A. GENERAL INTRODUCTION

The field of large animal trunk radiology is relatively new in veterinary medicine. Veterinary radiology has been mainly confined to the examination of the lower parts of the extremities and of the head. This is explained by the absence of powerful enough clinical x-ray units, as well as by the widespread belief that the technical and practical difficulties involved in trunk radiography are insurmountable. This is evidenced by Broom[5], even at the time when the first reports of the use of radiography in the study of the digestive tract of the weaned foal have appeared in the literature[1,20]

Drury[9], however, working with very young foals states: "We feel we may suggest with confidence that radiographs of quality could be obtained in larger subjects using apparatus of greater power, and if facilities could be more available to veterinary surgeons, there is no reason why large animal radiography should not become commonplace".

Although constant improvement of radiological equipment and the availability of powerful x-ray units for veterinary medicine have proved Drury's view, the digestive system of the horse has remained neglected even with the renewed interest in large animal radiography.

First reports of radiological examination of the trunk of large animals appeared in 1951. Alexander[1] and Muller[20] worked on the gastro-intestinal tract of ponies. Both employed contrast medium to study the topography of the digestive system. Several years later, Drury, Dyce & Merlen[9] reported on radiology of the neck and limb joints of a pony. Dyce[12] has studied the gastro-intestinal tract of a standing newborn foal.

Techniques employed by early workers[1,9,12,20] were extensively used in the research and clinical work reported in the following years. It is important to note that most of these reports[13,15,17,21,22,30,31] dealt with radiography of the bovine and not of the equine. Traumatic reticulitis, with intrathoracic complications and conditions of the abomasum were mainly studied. The few reports which were published about trunk radiography of the horse concerned the skeletal system[7,19,25,26].

No further reports appeared since the early work[1,12,20]. Only one report[23] described the radiology of the oesophagus of the horse. Textbooks[6,8,28] on veterinary radiology omit reference to the equine digestive system.

The purpose of this thesis is to make a contribution to the radiology of the equine digestive system.

With the availability of a modern powerful x-ray unit at the Department of Surgery, University of Pretoria Faculty of Veterinary Science, Onderstepoort, a research project was undertaken to study the normal gastro-intestinal system of the horse, and to establish useful procedures and techniques for its radiological examination.

Since the horse is a large, powerful animal, guidelines for the technique and procedures were the following:-

(a) The technique had to be as simple as possible.

(b) The animal had to stand up normally, thus eliminating casting.

(c) There had to be the least possible interference with the animal, to avoid the necessity of immobilization and/or anaesthesia.

(d) Use of the common preparations of radio opaque material had to be made.

A.1. Equipment and Methods in General

The project was accomplished by the use of a Triplex Optimatic 1023 (figures 1 and 2), made by Elema Schönander AB of Stockholm, Sweden. The machine has an output of 100 KV at 640 MAS or 200 KV at 320 MAS or 200 KV at 800 MA on 50 KV in extra short exposures.

Figures 1 and 2:

The x-ray unit which was used in the project. Note the suspension of the tube from the ceiling and the stationary grid.

All exposures were done through a grid. Wherever possible, use was made of the stationary grid fixed to the floor, otherwise a portable grid was used. The exposure factor ranged according to the area involved. Accounts are given in each section of the work.

All radiograms were made on either Kodak, Ferrania or Ilford high speed films 14 x 17 inches with a high speed intensifying screen.

Before any study was to begin, the animal received by i.m. route a dose of acetylpromazine. Forty-five minutes later the horse was brought into the x-ray room for radiography.

One tranquillization dose was often sufficient for the entire day. A second tranquillization was sometimes necessary after three to $3\frac{1}{2}$ hours, especially when complete relaxation was desired.

A.2. Experimental Animals

The experimental studies were made on four horses. At the beginning of the study, the following were the age and weight of each horse.

Horse No. 6237 - female - 3 years old -
of approximately 500 kgs. (1100 lbs.)

Horse No. 6295 - female - $3\frac{1}{2}$ years old -
of approximately 400 kgs. (880 lbs.)

Horse No. 6637 - female - 18 months old -
of approximately 350 kgs. (770 lbs.)

Horse No. 6626 - male - 14 months old -
of approximately 250 kgs. (550 lbs.)

Primary studies were done on the two younger horses. When the procedures were established, they were repeated on the heavier horses. Each procedure was repeated twice on each animal. When results varied, the studies were repeated until conclusions could be arrived at. If the exposure data varied considerably between the light and heavy horses, the variations are reported.

A.3. General Remarks

There were several problems involved with the radiological examination of the horse:

A.3.(a) Direction of exposure

In order to achieve a diagnostic quality radiograph the exposure must be of at least two planes at right angles. In some parts of the gastro-intestinal system of the horse, however, it was impossible to achieve this without complete anaesthesia because of anatomical considerations.

A.3.(b) Scattered radiation

Though the x-ray unit with which the project had to be carried out was powerful enough to produce the necessary kilovoltage for penetration of the tissue mass of the horse's trunk, this did not ensure diagnostic radiographs with clear definition. The higher the kilovoltage, the larger the amount of scattered radiation, which tended to diffuse the radiographic image. Minimum Kilovoltage had to be utilized but had the disadvantage of longer exposure.

A.3.(c) Exposure time

The time of exposure had to be as short as possible. In working with a non-anaesthetized animal, longer exposures increased the risk of movement during the exposure, which in turn produced unsharp lines in the radiograph. However, limiting the exposure time was related to the amount of x-rays (MA) which could be produced by the unit. Because of the size of the subject, the thickness of the tissue involved, limiting the exposure time to short exposures, could not always be achieved. It is understood, therefore, that the technique recommended for each section of the gastrointestinal tract of the horse was a compromise between the conditions relative to the part radiographed.

B. THE RADIOLOGY OF THE DIGESTIVE SYSTEM OF THE HORSE

B.1. Oesophagus

B.1(a) Anatomy:

The oesophagus extends from the pharynx to the stomach. It begins in the median plane above the anterior border of the cricoid cartilage of the larynx.

At the fourth cervical vertebra it passes to the left of the trachea and remains in that position up to the third thoracic vertebra. At the level of the third thoracic vertebra it passes dorsally to the trachea and continues to cross the aortic arch. At the crossing of the aortic arch it is pushed to the right of the median plane. It continues towards the oesophageal hiatus, where it is inclined towards the left, terminating at the cardia, immediately caudal to the diaphragm. The cardia is formed by a very strong circular muscle known as the cardiac sphincter. No other sphincter is present in its entire course.

B.1(b) Histology:

As in all animals, there are four layers which make up the oesophageal wall: An external fibrous sheath, the tunica adventitia; a muscular coat; a submucouse layer and the mucouse membrane.

The horse's oesophagus is unique in its histological structure. Whereas in all animals striated muscles are found throughout the oesophagus, in the horse they extend only up to the base of the heart, where it is replaced by smooth muscles. The mucosal lining of the oesophagus forms longitudinal folds at rest.

B.1(c) Physiology:

The act of deglutition is a slow peristalsis, where the food bolus is carried down the oesophagus at a rate of 30 to 40 cm per second. Water and liquids, however, travel down at a much faster rate, up to 150 cm per second.

For the purpose of study, the oesophagus was divided into three parts:

The cervical part, which terminates at the thoracic inlet;

The thoracic part, which terminates at the diaphragm;

The abdominal part, which terminates at the cardiac sphincter.

B.1(d) Experimental Data:

(See table 1)

TABLE 1: OESOPHAGUS DATA

Horse number	Total number of exposures	Diagnostic radiograms					Non diagnostic radiograms				
		Lateral projection		dorso-ventral projection		Total number of diagnostic radiograms	Under exposed	Over exposed	Motion	Excessive scattered radiation & other faults	Total number of non-diag. radiograms
		Plain	Contrast	Plain	Contrast						
6637	28	10	11			21	2	3	1	1	7
6626	19	5	9			14	1	2	2		5
6295	18	4	9			13	2	1	2		5
6237	7	1	4			5		1		1	2
Total	72	20	33			53	5	7	5	2	19
%	100	27	45			74	7	10	7	2	26

B.1.1. Cervical Oesophagus

B.1.1.(a) Techniques:

Plain exposure did not reveal the oesophagus. The normal oesophagus blended into the soft tissues of the neck and thoracic cavity and therefore was imperceptible on a radiograph unless contrast media were used.

In order to demonstrate the cervical oesophagus or any section of it, the following three techniques were used:

i) Stomach tube insertion.
ii) Air insufflation.
iii) Barium contrast medium intake.

(i) Stomach tube insertion was made by the routine method.

(ii) Air insufflation into the oesophagus was achieved by blowing hard into the stomach tube which was inserted only into the cervical oesophagus.

(iii) Barium sulphate was the most useful form of contrast in the studies of the oesophagus. The composition of the barium sulphate paste: Barium sulphate powder 250-300 gm; water 75-100 ml. Addition of 100-150 gm of sugar encourages the horse to lick the paste by himself. If, however, the horse refused to lick, the paste was put onto his tongue with a teaspoon. When using this technique, exposures were made after the last spoonful.

Lateral projection technique:

Exposure data for laryngeal-pharyngeal area:

For 250 kg horse:		For 500 kg horse:	
KV	65	KV	70
MAS	25	MAS	32
FFD	120 cm	FFD	120 cm

Exposure data for cervical oesophagus:

For 250 kg horse:		For 500 kg horse:	
KV	50	KV	50
MAS	20	MAS	25
FFD	120 cm	FFD	120 cm

Opening of oesophagus into the pharynx:

In order to demonstrate the proximal oesophageal opening, the pharyngeal-laryngeal area was exposed (figure 3).

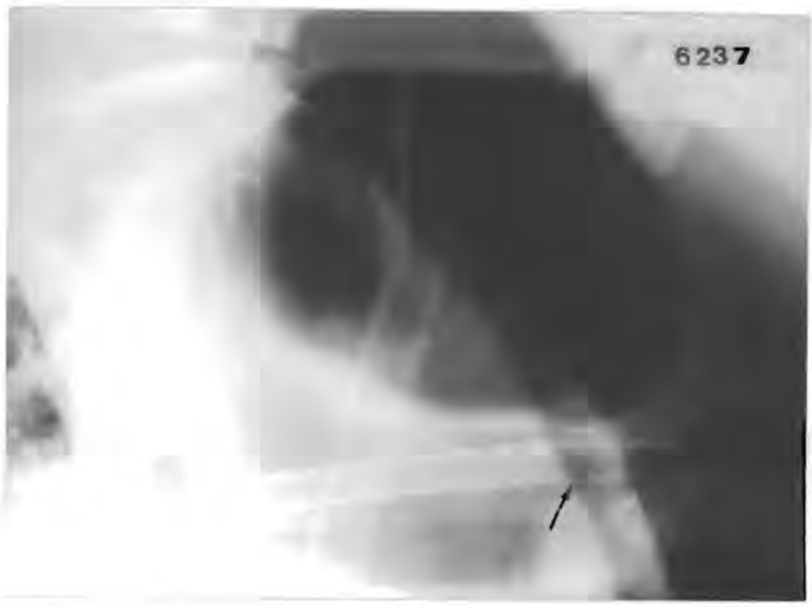


Figure 3:

The pharyngeal-laryngeal area. Note the tube passing through the pharynx into the oesophagus.
400 kg horse. KV 70 MA 32 FFD 120

B.1.1.(b) Findings:

(See table 2)

(i) Longitudinal folds of oesophageal mucosa were demonstrated (figures 4 and 5).

TABLE 2: OESOPHAGUS FINDINGS

Horse number	Longitudinal folds of mucosa demonstrated	Physiological sphincter at anterior end demonstrated	Normal course of cervical and thoracic demonstrated	Excessive barium accumulation at thoracic inlet	Narrowing indentation over the aortic arch	Abdominal section demonstrated
6637	+	+	+	+	+	-
6626	+	+	+	+	+	+
6295	+	+	+	+	-	-
6237	+	-	+	-	(±)	+

\+ = Definitely present

\- = " absent

no sign = not investigated

Figure 4:

The pharyngeal laryngeal area. Note the longitudinal folds of the mucosa.
500 kg horse. KV 70 MA 32 FFD 120.

Figure 5:

The cervical oesophagus at the leval of the fourth cervical vertebra. Note the longitudinal folds of the mucosa.
350 kg horse. KV 50 MAS 25 FFD 120.

(ii) Apparent physiological sphincter was seen at anterior end of the oesophagus (figures 6 and 7).

Figure 6:

The anterior part of the cervical oesophagus. Note the air captured in the lumen ofthe oesophagus around the tube.
350 kg horse. KV 70 MAS 32 FFD 120.

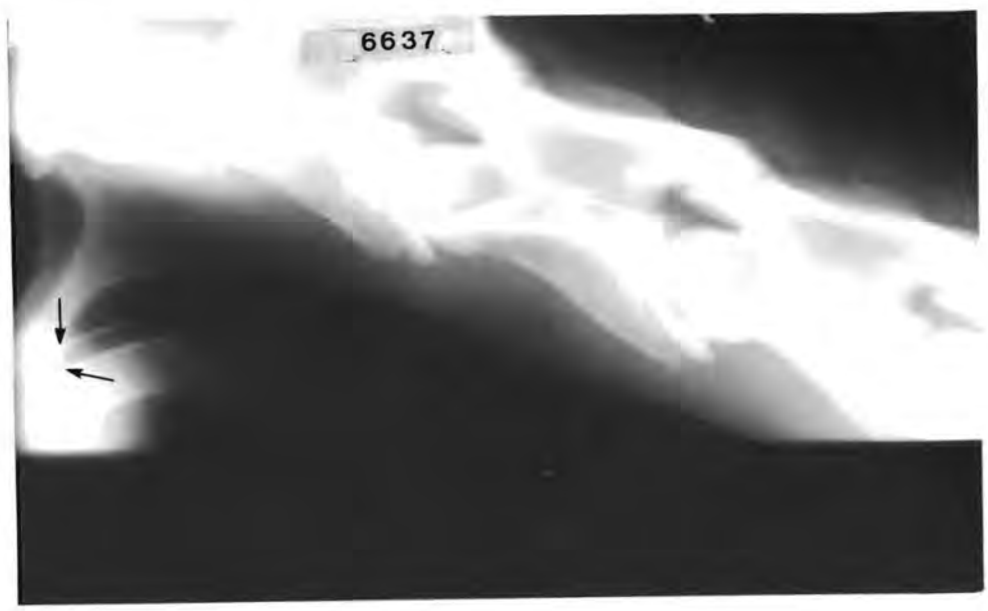


Figure 7:

The anterior end of the cervical oesophagus. Note the clamping down of the extreme end of the oesophagus on the inserted tube.
350 kg horse. KV 70 MAS 32 FFD 120.

(iii) The normal curve of the oesophagus was well demonstrated.

B.1.1.(c) Discussion:

(i) Longitudinal mucosal lining:

The demonstration of longitudinal mucosal folds in the cervical oesophagus is of considerable clinical importance. Alexander[2] has shown that oesophagitis obliterates the linear mucosal pattern of the normal oesophagus. Normally, the barium presents a homogeneous smooth appearance, but when oesophagitis is present - a fine stippling appears at the margins[2].

(ii) Technique of exposure:

The only work that made any note of the oesophagus in the limited number of studies previously mentioned, is the work of Drury, Dyce and Merlen[9].

In their experimental work they produced good radiographs of the upper cervical region with a stomach tube with the following exposure data:

KV 70; MAS 50; FFD 86 cm.

The radiographs produced in our project, with or without contrast media, were achieved with a smaller exposure and with a larger FFD. (KV 60; MAS 25; FFD 120 cm). This was possible due to the high speed screens used. Smaller exposures are very important factors in the radiography of animals since it shortens the exposure time needed, thus assuring sharp definition of images on the radiographs.

(iii) Advantages of barium paste:

Demonstration of the cervical oesophageal mucosa was successfully achieved by the use of thick barium paste. Barium paste had an advantage over barium meal not only in the fact that it could willingly be eaten by the horse, by licking it directly from the bowl (that is if sugar is added and the horse is fasted).

Its major advantage was in the fact that there was no need to radiograph the animal at the same time of feeding or drenching it with barium. While liquid barium meal disappeared completely from the cervical oesophagus minutes after the meal - thick barium paste stayed in the mucosal folds for at least 10-15 minutes after it entered the oesophagus. This was especially important when working with an anaesthetised horse because positioning of the animal for radiography tended to take some time.

This advantage resulted in a good set of radiographs of the cervical oesophagus.

One could clearly follow the course of the oesophagus as it was defined well. One could see that at the level of the fourth cervical vertebra it passed to the left of the trachea and at the level of the sixth cervical vertebra it moved slightly dorsally to enter the thoracic inlet. There was no doubt that this technique enabled a proper examination of oesophageal lumen, oesophageal mucosa and oesophageal course.

