraikan. Tinja mula diketahui membentuk dalam kolon berlingkar. Partikel kecil dan cecair mengalir dengan cepat melalui salur alimentari ($\bar{x}$ = 44.5 jam). Partikel yang mempunyai densiti hampir sama dengan jerami tertahan dalam rumen sementara logam berat tertahan dalam retikulum.*

ABSTRACT

The radiographic anatomy of the Lesser Mousedeer (Tragulus javanicus) *is described. The mousedeer has an extremely large stomach complex which fills the left and the ventral right of the abdomen. No omasum or caudodorsal blind sac were found. The reticulum usually lay cranioventrally on the left side abutting the diaphragm. The abomasal fundus lay caudal and ventral to the reticulum. The rate of passage of radiopaque substances along the alimentary tract is given. Faeces was first noted to form in the spiral colon. Small particles and fluid passed rapidly through the alimentary tract ($\bar{x}$ = 44.5 hr). Particles with densities approaching that of straw remained in the rumen whilst heavy metals were retained in the reticulum.*

INTRODUCTION

Little is known of the form and function of the digestive system of the Lesser Mousedeer (*Tragulus javanicus*). It is known that they may eat a variety of foods whilst browsing near or rooting in the forest floor. Leaves and particularly fruit are important in their diet (Medway 1977, 1978). In captivity, they eat a wide variety of food such as bananas, carrots, sweet potato, mixed grain hulled oats, commercial monkey pellets and alfalfa hay (Medway 1977, 1978) as well as *Ipomoea* leaves, long beans and peanuts (Morat and Nordin 1978, Nordin 1978). However details of their actual natural diet are lacking. It may be surmised that this animal, the smallest ruminant and smallest ungulate, need a high quality diet if microbial fermentation is to adequately supply its nutritional needs.

Vidyadaran *et al* (1982) in a general anatomical study of the mousedeer stomach reports the absence of an omasum. Morat and Nordin (1978) using marker studies determined that 95% excretion time were 107.5 ± 2.6h (mean ± SE) for sorghum grain and 54.9 ± 5.72h (mean ± SE) for chromium sesqui-oxide.

This study is to determine the radiographic anatomy of the alimentary tract of the *T. javanicus,* to ascertain the rate of passage of different radiopaque markers as well as to identify anatomical sites where markers may be retained.

MATERIALS AND METHODS

Animals

Eleven adult female *Tragulus javanicus,* born in captivity, were borrowed from the Institute of Medical Research, Kuala Lumpur. They were housed either singly or in groups of three in small cages 2' x 2' x 2' at the Animal House Facilities, Faculty of Veterinary Medicine and Animal Sciences, Universiti Pertanian Malaysia. The diet consisted of *Ipomoea* leaves, long beans, sweet potato, bananas and commercial rabbit pellets (Gold Coin) with *ad libitum* access to water. The weight of the animals ranged from 1.4 kg to 1.76 kg.

Radiography

Radiographs were taken using a Mobicon III condenser discharge, mobile x-ray apparatus, model MB101S. The exposure used was 4mAs and 44kV for lateral views and 6mAs and 45 kV for dorsoventral views at a focal distance of 90 cm. The image was recorded on Curix film (Agfa Gevaert) in combination with High-speed intensifying screens (Kyokko, 250). The radiographs were automatically processed (Protech M45). Plain radiographs were taken. Then either a dose of 20 mls of ultrafine suspension of barium sulphate (Barygen Fishimi Pharmaceuticals) or fifty 1-2mm radiopaque pellets either light weight as in straw or heavy metal were given by a stomach tube into the distal oesophagus.

The animals were positioned by gentle physical restraint on the x-ray table in both left lateral and donsoventral recumbency with the femora pulled caudally to prevent their superimposition upon the abdomen. No chemical tranquillizers were used. Each radiograph series consisted of left lateral and dorsoventral recumbent radiographs taken at 5, 15, 30 minutes then 1, 2, 8, 24, 30 and 48 hours following the administration of the contrast agent. When needed, additional radiographs were taken at intermediate times. Between radiographs, the animals were held in their cages.

RESULTS

In the absence of barium sulphate or similar radiopaque agent the alimentary tract structure could not be determined in the live animal. Occasionally gas within the viscus allowed a few intestinal loops or a segment of rumen to be seen. Overall the abdomen of the normal mousedeer had an amorphous granular appearance (*Figs. 1 and 2*).

