STUDIES RELATIVE TO TORSION OF THE BOVINE CECUM

Thesis for the Degree of M. S.
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Mark P. Rines

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by

Mark P. Rines

AN ABSTRACT

Submitted to the College of Veterinary Medicine of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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Approved Wade O. Brinker

Ten cases of torsion of the bovine cecum are reviewed. Seven of these were diagnosed at the Michigan State University Veterinary Clinic, the first in May 1953. Another occurred in Iowa in December 1953, and two were reported in 1957 from Oklahoma. The symptoms observed were similar to other types of intestinal obstruction in the bovine except that three of the cases had a watery diarrhea rather than the usual scanty, mucus covered feces. Blood did not regularly appear in the feces.

The condition is best diagnosed by rectal palpation of the distended cecum, but an unusual fullness of the right paralumbar fossa may be discernible. The failure to differentiate this condition from other types of intestinal volvulus and obstruction is proposed as an explanation for the limited number of recorded cases.

Although the earlier cases were successfully corrected by detorsion of the cecum via a laparotomy, the advisability of replacing ceca distended to four or five times their normal size, some with areas of avascular necrosis, was questioned. Recurrence of the torsion, the toxic effects of necrotic tissue, and the release of venous clots were considered as possible complications. One of the two cases reported from Oklahoma did recur, accounting for the only post-corrective fatality.

The desire to improve the operative correction of this condition led first to a study of the normal anatomy and then to the involvements of a torsion. Attempts to experimentally produce a torsion of the cecum were unsuccessful. A normal animal and a clinical case with a torsion were embalmed and studied in detail. These findings were compared with other clinical cases and other normal cadavers.

Mobility of the cecum in the normal bovine was found to vary considerably due to the width and extent of its only mesenteric attachment, the ileocecal fold of mesentery, and could predispose these structures to a torsion. The blood vessels to the area formed a consistent network which was described and illustrated. The nerves, for the most part, followed the blood vessels.

Torsions of the cecum cause a partial to a complete obstruction of the initial colon with either a clockwise or a counterclockwise rotation, when viewed through the right side of the abdomen. Ingesta passing through the relatively thick walled ileum distends the cecum, increasing the tension on the obstructed colon and on the associated blood vessels. In all but two of the clinical cases the cecum had displaced the greater omentum cranially and medially, allowing the cecum direct contact with the right abdominal wall.

The method of repair deemed most applicable for this condition was surgical removal of the entire cecum posterior to the ileocecal junction. A satisfactory operative procedure was evolved through ten cecectomies performed on normal animals. This procedure was then successfully used to repair a clinical torsion.

To ascertain the effect of cecectomizing a normal animal, four steers were put on a series of three digestion trials--one previous to the removal of the cecum, one two weeks after its removal, and then a final trial several months later. The coefficients of digestibility for their alfalfa hay ration showed no significant variance between the trials. In addition, three calves cecectomized when very young were compared to three similar, normal calves at about six months of age to detect any compensatory enlargement of the remaining intestines. No consistent increase in capacity of either the large or small intestine was apparent.

All experimentally cecectomized animals were observed after surgery for any sign of altered function. All recovered normally, and post mortem examination failed to reveal any post-operative complications. Periodic reports from the owner of the clinical case cecectomized by this procedure indicated that she had fully recovered and was performing creditably.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

INTRODUCTION

• During a three year period starting in May 1953, six cases of torsion of the cecum in cattle were presented at the Michigan State University Veterinary Clinic. These animals varied from three months to six years of age. Although female Holstein-Friesian cattle accounted for five of the six cases, this condition was first recorded in a valuable, five year old, Herford bull on May 7, 1953.

In general, the symptoms most frequently observed in these six cases were those characteristic of other intestinal obstructions. Anorexia, decreased milk production, and abdominal discomfort, followed by scanty evacuation of mucus covered feces, frequently indicate an obstruction. The cow may kick at her abdomen or lie down, only to get up again in a moment. The restlessness is otherwise accompanied by general depression. A gradual onset of symptoms characterizes an obstruction due to torsion of the cecum.

Preoperatively, a torsion of the cecum is best differentiated by rectal palpation, although an unusual fullness of the right paralumbar fossa may be distinguishable in the thinner cattle. A distended cecum is readily palpable just anterior to the brim of the pelvis and to the right of the midline. Only in the more advanced cases was the fecal material found to contain any appreciable amount of blood, comparable to an intussusception.

Operative correction was instigated in five of the six cases mentioned. Distension of the cecum varied from two to five times normal size. Two markedly distended ceca had areas of beginning necrosis, apparently due to impaired circulation. Correction was accomplished by detorsion of the cecum and associated structures. In three cases the size of the cecum necessitated temporary exteriorization through the right paralumbar abdominal incision and performance of a cecotomy to empty it. In one case having a minimum of involvement, the cecum was approached from an incision in the left paralumbar fossa. In all of these cases the cecum, ileum, and omentum were involved; however, the initial twisting, it seemed, could be either clockwise or counterclockwise, as determined by the direction of rotation necessary to return structures to their normal position. Recovery followed relocation in all five cases.

A torsion of the cecum reported at Iowa State College by Francis (11) presented similar symptoms. This three year old Holstein cow had been off feed for about five days, showed abdominal discomfort, and passed only small amounts of watery faces. A rectal examination revealed a large accumulation of fibrin and mucus in the rectum and a greatly distended cecum. Correction was made through a right paralumbar incision, and a cecum, distended to three times normal size, was taken to the outside for drainage. A degree of uncertainty was expressed concerning the normal positioning of the emptied cecum and involved intestines. Final decision was based upon relief of tension on the mesentery. The case improved daily and was discharged after a week of hospitalization.

Although the recovery rate in those cases reviewed was excellent, the possibility was apparent that cases could develop for which emptying and relocating the cecum would not suffice. The advisability of replacing within the abdominal cavity a greatly distended and atonic cecum was questioned, particularly those ceca having had an impaired circulation. Not only should the effects of necrotic tissue and the release of clots of venous blood be considered possibilities but also the increased probability for recurrence following the distension and stretching of the cecum and mesentery. This desire for improving the operative procedure and extending the knowledge of this condition led to the following investigations. These have, for convenience, been divided into three sections--(1) surgical anatomy, including the involvements in a torsion; (2) the method of repair; and (3) possible effects of this method of repair.

REVIEW OF THE LITERATURE

A review of the present veterinary literature could cause one to conclude that torsions of the bovine cecum are practically non-existant, but the Michigan State Clinic records do not seem to justify such a conclusion. Francis (11), in a student review, reports a "Partial Torsion of the Cecum of a Bovine," occurring on December 21, 1953. He also mentions the failure to find reference to this condition in the literature and concludes that ordinarily any displacement of the cecum would not sufficiently involve the intestines to cause obstruction.

Recently Jones, Johnson, and Moore (16) reported two cases of torsion of the bovine cecum. The symptoms observed were in general those common to intestinal obstruction, with one having diarrhea early in the course of illness. Correction was by laparotomy, cecotomy, and detorsion, with the eight year old Jersey cow recovering uneventfully. The other, a sixteen month old Guernsey bull, relapsed on the fifth post-operative day with recurrence of the torsion. Death followed a second detorsion in 36 hours. This animal reportedly lacked normal suspensory structures to the cecum and colon, and no attachment of the greater omentum to the duodenum was found.

A review of the medical texts indicates that a somewhat similar torsion can occur in man. According to Maingot (20) volvulus of the human cecum is usually attributable to congenital abnormalities such as the presence of a mobile mesocecum and mesocolon. Early symptoms are mild, progress slowly, and present increasingly severe colic. Signs of intra-abdominal inflammation appear as late manifestations. With due consideration for the difference in size, attachment, and function of the human cecum, the following review of the ailment in man by Wangensteen (33, p.385) offers much food for thought.

> Lecène comments upon the rarity of volvulus of the right colon and in 1910 says that he could find but four other cases reported from all of France. Faltin in Finland reported 28 cases in the five year period between 1897-1902. Faltin gave as explanation for this extraordinary frequency the large vegetable diet (especially potatoes) eaten there. Volvulus of the cecum is only possible in the absence of fixation of the cecum or in the presence of a mesocecum and mesocolon sufficiently mobile to permit torsion. In such cases the cecum usually exhibits a continuation of the mesentery possessed by the terminal ileum. Many cases present in addition, failure of complete rotation of the right colon (Rixford).
>
> Harvey noted unnatural free motion of the cecum and ascending colon in 13.3 per cent of examinations performed upon 105 infants at necropsy. Chalfant stated that unusual mobility of the cecum and ascending colon were present in about 20 per cent of persons of all ages.

The ceca of strictly herbivorous animals are comparatively much larger than is the cecum of man. Herbivores require in the course of their alimentary canal roomy storage compartments for the soaking and fermentation of their bulky food. In ruminants this requirement is fulfilled chiefly by the complex stomach, especially the rumen, and to a lesser extent by the cecum and colon (5).

The cecum in the adult bovine averages about 30 inches in length and five inches in width. Its rounded blind end commonly lies at the right side of the pelvic inlet while anteriorly the cecum is directly continuous with the proximal end of the colon (26). The anterior two-thirds of the cecum attaches to the terminal portion of the ileum by an ileocecal fold of mesentery (14). The ileum joins the large intestine near the ventral border of the last rib, forming the conventional demarcation between the cecum and colon. The greater omentum lies between the organs and the right abdominal wall (26).

Sisson and Grossman (26) describe the angiology of this general area as follows. The anterior, or cranial, mesenteric artery arises from the aorta just behind the celiac artery. It descends between the pancreas and the posterior vena cava and then inclines backward, crossing the colon as the latter emerges from the spiral mass. The first main branch to the intestines, the middle colic artery, passes to the colon as it emerges from its spiral arrangement and runs caudally along the terminal colon. The ileocecocolic artery, the second main branch, ramifies on the right face of the spiral part of the colon. It gives off the ileocecal artery, which divides into the ileal and cecal arteries. The third main branch, the ramus collateralis, runs in the mesentery in a curve along the ventral border of the coils of the colon. After giving off these three main branches, the continuing trunk of the cranial mesenteric pursues a course in the mesentery supplying all but the initial and terminal small intestine. It anastomoses at its distal extremity with the ramus collateralis.

The blood returns via the portal system. The portal tributaries are in general satellites of the corresponding arteries. Blood from the entire intestine, with the exception of part of the duodenum and the rectum, returns via the cranial mesenteric vein to the portal vein.

The few cecal lymph nodes situated along the attached surface of the cecum receive their afferent vessels from the cecum and ileum. Their efferent vessels go to the common intestinal efferent vessel either directly or via the colic or ileal nodes. The common intestinal efferent vessel runs upward and forward on the right side of the spiral mass of the colon, and reaches the ventral face of the posterior vena cava where it unites with the common efferent vessel of the gastric lymph nodes to form the intestinal trunk. The intestinal trunk proceeds between the aorta and vena cava, uniting with the lumbar trunk to form the cisterna chyli.

The neuro-anatomy of the viscera is best reviewed in the human medical texts. The efferent nerves which supply the visceral organs are components of the autonomic nervous system (sympathetic or parasympathetic), while the viscera are also innervated by afferent components of the spinal and cranial nerves (18).

Preganglionic sympathetic fibers arise in the thoracolumbar region of the spinal cord and pass out via the ventral root, white ramus, and sympathetic chain of ganglia and then either via the lesser splanchnic nerve through the celiac ganglion, or via the least splanchnic nerve, to the cranial mesenteric ganglion where the post ganglionic fibers originate. The right vagus supplies preganglionic parasympathetic fibers that pass through the celiac plexus and on to the cranial mesenteric ganglion where they, with postganglionic sympathetic fibers, join the blood vessels to the distal portion of the ileum, the proximal portion of the colon, and the cecum (23). The terminal colon and cranial portion of the rectum are supplied by nerves arising from the caudal mesenteric plexus with the parasympathetic supply coming from the sacral outflow (17). Thus, nerves lying in the mesentery include preganglionic parasympathetic, sympathetic, and afferent components (23).

In general, the nerves accompany the arteries through the mesentery. As they enter the intestinal wall, many of the sympathetic fibers remain associated with the intramural blood vessels. Some bundles of vagus fibers pursue courses through the mesentery not obviously associated with blood vessels (23).

According to Alvarez (2), when all the extrinsic nerves are cut, gastrointestinal peristalsis is more nearly normal than when the vagi alone are removed. When only the vagi are cut, food moves slowly, while cutting only the splanchnics causes rapid movement of food. However, the extrinsic nerves probably have little to do with the rate of rhythmic bowel contractions.

The motility of the cecum and spiral colon has been observed in a laparotomized calf and found to resemble that seen in the sheep. The cecum of ruminants, in comparison to the ceca of other herbivores, is relatively small and muscular. It appears to supply the propulsive force to overcome the resistance of the spiral colon and drive the ingesta onward. Reverse peristaltic waves also occur (5). Dukes and Sampson (6), studying the cecal motility in the sheep, found that at times peristaltic and antiperistaltic waves neutralize each other. They also note that antiperistalsis in the proximal colon and peristalsis in the cecum may occur alternately, allowing a mixing and exchange of ingesta.

Phaneuf (24) studies cecal motility in a sheep by making a closed pouch of the cecum and connecting it to the outside by a Pezzer catheter. Three types of motility were observed on the recording tambour due to pressure changes within the cecum: (1) slow tonus changes, positive and negative, occuring in an otherwise quiet cecum; (2) slow contractions of increasing amplitude and rhythmicity leading to (3) strong rhythmic contractions, with smaller changes of pressure in between. He found cecal motility uninfluenced by rumination, rumen motility, and the feeding of hay; however, arecoline did stimulate motility.

Phaneuf also used his cecal pouch to study the secretory activity of the cecum. He reports that the cecum of a sheep secretes 50 to 75 ml. of juice in 12 hours. The juice is distinctly alkaline and apparently contains no enzymes.

Markowitz (21) has stressed the role of intestinal secretions in intestinal obstructions of carnivores. Since the loss of electrolytes through vomition is not a significant problem in herbivores, other sources of debilitation following obstruction must be sought. Markowitz sites evidence that in the dog when fluid and electrolyte losses are controlled, obstruction of a portion of intestine secreting large quantities of intestinal juices causes severe distension with fatal consequences. Animals not suffering from fluid or electrolyte loss die showing a rather characteristic group of symptoms, commonly referred to as toxemia.

Hermann and Higgins (15) found that the general permeability of the colon wall to particulate graphite was not increased by obstruction alone, but in the combined presence of obstruction and injury to the mucosa, particulate graphite may enter directly into the circulation. In his review Markowitz (21) points out that distension of the intestine or strangulation of the blood supply damage the intestinal wall allowing penetration by the normal intestinal flora. In this way, bacteria or their products, in the presence of distension, are responsible for so-called "toxemia."

When obstruction is established in the lower part of the ileum, dogs survive much longer than with similar obstructions in the duodenum. This is explained by the loss of electrolytes and fluid by vomition in the latter, while giving electrolytes to a case affected with an obstructed ileum fails to lengthen survival appreciably. In these animals, antibiotics will aid in preventing the development of toxemia and thereby extend the survival period, but a patient that is unable to pass feces or flatus per rectum will surely die (21).

Bundschuh reviewed the literature on 110 cases of cecal volvulus in man. Of this total number 23 died without operation, and of the 87 submitted to surgery, 52 cases, or 60 per cent died (33).

Maingot (20) states that in man the clinical picture of cecal volvulus, or torsion, as a whole is that of a low small-gut obstruction with marked distention of the cecum.

The diagnosis is established or confirmed by x-ray examination. He recommends correction by detorsion when the gut is viable, preventing recurrence by performing cecopexy or right-sided cecocolopexy. He favors draining the cecum when markedly distended and feels that resection is indicated when reduction proves impossible or when the involved segment of gut is gangrenous.

Wangensteen (33, p.391) states his preference as follows:

> In cecal volvulus, detorsion and exteriorization of the damaged cecum and cecostomy may be considered the operative procedure of choice in instances in which the bowel is non-viable. Yet, primary resection with immediate closed anastomosis, if the distention is not too forbidding, is probably an even better operation.

In reference to the colon of man, Alexander, Arnett, and Magoun (1) warn of the difficulty in accurately determining how far a colon may be damaged by chronic intestinal stasis and recover. They mention the uselessness of operating upon a colon to rest it by a short circuiting operation when the entire wall has already become damaged beyond repair. Frank (12, p.213) expresses the opinion that "as a general rule volvulus or torsion of the intestine is incurable," when considering the prognosis in farm animals.

When examining the possible methods of repair for torsion of the bovine cecum the work of Phaneuf (24) acquires additional significance. In his studies on the motor and secretory activities of the ovine cecum he separated the entire cecum from the other intestines, making it into a closed pouch. Following this he observed no change in the general health of the sheep. The implications of this observation suggest a review of the function of the ruminant cecum.