(iv) Anterior oesophageal sphincter:

An apparent physiological sphincter existed at the entrance into the oesophagus from the oral cavity. Evidence of a sphincter is clearly seen in figures 6 and 7, where a widening of the oesophagus is seen at the oesophagus end at the point of the entrance of the stomach tube into it. The technique of producing this radiograph was by air insufflation into the oesophagus through the tube. The radiograph revealed thatthe oesophagus dilated under the pressure of the air, but it narrowed to a complete closure of its walls on the tube at the tube's entrance point into the oesophagus. This feature repeated itself in all radiographs made.

Such a functional sphincter is not mentioned in works on physiology, but its anatomical basis is fully described in works on anatomy. Sisson[29] describes it as follows:

"At the oesophageal origin two bundles nearly an inch wide arise from the wide posterior part of the pharyngeal raphe and from a tendon common to the crico-pharyngeaus and thyro-pharyngeus. These bundles decussate at their origin, diverge and pass to each side of the oesophagus. In the angle between them a deep layer of circular muscles is visible."

The act of deglutition therefore is apparently not a sliding of the bolus of moistened food into the opening of the oesophagus which according to Dukes[10] is opened by the pulling forward of the hyoid bone and the larynx. It is logical to assume that there is some mechanism by which relaxation of that anterior oesophageal sphincter is achieved. The nature of this mechanism, whether neural or humoral, remains to be studied.

B.1.2. The Thoracic Oesophagus

For the purpose of a radiological examination, the thoracic oesophagus was divided into three sections:

1. The thoracic inlet area.
2. The aortic arch area.
3. The oesophageal hiatus area.

The justification for the division lies in the fact that three physiological points of delay corresponding to the abovementioned areas exist in the act of swallowing.

B.1.2.(a) The thoracic inlet area:

The external markings of exposure are: dorsally - a line crossing the lower third of the spine of the scapula; posteriorly - a line perpendicular to the point of the olecranon; ventrally - a line crossing the lateral head of the humerus (figure 8). The area should be about 15 cm long.

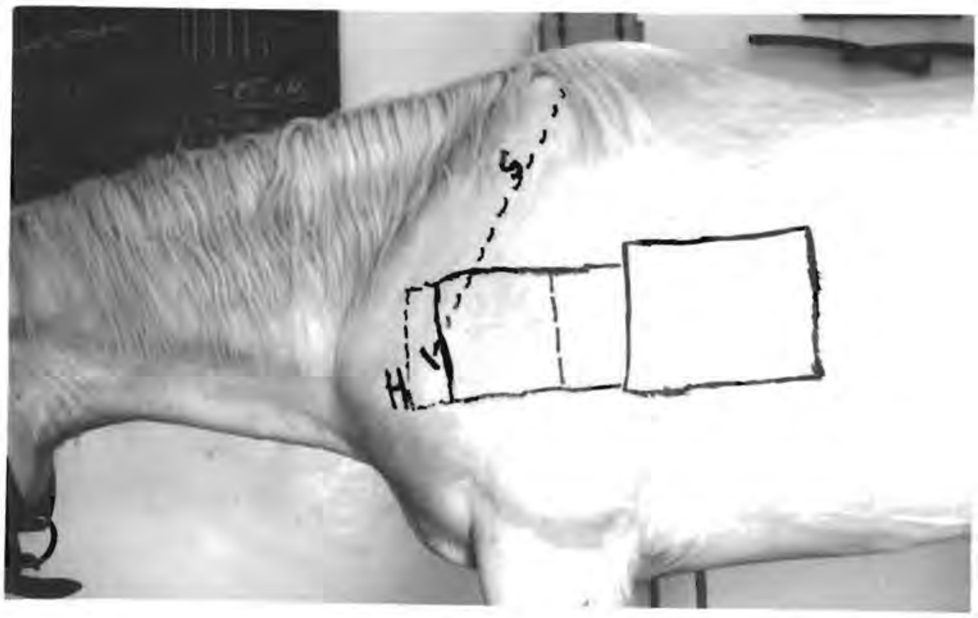


Figure 8:

The external markings for exposure of the thoracic inlet area. Note the line over the spine of the scapula(s) and the point over the lateral head of the humerus. (H).

(i) Exposure Data: (Lateral Projection)

For a 250 kg horse:		For a 500 kg horse:	
KV	85	KV	100
MAS	130	MAS	140
FFD	110 cm.	FFD	110 cm.

(ii) Findings: Radiographic findings at the thoracic inlet area were: (See table 2)

On the plain normal radiograph the following were seen:

1) The first, second and third rib.
2) The images of the two necks of the scapulae and the articulating fossae.
3) The narrow space between the first thoracic vertebra and the heads of the humerii.
4) No evidence of the oesophagus was seen.

After the use of a barium contrast meal, the following were observed:

i) Accumulation of barium at the lowest point along the courseof the thoracic inlet. This was clearly seen in radiographs made while the horse was eating the barium paste (figure 9), and in

Figure 9:

The thoracic inlet area. Note the longitudinal folds of the mucosa, and the accumulation of contrast media at the thoracic inlet itself. 250 kg horse. KV 85 MAS 130 FFD 100.

radiographs made while the horse was drenched with the barium (figure 10).

Figure 10:

The thoracic inlet area. Note absence of contrast media at the upgraded portion of the oesophagus and the accumulation at the thoracic straight section.
350 kg horse. KV 90 MAS 130 FFD 100.

ii) An upward course of the oesophagus was clearly seen after it passed the actual thoracic inlet (figure 11).

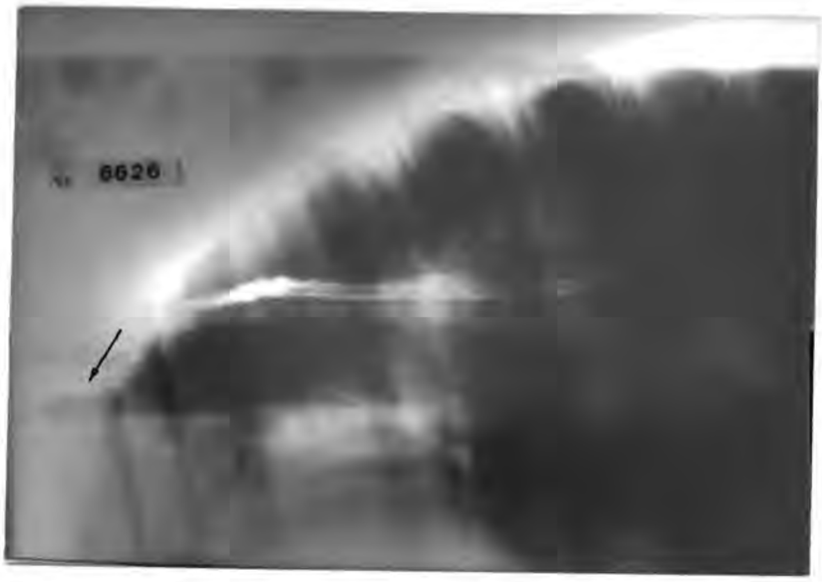


Figure 11:

The thoracic oesophagus. Note accumulation of contrast media at the thoracic inlet and the longitudinal folds of the mucosa.
350 kg horse. KV 80 MAS 130 FFD 100.

B.1.2.(b) Aortic arch area:

The course of the oesophagus in this area has been described previously. The study of this section was easier from the technical aspect since shorter exposures could be used. External markings of exposure: an area of 20 cm long and 15 cm wide, the centre of which is the half way point between the top of the "withers" of the horse (5th and 6th thoracic spines) and the manubrium sterni (figure 12).

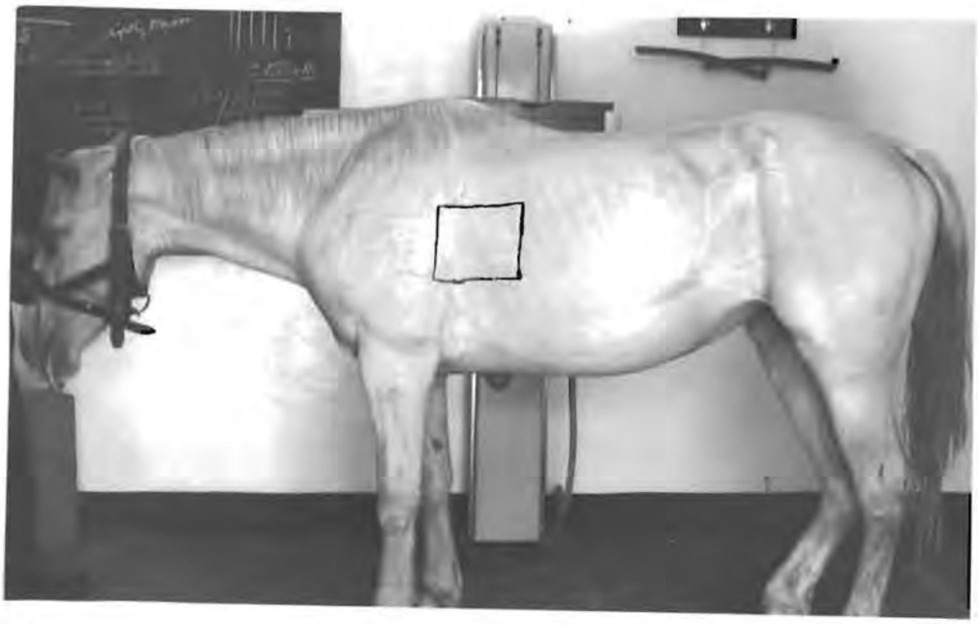


Figure 12:
The external marking for exposure of the aortic arch area.

(i) Exposure data:

For 250 kg horse:		For 500 kg horse:	
KV	80	KV	100
MAS	130	MAS	130
FFD	110 cm	FFD	110 cm

(ii) Findings:

The findings of the radiographic examination of the thoracic oesophagus at the aortic arch area were:

1) The oesophagus blended completely with the surrounding tissues on a plain radiograph.

2) Introduction of a stomach tube demonstrated the thoracic oesophagus.

3) Barium paste demonstrated the longitudinal mucosal folds of the oesophagus (figure 11).

4) A complete filling effect of the oesophagus in this area was achieved by a rapid drench of barium meal through a large diameter stomach tube.

5) In two of the horses studied there was a narrowing indentation in the thoracic oesophagus as it crossed the aortic arch (figure 13).

Figure 13:

The thoracic oesophagus at the aortic arch area. Note the complete filling achieved by rapid drench. Also note the narrowing indentation at the crossing of the aorta. 350 kg horse. KV 90 MAS 130 FFD 100.

iii) Discussion:

The thoracic oesophagus is an important section of the oesophagus as far as the radiologist and the clinician are concerned. The pathological conditions seen in the oesophagus are listed in the literature as follows:

1) Foreign bodies.
2) Cardiospasm.
3) Change in position.
4) Secondary stenosis.
5) Trauma and necrosis of the oesophageal mucosa.
6) Hypertonicity (oesophagismus).
7) Hypotonia.
8) Paresis.
9) Diverticulum.
10) Intra- or extra-oesophageal neoplasms.

Analysis of this list reveals that the majority of these conditions occur in the thoracic section of the oesophagus. Foreign bodies lodge mostly either at the thoracic inlet or at the aortic arch level. Diverticula, though occurring in the cervical portion as well, tend to appear at the thoracic inlet. In fact - except trauma and necrosis of the oesophageal mucosa, which occur more at the cervical portion of the oesophagus due to its proximity to the portal of entry of the aetiological agent - most other oesophageal conditions tend to appear in the thoracic portion of the oesophagus. Needless to say, therefore, that radiological examination of the thoracic oesophagus is of primary importance. The most striking feature of the contrast media radiographs is the accumulation of barium in a dilated portion of the oesophagus at the lowest point along its course i.e. at the centre of the thoracic inlet (figures 9 and 10). The reason for these dilations is quite obvious when the upward turn of the oesophagus behind that point is noticed (figure 11). This part of the oesophagus appears considerably narrower in the radiographs and the oesophagus only widens up again when its contour flattens after crossing the aortic arch (figure 13).

Another interesting finding was the indentation of the thoracic oesophagus as it crossed the aortic arch. This indentation was not seen at all in the empty or half-filled oesophagus. However, when the oesophagus was completely filled and exposure made at that moment, this indentation was clearly seen (figure 13).

One could question the nature of this indentation and suggest that it may be a peristaltic wave. However, experience with radiological examination of the alimentary tract of small animals has shown[29] that peristaltic waves of deglutition in the oesophagus, which starts at the pharynx, are abolished when a stomach tube is used. The same was observed in the oesophagus of the horse. Radiographs showed that the filling effect was by gravitation and not by peristaltis. All barium meal examinations were made using a stomach tube.

It is therefore likely that this indentation is the result of a pressure on the walls of the full oesophagus as it crosses the aortic arch between the aorta and azyguos vein.

It was reported[10] that in the study of deglutition of a standing dog, one observed three physiological points of delay of barium:

1. Thoracic entrance.
2. Bifurcation of the trachea.
3. Oesophageal hiatus at diaphragm.

In the horse there is a delay of passage of barium in the thoracic inlet and aortic arch crossing. No delay was observed at the oesophageal hiatus.

These findings support the clinical experience that most foreign objects lodge either at the thoracic inlet or at the aortic arch level.

B.1.3. The Abdominal Oesophagus

This section of the oesophagus is a very short one - only two or three cm. long. It is completely covered by the liver.

(i) Technique:

It was very hard to demonstrate this section of the oesophagus. Barium studies either by paste or meal did not reveal it. It was possible, however, to demonstrate the pattern of this section of the oesophagus by one technique only: filling up of a stomach tube with barium, blocking the ends, and inserting it into the stomach (figure 15).

Figure 15:

The abdominal oesophagus. Note the stomach tube passing through the diaphragm into the stomach.
400 kg horse. KV 130 MAS 160 FFD 120.

(ii) Exposure data:

Same as for a lateral exposure of the stomach.

(iii) Discussion:

The reason for the difficulty in demonstrating this section was the sharp descent of the organ into the stomach, and the speed by which the contents of the oesophagus passed down on to the cardia. One had also to take into account the very dense image of the liver which tended to diffuse the image of the barium-filled oesophagus.

B.2. Stomach

B.2(a) Anatomy:

The stomach of the horse is a sharply curved sac, which lies posterior to the diaphragm and liver. It has a greater curvature which faces the left side and a lesser curvature which faces the right side. The stomach is relatively small and it is situated in the dorsal part of the abdominal cavity.

When the stomach is in situ the oesophageal orifice, the cardia, lies in close proximity to the exit from the stomach, the pylorus - both situated at the lesser curvature. The pylorus is slightly lower than the cardia. About 5-6 cm from the pylorus there is a constriction which marks off the pyloric antrum from the rest of the right sac of the organ (figure 14).