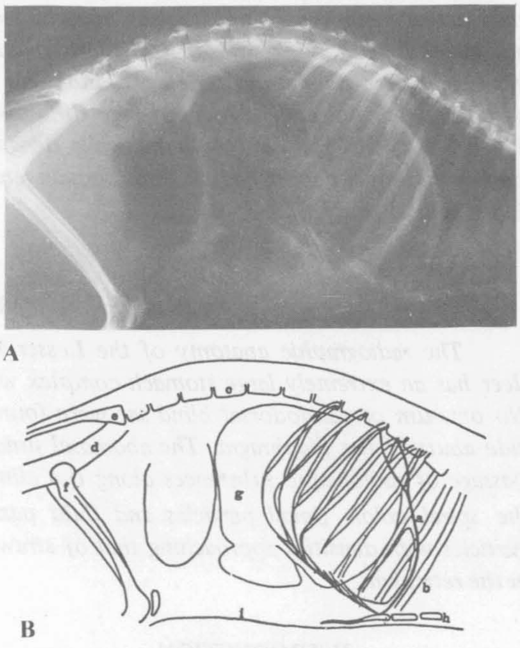

Fig. 1: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in lateral recumbency where a, diaphragmatic silhouette; b, ribs; c, lumbar vertebra; d, ilium; e, sacrum; f, femur; g, gas in rumen; h, sternum; i, floor of abdomen.

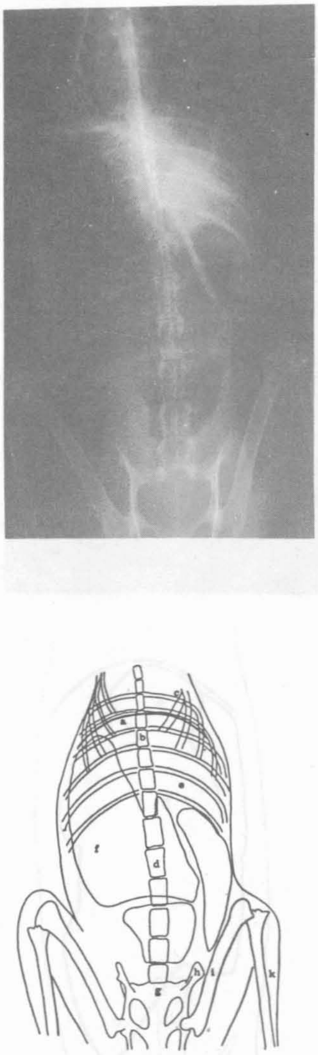

Fig. 2: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in dorsoventral recumbency where a, diaphragmatic silhoutte; b, thoracic vertebra; c, ribs; d, lumbar vertebra; e, region occupied by liver and right kidney; f, gas in rumen; g, sacrum; h, ilium; i, femur; k, tibia.

Contrast Studies – Anatomy

Barium sulphate delineated the form of the stomach and intestine of the healthy mousedeer. In its normal state the stomach complex occupied virtually the entire left of the abdomen and much of the right (*Fig. 3*). Early dorsoventral views show the liver to be lying entirely on the right side abutting the concavity of the diaphragm and extending caudally for up to 4 vertebral body lengths, well beyond the last rib (*Fig. 3*). In the early lateral radiographs contrast agent was absent from the caudodorsal quadrant (*Fig. 4*) in which the loops of intestine usually lay (Richardson *et al*, in press).

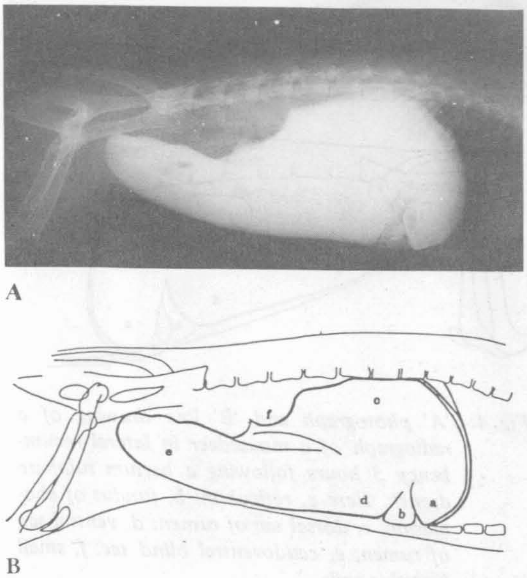

Fig. 3: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in lateral recumbency 10 minutes following a barium sulphate drench. Here a, reticulum; b, fundus of abomasum; c, dorsal sac of the rumen; d, ventral sac of the rumen; e, caudoventral blind sac; f, left kidney.