The cecum serves as a reservoir in which cellulose and other food constituents can soak and undergo bacterial fermentation. Cellulose is the main constituent of crude fiber of vegetable foods. The important end products of cellulose digestion are a mixture of volatile fatty acids, especially acetic, propionic, and butyric. Cellulose is, however, only partially digestible, even by ruminants, largely because of the lack of time for its complete fermentation as it passes through the alimentary canal. Further, certain intrinsically digestible constituents may pass undigested, owing to their imprisonment in the cellulose covering (5).

Trautmann and Asher (30, 31) studied the digestion of cellulose in the cecum of the goat through a cecal fistula. They concluded that cellulose does not remain in the cecum long enough for fermentation to occur. Neither were they able to demonstrate appreciable digestion of starch or absorption of sugars (30, 32) in the cecum. Other reports, however, dispute the conclusions of these workers.

Barcroft, McAnally, and Phillipson (4), Elsden (7), and Elsden, et al (8), cite the finding of volatile fatty acids in the cecum of sheep as conclusive evidence that bacterial fermentation does occur there, since none are present in the abomasum or small intestine. Still further proof is offered by the finding of these fatty acids in the cecal vein of sheep. They state that the volatile acids absorbed from the rumen together with the reticulum, omasum, and cecum supply a considerable part of the animal's energy requirements and that these are the only parts from which significant absorption occurs.

In a rather comprehensive review of the digestion in ruminants McAnally and Phillipson (22) give the following account.

> The concentration of volatile acids in the cecal ingesta is high compared with that in the contents of the abomasum or small intestine where only traces of the acids are found. . . . Volatile acids have largely disappeared from the ingesta by the time the material reaches the abomasum and they reappear in the large gut where fermentation again becomes active. Since sugars and other readily fermentable dietary constituents will most probably have disappeared in the rumen and small intestine, the source of the volatile acid in the cecum would seem to be cellulose.

McAnally and Phillipson criticize the work of Trautmann and Asher on two counts: First, that the barium meal, passed through a cecal fistula already fixed high in the flank, did not allow normal functioning or response from the cecum and, therefore, remained there only briefly, and second, that the plant material suspended within the cecum had not first been subjected to rumen digestion. They believe that digestion would set in sooner under more normal circumstances.

More recently Gray (13), working with sheep fed a ration of wheat straw and lucerne, has collected data concerning digestion in the large intestine. The data indicate that of the cellulose present in the fodder, 40 to 45 per cent was digested before the food passed into the abomasum, and an additional 15 to 20 per cent was digested in the large intestine. During this second fermentation 7 to 11 per cent disappeared in the cecum and 4 to 9 per cent in the colon. No appreciable loss occurred in the abomasum or small intestine. Since the cellulose was 60 per cent digestible, approximately 70 per cent of the cellulose digested was broken down in the rumen, 17 per cent in the cecum, and 13 per cent in the colon.

Probably the first attempt at analyzing the ration and the products of excretion and secretion of a cow to compute the difference was by Boussingault in 1939 (19). Today the procedures for determining ash, crude protein, ether extract, crude fiber, and nitrogen-free extract of feed or feces are well defined (30), and although other methods of determining digestibility are used, the total collection technique, involving the sampling of the feed and the total feces while the ration and intake are constant, has changed little since used by Henneberg and Stohmann about 1860 (9).

Staples and Dinusson (27) compared the relative accuracy between seven day and ten day collection periods in digestion trials and concluded that the degree of accuracy secured by the seven day collection period may be sufficient for many studies. Schneider and Ellenberger (25) insist that average figures, especially average coefficients of digestibility, are to be questioned when applied to individual cases in any kind of exact experimental work. They also say that the probable errors become smaller as the digestion coefficients become larger, because the more digestible nutrients are influenced less by the factor of irregularity of excretion, and that the longer the trial or the larger the sample the more accurate will be the data.

Since much of the work to date indicates that the cecum is primarily concerned with the digestion of cellulose the relationship of cellulose to the crude fiber analysis is important. McAnally and Phillipson (22) state that

> in the analysis procedure for the separation of crude fiber some cellulose is probably broken down and a small amount of other substance remains behind. However, the crude fiber fraction in digestibility trials may be taken to represent cellulose with a reasonable degree of accuracy.

Additional material of interest in this study of the bovine cecum pertains to the relative size of the intestines. Swett, Graves, and Miller (29) made numerous measurements of two cows. Respective measurements for a 927 pound Jersey cow and a 1585 pound Aberdeen Angus cow were length of the small intestine, 132.5 feet and 140.22 feet (or 17.24 and 9.5 feet per 100 pounds of empty body weight), and length of the large intestine, 34 feet and 41.49 feet (or 4.42 and

2.81 feet per 100 pounds of empty body weight). In another study Swett and Graves (28) examined 311 dairy cows and found that their total intestinal tract averaged 139.46 feet in length. The small intestine of the living calf is about seven times the body length, or about one-third the post mortem length, according to Espe and Cannon (10). They found that the large intestine does not show as great a difference in length between the living and the post mortem stages as does the small intestine, and further that variations in the ratio between body length and the length of the intestine depend more upon individuality than upon the age of the calf.

SURGICAL ANATOMY

Introduction

Knowledge of the structural relationships in an area to undergo surgical repair is a necessity so obvious as to require no special comment. Present literature can supply much of the desired information; however, written material can only serve as a supplement to personal contact with the tissue involved, or later, as a review.

In this investigation the abdominal structures were studied in general and the cecum in particular. Efforts were directed first toward the normal and then to the altered relationships in a clinical torsion. Finally, the task of producing a torsion of the cecum was attempted.

Experimental Procedure

The initial procedure included embalming a normal four month old Guernsey calf. Using pentobarbital sodium for deep anesthesia, the left common carotid artery was isolated and ligated and the artery proximal to the ligature cannulated. When bleeding was complete and the calf suspended in a standing position, embalming fluid consisting of five per cent phenol and five per cent formalin was forced through the carotid artery by gravity flow. After several days, liquid red latex was pumped through the carotid to fill the arterial system as an aid to dissection.

Dissection started with exposing the abdominal viscera through the right abdominal wall. From a point just anterior and lateral to the tuber coxae the incision through the skin and musculature, parallel to the midline, was extended anteriorly to the tenth intercostal space. The last three ribs were transected and a flap formed by directing an incision ventrally within the tenth intercostal space and another ventrally from the region of the tuber coxae to the flank. After freeing a portion of the diaphragm, lowering the abdominal flap allowed adequate exposure of the area.

With the calf remaining in a standing position, photographs were taken and notations made of the normal position of the abdominal organs with emphasis on the cecum. To continue the dissection in more detail the intestinal tract was removed by severing its dorsal attachments and transecting the rectum and proximal duodenum. The distribution of blood vessels was of particular interest and original detailed drawings were made of the vessels directly associated with the cecum. Further depth was given this work by inspecting numerous cattle at post mortem and examining the viscera of embalmed cattle of all ages used in the anatomy laboratory.

The second stage of the procedure followed very closely the first, except that it involved a clinical case of cecal torsion. This three month old Holstein calf was referred to the clinic with a history of inappetence and colic for the previous four days. Extensive examination of this size animal per rectum was impossible. After verification of the tentative diagnosis by laparotomy, the calf was purchased and embalmed immediately. The procedure for embalming, injecting latex, and dissection was similar to that used for the normal calf. The findings on this case and other cases of clinical torsion were compared.

The final phase of anatomical comparison of cecal torsion and the normal included attempts to experimentally produce this condition. Four normal dairy steers were used in eight attempts. The initial trials on two yearlings were approached with the idea of twisting the cecum through a laparotomy incision into the position of a clinical torsion. The approach was tried through both the right and left paralumbar fossae. A total of four trials on one steer were spaced at intervals varying from two weeks to two months. Further attempts on two, three month old calves were altered by first constricting the lumen of the colon just distal to the ileocecal junction. Number 00, medium chromic catgut with atraumatic needle attached was used for one trial, burying the suture into the submucosa and circling the colon to form a purse-string suture. In this case a lumen of one-half inch was left. One month later this same calf was re-operated and the procedure repeated with one variation. A synthetic, nonabsorbable suture material (0.30 mm Vetafil - Bengen & Co.) instead of catgut formed the purse-string. The other calf was similarly handled but the nonabsorbable suture was placed in a spiral around the colon, constricting it almost completely for a distance of three inches. In each instance, after constricting the colon, the cecum was twisted as much as possible before closing the laparotomy incision.

During these operations the two yearling steers were kept standing. Two per cent procaine hydrochloride solution and the paravertebral lumbar nerve block technique supplied the necessary anesthesia. For the younger calves an ultra-short acting barbituate (Surital - Parke-Davis) anesthetized them for the right paralumbar incisions. In all cases a synthetic suture material (0.30 mm and 0.60 mm Vetafil) was used to close the incisions. The animals were clipped and thoroughly scrubbed (Liquid Germicidal Detergent - Park-Davis) before operating, and aseptic technique employed.

Results and Discussion

Normal bovine. An appreciation of the relationships in the normal animal can be gained from Plates I through VI. Plate I shows the normal calf embalmed. A close-up of the right paralumbar fossa in II shows the cecum exposed. It has, however, been lowered from its normal position at the level of the pubis and displaced laterally toward the viewer. This allows a view of more related organs.

The approach through the right side of the animal reveals the greater omentum just inside the peritoneal cavity. The greater omentum separates all the intestinal mass, except the duodenum, from contact with the parietal peritoneum in the region of the right flank and paralumbar fossa. In its normal position then, the greater omentum, which appears as a two-layered continuation of the mesoduodenum, obstructs the view of the cecum. The free, caudal border of the greater omentum lies almost directly ventral to the tuber coxae. This free border may easily be grasped and displaced dorso-cranially, as in Plate II, exposing the intestinal mass.

The cecum lies horizontally and longitudinally in the standing animal, just medial to the greater omentum. It rests on the right, dorsal aspect of the mass of spiral colon which in turn overlies coils of small intestine. The relative position of the cecum, of course, depends upon the amount of ingesta present, but the blind end terminates normally just cranial to the pelvic inlet and slightly ventral to the pubis. The cranial end communicates directly with the colon in the region of the last rib.

The colon, after continuing cranially, turns dorsally just behind the liver. Continuing caudally from this turn, it lies dorsal to the cecum and medial to the duodenum. Ventral to the tuber coxae it again reverses directions, lying medial to its more proximal segment, until again behind the liver it takes a caudo-ventral direction, passing into the long double coils of spiral colon.

The ileum proceeds dorsally around the caudal end of the spiral colon. Straightening from the curls and kinks characteristic of that small intestine attached to the free border of the mesentery, the terminal ileum points cranially. It lies dorso-lateral to the spiral colon and ventro-medial to the cecum and joins the large intestine in the region of the last rib. This union serves to differentiate cecum from colon. The ileum approaches the cecum obliquely along its ventro-medial aspect but at its attachment passes beneath the large intestine, making its entry through the ventral surface. A comparison of Plate V and Plate VI will best illustrate this union.

The cecum has one mesenteric attachment. This same sheet secures the terminal ileum and attaches to the medial, or ventro-medial,border of the cecum, as shown in Plate III and Plate V. The proportion of cecum fixed by the ileocecal fold of mesentery varies from essentially all to less than two-thirds of its total length. The remainder of the cecum has no mesenteric attachment, giving great freedom of movement to the blind end. The ileocecal fold of mesentery is continuous with the mesentery engulfing the spiral colon and the mesentery to the rest of the ileum and jejunum. Therefore, the ileum continues from its rather free position on the border of mesentery dorso-cranially along the ventral surface of the ileocecal fold of mesentery which is fixed to the spiral colon ventro-medially and the initial colon crainally. Plate IV shows the ventral surface of the cecum and ileum with the mesentery to the small intestine spread over the spiral colon.

The degree of mobility of the cecum and terminal ileum undoubtedly varies considerably with the individual animal. Not only will the extent of the attachment cause variation, but also the width and flexibility of the ileocecal mesenteric fold will vary. The coils of spiral colon, held firmly to each other by areolar tissue and quite firmly supported by mesentery, however, do offer a stabilizing force. The initial portion of colon also has firm attachments. At the turn dorsally, just cranial to the ileocecal junction, the colon is so firmly fixed by its attachments behind the liver that it is, for practical purposes, immovable. Its continuation caudally and then cranially is snugly held by mesentery. A further stabilizing force, also subject to variability, is the bridging of the initial dorsal turn of the colon by areolar tissue and visceral peritoneum. It does not, however, ordinarily continue caudally sufficiently to support the cecum directly.

The cecum receives its blood supply via the cranial mesenteric artery. Plate III and Plate IV show the arterial stump where it was cut from the aorta. Plate V and Plate VI are original drawings made from the embalmed Guernsey calf. Neither the small cranial mesenteric branches to the pancreas and duodenum nor the middle colic artery supplying the distal colon are illustrated in these plates.

Plate IV and VI show the pathways of the larger arteries. The intestinal continuation of the cranial mesenteric artery supplies the jejunum primarily. It anastomoses with the ramus collateralis, which has skirted the lateral side of the spiral colon, to continue along the ileum. The ileocecocolic artery gives off branches to the spiral colon before continuing as the ileocecal artery. Further branching to supply the initial colon was a constant finding in all animals examined.

The pattern of anastomosing and branching of the ileocecocolic artery as it approaches the ileocecal junction could cause speculation on the exact division between cecum and colon. The similarity in the distribution of blood vessels for a short distance on the colon side of the ileocecal junction to those supplying the cecum could be construed as evidence that the cecum actually continues somewhat beyond the ileocecal junction. These vessels may be seen for comparison from a dorsal view in Plate V; however, the exact location of the cecocolic junction seems more academic than practical.

The definitive arterial supply to the cecum and ileum, shown in dorsal view in Plates III and V, presents an interesting network. Rather than a simple splitting of the ileocecal artery into single ileal and cecal arteries, the terminal ileum receives a dual supply which anastomoses with the cecal artery. This network, although subject to some variation, was consistent in essence and surprisingly similar in detail in all animals examined.

The ileocecal artery, after the initial branching in the region of the ileocecal junction continues to the cecum as the cecal artery. Very small arteries continue along both sides of the ileum, supplying this terminal portion. These anastomose with the arterial branches following cranially along the terminal ileum with blood from the ramus collateralis and cecal artery. The ileal artery is the direct continuation of the continuing trunk of the cranial mesenteric artery and the ramus collateralis. The artery on the cecal side of the ileum is labeled the accessory ileal artery in Plates III and V. It has a single anastomosis with the ileal continuation of the ramus collateralis near the caudal border of the ileocecal fold of mesentery and crosses dorsal to the ileum. The cecal artery also anastomoses with both the ileal and accessory ileal at this point and anastomoses with the accessory ileal at about three other points spaced along the ileocecal fold.

It appears that in the normal bovine the terminal ileum receives its greatest source of blood via the cecal and accessory ileal arteries. Although partially hidden in Plate V, the accessory ileal artery maintains a larger size than the ileal near the ileocecal junction and receives some relatively large anastomosing branches from the cecal artery. The ileal artery, on the other hand, is so small just caudal to the ileocecal junction that its supply would seem to come more from the ramus collateralis than the ileocecal artery.

The venous return from the cecum and ileum parallels the anastomosing network of arteries. The larger trunks join to form veins with names corresponding to the arteries that they accompany. The blood returns to the liver via the cranial mesenteric and portal veins.

Although no special effort was made to trace the lymphatic drainage or nervous innervation, the cecal lymph nodes are labeled where they appear in Plates III and IV. The nerves were observed to follow the pathways of the blood vessels rather closely with an occasional small branch running independently across the mesentery.

Clinical torsion. The second stage of anatomical observations deals with the findings in an embalmed clinical case, as illustrated in Plates VII through X. Plate VII shows the initial exposure of the affected area in relationship to the entire animal. Plate VIII is a close-up of this area, taken previous to manipulating the intestines. Note that the greatly distended cecum and colon lie in direct contact with the right abdominal wall, covering almost completely the area between the liver and the tuber coxae. A portion of distended small intestine (probably ileum) can be seen just medial to the large intestine.

Careful observation will reveal that the cecum is rotated clockwise in this view with the blind end pointing caudally in the lower right flank.

In Plate IX the blind end of the cecum has been rotated nearly 360 degrees counterclockwise from the position found in Plate VIII. This straightens the ileocecal fold of mesentery and presents a greatly distended curve of cecum and initial colon. The remaining curve, for the most part, indicates an increase in length over the normal for this animal. The cecal surface, directed laterally in both Plate VIII and Plate IX, would face dorso-medially in the normal animal. In Plate IX the initial colon is seen passing medial to the caudal fold of omentum where it assumes its normal size and position.