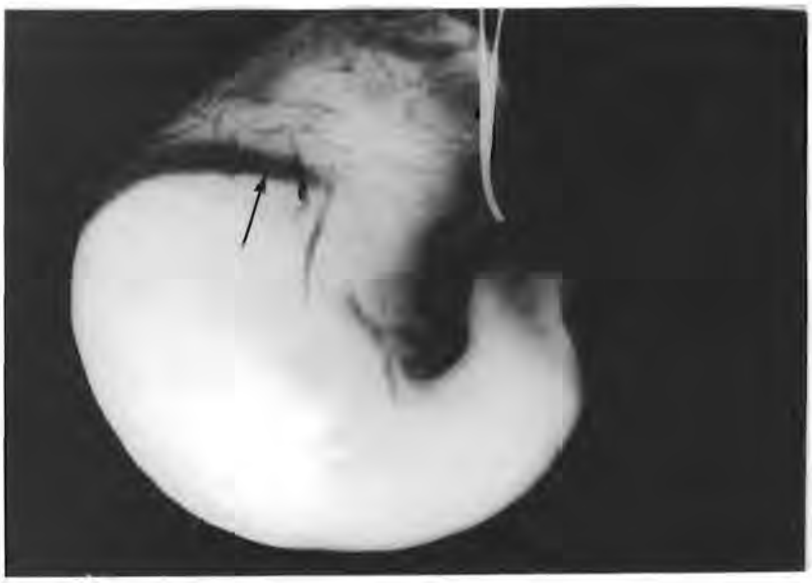


Figure 14:

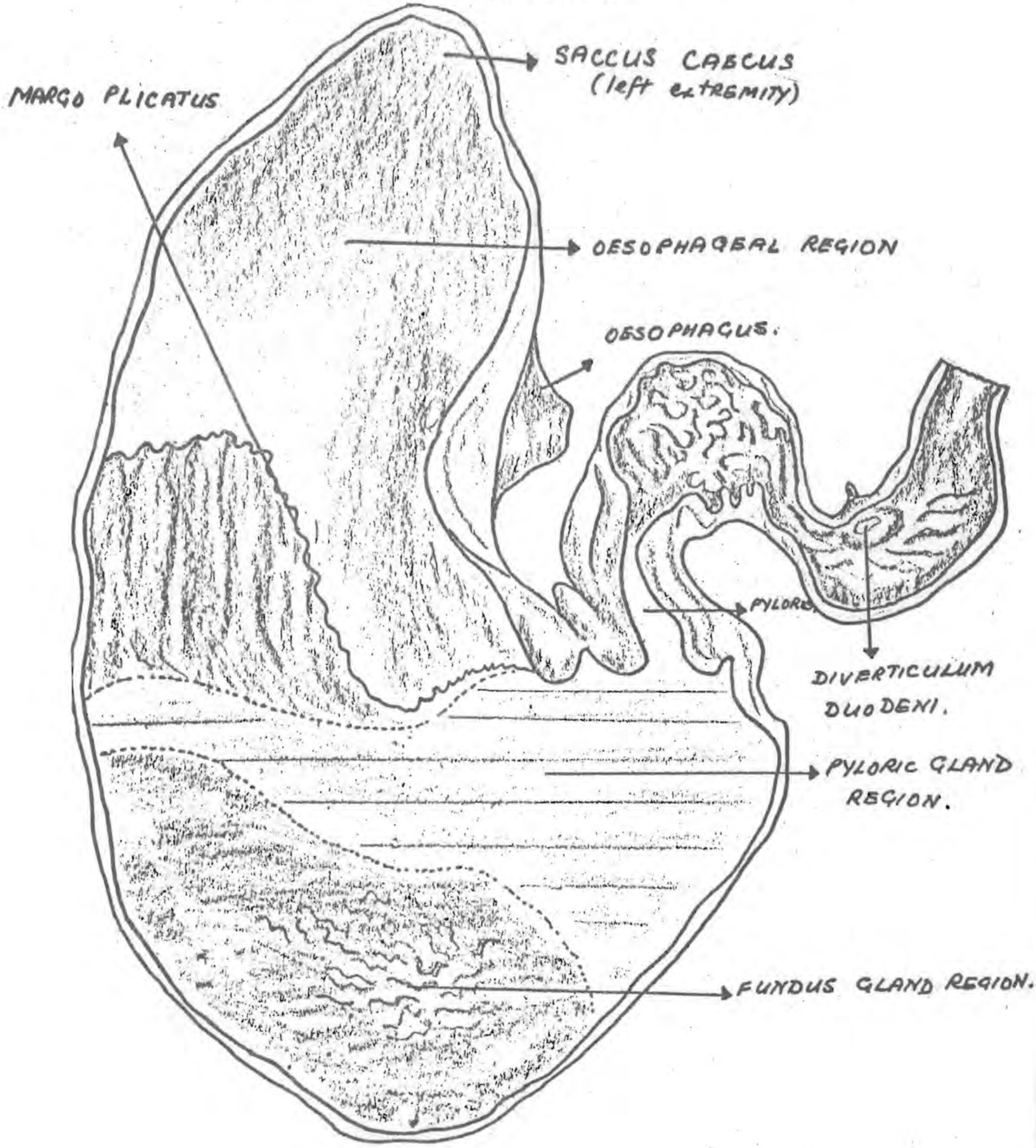
An abattoir specimen of the horse's stomach filled with barium. Note the constriction between the sacus ceacus and the pyloric region.
KV 50 MAS 25 FFD 150

The position of the pylorus itself is marked by a distinct constriction. Internally it presents a ring of circular muscle known as the pyloric sphincter (diagram 1).

The stomach is held in position mainly by the surrounding viscera and by five peritoneal folds.

DIAGRAM I:

FRONTAL SECTION OF STOMACH AND FIRST PART OF DUODENUM OF HORSE



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It receives blood from all the branches of the coeliac artery. It is drained by the gastric veins. It has a rich lymph drainage into the cisterna chyli. All its nervous supply is autonomic.

B.2(b) Histology:

The wall of the stomach is composed of the classical four layers: serosa, muscularis, submucosa and mucosa. In the empty organ the mucosa forms numerous high, mostly longitudinal, folds. The mucous membrane has a multitude of glands which open into the gastric pits - three parts having different glands are distinguished in the stomach: the cardia, the fundus and the pylorus region. The cardia area is also called the oesophageal region.

In the horse the oesophageal region is large, making up one third to two fifths of the mucous surface. It is nonglandular and is covered with stratified squamous epithelium continuous with that of the oesophagus. The cardiac gland zone is posterior the oesophageal part and is very narrow. The fundic gland zone is very large. The pyloric gland zone extends into the pylorus.

B.2(c) Physiology:

The organ has two major functions in digestion: It is a reservoir for swallowed food and it also digests food. The fact that the horse may swallow, during a meal, twice or three times the amount of food remaining in its stomach at the end of the meal was suggested[10] as a proof that the role of the stomach in digestion is rather a small one - since food passes very rapidly out of the stomach.

In the stomach the food is thoroughly moistened, softened and partially dissolved by gastric juice, and ground by the contraction of the muscular wall.

As the food enters the stomach through the cardia it is immediately exposed to the mixing action of the organ, which is possible by the presence of the external muscular coat. At the same time the food is subjected to large amounts of gastric juice which are being secreted by the gastric glands. The secretion of gastric juice is a continuous process in the horse. It was found that the horse secrets 10 - 30 litres of gastric juice daily[10].

Emptying starts immediately after the meal has begun. Ellenberger[14] reports that the stomach of the horse is really never empty. It always contains some particles of digested food from previous meals. As contractions of the stomach begin - food is being forced out to the intestines through the pylorus.

3.2(d) Experimental data:

(See table 3).

3.2.1. Techniques:

3.2.1(a)Lateral projection: (Right side).

(i) Area of exposure: an area of 10 cm wide and 15 cm long, the centre of which is the half way point between the lowest point on the back line and the lowest point on abdominal mid-line (figure 16).

TABLE 3: STOMACH DATA

Horse number	Total number of exposures	Diagnostic radiograms					Non diagnostic radiograms				
		Lateral projection		Dorso-ventral projection		Total number of diagnostic radiograms	Under exposed	Over exposed	Motion	Excessive scattered radiation & other faults	Total number of non-diag. radiograms
		Plain	Contrast	Plain	Contrast						
6637	27	1	5	1	13	20	3	1	1	2	7
6626	33	2	10	2	16	30	1	2			3
6295	21	1	1	1	14	17	2		1	1	4
6237	6		2		3	5			1		1
Total	87	4	18	4	46	72	6	3	3	3	15
%	100	5	21	5	52	83	7	3	3	3	17

Figure 16:

External markings for a lateral exposure of the stomach. Note the oblique line marking the diaphragm.

(ii) Exposure data:

For 250 kg horse:		For 500 kg horse:	
KV	115	KV	160
MAS	130	MAS	200
FFD	110 cm.	FFD	110 cm.

(iii) Air insufflation technique:

Air was inflated into the stomach through a stomach tube.

(iv) Contrast medium technique:

Barium meal was introduced into the stomach through a stomach tube. The volume was 1000 ml of barium sulfate solution containing 100 percent w/v for a 1 year old horse, and 2000 ml of the same solution for a 3 year old horse.

B.2.1(b)Dorso-ventral exposure:

(i) Area of exposure: An area of 10-15 cm long on the dorsal midline of the horse. Starting five cm behind the withers of the horse (5th and 6th thoracic spines). The area must be five cm wide on each side of the midline.

(ii) Cassette positioning: In order to achieve a dorso-ventral (dv) exposure, it was necessary to have the cassette under the horse's abdomen. This was achieved by using a four wheel trolley. The cassette was placed on the upper shelf of the trolley, the height of which was adjusted by adding several flat books or empty cassettes under the cassette used for the exposure. The cassette barely touched the abdomen. A portable grid (size 15/18, 75 lines per inch, ratio 6,5) was used above the cassette. By using the grid, the amount of scattered radiation was cut remarkably (figure 17).

Figure 17:

Positioning of animal and cassette for a dorso ventral exposure of the stomach. Note position of the tube (5 cm behind "withers" of the horse).

(iii) Exposure data:

For 250 kg horse: For 500 kg horse:

For 250 kg horse:		For 500 kg horse:	
KV	170	KV	170
MAS	160-170	MAS	200
FFD	110 cm.	FFD	110 cm.

8.2.2. Findings:

(See table 4).

(i) Size of thestomach varied considerably with the amount of its content.

(ii) Expansion of the stomach occurred towards the cranial part of the abdomen, i.e. towards the diaphragm (figure 18).

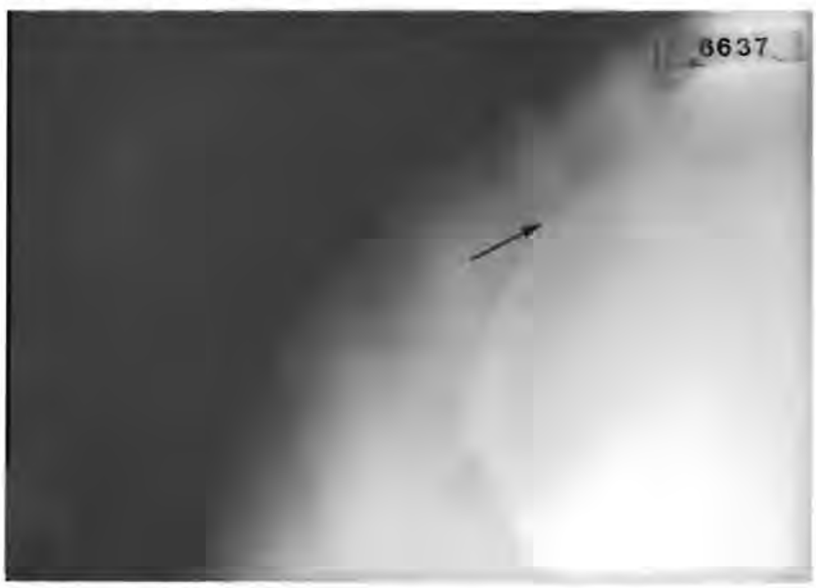


Figure 18:

Lateral exposure of the anterior aspect of a full stomach.
Note progressing proximity to the diaphragm.
350 kg horse. KV 130 MAS 200 FFD 100.

TABLE 4: STOMACH FINDINGS

Horse number	Variations in shape & size of stomach in same horse	Expansion occurs cranially	Position of pylorus		Food leaves stomach during meal	Emptying time of stomach studied (No. of experiments)
			Left of midline	Right of midline		
6637	+	+		+	+	4
6626	+	+	+		+	5
6295	+		+		+	2
6237	+			+	+	1

(iii) When the stomach contracted after a complete evacuation it retreated towards the caudal aspect, thus moved away from the diaphragm (figure 19).

Figure 19:
Lateral exposure of half full stomach. Note the fluid level of the barium meal.
250 kg horse. KV 110 MAS 170 FFD 100

(iv) Stomach position was not constant, even in the same animal. It varied considerably from time to time.

(v) Size and shape of the stomach were very irregular and determined by changed peristalsis. One hour after the meal it looked tubular like a section of a tyre (figure 20).

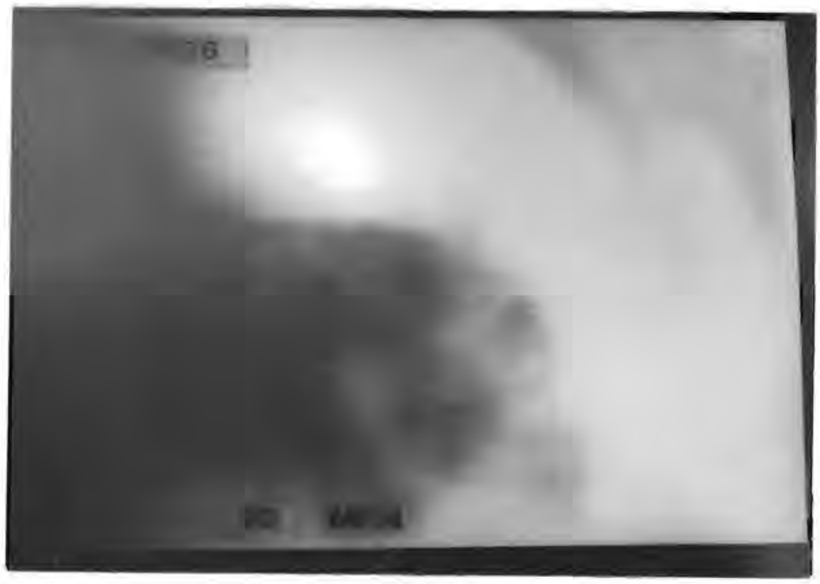


Figure 20:
Dorso-ventral exposure of stomach one and a half hours after barium meal drench. Note the tubular shape of the organ.
250 kg horse. KV 170 MAS 170 FFD 100.

(vi) The position of the pylorus was not fixed. In some cases it was to the right of the midline, in others - on the midline itself, under the thoracic vertebrae. In most cases, however, it was to the left of the midline (figures 21, 22 and 23).

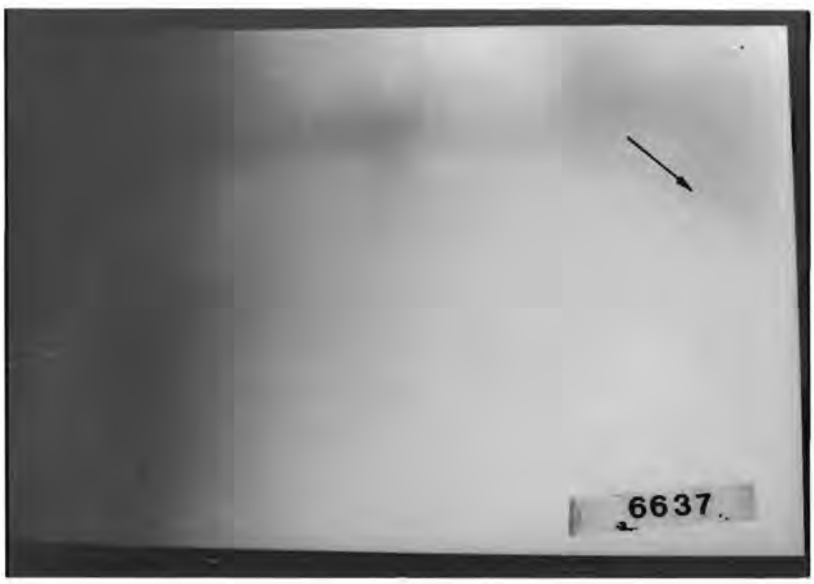


Figure 21:

Dorso-ventral exposure of a full stomach. Note that the position of the pyloric antrum is to the right of the midline (vertebral column).
350 kg horse. KV 170 MAS 200 FFD 100.

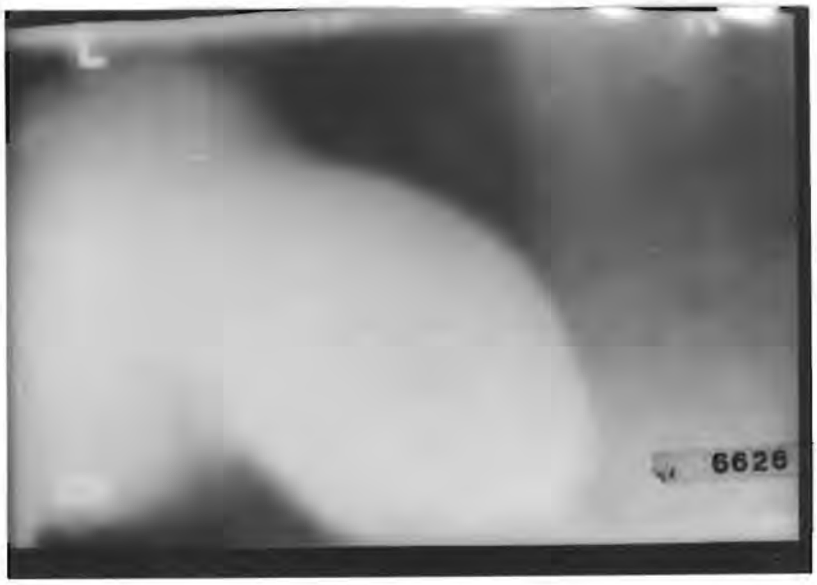


Figure 22:

Dorso-ventral exposure of a full stomach. Note that the position of the pyloric antrum is to the left of the mid-line (vertebral column).
250 kg horse. KV 170 MAS 170 FFD 100.

Figure 23:

Dorso-ventral exposure of the full stomach. Note the lesser curvature of the stomach. Note that the entire pyloric region is right of the midline.
350 kg horse. KV 170 MAS 200 FFD 100.

(vii) Lateral projection of the empty stomach after air insufflation provided information about the proximity of the stomach to the diaphragm. It also showed a fluid level (figures 19 and 24).

Figure 24:

Lateral exposure of an empty stomach after air insufflation.
Note stomach tube loops inside the stomach.
400 kg horse. KV 130 MAS 160 FFD 120.

(viii) It was not possible to demonstrate the stomach when the horse was not fasted.

(ix) Food started to leave the stomach immediately after the meal, and was seen in the pyloric antrum as early as 10 minutes after the beginning of the meal (figure 25).