When most clearly seen, the reticulum appeared to have a regular mottled appearance, probably where the barium sulphate had highlighted the depths and walls of the reticular cells. The reticulum appeared to have a pentagonal or rhomboidal shape in dorsoventral views (*Fig. 5*) and oval or triangular in lateral views (*Fig. 4*). Often the reticulum was found abutting the diaphragm dorsally, running between the seventh and eleventh intercostal spaces. In some animals, it was more ventral and cranial in position and ran between the sixth and seventh intercostal spaces. It was only in the earlier radiographs that the vertically or near vertically oriented reticuloruminal orifice could be seen. In later radiographs the reticulum and the dorsal sac of the rumen appear as one.

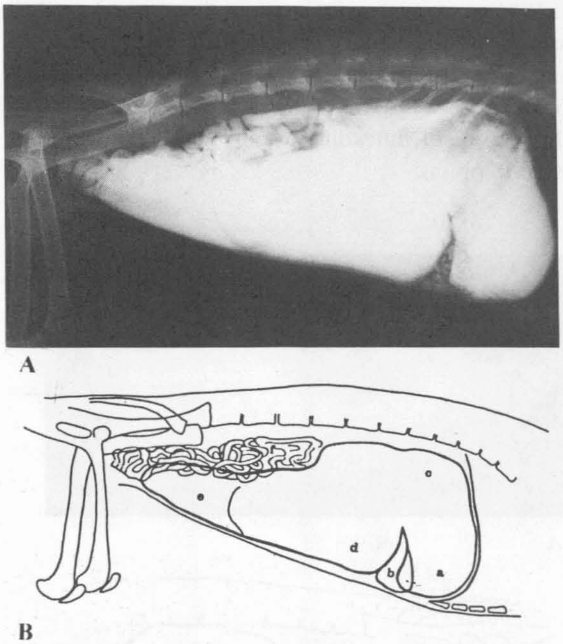

Fig. 4: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in lateral recumbency 3 hours following a barium sulphate drench. Here a, reticulum; b, fundus of abomasum; c, dorsal sac of rumen; d, ventral sac of rumen; e, caudoventral blind sac; f, small intestine coils.

The rumen lay on both sides of the abdomen. A dorsal sac, ventral sac and caudoventral blind sac of the rumen could be identified but no caudodorsal blind sac was present (*Figs. 3, 4, 5*). The dorsal sac was confined to the left side where it lay with its dorsal wall against the lumbar and thoracic hypaxial musculature from T10 to L5. At least one third and more likely half of its bulk lay below the thoracic cage. The dorsal sac extended cranioventrally across the caudal aspect of the diaphragm at intercostal spaces 10 to 8 where it became confluent with the reticulum. The reticular groove joining the cardia to the reticuloabomasal orifice was never visible. Caudally the dorsal sac ended as a cranially directed concavity level with lumbar vertebra 5–6. The orifice between the dorsal sac and ventral sac could not be seen easily, nor could the horizontal pillars which delineated the orifice.

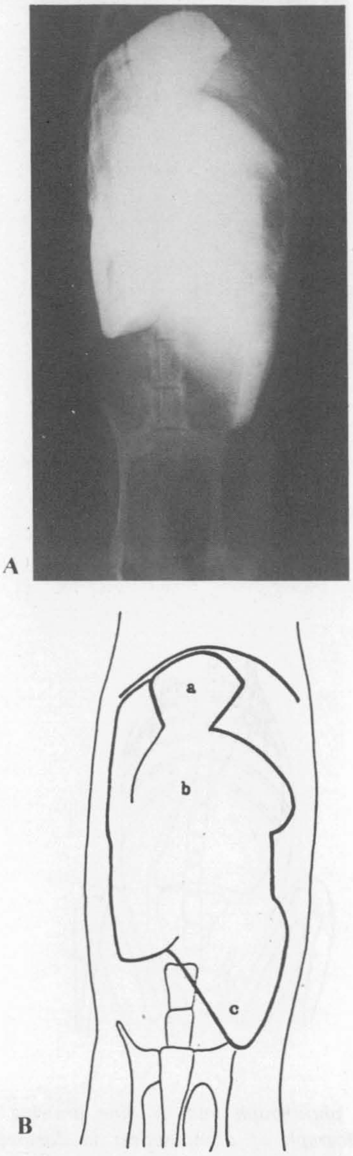

Fig. 5: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in dorsoventral recumbency 10 minutes after a barium sulphate drench. Here a, reticulum; b, dorsal sac of rumen; c, caudoventral blind sac.