The ventral surface and ileocecal junction in Plate X is shown by elevating the cecum and colon from its position in Plate IX. The ileocecal junction had assumed a medial position in the cecal torsion. Note that the terminal ileum at the ileocecal junction is essentially normal in size, while that just proximal to it is markedly distended.

Having an embalmed clinical case greatly simplifies accurately describing the relative positioning of structures involved in the torsion of a bovine cecum. Plates VII through X should do much to clarify this description. In this animal the caudal border of omentum and the iliac flexure of the duodenum were forced cranially and medially by the expanded cecum and initial colon. The point of greatest obstruction occurred cranial to the ileocecal junction where the initial portion of colon turned medial to the omentum. This constriction was caudal to the normal dorsal turn near the liver where the initial colon has its firm attachments. The fold of mesentery which supports the terminal ileum, cecum, and initial colon was rotated, twisting, and thereby diminishing, its longitudinal dimension. As viewed facing the right side of the animal, the mesenteric fold had received a clockwise twist sufficient to rotate the blind end of the cecum nearly 360 degrees. Of course, the side of the cecum and colon attached by mesentery remained central and somewhat medial, allowing the opposite side to gain the greatest linear expansion.

The terminal ileum, lying along the ileocecal fold of mesentery, necessarily passed through the twist. It received its greatest pressure along a short portion just proximal to the ileocecal junction. Possibly because of the greater relative thickness of its walls, the naturally smaller lumen, and greater mobility of its attachments, the ileum was not so completely obstructed as the colon. The greater mobility of the ileal attachments refers to the fact that the terminal ileum ran along the twist rather than perpendicular to it as did the firmly fixed cranial portion of initial colon.

That the colon is not completely constricted either, at least in the early stages, would be indicated by the more gradual onset of symptoms than in certain other intestinal obstructions (for example, intussusception). It would seem logical from the progressively increasing tension along the small intestine and the marked distension of the cecum and initial colon that, as the cecum distends, it exerts greater pressure on the terminal ileum, causing greater distension of the small intestine. The greater the distension of the cecum and initial colon, also, the more complete will be the obstruction of the colon. This will result in more severe symptoms. Further, as the pressure increases within the intestinal tract, the pressure exerted upon the associated blood vessels increases.

By correlating the findings in cases of cecal torsion operated on in the clinic with those apparent in the embalmed specimen, interesting points arise. The rather constant occurrence of increased abdominal fluid, as in other types of torsion, or volvulus, could indicate impaired circulation. The thinner walled, low pressure veins and lymph ducts are more susceptible to occlusion by external pressure than the arteries. This results in edema and may account for the increased abdominal fluid. In more severe cases, areas of beginning necrosis in the cecal wall were the apparent result of an inadequate blood supply.

As determined by the necessary manipulation to relieve the torsion, the cecum and its mesentery may become twisted either clockwise or counterclockwise, when viewing the animal's right side. In general, other findings were the same in those cases known to be twisted counterclockwise as clockwise, however, most of these cases, like the embalmed heifer, rotated clockwise.

One structure which does occasionally vary distinctly in location is the omentum. Early in December 1956, the seventh case of bovine cecal torsion was presented at the clinic with a history of diarrhea for two days. She had refused feed and manifested abdominal pain the previous evening. The distended cecum was palpable per rectum. A laparotomy revealed the omentum in its normal position, while the torsion was otherwise similar to those previously described. Likewise, the recent report from Oklahoma (16) describes the greater omentum in normal position in one case, but in the other the omental attachment to the duodenum was not found.

Experimental torsion. With some understanding of the structures involved in a torsion of the bovine cecum the next step logically follows: to produce the torsion experimentally.

Relocation of the normal cecum in the position of a torsion was attempted first. However, the five laparotomies performed on two yearling steers through either the left or right paralumbar fossa failed to produce a clinical torsion. The ileocecal fold of mesentery was stretched and twisted as much as possible in each attempt, and the repeated operations on one steer increased the mobility of this mesentery. Adhesions resulting from the trauma of manipulation finally discouraged further attempts with this animal. No sutures were used to fix the twisted cecum, and on repeat operations the cecum lay in essentially the normal position. Following each laparotomy these steers recovered without interruption.

The possibility that alteration in the normal patterns of cecal motility could result in a torsion was not explored further. But knowing that obstruction of the initial colon does occur in a torsion of the bovine cecum, the idea that a cecal torsion could follow partial obstruction of the colon seems plausible. Two, three month old calves were used in this pursuit, with three attempts.

The laparotomy with artificially produced colonic obstruction caused decreased feed intake and some abdominal distress. Symptoms were most apparent about the third day following surgery, but by the end of one week fecal passage had returned to normal and recovery followed. When the one calf was re-operated a month following the initial constriction, only scarring remained. Undoubtably, nearly normal passage was established by the stretching or migrating of the constricting sutures.

Obstruction of the initial colon certainly could be achieved by transecting the colon just distal to the ileocecal junction and closing both ends. This would ensure

complete obstruction with eventual death, but the symptoms of clinical torsion do not indicate complete obstruction early in its course. No unusual, consistent findings were recognized in the clinical cases which would reveal special predisposing factors. One would strongly suspect, however, that anatomical variations in the size and attachments of the cecum could alter individual susceptibility.

METHOD OF REPAIR

Introduction

The 100 per cent recovery rate of the first five bovines with cecal torsions received at the Michigan State Clinic offers no opportunity for improvement of the records. However, the physical appearance of the more severely affected ceca as they were replaced seemed less desirable.

Possibilities for altering the original procedure of laparotomy, cecotomy, when necessary, and detorsion would include the addition of cecopexy. This should eliminate any chance of recurrence but certain complications merit mentioning. Most obvious is the normal position of the omentum which separates the cecum from the abdominal wall. Attaching the cecum to the wall at several points along its course would prevent the omentum from returning to this position. Attaching the cecum to other supporting structures (for example, the mesentery supporting the spiral colon) would be mechanically difficult. The increased size of the cecum, even after draining its contents, complicates returning it to exactly its proper place. And most important, cecopexy would not improve the physical condition of severely affected ceca.

Since removal of the cecum could eliminate all problems of an atonic, devitalized cecum, as well as the possible recurrence of a torsion, this approach was considered most worthy of trial.

Experimental Procedure

A total of ten cecectomies were performed on normal steers or calves varying in age from two weeks to two years. The surgical procedure was altered as problems arose, in an attempt to find the best method. The resulting procedure was then used on a clinical case.

The first cecectomy was performed on a two week old Jersey calf. An ultra-short acting barbituate (Surital - Parke-Davis) provided general anesthesia. The right paralumbar fossa was clipped and scrubbed (Liquid Germicidal Detergent - Parke-Davis) and aseptic technique employed. With the calf on its left side a dorso-ventral incision large enough to admit a hand was made midway between the last rib and tuber coxae. The cecum was located, brought to the outside, and ligatures of size A Nylon placed with a suturator along the ileocecal fold of mesentery on either side of a line halfway between the cecum and ileum. By cutting between these two nearly continuous rows of ligatures the cecum was freed with little regard for the position of blood vessels. A pair of Carmalt forceps were applied side by side as near as possible to the ileocecal junction. With the tips of the forceps at the mesenteric border of the cecum and the jaws slightly nearer the junction with the colon, a good blood supply was assured the remaining part and virtually all the cecum caudal to the ileocecal junction removed. The cranial stump was closed with size 00, medium chronic catgut and atraumatic needle, using the Parker-Kerr method of oversewing a clamp. The peritoneum and muscles of the abdominal wall were closed with a single, simple continuous, nonabsorbable suture (0.40 mm Vetafil-Bengen & Co.) and the skin brought in apposition with simple interrupted sutures of the same material.

Cecectomies were performed on two more young calves in essentially the same manner except that more certainty was displayed in ligating blood vessels. With a better understanding of the blood supply to the cecum, the anastomosing branches between the cecal and accessory ileal arteries and veins were readily uncovered and double ligated with size A nylon before cutting them. The three cecectomized calves were utilized in another portion of this investigation.

All other cecectomies were performed with the animal standing. A solution of two per cent procaine hydrochloride and the paravertebral lumbar nerve block technique provided anesthesia for the right paralumbar approach in these cases. For the first attempt with a standing animal, a yearling Hereford steer, the same general techniques were followed as used on the calves. With a similarly placed incision large enough to easily admit an arm, the omentum reflected cranially, and the cecum held to the outside, the vessels were ligated, the mesenteric attachment cut, forceps applied, the cecum removed, the stump inverted, and laparotomy incision closed. Size A nylon delivered from a suturator was used for ligation. For the intestinal closure, size 00, medium chromic, intestinal catgut with atraumatic needle attached was again used, but two, six and a half inch Carmalt forceps, one directed from either side were necessary to completely traverse the cecum. With this modification, the stump was closed by the Parker-Kerr method. The abdominal suture pattern was the same as previously used but with larger material (0.60 mm Vetafil).

Four Holstein steers under study in another part of this investigation were cecectomized between ten and twelve months of age. The procedure was varied to allow for improvements, and two, two year old Jersey steers provided for further testing. The variations were as follows: moving the laparotomy incision within the right paralumbar fossa; injecting a two per cent solution of lidocaine hydrochloride (Zylocaine Hydrochloride - Astra) around each nerve in the ileocecal fold of mesentery before ligating or cutting blood vessels or nerves; using size 00, medium chromic catgut and 0.30 mm Vetafil to ligate the cecal artery and vein; substituting nine inch Doyen intestinal clamps with longitudinal serrations for the six and a half or eight inch Carmalt forceps, or using a 13 inch Payr clamp undersewing as well as oversewing the clamp when closing the intestinal stump; using a 0.30 mm Vetafil and either a straight or a curved, taper point needle to close the intestinal stump; and closing the skin incision with a continuous, buried suture of 0.30 mm Vetafil.

During the last experimental cecectomy on a Jersey steer a series of pictures were taken to illustrate the procedure. Finally, this method of repair for torsion of the bovine cecum was used December 4, 1956, on the seventh case received at the Michigan State Clinic.

Results and Discussion

With no specific surgical procedure already available for cecectomizing a bovine, a satisfactory procedure was evolved by the trial and evaluation of various techniques. Although all ten experimental cecectomies were successful to the extent that the ceca were removed without any fatalities, much valuable information and experience was gleaned from each.

The removal of the first cecum revealed the need for thorough knowledge of the blood vessel distribution to this organ. For an efficient, practical, surgical procedure, the surgeon must locate and ligate these fat-covered vessels with a minimum of searching. Excessive probing through the area is not only time consuming in itself, but capillary hemorrhage from the disturbed fat will further obscure the view. The anastomosing branches of the cecal arteries and veins were located and ligated where they traverse the ileocecal fold of mesentery (Plate V) and the cecal artery and vein ligated just caudal to their passing over the terminal ileum. Transecting these arteries, veins, and nerves, supplying in part the terminal ileum, causes this portion of intestine to shrink and lose color, at least for the duration of the operation.

Transfering from a calf under general anesthesia to the standing animal created more problems than originally anticipated. Of course, in the young calf the liver fills a larger percentage of the abdominal cavity than in the adult and on the right side extends well behind the border of the ribs. For this reason, the laparotomy incision was placed in the middle of the right paralumbar fossa. When the incision is similarly placed in the older animal, great difficulty is encountered in exposing the entire cecum due to the firm attachments of the initial colon. The last rib defines the cranial border of the paralumbar fossa, and on the right side, the kidney modifies the dorsal extent of an incision. Perirenal fat causes a medial divergence of the peritoneum. Locating the incision ventral to this fat depot simplifies closure and adequately exposes the cecum.

The change from general anesthesia to local anesthesia for the standing animal had an accompanying complication. The paravertebral lumbar nerve block adequately anesthetizes the right paralumbar fossa but does not anesthetize the viscera. Ordinarily the intestines can be handled without anesthesia, however, when large nerves are ligated, cut, or otherwise directly stimulated, as in removing the cecum, colicky symptoms occur immediately. The animal treads from side to side and, as restlessness progresses, will invariably attempt to lie down. After the first standing operation, these exasperating developments were prevented by injecting two per cent lidocaine hydrochloride (Xylocaine - Astra) around the blood vessels before ligating them and directly on nerves found free in the ileocecal fold of mesentery.

Further changes in procedure logically resulted from the increased size of the structures. A suturator equipped with size eleven needle and size A nylon still satisfactorily ligated all vessels except the large main trunks of the cecal artery and vein. For more security either size 00 medium chromic catgut or 0.30 mm Vetafil was used here.

The size of the cecum itself required an instrument larger than the six and a half inch Carmalt forceps used on the calves. The jaws have two inches of clamping surface, and eight inch Carmalt forceps have only two and a half inches of surface. By putting two Carmalt forceps end to end the necessary distance was bridged but the danger of leakage was greater. Nine inch, longitudinally serrated, Doyen intestinal clamps will extend across most ceca and would seem a logical choice; however, considerable tension is required to expose the ileocecal junction, and the danger of this limber clamp slipping off the cut stump caused its immediate abandonment. Instead, a 13 inch Payr clamp served to hold the stump during closure.

Along with the various clamps, undersewing, as well as oversewing, was tried on these larger ceca. A continuous suture directed back and forth through the apposed intestinal walls gives added security against hemorrhage and leakage from the stump. This suture was placed close to the colon side of the clamp before cutting off the cecum. After removal of the cecum the clamp was then oversewn using the Parker-Kerr method. As a substitute for catgut, 0.30 mm Vetafil was used for closing the stump. This very strong, non-capillary, nonabsorbable material does not have an attached needle, but taper point, straight (for undersewing) and half circle (for oversewing) needles were threaded.

Even though the closure of the laparotomy incision has less direct affect on the success of the operation, for variation a continuous buried suture was tried in place of the simple interrupted skin sutures. Using 0.30 mm instead of the 0.60 mm Vetafil and a number eight, half circle, cutting edge needle, the usual pattern of the subcuticular suture was altered for ease in penetrating the tough bovine skin. Starting at the dorsal commissure of the incision, the needle is directed from the subcutaneous side into the dermis, splitting the thickness of the cut skin edge. The needle is then inserted at a similar depth into the cut edge of the other side and directed out on the subcutaneous side. This imitates the regular subcuticular suture, and the knot is similarly buried in the subcutaneous tissue.

From this start the needle is directed as before, leaving the subcutaneous side, coming out of the cut edge, into the other cut edge, and out in the subcutaneous area. This is continued to the ventral commissure where the final knot is buried in the usual manner. The needle, traveling in this pathway, penetrates the skin layers with much greater ease than when directed into the cut edge and out, in a plane parallel to the skin surface. This, plus the superior strength of the synthetic suture material, makes it both a pratical and efficient method of closure.

To combine the variations judged best in these trials, Plates XI through XVI illustrate the evolved procedure for removal of the bovine cecum. Plate XI--A shows the initial incision. Note that the incision lies well below the right kidney near the cranial edge of the paralumbar fossa. The paravertebral lumbar nerve block gives adequate anesthesia for the laparotomy incision, and after completion of the incision, the omentum is reflected cranially and the cecum exposed (Plate XI--B). The injection of the local anesthetic (two per cent Xylocaine) around the blood vessels and nerves, as in Plate XII--A, is done with a sterile syringe and needle before ligating or cutting these structures. The ligation of all vessels except the main cecal trunks is performed with the aid of a suturator using size A nylon (Plate XII--B). The anastomosing branches of the cecal artery and vein are uncovered and ligated twice, about midway between the cecum and terminal ileum, and the ileocecal fold of mesentery cut on a line between the ligatures. The larger cecal artery and vein are ligated just caudal to the ileocecal junction with 0.30 mm Vetafil and then cut.

With the mesenteric attachment of the cecum freed, a 13 inch Payr clamp is applied just caudal to the ileocecal junction (Plate XIII--A). The tips of the clamp are placed nearest the terminal ileum, keeping the angle of the jaws cranial to assure a good blood supply to the remaining intestine. As illustrated in Plate XIII--B, the clamp is undersewn, using 0.30 mm Vetafil and a straight, taper point needle, before the cecum is removed. To prevent leakage at the time of removal a nine inch Doyen intestinal clamp can be placed close to the Payr clamp. A scapel is used to trim the cecum from the Payr clamp, and then the clamp is oversewn with 0.30 mm Vetafil and a number two, half circle, taper point needle, as in Plate XIV--A. By releasing the clamp gently and holding the free ends of suture used to oversew the clamp, the clamp is slipped out and the stump inverted. To complete the procedure known as the Parker-Kerr method of closing an intestinal stump, one end of the suture may be continued back along the closure with a continuous Lembert stitch and tied to the original end. The end is completely closed in Plate XIV--B ready to go back into the abdominal cavity.