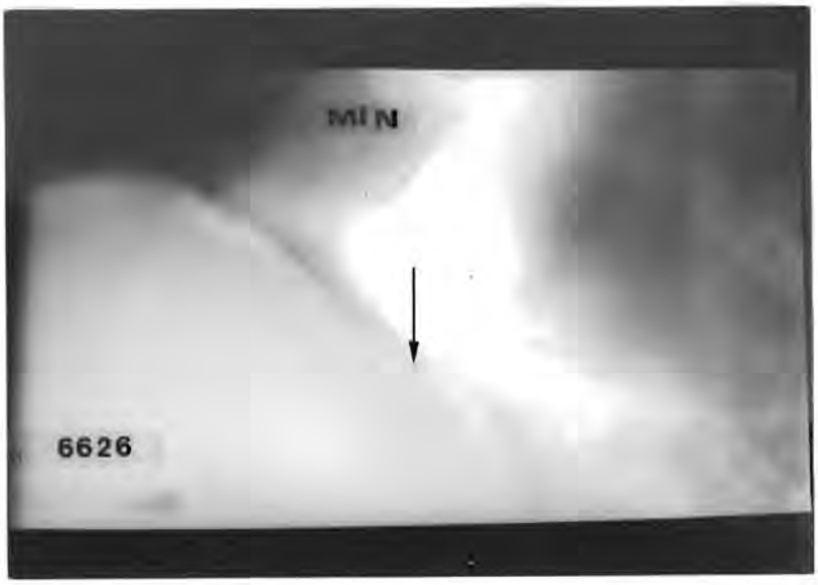


Figure 25:

Dorso-ventral exposure of the pylorus 10 minutes after barium meal drench. Note the pylorus directly on the midline. 250 kg horse. KV 170 MAS 170 FFD 100.

(x) Gastric emptying time varied considerably with the type of food consumed. (See table 5). (Figures 26, 27, 28 and 29).

TABLE 5: FOOD REMAINING IN STOMACH

Meal before study	Contrast Media	30 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	290 m	300 m	360 m	390 m	420 m	450 m	Horse studied	Nomber of studies
None	Barium sulphate 900 ml.	+	+	+	+	+	±	-	-	-	-	-	-	-	-	6637 6626 6295 6237	2 3 1 1
2 lbs. of feed	Barium sulphate 900 ml.	+	+	+	+	+	+	+	+	+	±	-	-	-	-	6626 6295	2 1
Hay ad libtum	Barium sulphate 900 ml.	+	+	+	+	+	+	+	+	+	+	±	-	-	-	6637	1
Green Lucerne	Barium sulphate smeared + soaked on Lucerne	+	+	+	+	+	+	+	+	+	+	+	+	+	±	6637	1

Note: The ± sign is for the stage when last traces of contrast media are seen at the pylorus only.

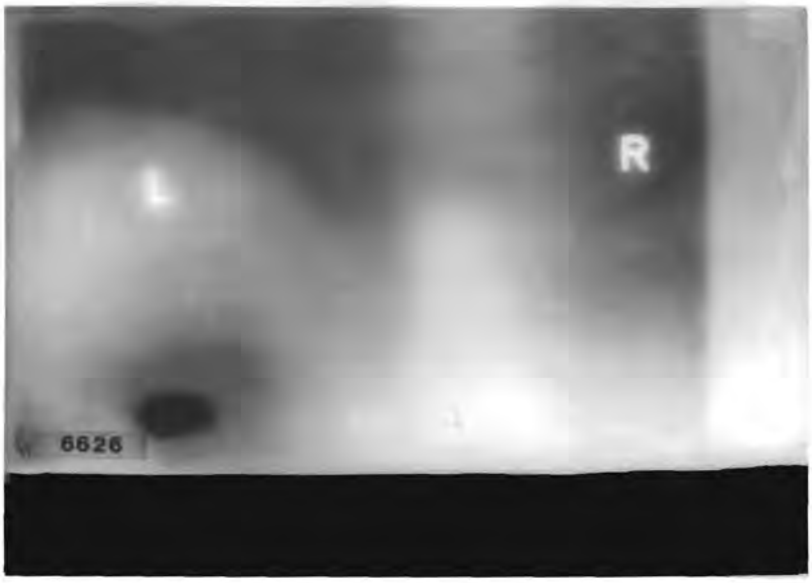


Figure 26:

Dorso-ventral exposure of the pyloric antrum 120 minutes after the drench of barium meal. Note contrast media in stomach. 250 kg horse. KV 170 MAS 170 FFD 100.

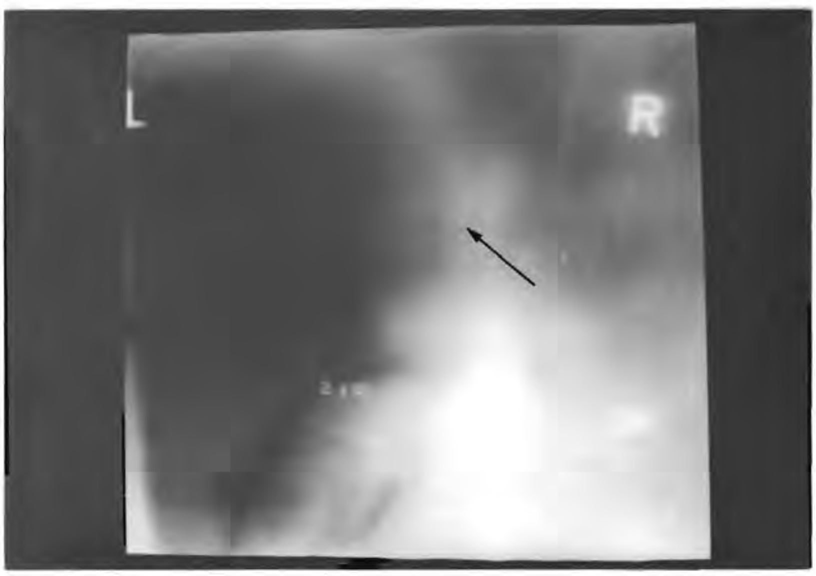


Figure 27:
Dorso-ventral exposure of the pyloric antrum 210 minutes after the drench. Note the small amount of contrast media left. Most contrast media seen in duodenal loops.
250 kg horse. KV 170 MAS 170 FFD 100.

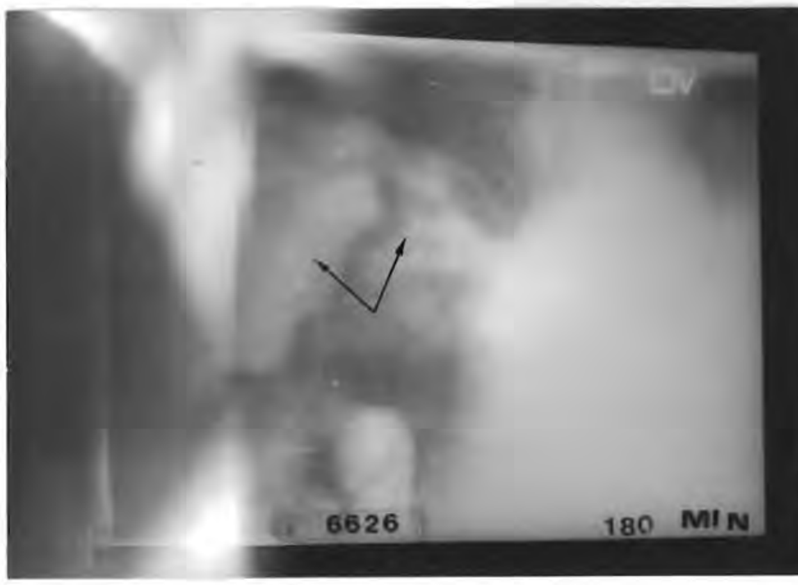


Figure 28:

Dorso-ventral exposure of the pyloric antrum 180 minutes after 2 kg of concentrates mixed with barium was consumed. Note large amounts of contrast present yet in stomach. 250 kg horse. KV 170 MAS 170 FFD 100.

Figure 29:

Dorso-ventral exposure of pyloric antrum of the horse 210 minutes after the meal. Note the mucosal folds of the contracted stomach. Most barium is in the duadenum. 350 kg horse. KV 170 MAS 200 FFD 100

B.2.3. Discussion:

(i) Technique:

Reference to techniques of study of the stomach of the horse were made in the literature [1,9,12]. However, of those who published any data only Drury et al[9] worked on a relatively grown horse. Other references[1,12] concern suckling or neonatal foals. In his studies Drury et al[9] made radiographic studies on a 200 kg pony. His exposure data were KV 85, MAS 240, FFD 80.

When these data are evaluated against the radiographs he produced, it appeared that he had to compensate for a low kilovolt output of his unit by increasing time of exposure. The studies had to be carried out on an anaesthetised animal, in a recumbent position, with artificial suspension of respiration.

It is a great advantage if one could have a more powerful unit which could produce higher kilovolts and cut short the time of exposure.

The best is to enable the examiner to take short exposures on a standing animal, as has been done in this work.

It was established in agreement with previous findings that the dorso-ventral exposure is the only way to study the stomach and its parts. This view was expressed in previous publications[1,9,12]. Dyce[12] states: "In the lateral projection it is rarely possible to determine much of the conformation of the <u>pars pylorica</u>......" "The form of the stomach is demonstrated best in the dorsal view".

In order to establish the reason for the difficulty to demonstrate different parts of the stomach in lateral projection, an examination of isolated stomachs of adult horses was undertaken at an early phase of this research project. Four isolated fresh stomachs of horses from an abattoir have been washed and filled up with barium solution, after the pyloric and cardiac openings have been clamped (figure 14). When the stomach was filled, one could easily see that the cardia and pylorus lie on almost the same plane as the saccus caecus, thus overlapping on lateral projection of the organ.

The lateral projection, however, has its value: it is a better way to demonstrate the cranial border of the stomach and its relationship with the diaphragm. The lateral projection was the method by which the cranio-caudal expansion of the stomach was determined. It was established that the stomach moves cranially towards the diaphragm when it is filled up, and away from it - caudally as it empties. This observation is not in accordance with Dyce[11], who states that: "In the adult horse the long axis is generally inclined cranio-ventrally.... as it contracts, the stomach withdraws from the abdominal parts." The relationship of the stomach with the diaphragm is a matter which warrants further examination.

(ii) Position of the stomach:

The exact place of the stomach in the abdominal topography is a controversial subject. Even in anatomy text books there are disagreements. Sisson[29] says that the stomach is situated mainly to the left of the midline. Ellenberger-Baum[14] says that at the plane of the scapular neck, the stomach extends considerably to the right of the midline (Diagram II).

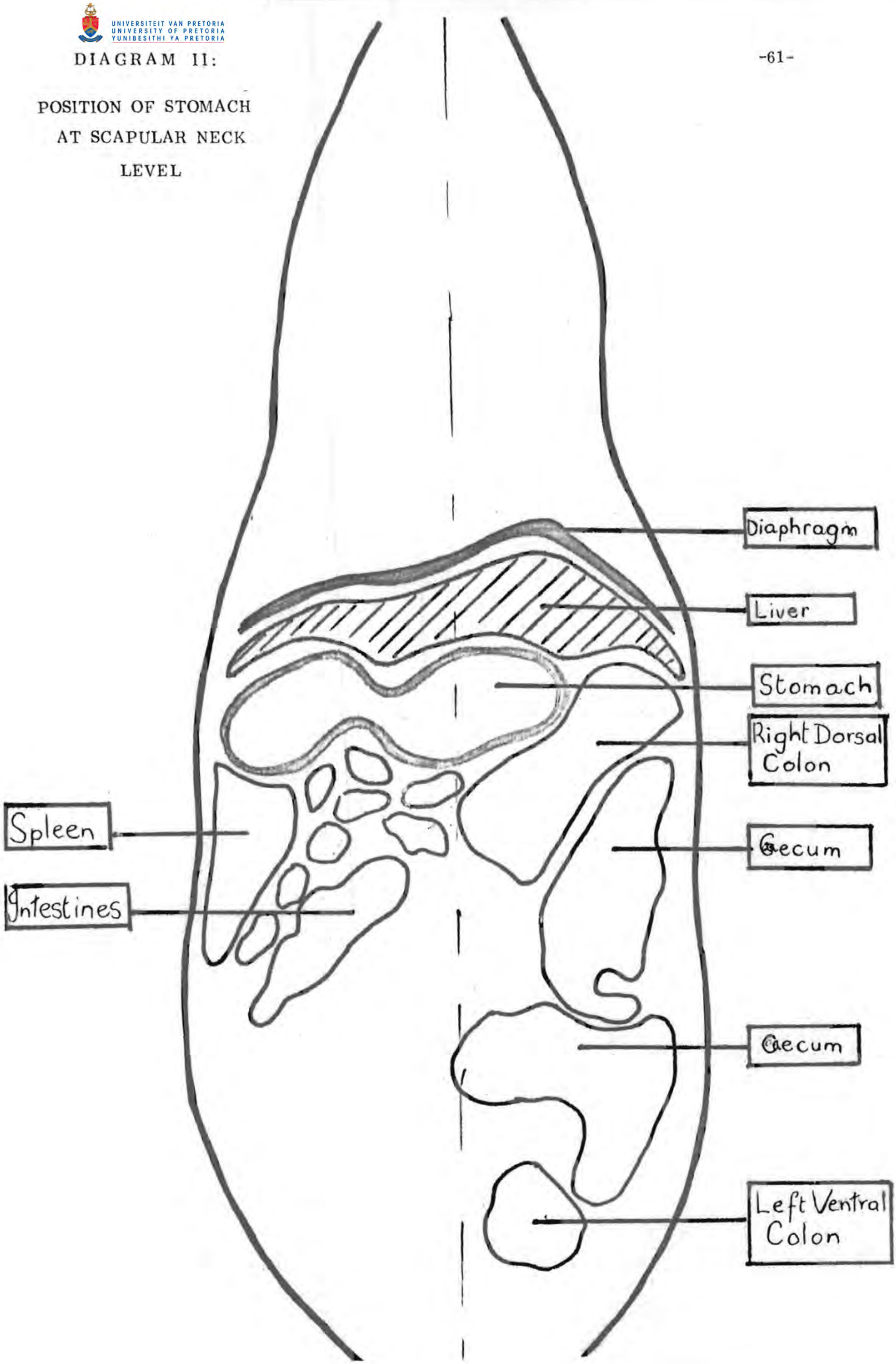
Reports in the literature vary. Dyce[12] says that its skeletal relations vary with the volume and the phase of respiration, and that the greater part of the organ is found to the left of the midline, and on occasion only the prepyloric section extends into the right half of the abdomen. More commonly, according to Dyce, "only the narrow pyloric limb passes below the vertebrae and for some considerable way to the right."

Alexander and Benzie[1] found the stomach to be on the left of the median plane. Drury et al[9] reports the pyloric antrum and sinus to overlie the vertebral column.

The studies in this project have shown that there is no constant place for the stomach or the pylorus in the topography of the abdomen of the horse. It is true that the bulk of the stomach is always to the left of the midline, but the prepyloric area and the pylorus antrum are often found either on the midline or completely to the right of it.

DIAGRAM II:

POSITION OF STOMACH
AT SCAPULAR NECK
LEVEL



(iii) Gastric emptying time:

Some information about the subject has been reported before[1], but dealt with the rate of passage of milk-barium mixture through the gastro-intestinal tract of a suckling foal, as compared to passage of barium solution in a four months old weaned foal.

It is interesting to note that the time which was reported for a complete emptying time of barium meal of the stomach of a weaned four months old foal was the same as was found for an adult horse in this work. (There were differences in other parts of the tract between a suckling and weaned foal).

This study revealed that the apparent emptying time of the stomach is shortest with a barium meal, longer with hay and longest with green fodder. Food does not leave the stomach until it is completely saturated by gastric juices. This process is shortest with concentrated feed, longer with hay which is partly broken by the process of the curing and bailing, and longest with green fodder cut just before being offered to the horse.

The study has confirmed previous reports [10,14] that the stomach of the horse does not hold all the contents of an entire meal. The fact that food was seen at the pyloric antrum and duodenum as early as 10 minutes after the meal, indicated that there was some digested food from a previous meal in the stomach, in spite of 24 hours fast. Dukes[10] reports findings of early workers that the stomach of the horse does not empty itself between meals, nor does it empty itself completely even after a 24 hours fast. It is probably this digested food from previous meals which leaves the stomach first as soon as stomach movements begin.

B.3. Small Intestines

B.3.1. Duodenum

B.3.1(a) Anatomy:

The duodenum is the first part of the small intestine, and is the only fixed part. It is about 90-120 cm long and is divided into three parts. The first part begins behind the pylorus, and is directed caudally for a short distance. It then turns dorsally and continues cranially for 10-15 cm to turn again caudally by a ventral convexity. This part is in contact with the middle and right lobes of the liver, and to the right of the midline. In this section, about 12-15 cm from the pylorus, the pancreatic duct and the bile duct open into the duodenum. The second part passes ventral to the right lobe of the liver and reaches the right kidney and the base of the caecum. The third part passes from the right side of the body to the left behind the root of the mesentery.

The sacculation of the duodenum has a diameter of about 7-10 cm. Only the first part of it is well fixed. The second and third parts are loosely attached.