The ventral sac of the rumen lay on the left floor of the abdomen and extended across to the right side. It usually extended between T13 and L6 but occasionally it stretched from T11 to S3 (*Fig. 3*). Both its cranial and caudal borders curved obliquely upwards. A distinct outline of the pillar associated with the caudoventral coronary groove was visible. This pillar was oriented obliquely upwards from the ventral abdominal floor in the vicinity of L5 dorsally and slightly caudally to L7. Sometimes the pillar lay vertically.

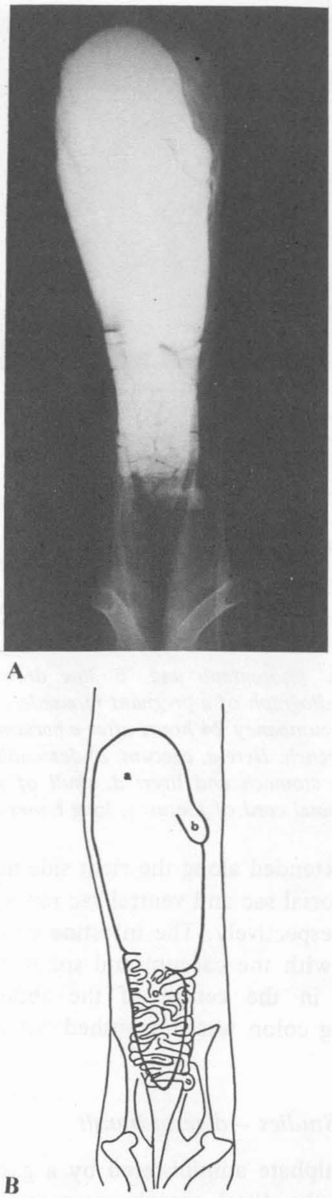

Fig. 6: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in dorsoventral recumbency 2.5 hours after a barium sulphate drench. Here a, dorsal sac of rumen; b, pylorus; c, caudoventral blind sac overlain by small intestine coils.

The caudoventral blind sac extended from where the ventral sac ended and ran along the abdominal floor to virtually enter the pelvic cavity. This sac ran from L5 to S3. It was cone-shaped with its greatest circumference being at its junction with ventral sac. The left side of this junction was approximately at L4 and the right was at L5. Parts of the abomasum were visible on both sides of the abdomen. From a left lateral radiograph, its fundic portion could be seen lying caudoventrally to the reticulum and cranial to the ventral sac of the rumen (*Figs. 3 and 4*). From dorsoventral views the pylorus could be seen, occasionally, on the right side adjacent the hepatic porta (*Fig. 6*). Only the initial one to two centimeters of the duodenum could be seen regularly. The bulk of the jejunum usually lay as a coiled mass in the caudodorsal quadrant of the abdomen (*Fig. 6*). Often a few of these coils extended caudally to the pelvic entrance. Occasionally the jejunal coils were seen sandwiched between the abomasum and reticulum or were seen lying adjacent the hepatic porta.

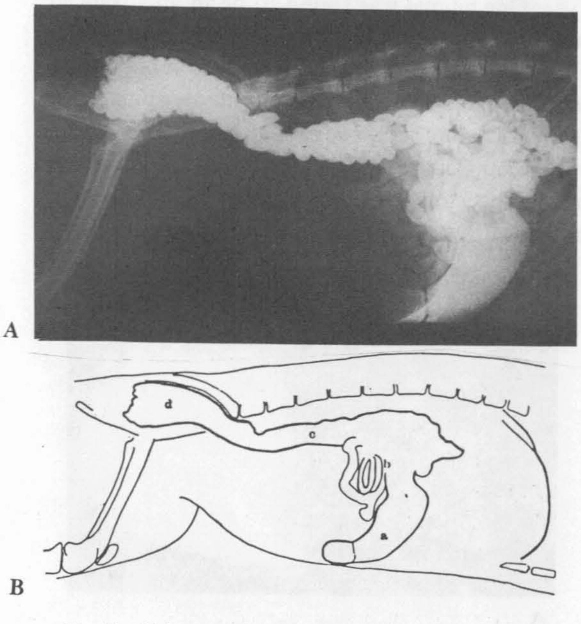

Fig. 7: 'A' photograph and 'B' line drawing of a radiograph of a mousedeer in lateral recumbency 21 hrs following a barium sulphate drench. Here a, caecum; b, spiral colon; c, descending colon with faecal pellets; d, rectum with faecal pellets.