When the intestinal stump at the ileocecal junction falls back into the abdominal cavity, the omentum will again obscure its view (Plate XV--A), and the operation is complete except for closing the abdominal incision. A simple continuous suture of 0.60 mm Vetafil placed well back from the cut edges closes the peritoneum and muscle layers. This suture, shown in Plate XV--B, should be pulled very tightly before tying. The buried skin suture of 0.30 mm Vetafil, being placed in Plate XVI--A, gives good skin closure and does not require removal. The closed incision is shown in Plate XVI--B the day following surgery.

An alternate closure for the skin is the simple interrupted sutures of 0.60 mm Vetafil placed well back from the skin edges. These exposed sutures have caused no abscessation when left for over a year, but normally they are removed after eight to ten days.

When a three year old cow with symptoms of abdominal discomfort following two days of diarrhea was diagnosed on rectal examination as having a torsion of the cecum, the method of repair just described was used. The procedure was followed without difficulty, and uneventful recovery resulted. Although off feed and down on milk when brought to the clinic, she began eating soon after surgery, milk production increased, and six days after the cecectomy she returned home.

THE CECECTOMIZED BOVINE

Introduction

A new corrective procedure requires evaluation, not only of the techniques involved, but also of the end product. Ideally the result should eliminate the undesirable without impairing the desirable. Engaging in this line of reasoning, certain factors were examined to evaluate the normalcy of the cecectomized bovine.

Since cellulose digestion is believed a primary function of the cecum, the ability of the cecectomized bovine to digest cellulose should be given primary consideration. The possibility that the cecum supplies a propulsive force to push the ingesta through the spiral colon rates thoughtful observation and comment, while gross compensations by other organs to perform the functions of the cecum receive conservative comparisons. To these more specific considerations are supplemented observations of operative recovery, post mortem examination of experimental cases, and the response of a clinical case.

Experimental Procedure

To estimate the effect of removing the cecum on cellulose digestion, four similar Holstein-Friesian steers were purchased. After a variable period, exceeding one month, for observation and clinical examination, these normal steers were singly put on digestion trials. With a normal established, the ceca were removed and a second digestion trial started in two weeks. A third series of trials followed the cecectomies by a period varying from three and a half to five months. The same procedures were followed for all trials.

Using seven day preliminary periods and seven day experimental periods, the steers were fed only alfalfa hay from the same lot previous to and during the trials. The daily feedings were kept as near constant as possible for a given trial and hay samples were saved for grinding into a composite at the end of each experimental period. One per cent samples of the daily aliquot of feces were refrigerated as composited, and concentrated hydrochloric acid totaling 15 milliliters was added to each. These samples of hay and feces were analyzed, according to the procedures described by the Association of Official Agricultural Chemists (3) for ash, crude protein, ether extract, crude fiber, and nitrogen-free extract. Water intake was recorded automatically with a meter; and steer weights were recorded at the beginning and end of the experimental period. The steers remained on the digestion trial stand throughout the trials except for a trip to the scales at the start of the experimental period.

All of the steers and calves cecectomized for the different portions of this study were carefully observed

following surgery, but no medication was administered after the day of surgery. The three young dairy calves used for performing the initial cecectomies were kept until between five and six months had transpired after the operations. They were kept with three similar, normal, dairy calves until between six and six and a half months of age. At this time they were euthanized with electricity and examined.

After the general visual comparison between these normal and cecectomized calves, the entire intestinal tract was immediately stripped from its mesentery. The intestines were kept intact with the small and the large intestine separated. A hose inserted into the end of each length of intestines connected it to a metal cylinder. Water running into the cylinder washed the ingesta from the intestines. The open end of the intestines was then tied and the cylinder allowed to fill to a constant height above the floor. This ensured having the same pressure in each length of intestine. When the water reached the given height, the water within the intestine was held there and the intestine gathered into pails. By draining the intestine and saving all its contained water, a volume figure at a standard water pressure was recorded.

The viscera of the four steers used for the digestion trials were also visually examined at the time of slaughter, between five and eight months after surgery. The size, condition, and appearance of the terminal ileum and initial colon were carefully noted and further examinations made for adhesions or other complications caused by surgery.

Periodic inquiry about the performance of the clinical case operated in December 1956, completed the evaluation of the cecectomized bovine.

Results and Discussion

The dates of the digestion trials and cecectomies for the four Holstein-Friesian steers are listed in Table 1. The steers are designated by their ear tag numbers, and steer number 4947 is shown on the digestion trial stand in Plate XVII. Table 2 contains the total intake of hay and water, total excretion of feces, and the weight gain or loss during each seven day experimental period. Two of the steers, 4949 and 4948, consumed less hay in their second trials than in their first and failed to maintain their weight. This could indicate retarded recovery from surgery; nevertheless, they appeared healthy in every other way.

Tables 3 and 4 list the chemical composition of the hay and feces respectively for each of the trials. Although the hay was all from the same lot, some slight variation in composition exists. A comparison of the hay samples on a dry basis is available in Table 5 along with the coefficients of digestibility for dry matter, protein, crude fiber, and ether extract.

Since this study is concerned with whether or not these steers digest their ration as well without a cecum as with one, the percentage of the nutrient digested, or the digestion coefficient, is a useful point of reference. With cellulose recognized as the principle constituent digested in the cecum, the coefficients of digestibility of crude fiber should show the greatest variation between the first trials and the second and third trials. However, an analysis of variance for the four steers of the digestion coefficient of crude fiber, and each of the other digestion coefficients, showed no significant variation between the three trials. Therefore, these data indicate that these steers digested their ration of alfalfa hay as well without their ceca as with them.

That the cecum serves as a propulsive force to start the ingesta through the spiral colon can not be entirely disputed on the basis of this study, but observations of cecectomized animals immediately following surgery fail to emphasize it as a necessary force. Rumination, peristalsis, and defecation proceeded with little or no interruption. Nothing simulating an adjustment period was discernible.

Conceivably some gross compensation by the large or even the small intestine could replace the cecum in function. Because one would expect this to develop in a young, growing calf, if at all, and because three such calves were cecectomized early in the investigation, the capacity of the large and small intestines of these three calves were compared with the capacity of three similar, normal calves grown in the same environment. The volumes in liters are listed in Table 6.

Although this comparison is limited in scope as well as numbers, these figures indicate no consistent enlargement of the intestines of the cecectomized calf over the normal. Plate XVIII shows cecectomized calf number 4906 just before euthanasia, while Plate XIX shows the viscera of this same calf. The only difference observable between the intestines of these two groups was either the presence or absence of the cecum. In this volume study the standard water pressure was sufficient to distend the entire length of intestine equally, when the maximum pressure was reached gradually. Plate XX shows a length of small intestine under pressure.

A post mortem check of all cecectomized animals failed to reveal any post-surgical adhesions. The laparotomy incisions had healed smoothly. No remnants of a cecum caudal to the ileum persisted (Plate XIX). In fact, the ileum seemed to enter directly into the end of the initial colon rather than at an angle. Even though severing the nerves and vessels to the terminal ileum caused it to shrink and lose color during surgery, several months afterward this portion of ileum appeared like the rest. Remains of the mesentery formerly attaching the cecum to the terminal ileum had disappeared, and lesions indicating that a cecum was ever present were practically non-existent.

The proof of any new surgical procedure can only follow its application to clinical cases; therefore, the progress of the three year old Holstein, from which the cecum was removed as a means of eliminating the cecal torsion, was followed with anticipation and great expectation. This cow had calved about five or six weeks before the attack. Milk production dropped to nearly nothing during two days of distress, but she returned home six days after surgery and, according to the owner, within another week had regained her previous production level. She was bred to calve at the regular yearly interval, and eight months following surgery she was normal in every way. At this time the owner enthusiastically reported that her milk production for the lactation had, except for the period of illness, paralleled and equalled that of her half sister of the same age. These two cows calved within a few days of each other, were both bred to calve again about the same time, and stand side by side in his barn.

SUMMARY

A total of ten cases of torsion of the bovine cecum were reviewed. Symptoms similar to those associated with other types of intestinal obstruction characterize the illness with an additional finding of watery feces, or diarrhea, in three of the cases. The feces did not contain quantities of either fresh or decomposed blood. Palpation of the distended cecum per rectum provides the best means of differentiating this condition. Failure to differentiate torsions of the cecum from similar types of volvulus and obstruction may account for the limited number of cases recorded.

Seven of these ten cases were diagnosed at the Michigan State University Veterinary Clinic. The first five were successfully corrected by detorsion via a laparotomy. Another case, reported in Iowa, was successfully handled in the same manner, but the possibility of recurrence and the generally poor condition of the ceca in some of these early cases stimulated the pursuit of a superior corrective procedure. Of the two cases reported recently from Oklahoma, one recovered following detorsion, but the other did recur, accounting for the only post-corrective fatality.

The investigation proceeded first with a study of the normal anatomy involved and then with the involvements of a

torsion. An embalmed, normal animal and one of the clinical cases, embalmed without correcting the torsion, enabled detailed examination and comparison. Additional findings gleaned from the other clinical cases and examination of other normal cadavers broadened the scope of this study.

The cecum has only one mesenteric attachment, the ileocecal fold, and the extent of this attachment varies greatly. Thus, the natural mobility of the cecum varies with the individual bovine. Less variation was observed in the normal distribution of blood vessels. A rather consistent network of vessels lies in the ileocecal fold of mesentery. These were described and illustrated, while the nerves, for the most part, were found accompanying the vessels.

In a cecal torsion, this normally horizontal structure, when viewed through the right side of the standing animal, may rotate either clockwise or counterclockwise, twisting and partially obstructing the initial colon. Ingesta in the relatively thick walled terminal ileum continues to force its way into the cecum, distending it. A distending cecum can eventually completely obstruct the flow of ingesta through the initial colon and may impair its own blood supply. In two of the clinical torsions reviewed the omentum lay in its normal position between the large intestine and the right abdominal wall, but commonly it was displaced cranially allowing the cecum direct contact with the wall.

Several attempts to experimentally produce a torsion of the cecum were unsuccessful.

With a better understanding of the existing problem, the development of a procedure for an improved method of repair was undertaken. The chosen approach involves removal of the entire cecum caudal to the ileocecal junction. The techniques evolved through a series of ten experimental cecectomies on normal bovines. This procedure, described in detail, was then used to repair a clinical torsion presented at the Michigan State Clinic.

The evaluation of this method of repair was attacked from several different angles. The cecectomized animals were watched for signs of altered functions, but all recovered without complication. Since the cecum functions primarily as a storage compartment for the digestion of cellulose, four similar steers fed a ration of alfalfa hay were each put on a series of three digestion trials. With the first trial serving as a normal, the ceca were then removed, and surgery was followed in two weeks and then several months by the second and third trial. The coefficients of digestibility for the constituents of the alfalfa hay ration showed no significant variance between the three trials, indicating that these steers digested this same hay as well without their ceca as they did with them.

Post mortem examination of the animals revealed no marked alteration in the viscera except the absence of a cecum and its attachment. The intestines of three calves cecectomized when young were compared with three normal and similar calves at about six months of age. No consistent increase in capacity of either the large or small intestine was apparent.

The effort that went into perfecting this corrective surgical procedure seemed justified and such points as the exact location for the laparotomy incision, the use of a local anesthetic on the mesenteric nerves to prevent colic, the pattern of blood vessels in the ileocecal fold of mesentery, a satisfactory intestinal clamp, and improved materials and methods for closing an intestinal stump gained real meaning when actually applied to a case of cecal torsion. The result was a smooth operation and a rapid recovery. The performance of this case alone expresses sufficient gratitude for the work involved.

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TABLES

TABLE 1

DATES OF DIGESTION TRIALS

Steer	Trial	Preliminary Period	Experimental Period	Cecectomy
4949 -	1	7-14-55 to 7-20-55	7-21-55 to 7-27-55	7-28-55
	2	8-11-55 to 8-17-55	8-18-55 to 8-24-55	
	3	1-4-56 to 1-10-56	1-11-56 to 1-17-56	
4947 -	1	7-28-55 to 8-3-55	8-4-55 to 8-10-55	9-14-55
	2	9-28-55 to 10-4-55	10-5-55 to 10-11-55	
	3	1-18-56 to 1-24-56	1-25-56 to 1-31-56	
4950 -	1	9-14-55 to 9-20-55	9-21-55 to 9-27-55	10-12-55
	2	10-26-55 to 11-1-55	11-2-55 to 11-8-55	
	3	2-1-56 to 2-7-56	2-8-56 to 2-14-56	
4948 -	1	10-12-55 to 10-18-55	10-19-55 to 10-25-55	10-26-55
	2	11-9-55 to 11-15-55	11-16-55 to 11-22-55	
	3	2-15-56 to 2-21-56	2-22-56 to 2-28-56	

TABLE 2

TOTALS FOR SEVEN DAY EXPERIMENTAL PERIODS

Steer	Trial	Hay (lb.)	Water (gal.)	Feces (lb.)	Initial Weight (lb.)	Weight Gain or Loss (lb.)
4949 -	1	94.5	32	158.5	549	+ 3
	2	84.0	34	132.5	560	- 5
	3	105.0	34	173.0	747	+ 8
4947 -	1	120.0	45	237.0	635	+ 6
	2	128.0	49	216.5	701	+ 7
	3	158.0	53	268.5	863	+12
4950 -	1	118.0	43	212.0	695	+ 4
	2	132.0	52	260.5	721	+ 5
	3	158.0	67	351.0	908	+10
4948 -	1	125.0	46	264.5	690	+ 2
	2	108.0	43	222.5	702	- 8
	3	146.0	58	321.0	847	+11

TABLE 3

CHEMICAL COMPOSITION OF HAY SAMPLES*

Sample	Water	Ash	Protein	Ether Extract	Crude Fiber	Nitrogen-Free Extract
4949-1	10.22	5.64	14.56	2.20	26.04	41.34
2	9.59	5.71	14.44	1.79	25.22	43.25
3	7.45	5.70	13.63	1.62	29.00	42.60
4947-1	9.78	5.46	13.88	2.01	27.31	41.56
2	8.70	5.88	12.81	1.88	29.95	40.78
3	7.74	5.46	13.38	1.75	30.16	41.51
4950-1	10.14	5.49	13.69	1.86	27.16	41.66
2	8.54	6.04	14.69	1.54	26.30	42.89
3	7.90	5.98	14.69	1.65	28.52	41.26
4948-1	8.76	5.39	12.94	1.62	31.62	39.67
2	8.39	5.34	13.31	1.66	30.39	40.91
3	8.01	5.82	13.88	1.58	30.17	40.54

*Chemical composition expressed as a percentage.

TABLE 4

CHEMICAL COMPOSITION OF FECES*

Sample	Water	Ash	Protein	Ether Extract	Crude Fiber	Nitrogen-Free Extract
4949-1	80.48	2.13	2.26	0.93	7.43	6.77
2	78.27	2.24	2.59	1.03	8.36	7.51
3	81.27	2.11	2.04	0.65	7.27	6.66
4947-1	80.80	1.93	2.43	0.76	7.38	6.70
2	78.65	2.11	2.56	0.87	8.16	7.65
3	80.05	1.73	2.16	0.79	8.09	7.18
4950-1	80.58	2.26	2.34	0.86	7.34	6.59
2	81.09	2.17	2.48	0.77	6.73	6.76
3	82.15	1.82	2.20	0.63	6.84	6.36
4948-1	81.36	1.64	2.11	0.71	7.60	6.58
2	82.16	1.58	1.95	0.58	7.25	6.48
3	82.25	1.68	2.10	0.61	6.97	6.39

* Chemical composition expressed as a percentage.

TABLE 5

CHEMICAL COMPOSITION OF HAY SAMPLES ON A DRY BASIS AND THE COEFFICIENTS OF DIGESTIBILITY*

	Chemical Composition					Coefficients of Digestibility			
Sample	Ash	Protein	Ether Extract	Crude Fiber	Nitrogen-Free Extract	Dry Matter	Protein	Crude Fiber	Nitrogen-Free Extract
4949-1	6.28	16.22	2.45	29.00	46.05	63.53	73.98	52.13	72.54
2	6.32	15.97	1.98	27.89	47.84	62.08	71.72	47.69	72.61
3	6.16	14.73	1.75	31.33	46.01	66.59	75.33	58.69	74.25
4947-1	6.05	15.38	2.23	30.27	46.07	57.97	65.43	46.63	68.16
2	6.44	14.03	2.06	32.80	44.67	60.45	66.22	53.91	68.28
3	5.92	14.50	1.90	32.69	44.99	63.25	72.56	54.42	70.61
4950-1	6.11	15.23	2.07	30.22	46.36	61.17	68.92	51.45	71.58
2	6.60	16.06	1.68	28.76	46.89	59.19	66.68	49.51	68.89
3	6.49	15.95	1.79	30.97	44.80	56.95	66.74	46.72	65.76
4948-1	5.91	14.18	1.78	34.66	43.47	56.77	65.51	49.15	64.91
2	5.83	14.53	1.81	33.17	44.66	59.88	69.80	50.85	67.36
3	6.33	15.09	1.72	32.80	44.07	57.58	66.73	49.22	65.35

*Chemical composition expressed as a percentage.