B.3.1(b) Histology:

The wall of the duodenum consists of the four layer coats: serosa, muscularis, sub-mucosa and mucosa. The muscular layer consists of external longitudinal and internal circular layers, the latter being thicker. The submucous layer contains alveolar glands. Their duct perforates the mucosa and opens up into the intestinal lumen.

B.3.1(c) Physiology:

The material leaving the stomach - the chyme - undergoes important changes in the duodenum: It is exposed to the enzymatic action of pancreatic juice which digests the fats in the chyme, and act on carbohydrates. It is being exposed to the action of the duodenal gland secretions, which are believed to contain amylase. Fats and higher fatty acids are digested mostly in the duodenum by the action of the bile, which activates the pancreatic enzymes. These digestive actions are being accomplished while the peristaltic movements push the duodenal contents forward. Not much is known on the nature and types of these movements in the horse.

B.3.1(d) Experimental data:

(See table 6).

B.3.1.1(a) Techniques:

Two techniques were used: I) dorso ventral projection, and II) lateral projection.

I) Dorso-ventral projection:

i) Area of exposure: For the duodeno-pyloric junction an area of 15 cm long and 10 cm wide, immediately to the right of the dorsal mid-line, 10 cm caudal to the withers of the horse. This area corresponds to the area of exposure of the stomach, except for being entirely to the right of the midline.

For the first part of duodenum an area of 15 cm long and 10 cm wide, immediately caudal to the area previously described, and five cm away from the midline to the right.

ii) Exposure data:

For 250 kg horse:		For 500 kg horse:	
KV	170	KV	170
MAS	160-170	MAS	200
FFD	110 cm.	FFD	110 cm.

TABLE 6: SMALL INTESTINES DATA

Horse number	Total number of exposures	Diagnostic radiograms					Non-diagnostic radiograms					
		Lateral projection		Dorso ventral projection		Total number of diagnostic radiograms	Under exposed	Over exposed	Motion	Excessive scattered radiation & other faults	Total number of non diagnostic radiograms	
		Plain	Contrast	Plain	Contrast							
6637	18	2	1	2	8	13	2			3	5	
6626	31	2	6	2	15	25	3			3	6	
6295												Horse injured himself and was not available for research.
6237	8	1	1	2	2	6	1			1	2	
Total	57	5	7	6	25	44	6			7	13	
%	100	9	13	11	43	76	11			13	24	

II) Lateral projection:

i) Area of exposure: Same as for lateral projection of the stomach.

ii) Exposure data: Same as for lateral projection of the stomach.

Contrast media: 1 kg of w/v barium sulphate meal, introduced into the stomach by a stomach tube.

B.3.1.1(b) Findings:

(See table 7).

i) Contrast medium was essential. It was possible to demonstrate clearly the first part of the duodenum (figure 30).

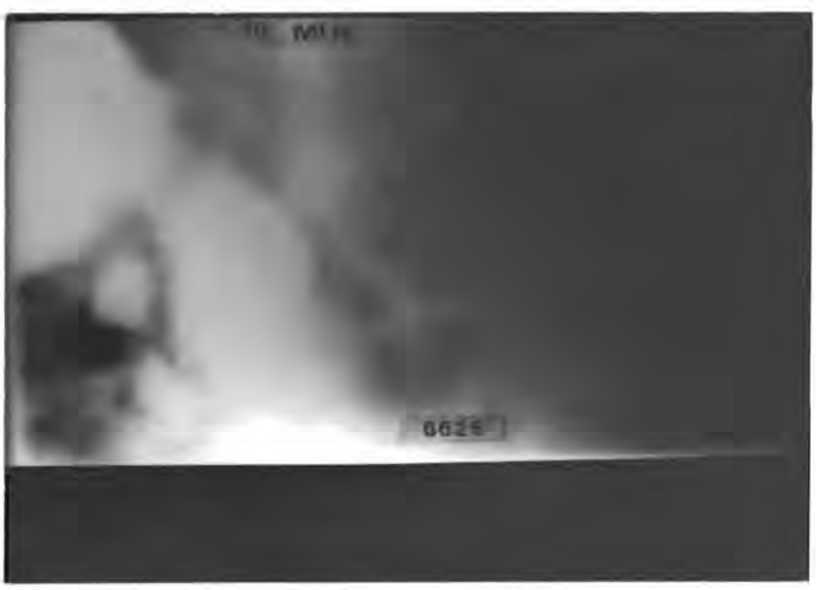


Figure 30:

Dorso-ventral exposure of the sigmoid section of the duodenum immediately after barium drench. 250 kg horse. KV 170, MAS 170, FFD 100.

TABLE 7: SMALL INTESTINES FINDINGS

Horse number	Contrast medium essential	Pyloro-duodenal junction demonstrated	Sigmoid section of duodenum demonstrated	Coils of ileo-jejunum demonstrated	Identification of parts beyond sigmoid section of the duodenum
6637	+	+	-	+	-
6626	+	+	+	+	-
6295					
6237	+	+	+	+	-

However, within 15 minutes after drenching, the image of the duodenum was obliterated by barium in other segments of the small intestines (figure 31).

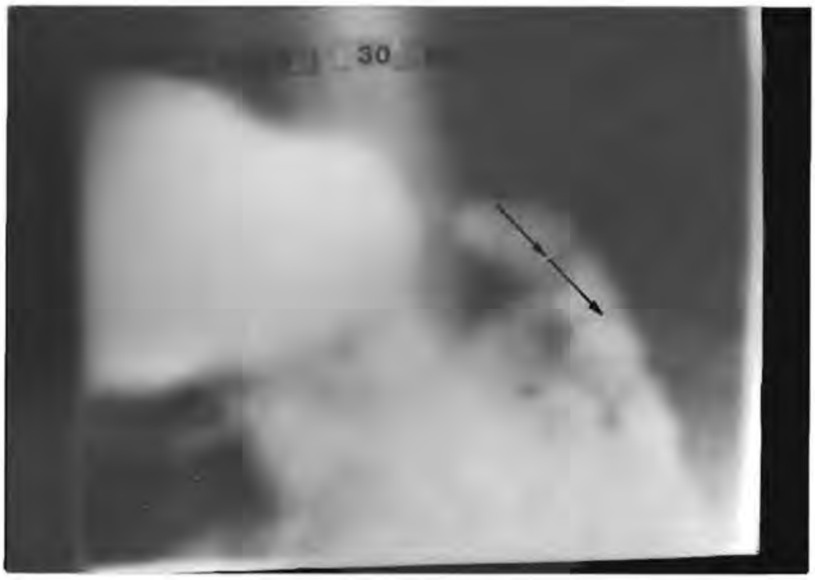


Figure 31:

Dorso-ventral exposure of the sigmoid section of the duodenum 30 minutes after the drench. Note obliteration of the contour of the section.
250 kg horse. KV 170 MAS 170 FFD 100.

ii) It was possible to demonstrate the pyloro-duodenal junction. This also was clear only within the first ten minutes after drenching the animal with the contrast medium (figure 30).

iii) It was possible to demonstrate sections of the first part of the duodenum behind the sigmoid section (figure 32).

Figure 32:

Dorso-ventral exposure of the duodenum posterior to the sigmoid section.
350 kg horse. KV 170 MAS 200 FFD 100

iv) The parts of the duodenum beyond the middle lobe of the liver vary in their abdominal position. These parts were seen directly below the midline and to the right of it (figure 32).

v) It was not possible to demonstrate clearly any part of the duodenum by lateral projection.

vi) The place of the sigmoid section of the duodenum was not constant. It varied from under the vertebral column to the right of it.

5.3.1.1(c) Discussion:

i) Techniques: It was not possible to demonstrate the duodenum by lateral projection. This is because the first part of the duodenum lies in the same horizontal plane as the stomach. The stomach silhouette completely masked the duodenum when a lateral projection was made. Only dorso-ventral projection eliminated this problem. The same findings are reported by Dyce[12], though he only occasionally identified the duodenum.

It was found that the quantity of stomach content evacuated into the duodenum did not vary with the total content of the stomach, thus a quantity of 2 or 3 kilos of barium introduced by stomach tube, was drained into the duodenum by peristaltic waves similar in size to those of a quantity of only one kilo of barium meal in the stomach. It is therefore sufficient to introduce one kilo of barium sulphate meal for the purpose of study of the first part of the duodenum.

ii) Position of the duodenum: The results of this study are not in accordance with findings reported previously. Alexander and Benzie[1] reported that the position of the duodenum was constant. They, however, did not identify any part of the duodenum other than its beginning. In our study it was possible to demonstrate sections of the duodenum caudal to the sigmoid section. These sections varied in their position, a fact which corresponds to the anatomy texts[14,29].

These sections, however, could only be clearly identified within the first thirty minutes after drenching of the horse. After that - the contour lines were obliterated by superimposed barium filled coils of the intestines (Figures 33 and 34).

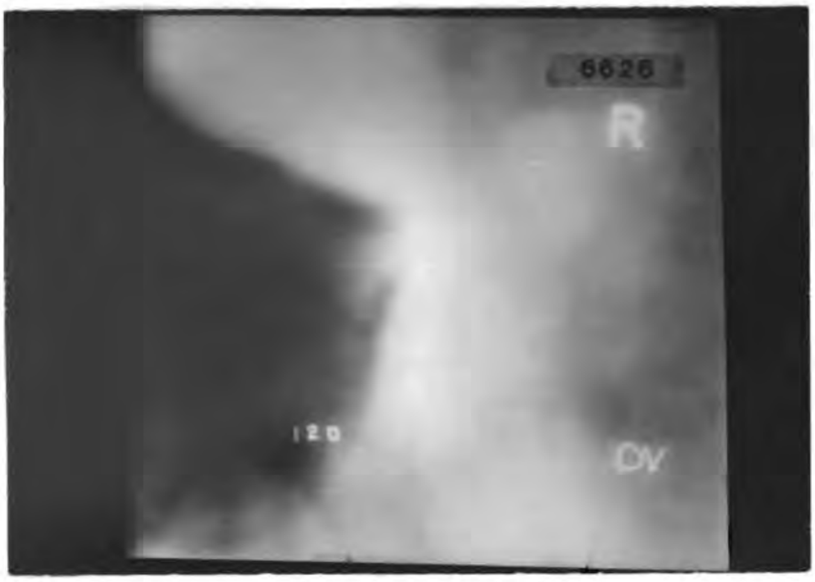


Figure 33:

Dorso-ventral exposure of the duodenum 120 minutes after the drench. Note complete distortion of the contour of the duodenum by superimposing duodenal coils. 250 kg horse. KV 170 MAS 170 FFD 100.

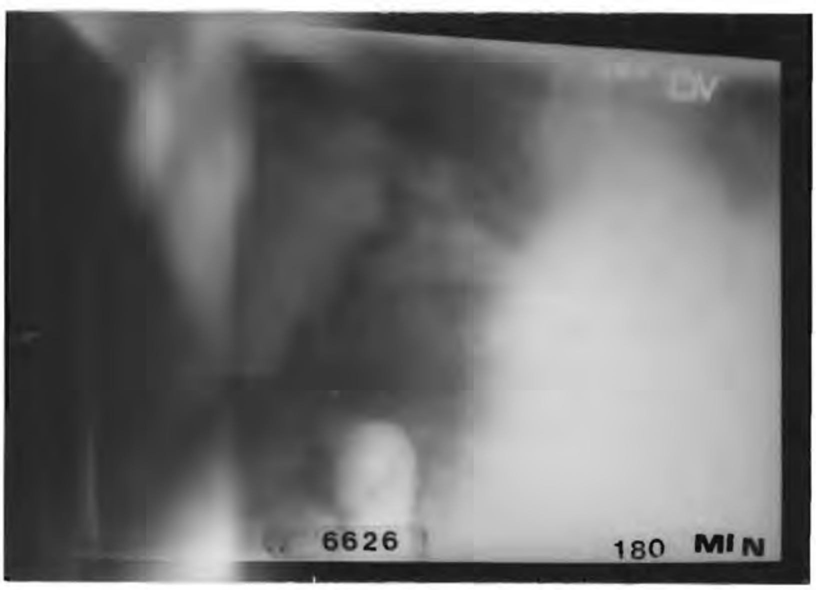


Figure 34:

Dorso-ventral exposure of the first section of the duodenum 180 minutes after the drench. Note loss of any architecture. 250 kg horse. KV 170 MAS 170 FFD 100.

iii) Weight of subject: In spite of all efforts, it was not possible to produce good radiographs of the duodenum on a horse weighing 400-500 kilos. This is where the limitation of the machine was noticed most. Making dorso-ventral exposures of the duodenum involved penetration of the thickest part of the abdomen - thicker than the area of the stomach or the pelvis. In this part, increased kilovolts and milli ampers were needed, which resulted in longer exposure time and increased amount of scattered radiation. Motion and scattered radiation interfered seriously with the production of good radiographs.

It seems as if larger and heavier horses may have to be anaesthetized for radiological examination of the duodenum.

B.3.2. Ileo-jejunum

B.3.2(a). Anatomy:

The mesenteric part of the small intestine is conventionally subdivided into jejunum and ileum, though no clear demarkation between the two exist. This part of the digestive system varies so much in position, that no description of its abdominal relationship is possible. It lies in numerous coils all over the abdomen, but chiefly in its left dorsal part. The diameter of the coils is 6-7½ cm. They are suspended from the dorsal abdominal wall by the great mesentery.

B.3.2(b). Histology:

The histological structure is similar to that of the duodenum, with the addition of two more structures that appear throughout its length: The intestinal glands and Peyer's patches. The intestinal glands are simple tubular glands which open into the lumen of the intestines. Peyer's patches are aggregated nodules of lymphoid tissue which are situated chiefly on the mucosa opposite the mesenteric attachment. These are large structures that may reach the size of 17 cm x 38 cm in a young horse.

B.3.2(c). Physiology:

Several phases of the digestive process take place in the jejuno-ileal section. These include amongst others, the digestion of fats by bile, change of pH of the chyme from acid to alkali, soaking the chyme with mucin and mucin-like substances, hydrolysis of bisacharides into glucose molecules and digestion of available proteins.

B.3.2.1(a). Techniques:

Two techniques were used: I) lateral projection, and II) dorso-ventral projection.

I) Lateral projection:

Area of exposure: Anterio-lateral abdomen on the right side. (Coils of small intestines change their position with peristalsis).

Exposure data:

For 250 kg horse:		For 500 kg horse:	
KV	110	KV	130
MAS	160-170	MAS	170
FFD	110 cm.	FFD	110 cm.

II) Dorso-ventral projection:

Area of exposure: Any area on the left side of the lowest point on the dorsal midline of the horse.

Exposure data:

For 250 kg horse:		For 500 kg horse:	
KV	160	KV	170
MAS	160	MAS	200
FFD	110 cm.	FFD	110 cm.

Contrast medium: Same composition and amount as for the duodenum.

B.3.2.1(b) Findings:

(See table 7)

i) It was possible to demonstrate coils of small intestines, but only after making several scanning radiographs of the lateral abdomen (figures 35 and 36).

Figure 35:
Dorso-ventral exposure of small intestines.
350 kg horse.
KV 170 MAS 200
FFD 100.

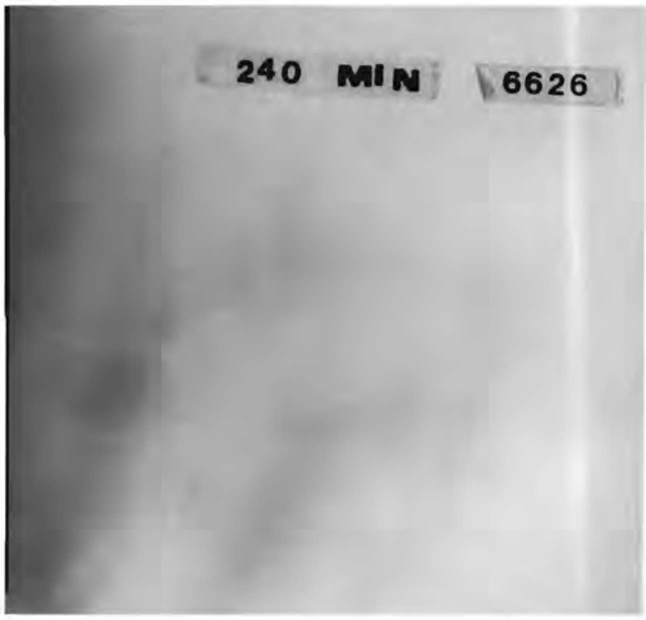


Figure 36:

Dorso-ventral exposure of small intestines.
250 kg horse. KV 170 MAS 170 FFD 100.

ii) It was not possible to differentiate the sections of the ileo-jejunum part of the small intestines.

iii) It was not possible to interpret fully the radiograms which were made.

iv) It was possible to produce definite images of small intestinal coils by the dorso-ventral projection. Lateral projection produced definite contours of intestinal coils too.

v) Shortly after drenching, peristalsis of barium could be seen on lateral projection (figure 37).