The large intestine was radiographically more complex than the small intestine. The caecum usually lay with its base to the right mid dorsal flank, its body in the mid abdomen and its apex to the left flank. Sometimes the caecum ran caudally, remaining on the right side whilst on other occasions the body of the caecum lay in the cranioventral sector of the abdomen.

The caecum was continuous with the short straight segment of ascending colon which after about 90 cm became coiled upon itself as the spiral colon (*Fig. 7*).

The spiral colon lay in the dorsal right of the abdomen between L2 and L6. Details of the spiral and subsequent irregularly arranged colonic loops could not be determined. However, it was in the spiral colon that elongate faecal pellets of low radiopacity were seen first. Further along the colon especially in the descending colon, the pellets were shorter and had a greater radiodensity. The descending colon was a dorsal midline structure which had a wide diameter and regularly accomodated 100–200 faecah pellets (*Fig. 7*). These pellets were clumped as large masses not as individual units.

One animal was found to be in an advanced state of pregnancy. In fact she gave birth to a healthy offspring during the radiographic series. In this animal the foetus lay with its spine lying against its mother's abdominal floor. The uterus with foetus, occupied the caudal half of the abdomen. The stomach complex plus intestine were pushed forward (*Fig. 8*). The caudoventral blind sac still extended along the right side as far as L6 but the dorsal sac and ventral sac ran as far as L3 and L4 respectively. The intestine was crammed forward, with the caecum and spiral colon lying vertically in the centre of the abdomen. The descending colon was not pushed out of position (*Fig. 9*).

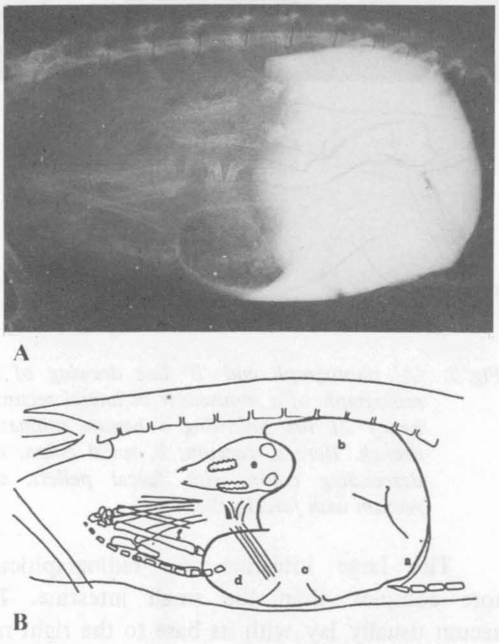

Fig. 8: 'A' photograph and 'B' line drawing of a pregnant mousedeer in lateral recumbency 5 minutes after a barium sulphate drench. Here a, reticulum; b, dorsal sac of rumen; c, ventral sac; d, caudoventral blind sac; e, skull of foetus; f, long bones of foetus.

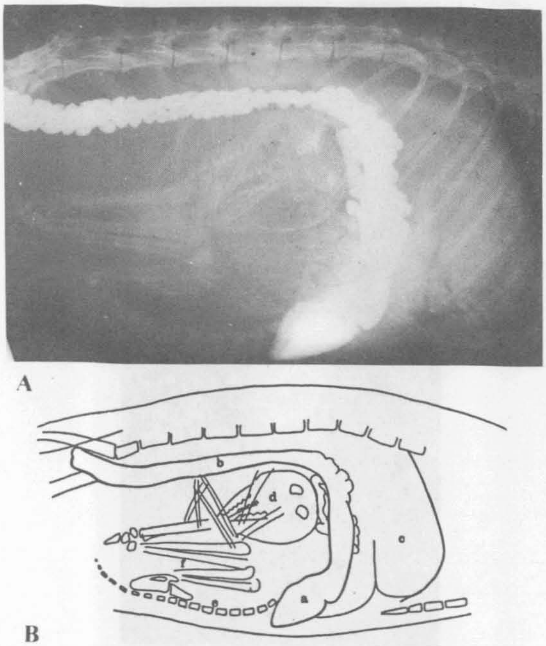

Fig. 9: 'A' photograph and 'B' line drawing of a radiograph of a pregnant mousedeer in lateral recumbency 24 hours after a barium sulphate drench. Here a, caecum; b, descending colon; c, stomach and liver; d, skull of foetus; e, spinal cord of foetus; f, long bones of foetus.