TABLE 6

A COMPARISON OF INTESTINAL CAPACITY OF NORMAL AND CECECTOMIZED CALVES*

	Calf	Large Intestine	Small Intestine
Normal Group	4907	7	22
	4901	9	24
	4905	12	32
Cecectomized Group	4904	10	23
	4902	7	21
	4906	8	26

*Capacity expressed in liters of water contained at a standard pressure.

PLATES

Plate I. Normal Calf, embalmed

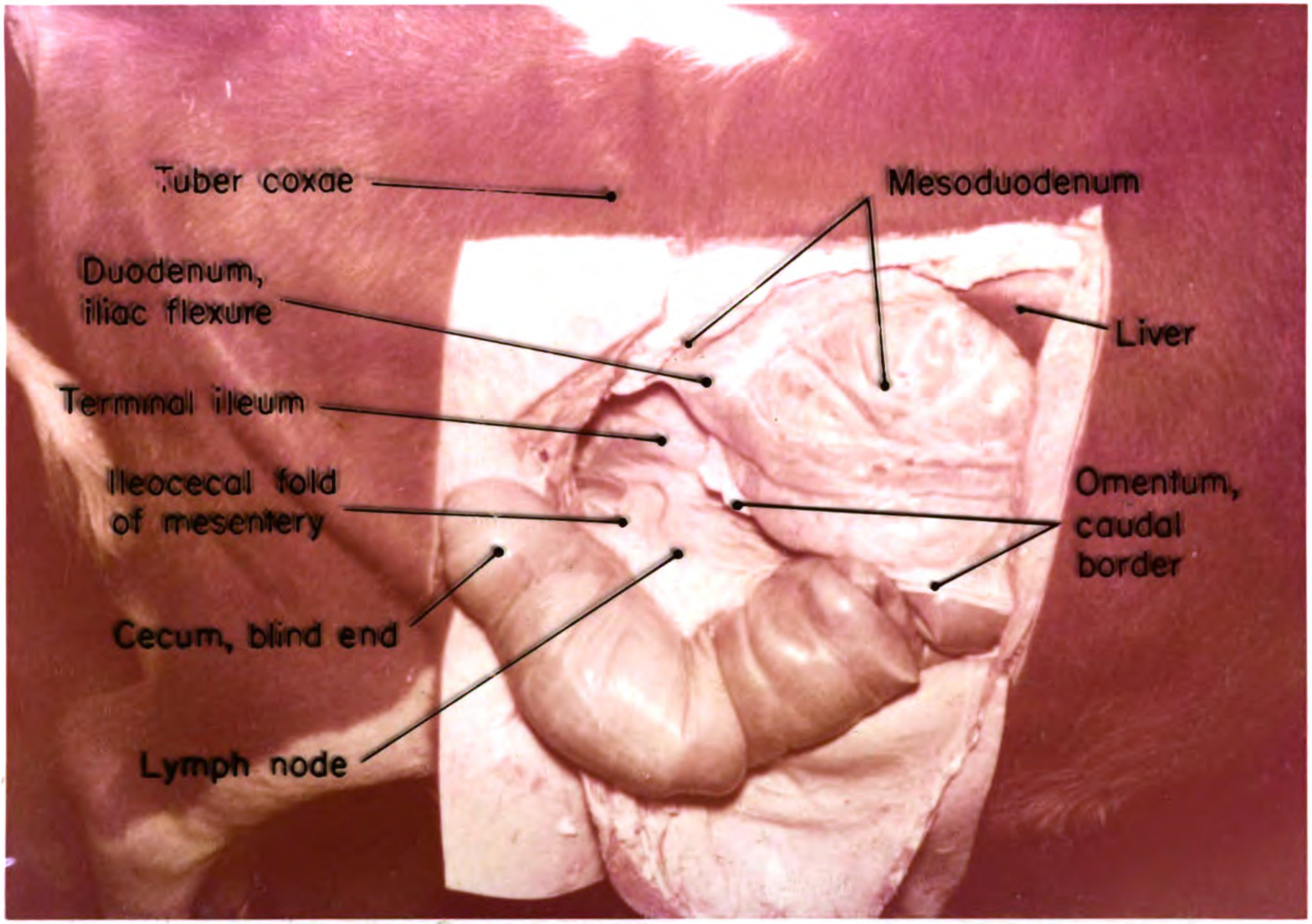
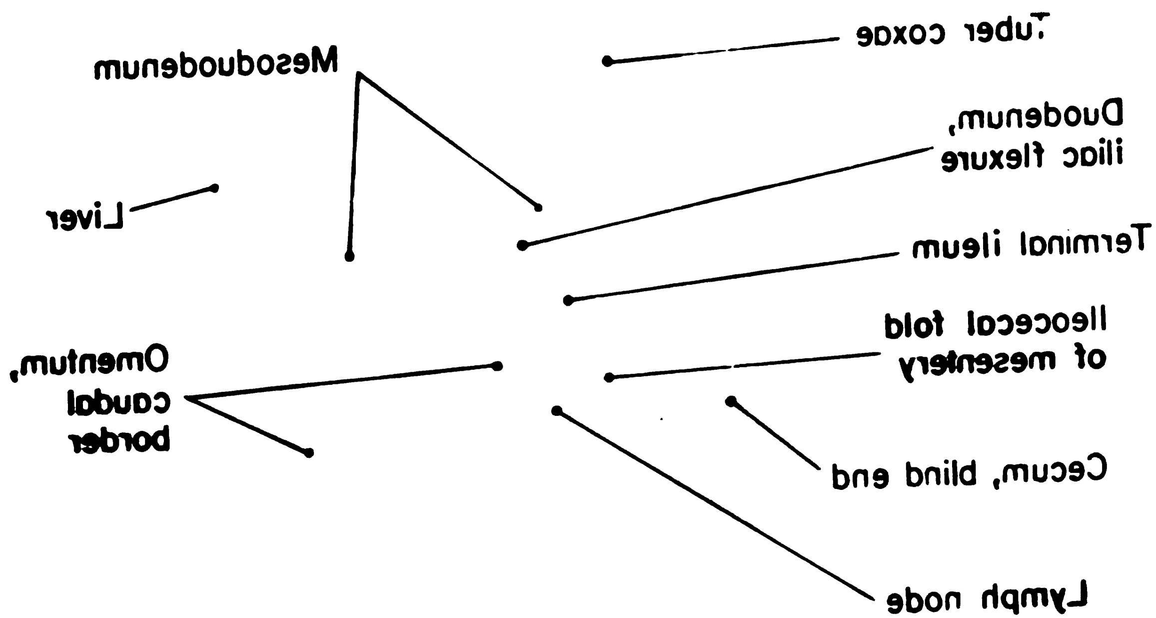


Plate II. Normal calf, cecum exposed



Mesoduodenum
Liver
Omentum, caudal border
Tuber coxae
Duodenum, iliac flexure
Terminal ileum
Ileocecal fold of mesentery
Cecum, blind end
Lymph node

Plate II. Normal calf, cecum exposed

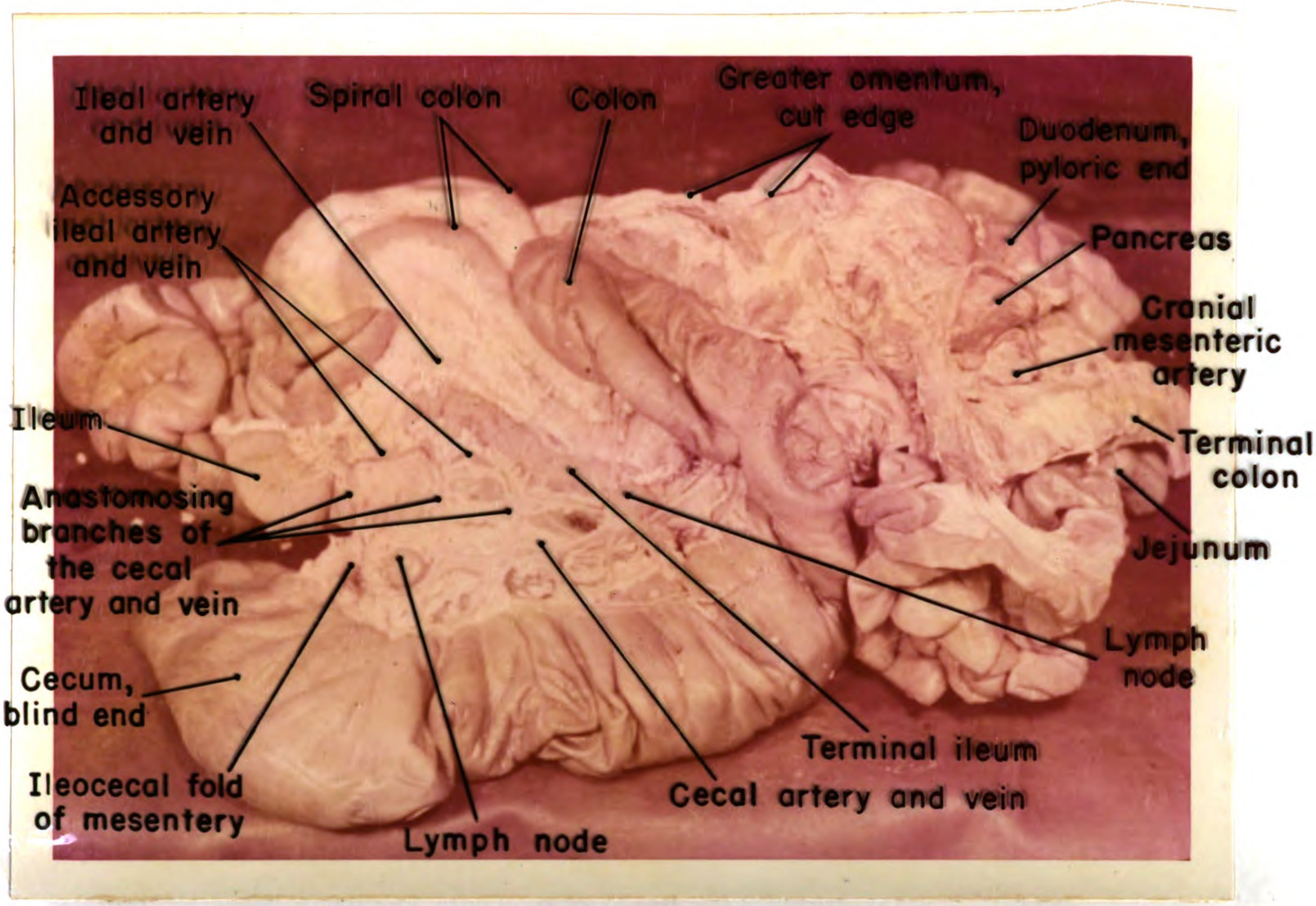
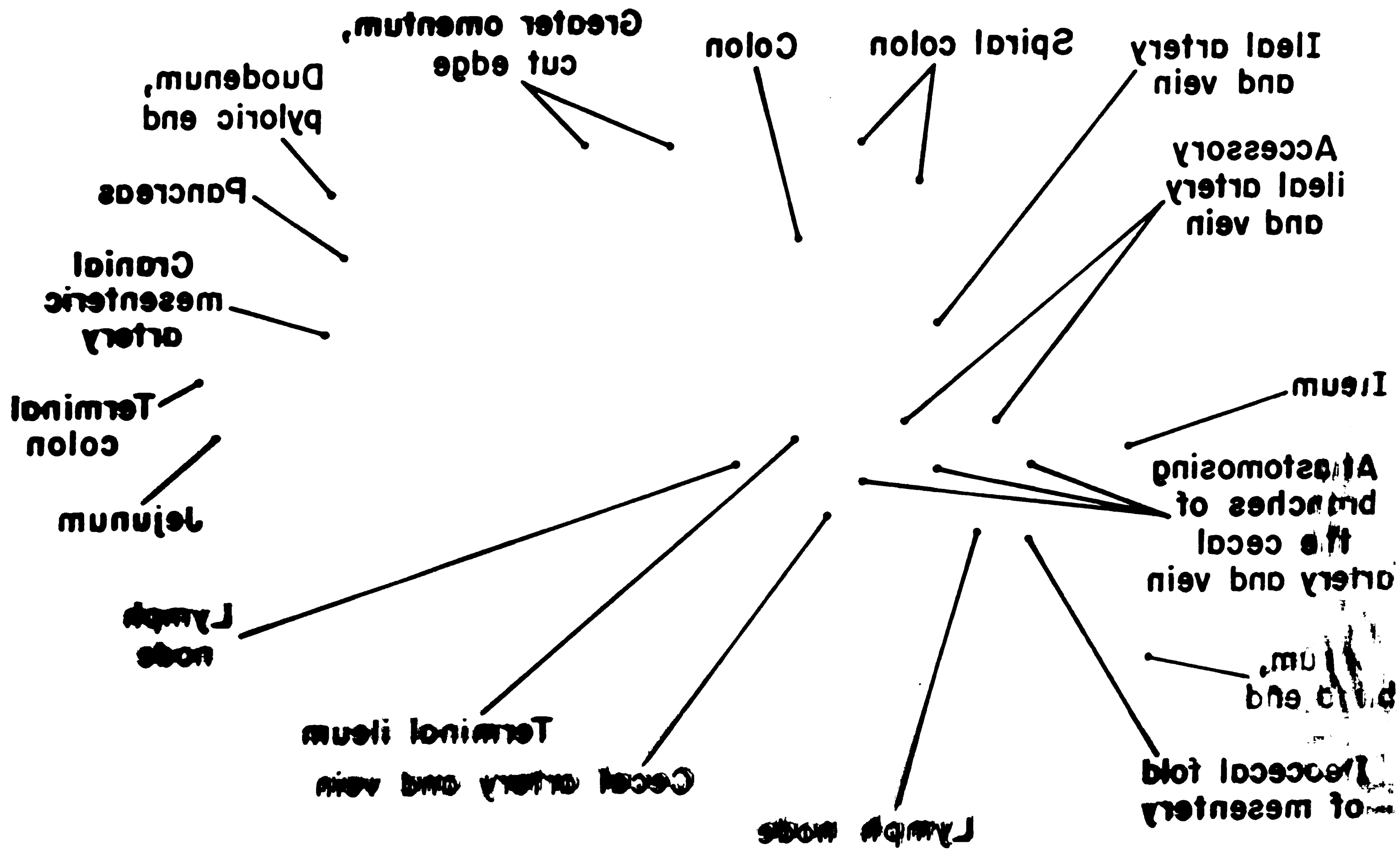


Plate III. Normal intestines, dorso-medial view of cecum



Greater omentum, cut edge
Colon
Spiral colon
Ileal artery and vein
Duodenum, pyloric end
Pancreas
Cranial mesenteric artery
Accessory ileal artery and vein
Terminal colon
Jejunum
Ileum
Lymph node
Terminal ileum
Cecal artery and vein
Lymph node
Ileocecal fold of mesentery