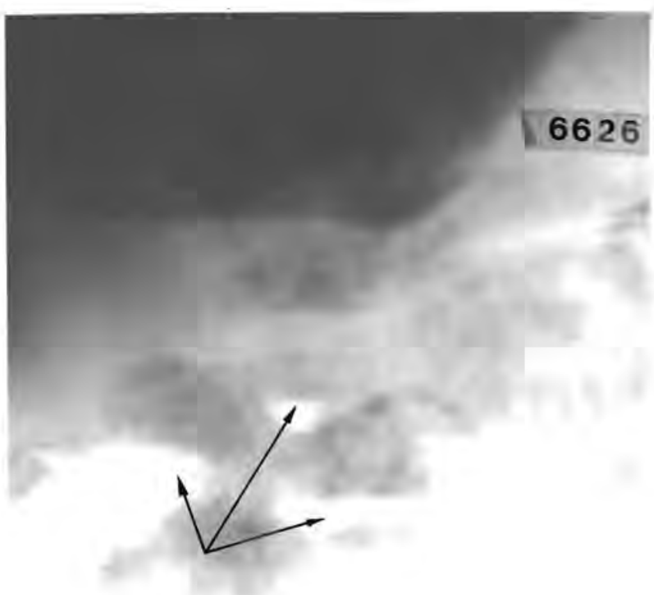


Figure 37:

Lateral exposure of small intestines. Note sections of intestines separated by peristallic waves.
250 kg horse. KV 110 MAS 170 FFD 100.

B.3.2.1(c) Discussion:

The small intestines are an important part of the clinical examination of digestive disturbances in the horse. There are numerous conditions which originate in faulty function of this section of the gastro-intestinal tract. The condition which commonly calls for examination of the small intestine is colic. Colic may originate in the small intestines due to hyper-peristalsis, gas accummulation, intussusception and parasitic infestation. To the clinician a radiological examination of the small intestines may prove of great value.

It is interesting to note that the few previous records of radiological examination of the gastro-intestinal tract of the foal presented fairly good radiographs of the mesenteric parts of the small intestines[1,12]. However, Dyce[12] in his discussion comments that the salient distinction of the gastro-intestinal tract of the neonatal foal appeared to be its relatively narrow caliber. The difference in caliber of the intestinal coils between the new born foal and a grown horse may well explain the difficulty in producing small intestine radiographs. The major factor which interferes with the identification of sections of the mesenteric parts of the small intestines is their constant motion with peristalsis and repeated change of disposition.

Another important obstacle in producing diagnostic radiographs of mesenteric small intestines is their being superimposed on a relatively full stomach and on other intestinal coils full of barium. By the time the stomach empties enough barium is present in the large intestines to superimpose on the jejuno-ileum complex to obliterate its contour.

It seems, therefore, reasonable to assume that by still radiography it will not be possible to identify sections of the mesenteric parts of the small intestines.

B.4. LARGE INTESTINES

B.4.1. Caecum

B.4.1(a) Anatomy:

The caecum of the horse occupies a large part of the right half of the abdomen, and is in extensive contact with the body wall. It consists of a base, a body and an apex. The base is situated at the right sublumbar region. It is curved - the greater curvature is dorsal, the lesser curvature ventral. The body extends downwards and forwards from the base, and rests on the ventral wall of the abdomen. The apex lies on the abdominal floor, slightly to the right of the median plane (Diagram III).

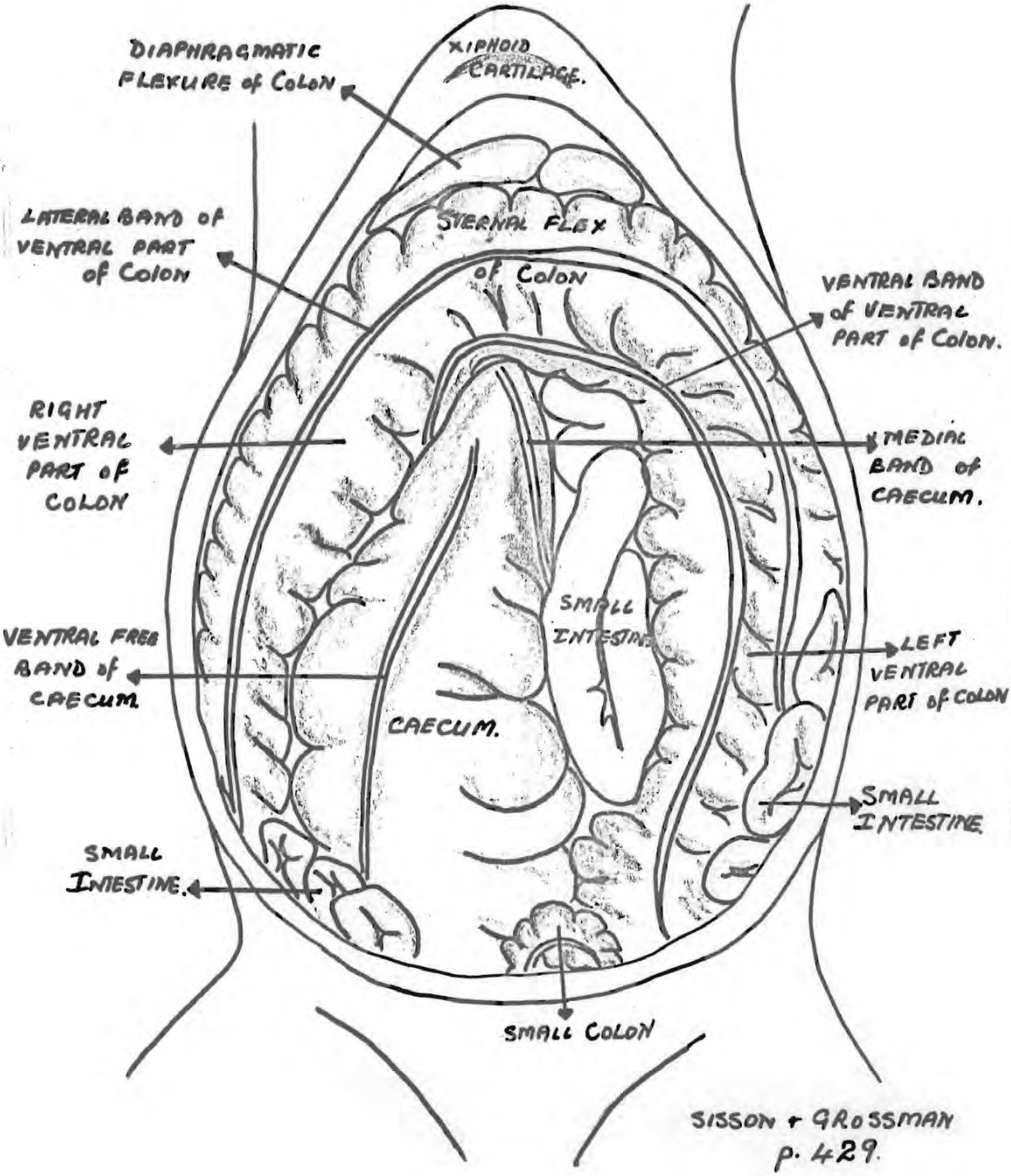
The caecum has four longitudinal bands, situated on the dorsal, ventral, right and left surfaces. The caecum is 3 - 3.7 metres long and its average diameter is 25 cm.

The ileo-caecal orifice is situated in the lesser curvature of the base, about 5 - 7 cm to the right of the median plane. The end of the ileum is partially telescoped into the caecum, so

DIAGRAM III:

ABDOMINAL VISCERA OF HORSE

VENTRAL VIEW



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that the orifice is surrounded by a fold of mucose membrane which encloses a thick circular muscle - the sphincter ilei.

The caeco-colic orifice is situated about 5 cm laterally to the ileo-caecal orifice, separated from it by a large fold of mucosa, which projects into the interior of the caecum.

B.4.1(b) Histology:

The wall of the caecum consists of the four layers - serosa, muscularis, sub-mucosa and mucosa. The submucose layer is very rich with blood vessels and nerves.

B.4.1(c) Physiology:

The caecum of the horse, as in other simple stomach herbivorous animals, functions mainly as a reservoir in which cellulose and other foodstuffs undergo bacterial fermentation.

The material passes into the caecum from the ileum. It is being mixed there due to the motility of the organ. There are three basic types of caecal motility:

i) Large contractions which travel all along the caecum from the base to the apex or vise versa.

ii) Smaller contractions of local nature, which are probably sacculation motility.

iii) Changes in tonus of different parts of the caecum at different times.

Studies have shown[10] that food enters the caecum through the ileo-caecal orifice, travels down the caecum towards its apex, and then travels back towards the caeco-colic orifice, to leave the organ on its way to the colon.

Food enters the caecum about $1\frac{1}{2}$ hours after the meal, and takes at least six hours to pass through and leave the caecum.

B.4.1(d) Experimental data: (See table 9)

B.4.1.1. Techniques:

Preparation of the animal for study of the caecum:

i) The horse received only bran diet for three days.

ii) On the fourth day the horse was drenched with one kilo of mineral oil (paraffin oil) by stomach tube.

iii) The horse was then fasted for twenty-four hours.

TABLE 8: LARGE INTESTINES DATA

Horse number	Total number of exposures	Diagnostic radiograms					Non diagnostic radiograms				
		Lateral projection		Dorso-ventral projection		Total number of diagnostic radiograms	Under exposed	Over exposed	Motion	Excessive scattered radiation & other faults	Total number of non-diag. radiograms
		Plain	Contrast	Plain	Contrast						
6637	28	1	19			20	4	1		3	8
6626	21	1	16			17	3			1	4
6295	25		21			21	4				4
6237	18		8			8	5	2	1	2	10
Total	92	2	64			66	16	3	1	6	26
%	100	2	69			71	18	3	1(+)	7(-)	29

iv) Three kilos barium suspension weight per volume (w/v) was given by stomach tube 3½ hours prior to the beginning of radiography.

Three techniques have been employed: I) Lateral projection in standing position, II) Dorso ventral projection in standing position, and III) Lateral projection in an anaesthetized casted horse.

I) Lateral projection in standing position:

Area of exposure:

i) Base of the caecum: The sub-lumbar region on the left side.

Boundaries:	dorsally	-	iliac crest
	ventrally	-	tuber ischii
	caudally	-	midshaft of the femur
	cranially	-	the last rib.

ii) Body of the caecum: The area immediately ventral to the previously discussed area.

iii) Apex of the caecum: An area the centre of which is ten cm caudal to the xiphoid cartilage.

Exposure data:

KV 130
MAS 160
FFD 110 cm.

II) Dorso-ventral projection:

It was found that there was no way to place the cassette in order that the sublumbar region would be demonstrated.

It was, however, possible to place the cassette properly for an exposure of the apex of the caecum. This was done with the assistance of a trolley, in the same way as was done in the stomach studies.

Area of exposure: An area of 15 cm along the dorsal midline, immediately posterior to the withers of the horse.

Exposure data:

KV 160
MAS 170-200
FFD 110 cm.

III) Lateral projection in an anaesthetized horse:

i) Anaesthetic procedure:

The horse was premedicated with 20 mg acetylpromazine (Acetylpromazine(R) Boots Pure Drug Co. S.A. Pty. Ltd.) given intravenously, prior to the induction of anaesthesia by the Pentothal injection (Pentothal(R) Abbot Laboratories S.A.) intravenously, followed by two percent fluothane inhalation. Before exposures were made, pulmonary hyperventilation was done. Cessation of respiration for about ten seconds followed. Exposures were made at that time (figures 38 and 39).

Figure 38: Preparation of the horse for radiography of the caecum. Note anaesthetic machine and ventilation bag.

Figure 39:
Positioning of the tube for radiography of the caecum.

ii) Area of exposure:

As previously described in technique No.1.

iii) Exposure data:

Base of caecum:	KV	140
	MA	20
	TIME	8.0 sec.
	FFD	80 cm.

Body of caecum:	KV	150
	MA	25
	TIME	8.0 sec.
	FFD	100 cm.
Apex of caecum:	KV	130
	MA	50
	TIME	5.0 sec.
	FFD	100 cm.

E.4.1.2. Findings: (See table 9).

i) It was not possible to produce diagnostic radiographs in techniques No.1 and No.2.

ii) It was possible to produce diagnostic radiographs only if exposures were made of an anaesthetized horse (technique No.3).

iii) Using technique No.3 with long slow exposures, the base and the apex of the caecum were demonstrated well (figures 40 and 41).

TABLE 9: LARGE INTESTINES FINDINGS

Horse number	Parts of caecum demonstrated	Pelvic flexure demonstrated		Time after drenching of appearance of contrast media in the pelvic flexure				Time taken for a complete filling of pelvic flexure					Position of pelvic flexure		Demonstration of small colon and rectum
			No. of experiments	4 h.	5 h.	$5\frac{1}{2}$ h.	6 h.	1 h.	$1\frac{1}{4}$ h.	$1\frac{1}{2}$ h.	$1\frac{3}{4}$ h.	2 h.	inside pelvic inlet	outside pelvic inlet	
6637	+	+	2			+	+				+ +			+	+
6626	+	+	2		+	+			+			+	+		+
6295		+	1	+					+			+	+		+
6237		+	2	+ +					+	+				+	+

Figure 40:

Lateral exposure of the base of the caecum.
350 kg horse. KV 150 MA 25 TIME 8.0 sec. FFD 100.

Figure 41:
Lateral exposure of the apex of the caecum.
350 kg horse. KV 110 MA 50 TIME 5.0 sec. FFD 100.

iv) It was not possible to clearly demonstrate the body of the caecum in any technique.

v) An amount of three kilos of contrast medium was found to be insufficient to achieve a complete filling effect of the caecum.

vi) In the radiograms of the apex of the caecum, the longitudinal bands of the colon were clearly seen (figure 42).

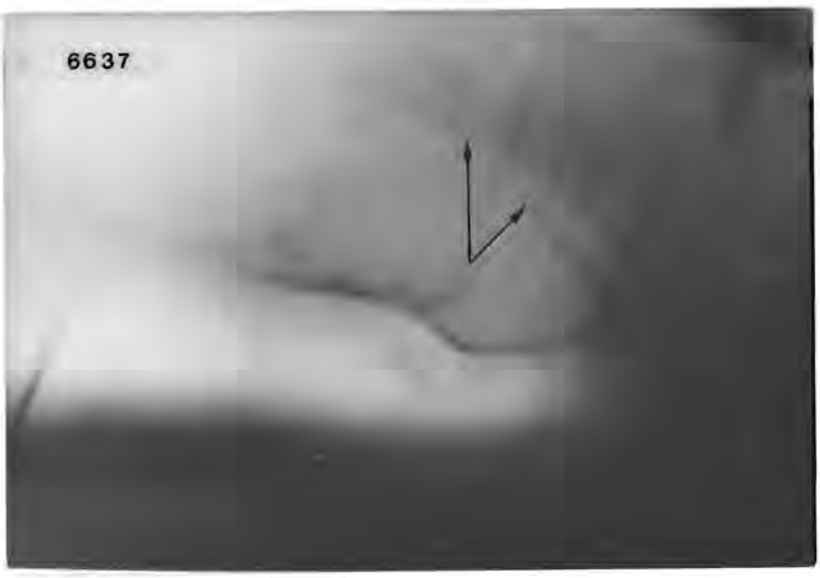


Figure 42:

Lateral exposure of the apex of the caecum. Note the longitudinal bands on the adjacent colon.
350 kg horse. KV 110 MA 50 TIME 5.0 sec. FFD 100.

vii) Accumulation of most of the barium in the caecum takes place about 4-5 hours after the barium drench.

viii) In the studies of the caecum it was seen that the barium does not cling to the mucosa.