Contrast Studies – digesta transit

Barium sulphate administered by a gastric lavage tube into the distal oesophagus gave an estimate of the movement of the fluid/small particle phase of digesta along the alimentary tract. Radiopaque pellets administered similarily, dispersed through the rumen and reticulum. The light weight pellets remained spread throughout the rumen for about 48 hours (*Fig. 10*). During this time, surprisingly, the heavy metal impregnated plastic gradually dissolved. By 72 hours the pellets in their original form did not exist, rather they had collapsed to tiny fragments (0.1 mm) which initially collected in the reticulum (*Fig. 12*) and were then passed through the abomasum and ultimately eliminated from the body.

The heavy pellets were swallowed and dispersed throughout the rumen and the reticulum (*Fig. 11)* but within 3 hours these were all collected into the reticulum (*Fig. 12*) where most remained in excess of 10 days. After 4–5 days, 1–2 of these pellets passed through the reticulo-abomasal orifice and then along the alimentary tract and were eliminated in the faeces. It is estimated that in excess of 30 days would be necessary for the complete elimination of the 50 heavy pellets. The times of first entry of barium sulphate or radiopaque pellets into the small and large intestine is given in Table 1.

The time it took for the stomach, small intestine and the entire alimentary tract to be devoid of barium sulphate or radiopaque pellets is given in Table 1, as an estimate of the time at which faecal pellets, incorporating contrast agent, were first formed.

DISCUSSION

This study reports the normal radiographic anatomy of the mousedeers gastrointestinal tract. As in other ruminants the stomach complex is the dominant feature of the abdomen. In the mousedeer, it occupies virtually the entire left side of the abdomen as well as fills the ventral right side. The ventral sac of the rumen with its continuation, the caudoventral blind sac, is the largest chamber, occupying most of the floor of the abdomen. In fact the caudoventral blind sac occasionally extends into the pelvic cavity. The caudoventral coronary grooves with their associated pillars are constant features being routinely visible in the caudoventral abdominal region. No caudodorsal blind sac was seen. The dorsal sac appears to be restricted to the left side and has no special features. The longitudinal pillars delineating the orifice between the dorsal and ventral sacs were seen occasionally but were not seen clearly or routinely.

The reticulum was a little more mobile than initially expected. It was found lying most often cranioventrally adjacent to the left concavity of the diaphragm but occasionally it lay against the diaphragm but in the craniodorsal quadrant. No reticular groove was seen radiographically at any stage yet upon dissection it was present (Vidyadaran *et al,* 1982, Langer, 1988). Heavy particles were held for a long period in the reticulum. How and why these particles were ultimately passed into the abomasum is not known.

The gross radiographic anatomy of the mousedeer's small intestine is unremarkable. The passage of digesta with enclosed radiopaque markers is rapid and would need fluoroscopic

TABLE 1

Passage time of barium sulphate and radiopaque pellets through the alimentary tract.

	Barium Sulphate Suspension (n=6)		Radiopaque Pellets (Heavy)
	Mean	Range	
Contrast agent first through pylorus (h)	1.3	0.3 – 2.0	4 days
Stomach empty of contrast agent (h)	16.5	12.0 – 22.0	30 + days
Small intestine empty of contrast agent (h)	20.8	18.0 – 24.0	30 + days
Contrast agent first into large intestine (h)	7.0	6.0 – 9.0	4.5 days
Faecal pellets first formed (h)	7.2	5.5 – 9.3	4.6 days
Alimentary tract devoid of contrast agent (h)	44.5	36.0 – 48.0	30 + days

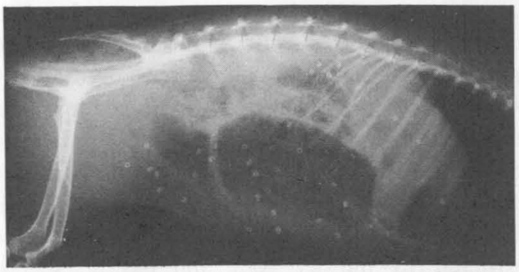

Fig. 10: A photography of a radiograph of a mousedeer in lateral recumbency 4 hours after the administration of light weight radiopaque pellets. Here the pellets are dispersed throughout the rumen and reticulum.