Plate III. Normal intestines, dorso-medial view of cecum

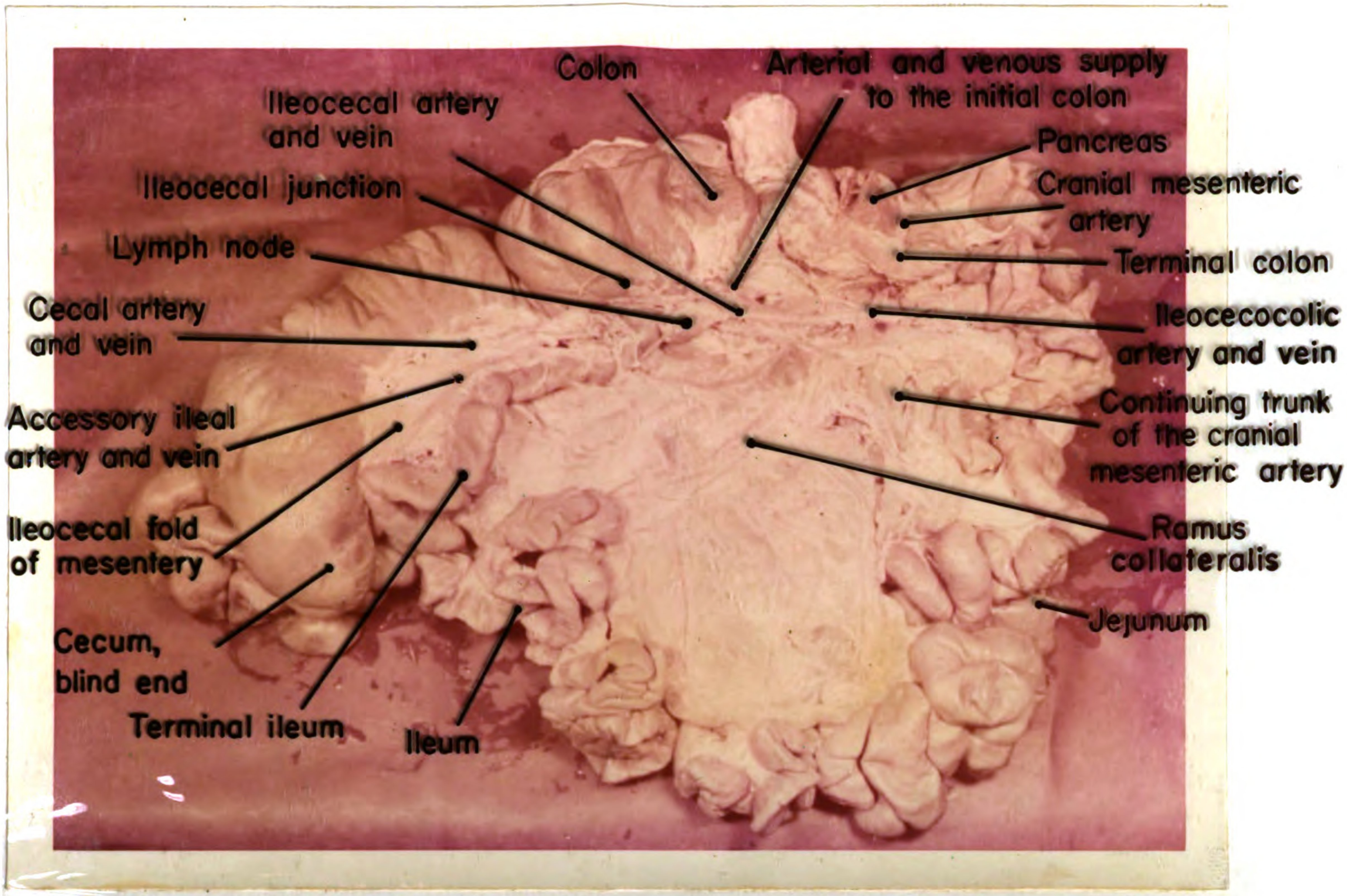


Plate IV. Normal intestines, ventro-lateral view of cecum

Arterial and venous supply to the initial colon
Colon
Ileocecal artery and vein
Pancreas
Cranial mesenteric artery
Ileocecal junction
Terminal colon
Lymph node
Ileocecocolic artery and vein
Cecal artery and vein
Continuing trunk of the cranial mesenteric artery
Accessory ileal artery and vein
Ramus collateralis
Ileocecal fold of mesentery
Jejunum
Cecum, blind end
Ileum
Terminal ileum

Plate IV. Normal intestines, ventro-lateral view of cecum

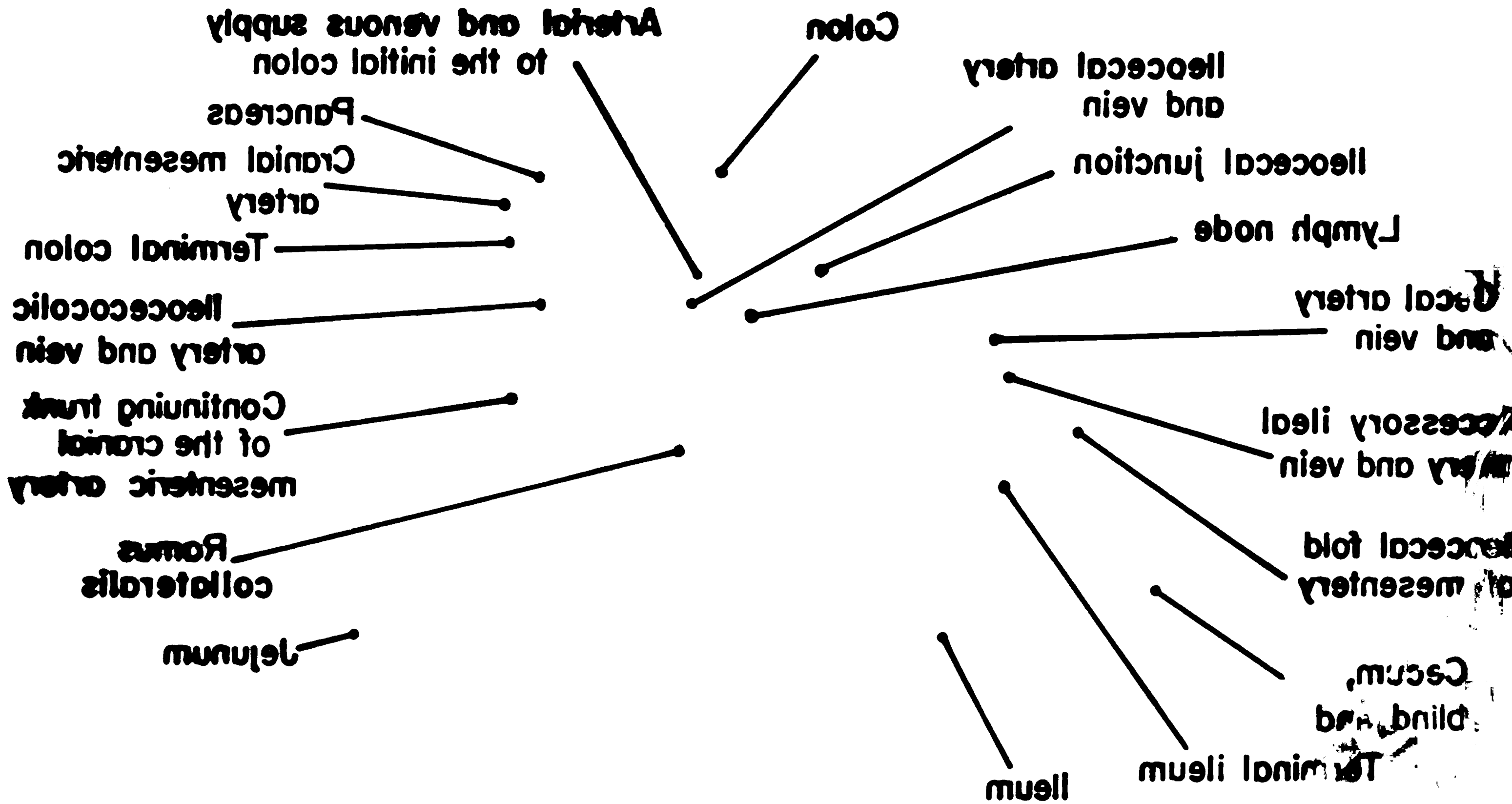

Arterial and venous supply to the initial colon
Pancreas
Cranial mesenteric artery
Terminal colon
Ileocecocolic artery and vein
Continuing trunk of the cranial mesenteric artery
Ramus collateralis
Jejunum
Colon
Ileocecal artery and vein
Ileocecal junction
Lymph node
Cecal artery and vein
Accessory ileal artery and vein
Ileocecal fold of mesentery
Cecum, blind end
Terminal ileum
Ileum

Plate IV. Normal intestines, ventro-lateral view of cecum

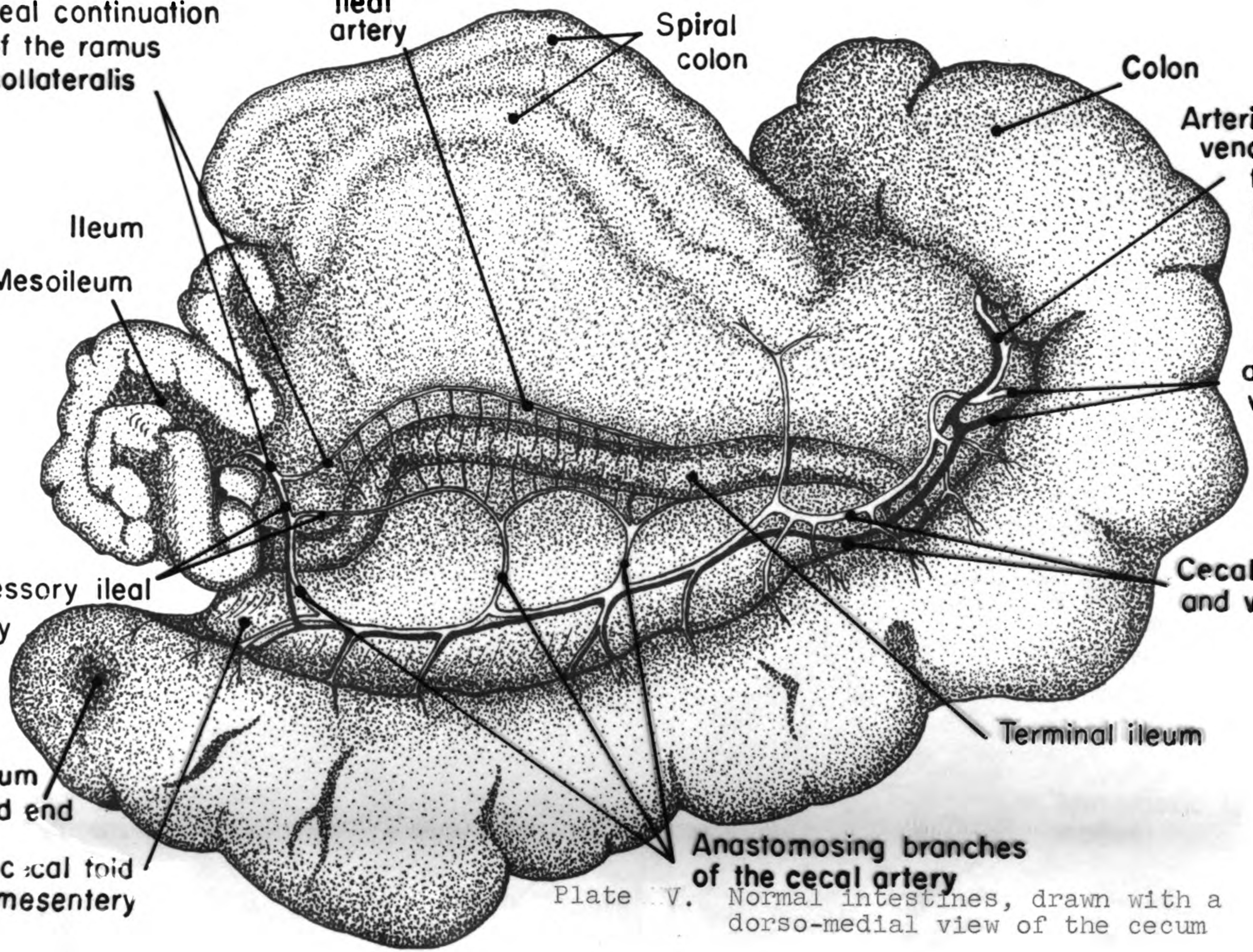
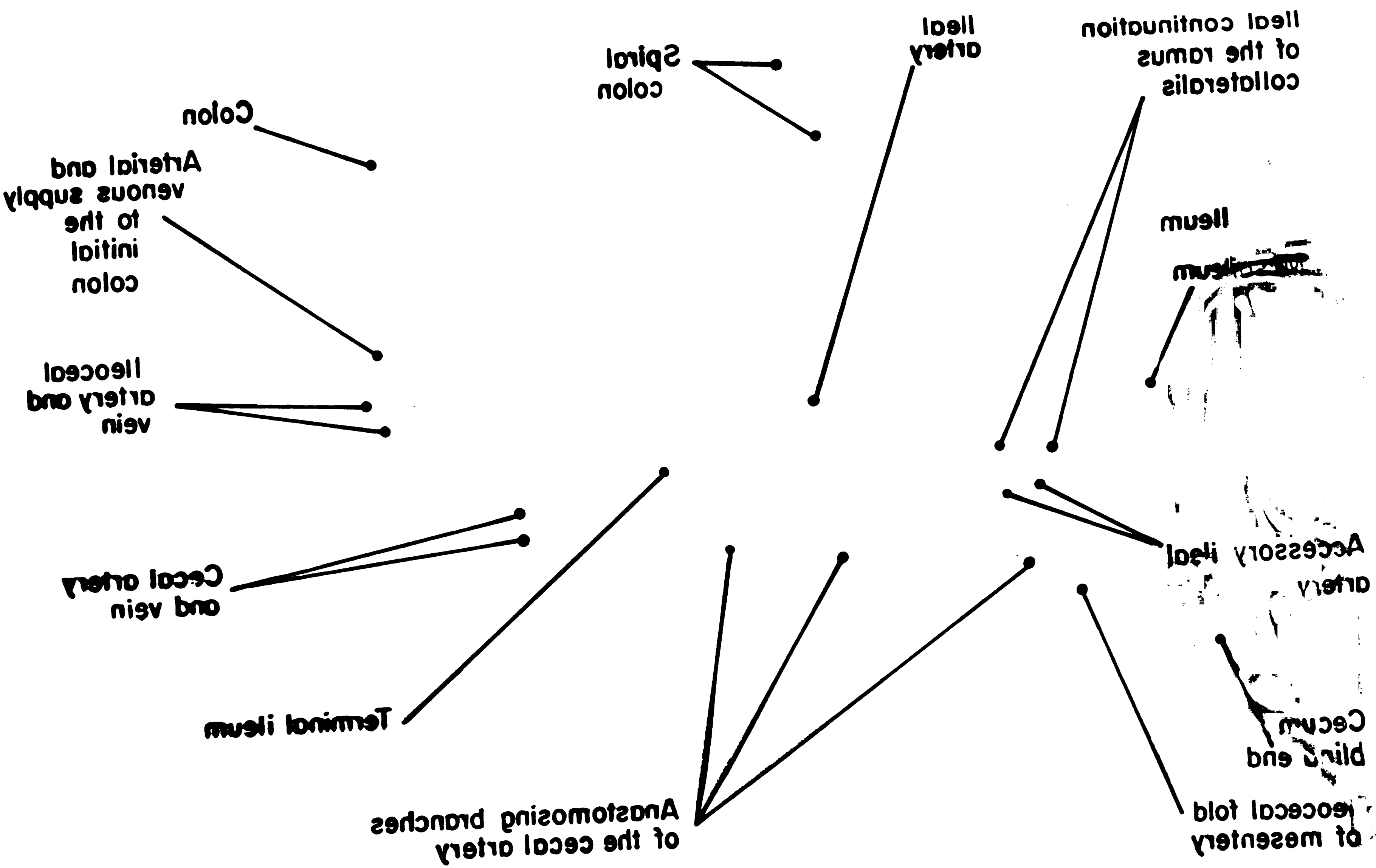


Plate V. Normal intestines, drawn with a dorso-medial view of the cecum


Colon
Arterial and venous supply to the initial colon
Ileocecal artery and vein
Cecal artery and vein
Terminal ileum
Anastomosing branches of the cecal artery
Spiral colon
Ileal artery
Ileal continuation of the ramus collateralis
Ileum
Accessory ileal artery
Cecum and blind end
Ileocecal fold of mesentery