B.4.1.3. Discussion:

i) Projection:

Several reasons existed for the fact that it was not possible to produce diagnostic radiographs by using techniques No.1 and No.2.

a) Small intestinal coils normally fill up most of the upper left abdomen. At the time the contrast medium reached the caecum these coils were still full of barium. The silhouette of these small intestinal coils was superimposed over the caecum, and interfered with production of radiographs of the caecum.

b) In normal digestive processes, the contents of the caecum keep moving out of the organ at the same time as more contents come in. By the time a considerable amount of contrast medium was present in the caecum, a lot of it was also present in the ventral colon; thus was superimposed over the caecum in a lateral projection (diagram III).

c) Dorso-ventral projection was technically impossible. The abdomen of the horse is oval, and there was no way by which a cassette could be pressed to the body wall right at the level of the caecal body. It was only possible at the apex where the x-ray beam had to penetrate through sections of the colon full of contrast medium. No diagnostic radiograph was therefore possible even of the apex in a dorso-ventral projection.

ii) Anaesthesia:

The advantage of general anaesthesia was in two facts:

a) It caused a relaxation of the abdominal wall. This enabled closer proximity of the caecal apex to the cassette underneath.

b) It enabled interruption of respiration. When respiration was suppressed a low MA with long exposure was used. This technique proved to bring about details in the radiographs which were not brought out in a high MA exposure. These facts were recognized by Drury et al[9]. Although he was using a pony in his investigation he resorted to suppression of respiration. Drury et al[9] also mentioned that the right ventral colon is super-imposed over the body of the caecum. Dyce[12], working on a four-days old pony, radiographed the caecum in standing position. He reported that it was difficult to obtain satisfactory radiographs of the caecum, since "as a rule the caecal image appeared to be continuous with those of neighbouring parts of the bowel[12]".

iii) Volume of contrast medium:

The caecum of the horse is an enormous organ, with a capacity in an adult horse exceeding 25 litres. A quantity of 2-3 litres of contrast medium given as a drench to the horse only accentuated somewhat the contours of the caecum. If one has to increase the volume of contrast medium to achieve a complete filling of the caecum, a starting volume of at least 10 litres must be used.

iv) Filling time of the caecum:

There is only one reference in the literature to the time of the filling of the caecum. Alexander and Benzie[1] found that in the weaned foal the caecum contains the contrast medium from three to six hours after the meal. At that time, the right and left ventral colons were also filled. The findings in this study correspond well with those reported by Alexander and Benzie[1].

v) Mucosa contour:

It is assumed that the fact that the barium did not adhere to the mucosa was a result of the mineral oil drench given to the horse 24 hours prior to the examination.

vi) Clinical application:

The fact that it was not possible to produce diagnostic radiograms of the caecum by using techniques No.1 and No.2 is of a considerable significance to radiologists. These studies have shown that the caecum is the only section of the gastro intestinal tract that requires casting of the horse. The studies have also shown that casting of the horse is not sufficient - but a general anaesthesia accompanied by cessation of respiration is important if radiographs of any quality are to be obtained.

Taking into account three days of preliminary diet followed by mineral oil drench prior to the studies, one is inclined to conclude that radiological examination of the caecum of the horse will not become a common procedure in the near future.

B.4.2. Colon

B.4.2(a) Anatomy:

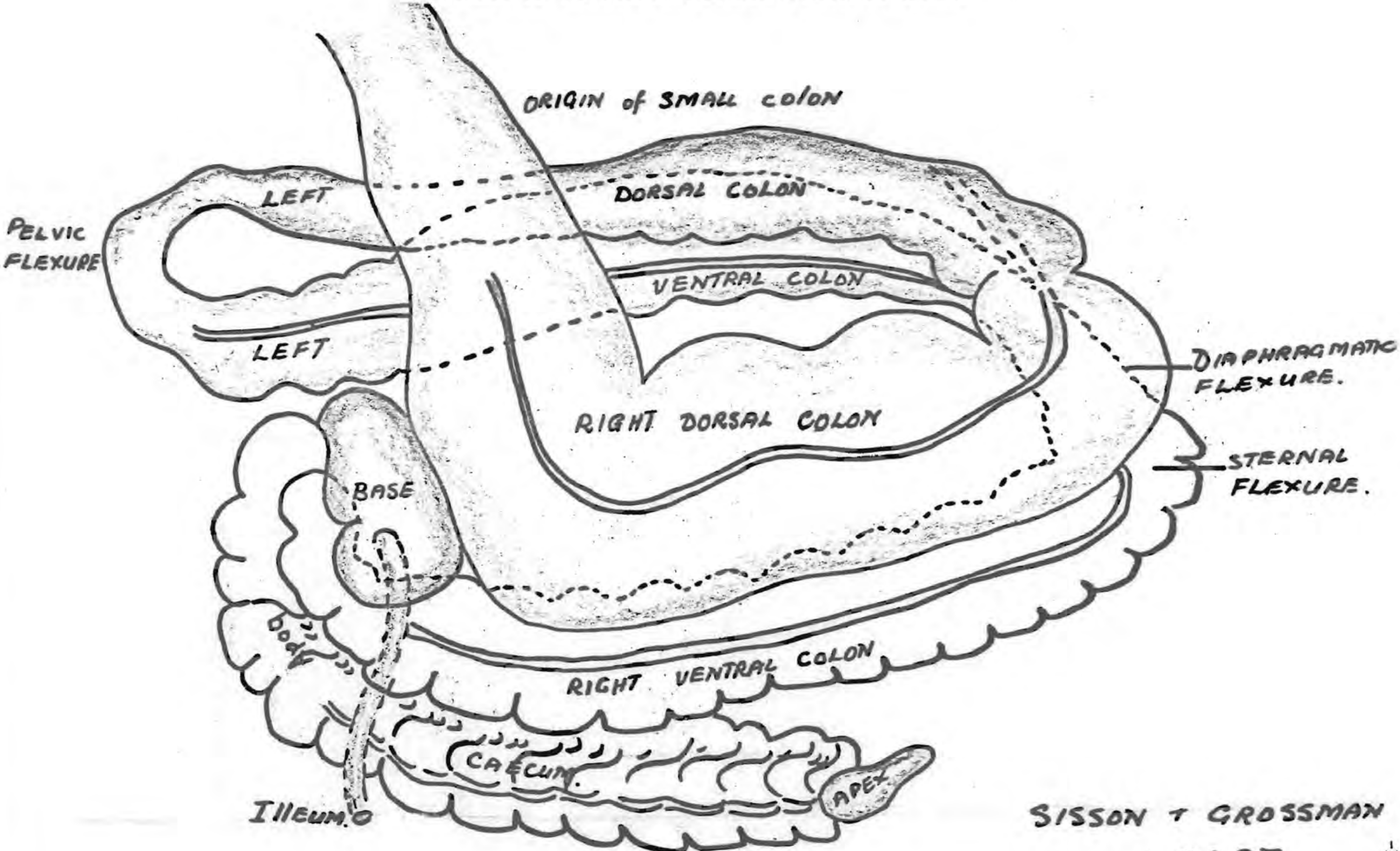
The colon begins at the caeco-colic orifice and terminates at the rectum. It is divided into the great and the small colon. The great colon is 3 - 3.7 metres long, and its average diameter is 25 cm. In situ it is folded in a way that it consists of four parts, which are designated by their position: The right ventral, the left ventral, the left dorsal and the right dorsal colon. These are the sternal flexure, between right ventral and left ventral colon, the pelvic flexure between the left ventral and left dorsal colon, and the diaphragmatic flexure between the left dorsal and right dorsal colon (diagram IV).

The diameter of the colon varies greatly. At its origin it is about 5 - 7.5 cm, for most of the ventral parts it is 25 cm. At the pelvic flexure and hereafter it decreases to 8-9 cm and increases greatly behind the diaphragmatic flexure to about 50 cm.

The small colon begins at the termination of the great colon, ventral to the left kidney, and terminates in the rectum at the pelvic inlet. Its length is about 3.5 metres and its diameter 7.5 - 10 cm.

DIAGRAM IV:

DIAGRAM OF CAECUM AND LARGE COLON OF HORSE



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B.4.2(b) Histology:

The colon is built of the normal four coats: serosa, muscularis, submucosa and mucosa. At the pelvic flexure the muscular coat is a transition between the elastic fibers of the ventral colon to the muscular fibers of the dorsal colon. The submucosa and mucosa do not present special features except for the fact that the mucosa is thicker than in the small intestines. Mucosal glands are numerous, and their secretion is mainly mucous.

Blood supply and innervation:

The arteries come from the anterior and posterior mesenteric and internal pudic arteries. The veins go to the portal vein. The nerves are derived from the mesenteric and pelvic plexus of the sympathetic.

B.4.2(c) Physiology:

The colon has an important role in digestion: It is the compartment in which (together with the caecum) maceration, fermentation and solution of fibrous portions of the food take place. It is also a place where some synthesis of nutritional elements occurs. It is in the colon where fluid reabsorption takes place. Bacterial action in the colon effects mainly carbohydrates, but proteins are digested to some extent, too.

The colon shows at least three kinds of motor activity: peristalsis, reverse peristalsis and sacculation. The peristaltic movements travel at a slow rate compared to the similar movements in the small intestines. Antiperistalsis occurs at the proximal part of the colon, around the caeco-colic orifice.

Pre-study consideration:

Due to the enormous diameter of the colon, its radiological examination becomes impractical. The part which is much narrower in diameter is the pelvic flexure of the colon, and proved to be the only part of the colon amenable to radiographic investigation.

B.4.2.1. The Pelvic Flexure:

The pelvic flexure has few sacculations. Its diameter is markedly smaller than that of the left ventral colon, and is only 7 - 8 cm.

It is not attached transversally, and is variable in position, but is usually directed against the posterior part of the right flank.

It has one band along its lesser curvature.

B.4.2.1(a) Technique:

i) Projection:

Lateral projection only (right side).

ii) Area of exposure: The pelvic inlet area.

Exposure area boundaries -

Dorsally	-	5 cm ventral to the iliac crest.
Ventrally	-	A line crossing mid-shaft of the femur.
Cranially	-	A line crossing the iliac crest.
Caudally	-	A line crossing the tuber ischii.

(Figures 43 and 44).

Figure 43:
External markings for exposure of the pelvic flexure.

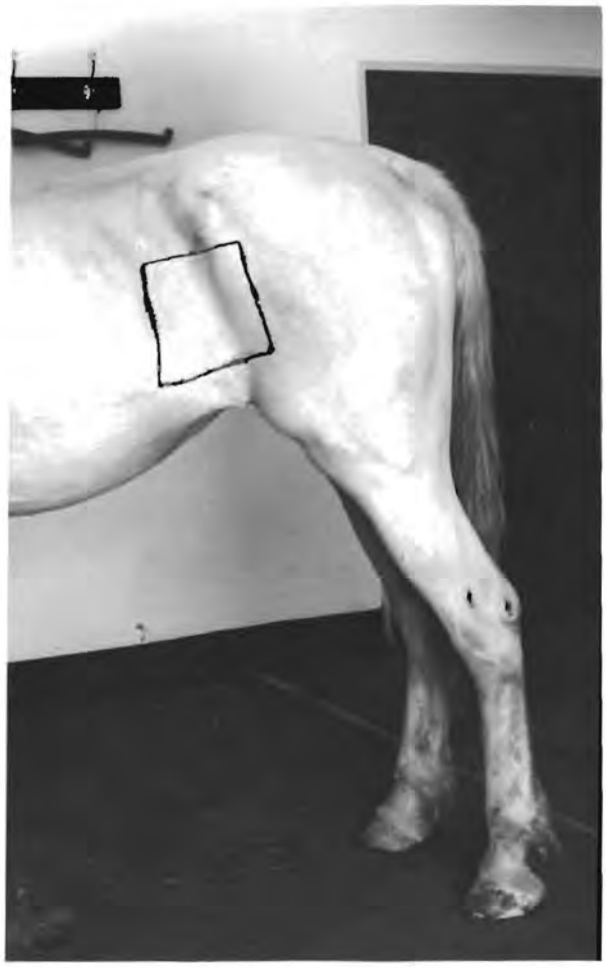

Figure 44:
External markings for exposure of the pelvic flexure.

iii) Exposure data:

KV	130
MAS	130-160
FFD	110 cm

B.4.2.1(b) Findings:

i) It was possible to demonstrate clearly the pelvic flexure of the colon (figure 45).

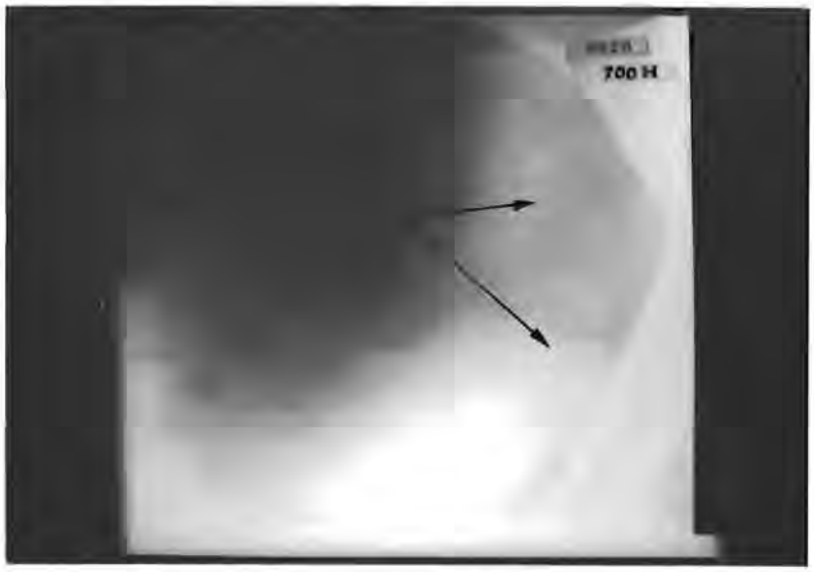

Figure 45:

Lateral exposure of the pelvic flexure of the colon, seven hours after barium drench. Note contrast media filling the entire flexure.
250 kg horse. KV 140 MAS 160 FFD 100.

ii) A volume of 2000 ml. of barium sulphate w/v contrast medium was sufficient to produce good quality radiographs.

iii) Contrast medium started to appear in the pelvic flexure about five hours after drenching the animal.

iv) There appeared to be a physiological obstacle in this section of the bowel. The contents of the colon moved up the flexure very slowly. One and a half to two hours had passed in different studies from the time of appearance of the contrast medium in the lower end of the flexure until the filling of the flexure.

v) A considerable amount of gas preceeded the contents of the colon, as it moved up the flexure (figures 46, 47, 48 and 45).

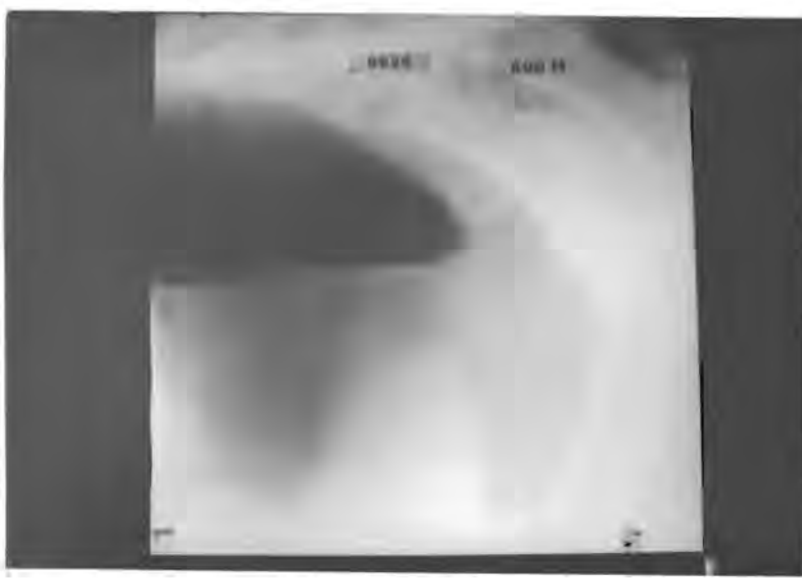

Figure 46:
Lateral exposure of the pelvic flexure of the colon, five hours after the drench. Note the partial filling.
250 kg horse. KV 140 MAS 160 FFD 100.

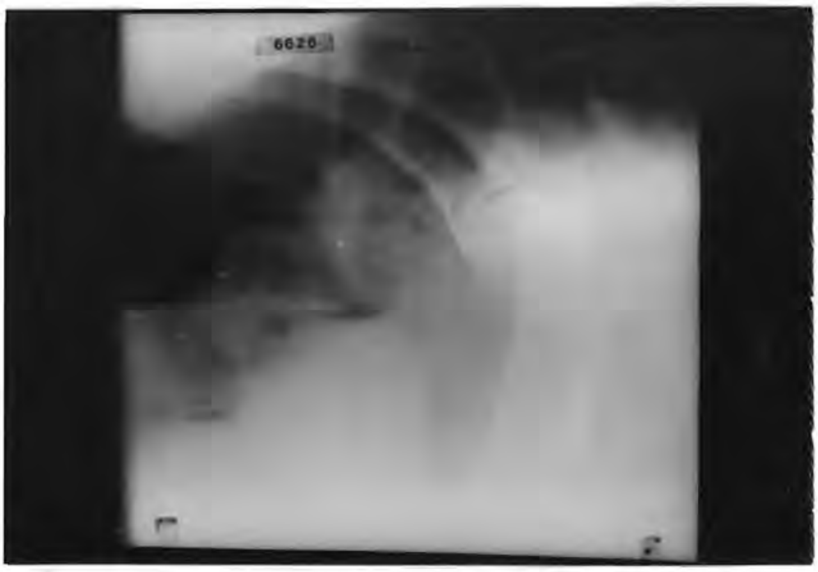

Figure 47:

Lateral exposure of the pelvic flexure of the colon five hours and forty-five minutes after barium drench. Note the partial filling.
250 kg horse. KV 140 MAS 160 FFD 100.