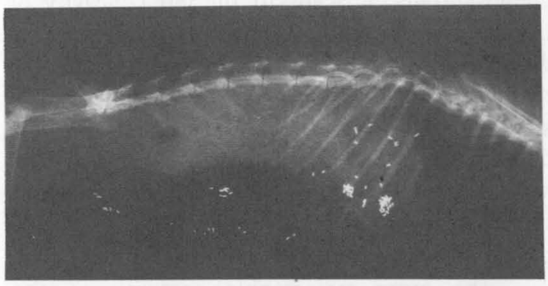

Fig. 11: A photograph of a radiograph of a mousedeer in a lateral recumbency 5 minutes after the administration of heavy radiopaque pellets. The pellets lie in the rumen and reticulum.

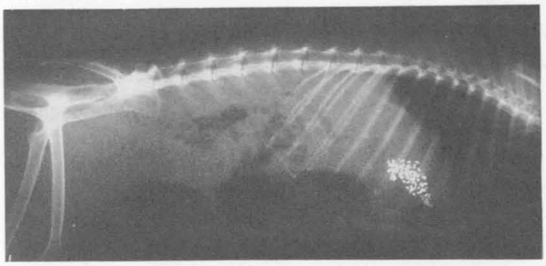

Fig. 12: A photograph of a radiograph of a mousedeer in lateral recumbency 6 hours after the administration of heavy radiopaque pellets. The pellets all lie in the reticulum.

techniques to clarify. Like the Tammar wallaby (Richardson and Wyburn, 1980) the mousedeer has a simple small caecum which is probably only of secondary importance in digestion. Again, as in studies on kangaroos the caecum probably does not retain preferentially, either the liquid or the particulate phase of the diet (Hume, 1982). Whilst the present study does show that the final clearance of barium sulphate from the caecum takes a long time, the final clearance of this agent from the alimentary tract is difficult to determine. Radioisotope studies would certainly clarify such issues.

The observation of faecal pellet formation being initiated in the spiral colon agrees with the observations by Macrae *et al,* (1973) of similar events in the spiral colon of the sheep.

Pregnancy has a major effect on the abdominal topography where the enlarged uterus pushes most of the rumen complex and the entire intestine forwards into the cranial half of the abdomen. In these cases the caecum and spiral colon become located towards the cranial midline of the abdomen immediately in front of the uterus.

Parra (1978), utilizing information on fermentation rates in many species of Artiodactyla of quite different body weight as well as data on the Langur monkey, Quokka, rabbit, porcupine and pig, calculates that in animals of less than 10 kg body weight, foregut fermentation is a less viable strategy than hindgut fermentation to meet the energy requirements of these smaller herbivores. Yet there a few species of herbivores and folivores below this arbitrary limit and the Lesser mousedeer is well below.

For a forestomach fermenter, the size of the stomach complex relative to its body weight is critical. With a drop in body weight the metabolic rate per unit weight increases but the stomach size is limited, so much so that there is a disproportionately small amount of food available for fermentation (Parra, 1978). Fermentation rate cannot increase sufficiently, a possible compensatory mechanism, is the animal must improve the quality of its diet, increase the rate of passage of digesta or do both (Mertens, 1973).

Generally an increase in the rate of passage of digesta drops the apparent digestability of the food. This drop is greater for poor quality high fibre foods than it is for food of higher quality (Blaxter, 1963). It is possible that the absence of an omasum in the mousedeer allows an increase in the passage rate of its digesta.

This coupled with a selection of more nutritious, higher quality portions of plants such as fruits, nuts, tubers and fresh shoots would probably allow the retention of forestomach fermentation in such a small ruminant. Detailed documentation of food actually ingested by mousedeer in their natural situation is necessary to clarify the issue. Similarly nutritional analysis of their actual diet, not supposed diet, is needed.

ACKNOWLEDGEMENTS

We wish to thank Encik Ganesamurthy, Encik Hamdy and Encik Sivasoorian for their able technical assistance. We thank Encik Palaniandy for his radiographic assistance and the Department of Clinical Sciences for allowing us the use of their facilities.

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(Received 23 May, 1988)