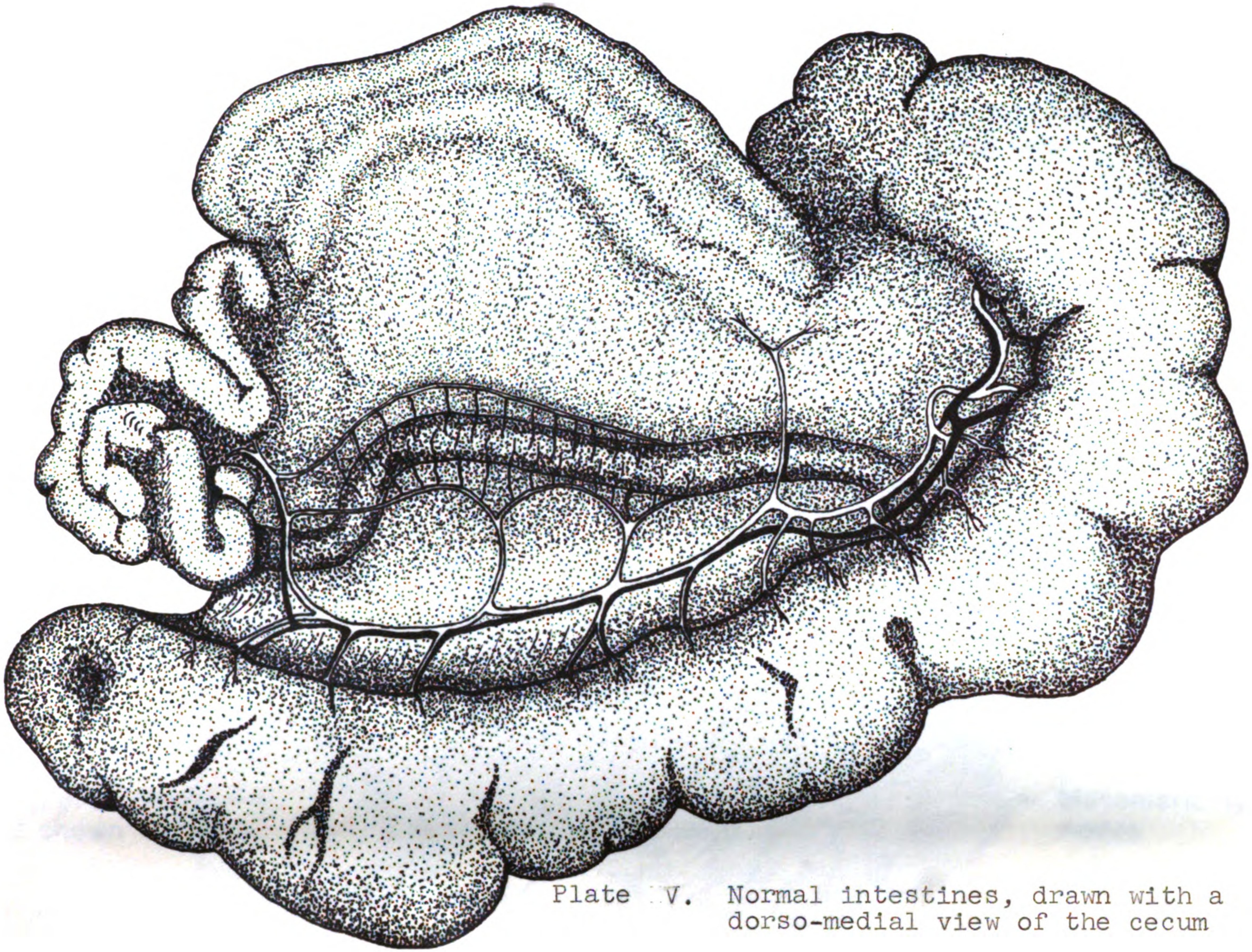


Plate V. Normal intestines, drawn with a dorso-medial view of the cecum

Arterial and venous supply to

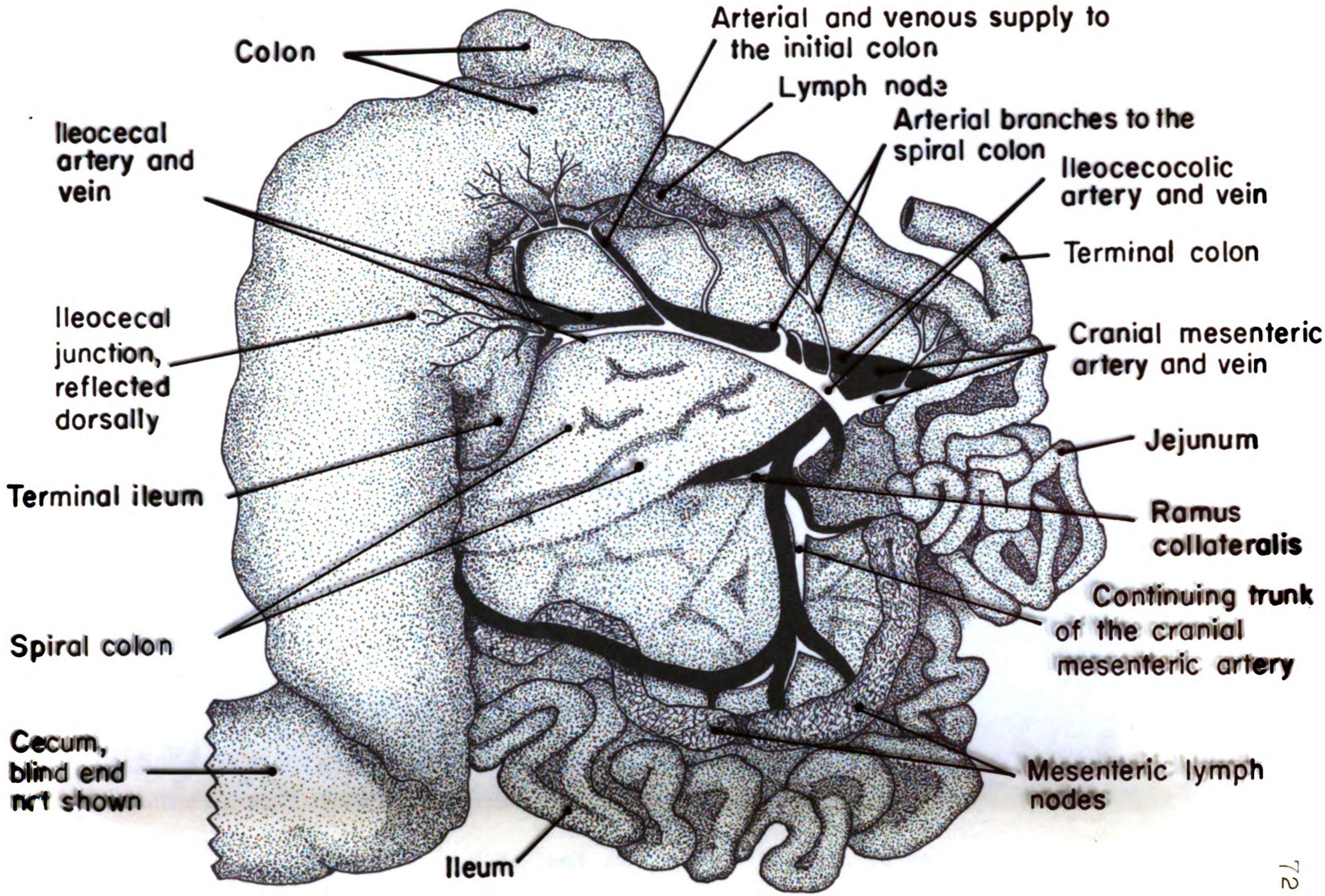
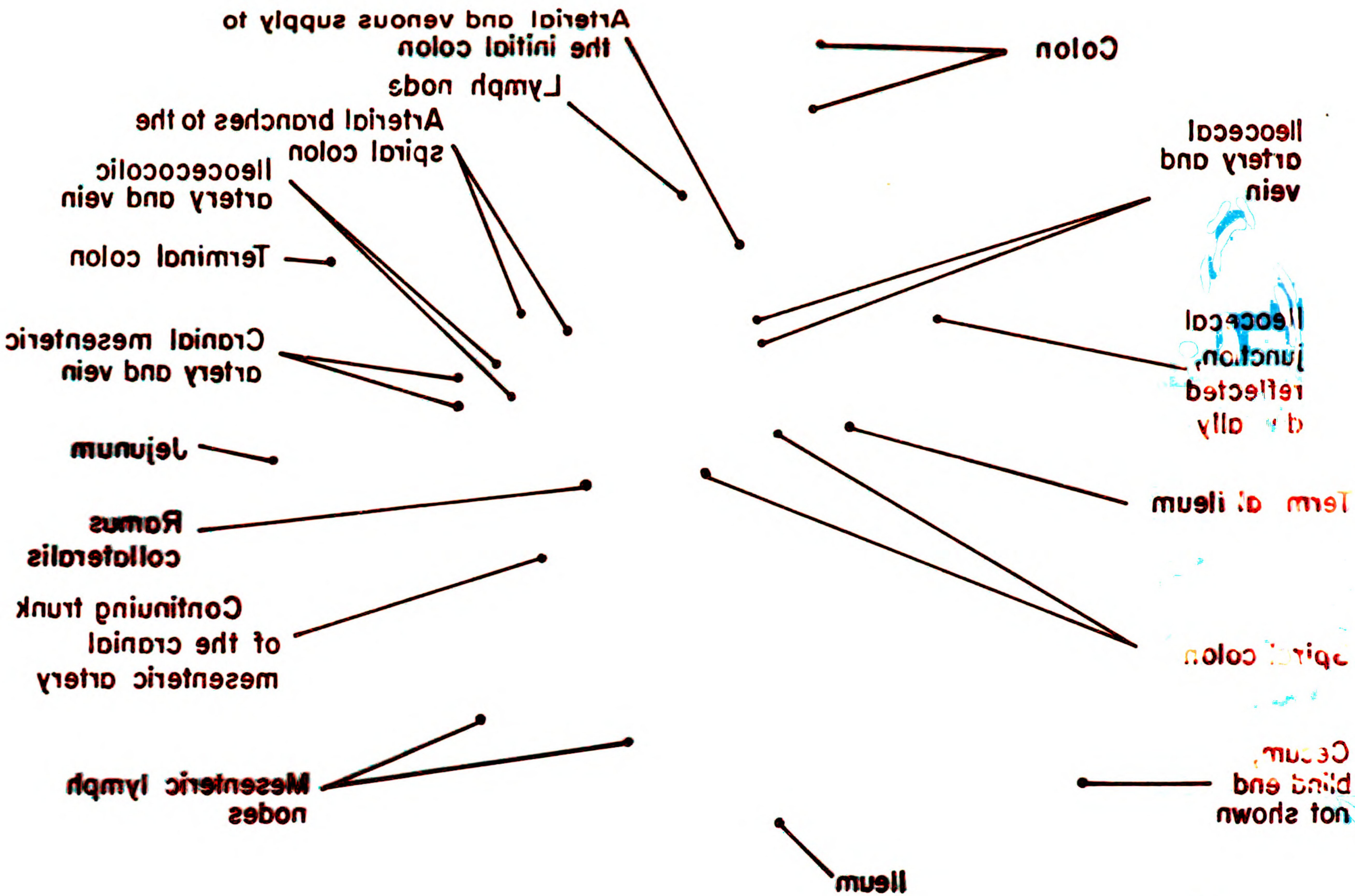


Plate VI. Normal intestines, drawn with a ventro-medial view of the ileocecal junction



Arterial and venous supply to the initial colon
Lymph node
Arterial branches to the spiral colon
Ileocecocolic artery and vein
Terminal colon
Cranial mesenteric artery and vein
Jejunum
Ramus collateralis
Continuing trunk of the cranial mesenteric artery
Mesenteric lymph nodes
Ileum
Colon
Ileocecal artery and vein
Ileocecal junction, reflected
blind end not shown

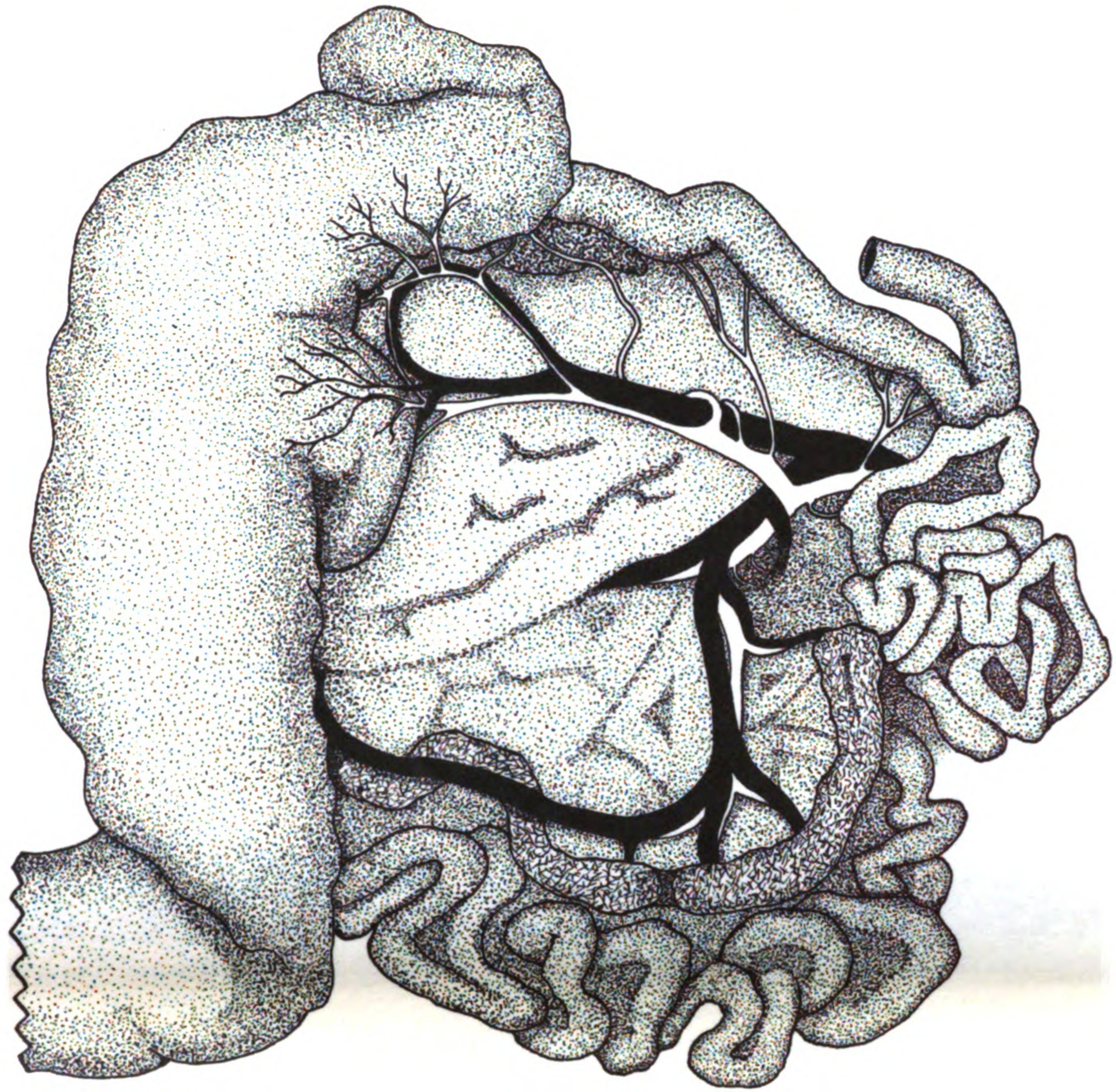


Plate VI. Normal intestines, drawn with a ventro-medial view of the ileocecal junction