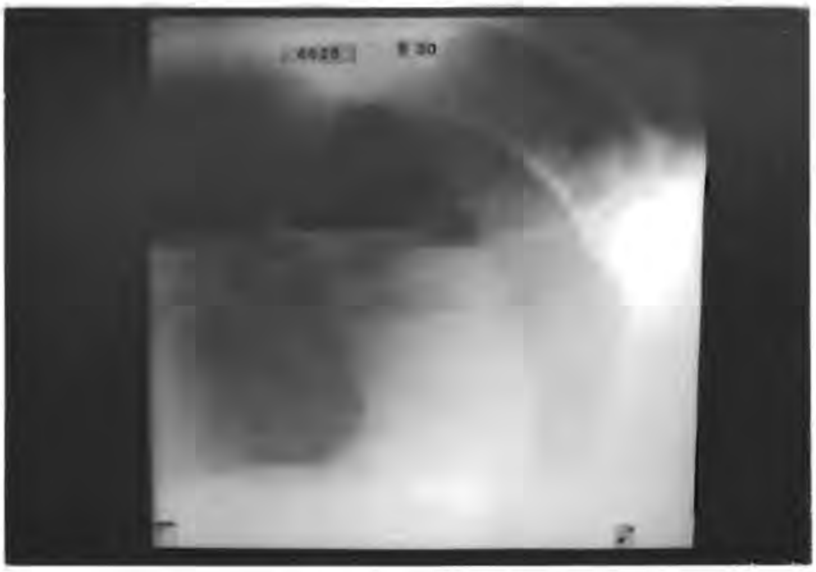

Figure 48:

Lateral exposure of the pelvic flexure six and a half hours after the barium drench. Note the rising level of the flexure filling.
250 kg horse. KV 140 MAS 160 FFD 100.

vi) Variations were seen in the position of the flexure in different horses.

B.4.2.1(c) Discussion:

i) Technique:

a) Lateral projection has proven very satisfactory. No dorso-ventral projection was possible due to anatomical reasons: it was not possible to fix a cassette directly under the abdomen at the proper point.

b) The volume of contrast medium sufficient to produce diagnostic radiographs was remarkably small compared to the amount needed to demonstrate the caecum. This could be explained by the fact that the smaller lumen of the colon at the flexure brings about concentration of its contents.

ii) Rate of passage:

No account of the fact that the filling of this section is very slow could be found in the literature. This slow rate of filling of the flexure ($1\frac{1}{2}$-$2\frac{1}{2}$ hours) was found continually (table 9).

There could be several explanations of this phenomenon:

a) This section of the colon is directed dorsally. Moving bowel contents in an upward direction may require pressure build-up from below.

b) Barium suspension is a heavy suspension. Micropaque(R) (Damancy & Co. Ltd., England) the commercial preparation which was used in the studies, is a w/v suspension. Two kilos of that suspension contains two kilos of barium sulphate salt. The slow rate of filling of the pelvic flexure may be a specific phenomenon characteristic only of colon contents which contain barium.

Against this explanation one could bring the fact that the same Micropaque(R) suspension was also used in the study of the stomach and duodenum, and no slowing down of the filling of the sigmoid section of the duodenum was noticed. The sigmoid section of the duodenum has an upward direction in its proximal part. Besides, the peristaltic force of the bowel is much too powerful to be seriously affected by the barium.

The writer is of the opinion that there is a definite physiological obstacle in the pelvic flexure. This obstacle composed - the upward direction of the colon, and the narrowing of the lumen. This obstacle may well explain the high frequency of the impaction colics which originate at this site.

iii) Position of the pelvic flexure:

Variations in position of the pelvic flexure are explained[29] by the fact that there are differences in the length of the ventral colon. In subjects in which this part of the colon is relatively long, the pelvic flexure usually bends to the right across the pelvic inlet. In other cases where the ventral colon is relatively short, the pelvic flexure lies inside the pelvic cavity.

B.4.3. Rectum

B.4.3(a) Anatomy:

The rectum is the terminal part of the digestive tract. It extends from the pelvic inlet to the anus. Its length is about 30-40 cm. Its direction may be oblique or straight. Its first part is made of coils, as those of the small colon. Its caudal part forms a flask shaped dilation termed the ampulla recti.

The rectum usually lies in the median position, related ventrally to the bladder, laterally to the small colon to the left, and the pelvic flexure to the right.

B.4.3(b) Histology:

As the colon.

B.4.3(c) Physiology:

Physiologically it is a continuation of the colon. Its significance is in the fact that it serves as the temporary storage of the faecal balls.

B.4.3.1. Technique:

i) Preparation: The faeces were removed manually. One ml Neostigmine (Neostigmyl (R) Milborrow & Co. Pty. Ltd.) was given intramuscularly one hour prior to the examination.

ii) Projection: Lateral projection only (either side).

iii) Area of exposure:

Dorsally	-	the tuber coxii level.
Ventrally	-	5 cm below tuber ischii level.
Cranially	-	a perpendicular line from the patella of the corresponding leg.
Caudally	-	the tail.

(figure 49).

Figure 49:
External markings for exposure of the rectum.

iv) Exposure data:

KV 130-140

MAS 130-160

FFD 110 cm.

v) Contrast medium:

Enema of barium suspension. Mixture made of one kilo barium sulphate powder in 2000 ml of warm water. The enema introduced to the rectum via a stomach tube.

B.4.3.2. Findings:

i) The rectal ampula was demonstrated well (figure 50).

Figure 50: Lateral exposure of the rectal ampula, after barium enema. 250 kg horse. KV 130 MAS 130 FFD 100.

ii) Volume of 2000 ml of enema proved better than larger volumes. Larger volumes initiated defecation reflexes and caused expulsion of most of the contrast medium.

iii) Warm contrast enema penetrated to several distal coils of the small colon (figure 51).

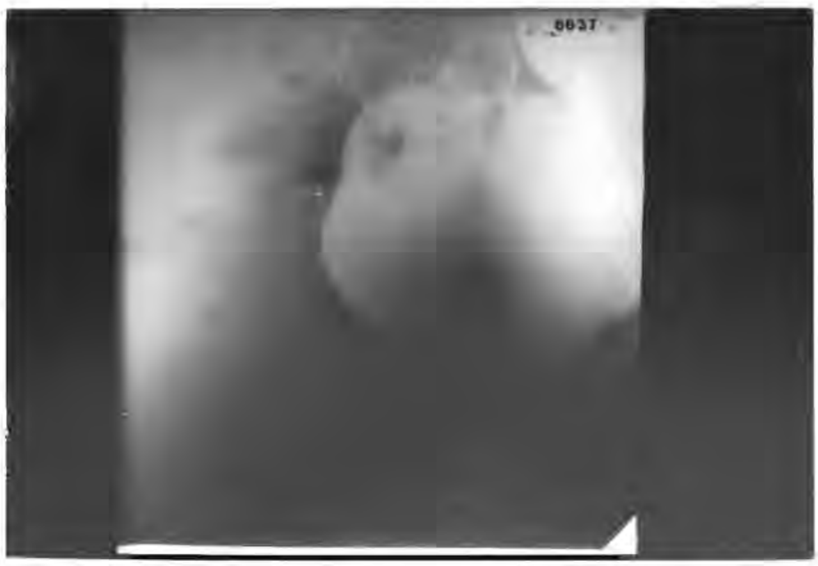

Figure 51:
Lateral exposure of posterior part of the small colon one hour after barium enema.
350 kg. horse. KV 140 MAS 140 FFD 100.

iv) One and a half hours was the longest time an enema was retained by a horse.

v) Small colon coils were found to be full of contrast media $1\frac{1}{2}$ hours after the barium enema was given (figure 52).

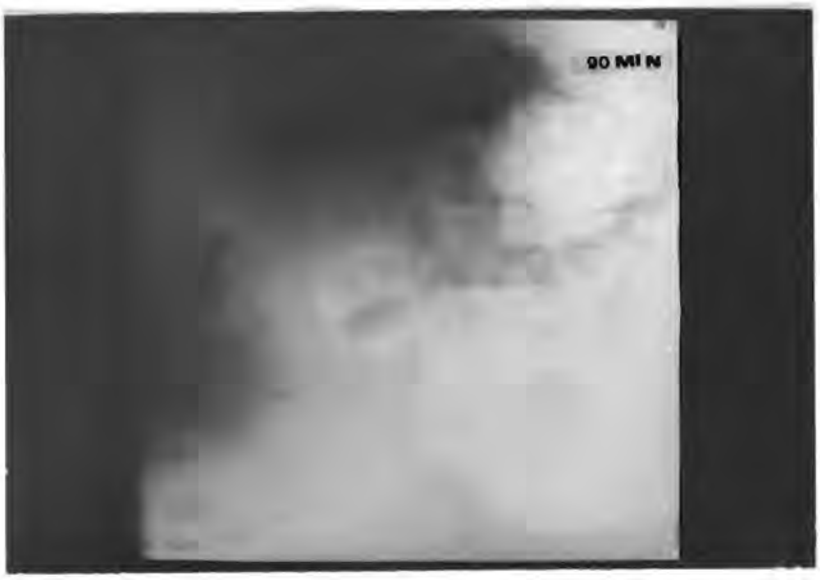

Figure 52:

Lateral exposure of posterior segments of the small colon one and a half hours after warm barium enema. Note fecal balls in the colon segments.
350 kg horse. KV 140 MAS 140

B.4.3.3. Discussion:

The rectum of the horse is very accessible for manual rectal examination. Consequently rectal radiography is not a necessity for clinical work in equine medicine. In the human, enema is an accepted technique to demonstrate the rectum and the colon. The technique in human radiology is effective because one could communicate with the patient and prevent defecation due to pressure exerted on the rectum and the colon by the large volume introduced and gravitation force used. It is impossible to prevent defaecation of the horse, which is an invariable result of increased volume and gravitation force of the enema.

The partial success to demonstrate several posterior coils of the small colon should be viewed with these facts in mind. It was possible to demonstrate several coils of the small colon even when there were fecal balls present in these coils. If measures are taken to assure complete emptying of the small colon (acetylcholine, physostigmine) - gravitation of the enema will probably result in deeper penetration of the contrast media into the small colon. But it must be expected, however, that the entire small colon will never be demonstrated by this technique, since defaecation and expulsion of the contrast media will occur before it reaches the full length of the small colon.

C. GENERAL DISCUSSION AND CONCLUSIONS

i) The Needs:

There has been a marked difference in the achievements of canine and feline radiology as compared with that of the larger domestic animals. Radiology is an essential tool in scientific research and clinical work. In basic research - studies on the physiology of the digestive system could be assisted markedly by availability of radiological techniques. The equine digestive system is a very sensitive and delicate system. Disturbances in the function of the system occur often, and are results of sudden change of food, of parasitic infestation, of nervous excitement, bacterial toxins and of viral and bacterial diseases.

In the bovine, the physiology of the digestive system has been studied extensively with the assistance of fistulas - In the equine relatively little is known in this field. Every section of the equine digestive system has problems which remain unsolved. In the oesophagus - the predisposition of the horse to choke remains to be studied. The normal process of deglutition is not well understood yet, and opinions vary about its exact mechanism[10]. In the stomach, the emptying time is a controversial subject[10,14]. The exact rythm of stomach peristalsis is unknown, - whereas it is very well known in the bovine. Variations in position of the stomach with peristalsis have been studied before, but only by one worker. Very little is known about the mode of interference of the Gastrophilus parasites with the action of the stomach.

In the small intestines a problem such as hyperperistalsis needs investigation. These peristaltic rushes may occasionally cause invagination, which is an acute clinical problem. The action of the ileo-caecal valve is not clearly understood yet[10]. The mechanism of the voluminous caecum in the horse is relatively unknown. The caecum is a closed sac and food enters and leaves the organ at the same time. Understanding of the physiology of the caecum involves a clear picture of the pattern of movement of the ingesta inside the organ. The caecum is a site of colics, a problem which calls for investigation.

The colon of the horse is arranged in a certain constant manner - having dorsal and ventral layers, being folded with flexures in each layer. Do these flexures present points of delay in the passage of ingesta? At what rate do the ingesta travel along the colon? Such problems and others remained unsolved due to the lack of techniques and equipment to investigate the matter.

Colic in horses is one of the most acute conditions in veterinary medicine. Four clinico-pathological syndrome occur in the digestive system of the horse:

1. Intussusception
2. Torsion
3. Impaction
4. Tympany

These conditions, with the exception of impaction, appear in an acute form. Even impaction, which may appear in a mild form at first, tends to progress rapidly to an acute one.

Several problems are presented to the clinician when an acute colic case is brought for treatment:

1. The anatomical diagnosis - which implies recognition of the part involved.
2. Pathological diagnosis - which implies clarification of the disease process.

3. Physio-pathological diagnosis - which implies evaluation of the degree of impairment of the function of the part involved.

4. The degree of emergency.

Only when these problems are solved can the course of action be determined, whether surgical invention or conservative approach. Radiography of the digestive system in cases of colic is an invaluable assistance to the clinician.

ii) The Contribution:

(See table number 10 and table number 11).

Though the number of experimental animals is small - (the only way to accomplish such basic pilot studies) - the number of exposures made is large enough to draw some statistical conclusions. Evaluation of the data reveals the following:

1. There is not much difference in the percentage of success of the techniques involved between the group of younger horses and the mature horses. In the two younger horses, 66 percent of the radiographs for the oesophagus were diagnostic, as compared to 60 percent in

the older horses. The stomach diagnostic radiographs in the younger horses were 80 percent, as compared to 77 percent in the older horses. In the small intestine, 71 percent of the radiographs in the younger horses were diagnostic, and 67 percent in the older horses. As for the large intestines, in the younger horses 70 percent were diagnostic radiographs as compared to 53 percent in the older ones. The last figures, however, was lowered markedly by the presence of an abdominal scar on one of the older horses. Age as such does not in itself create a difference, but age is involved with two factors which create differences for radiography: bone density and tissue mass.

The fact that the degree of success is about the same in the two groups, indicates that the techniques employed were in order, and could be regarded as suitable for all horses.

2. The degree of success in radiological examination of the different parts of the system varies. It appears as if the stomach is the part which promises the highest degree of success in radiography (80 percent) and that the other parts promise only a slightly lower

TABLE 10: SUMMARY OF DATA

	Oesophagus		Stomach		Small-intestines		Large-intestines		Total number of radiograms for the specific horse
	diag. rad.	non-diag. rad.	diag. rad.	non-diag. rad.	diag. rad.	non-diag. rad.	diag. rad.	non-diag. rad.	
6637	21	7	20	7	13	5	20	8	101
6626	14	5	30	3	25	6	17	4	104
total I	35	12	50	10	38	11	37	12	205
6295	13	5	17	4			21	4	64
6237	5	2	5	1	6	2	8	10*	39
total II	18	7	22	5	6	2	29	14	103
grand total	53	19	72	15	44	13	66	26	308
total for section	72		87		57		92		
% of grand total	74	26	83	17	77	23	72	28	100

* Horse had a large abdominal scar tissue.

degree of success (72 percent, 74 percent, 77 percent). These differences must be viewed in the light of two facts:

a) The work on the oesophagus was done mainly at the preliminary phase of the research, when there was not enough knowledge of the use and possibilities of the x-ray unit. This naturally resulted in a larger percentage of non diagnostic radiographs than objective difficulties warranted. The actual fact is, that the radiography of the oesophagus is less complicated than that of the other parts of the system by involving shorter and small exposures, and could be expected to give even greater success than radiography of the other parts.

b) The high percentage of success of the radiography of the stomach (83 percent) should also be seen in the light that this system was studied very extensively, and a higher degree of proficiency was reached in the technique. One should expect the same degree of success in stomach examinations as was achieved in other parts of the system, if a normal series of studies would have been made.

TABLE 11: COMPARISON OF SUCCESS IN THE TWO AGE GROUPS

	Oesophagus		Stomach		Small intestines		Large-intestines	
	diag. rad.	non-diag. rad.	diag. rad.	non-diag. rad.	diag. rad.	non-diag. rad.	diag. rad.	non-diag. rad.
Group I (younger horses)	35	12	50	10	38	11	37	12
	66%	34%	80%	20%	71%	29%	70%	30%
Group II (older horses)	18	7	22	5	6	2	29	14
	60%	40%	77%	23%	67%	33%	53%	47%

3. In spite of the large number of radiographs made in the study of the large intestines, the percentage of success is the smallest one of all sections. This corresponds well with the presence of a large amount of scattered radiation, which is seen on radiographs of segments of the large intestines. These extensive amounts of scattered radiation are the reason for the smaller degree of success in radiography of the large intestines - as compared to the other parts.

The causes for the excessive scattered radiation are:

a) The bulk of the large intestines (caecum, colon) lies in the widest diameter of the horse's abdomen.

b) The anatomical structure of the horse's digestive tract causes superimposition and complete overshadowing of the large intestine sections radiographed.

iii) Conclusions:

The results of this study support the following claims:

1. Equine abdominal radiography is feasible.

2. Radiography of the digestive system of the horse is within the scope of the available modern x-ray units.

3. A 70-75 percent success could be expected in studies of every section of the horse's digestive system, except the colon.

4. With the exception of the caecum and colon, the studies of the digestive system of the horse could become a routine clinical procedure.

5. With the exception of the pelvic flexure, colon radiography is the most difficult section for radiography, and does not promise any degree of success.

6. The techniques recommended in this study could be regarded as applicable to both younger and older horses, and to horses of different weights.