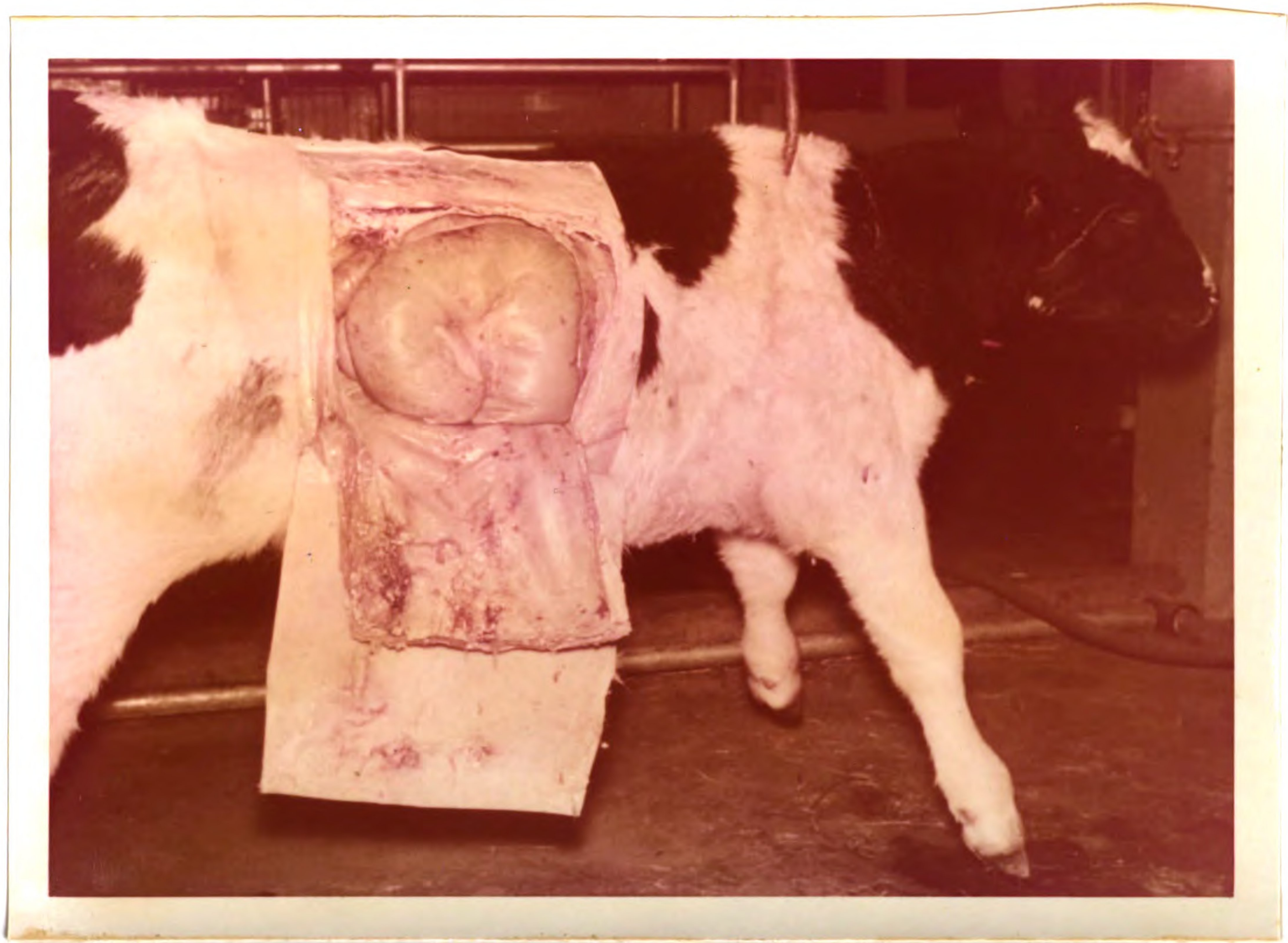


Plate VII. Clinical cecal torsion, embalmed

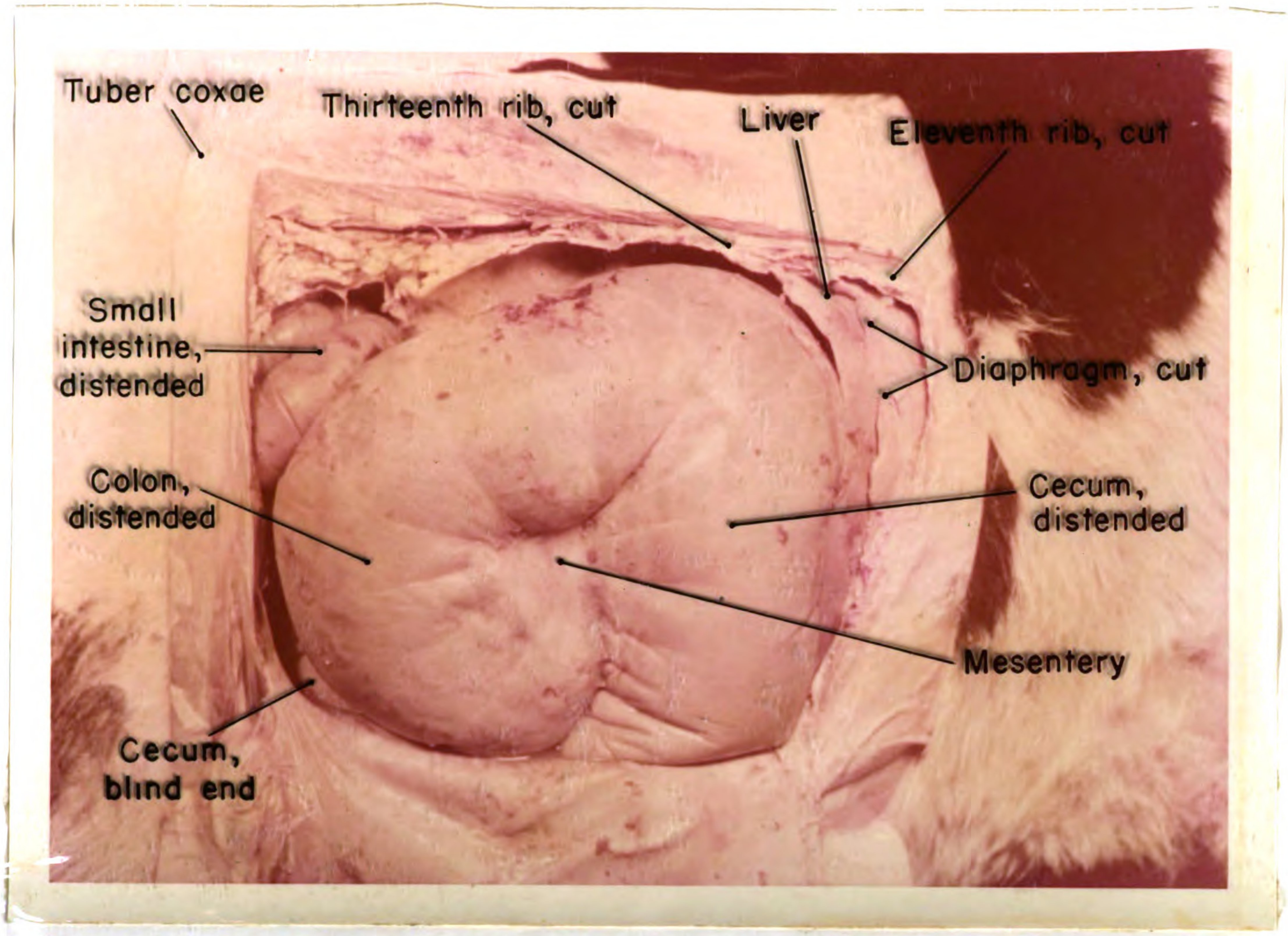
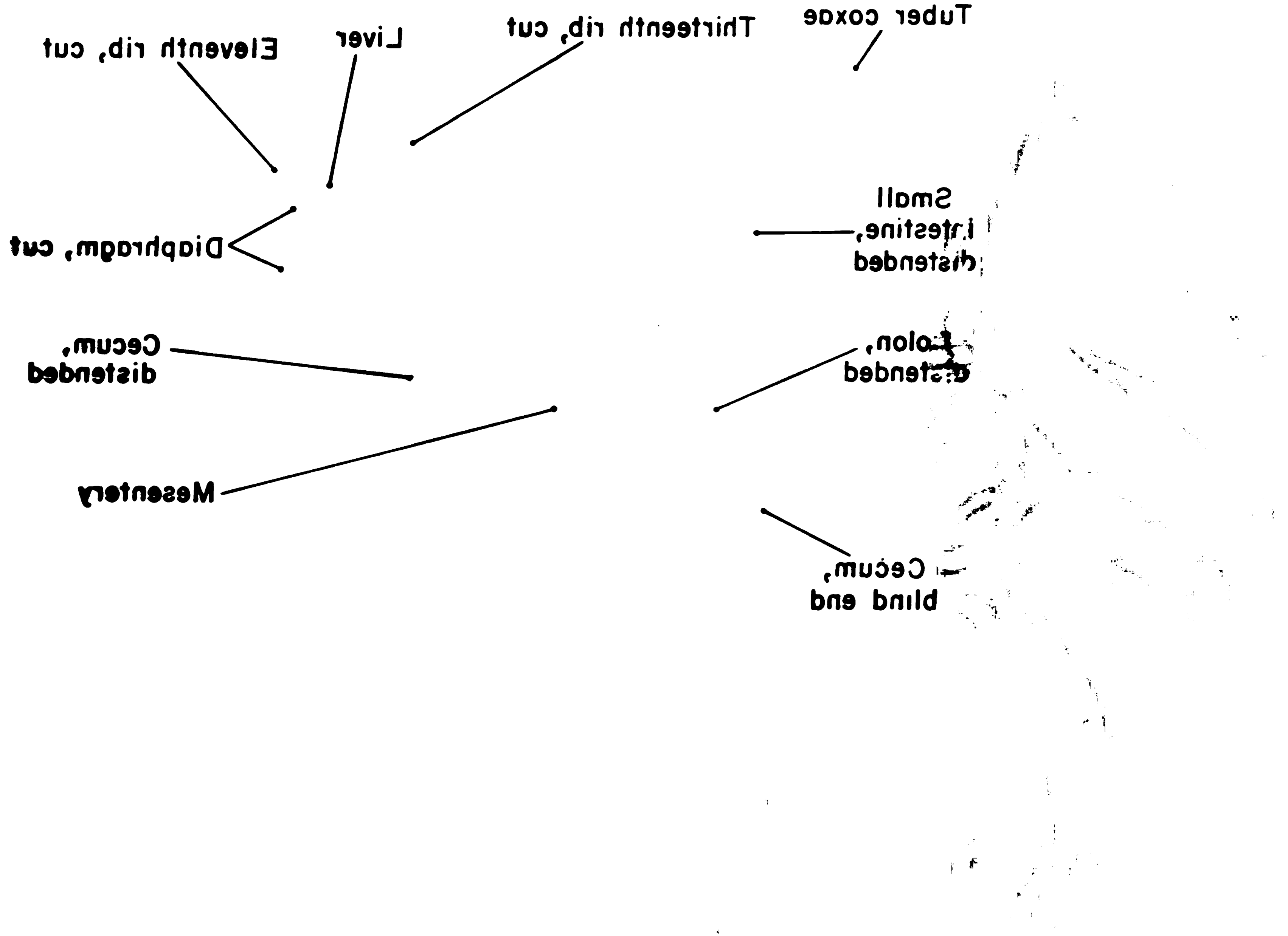


Plate VIII. Cecal torsion before manipulation



Eleventh rib, cut
Liver
Thirteenth rib, cut
Tuber coxae
Diaphragm, cut
Small intestine, distended
Cecum, distended
Colon, distended
Mesentery
Cecum, blind end

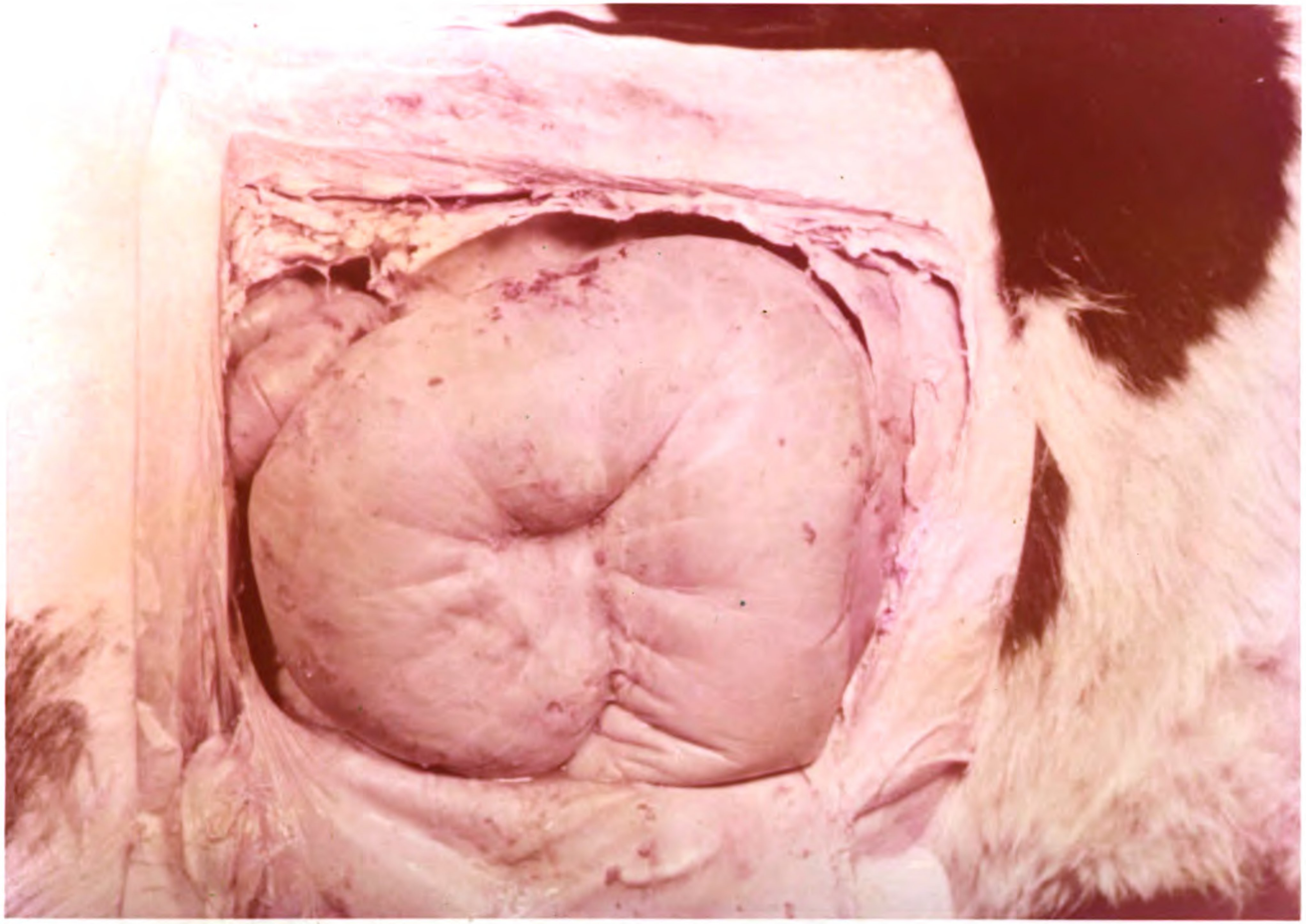


Plate VIII. Cecal torsion before manipulation

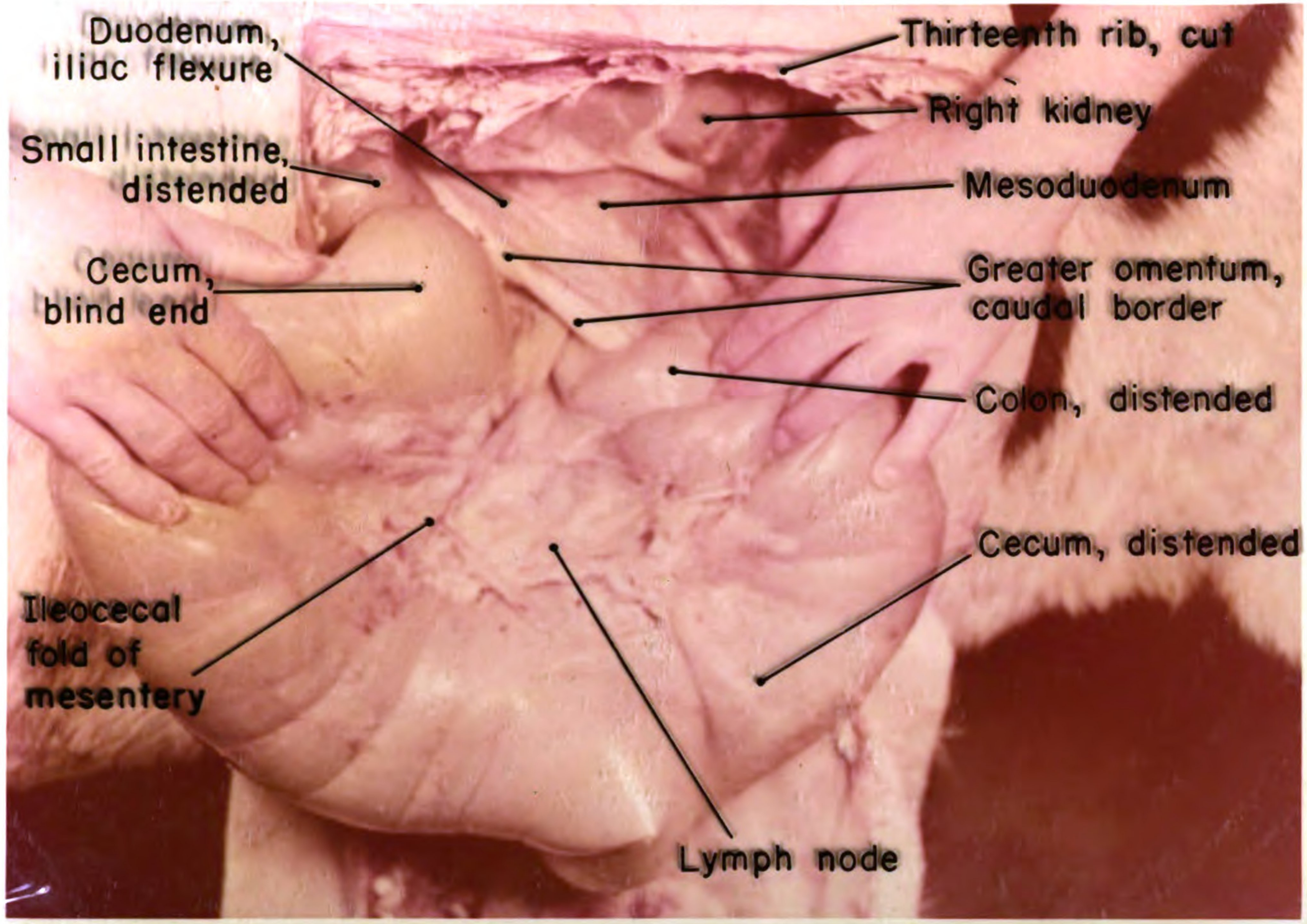
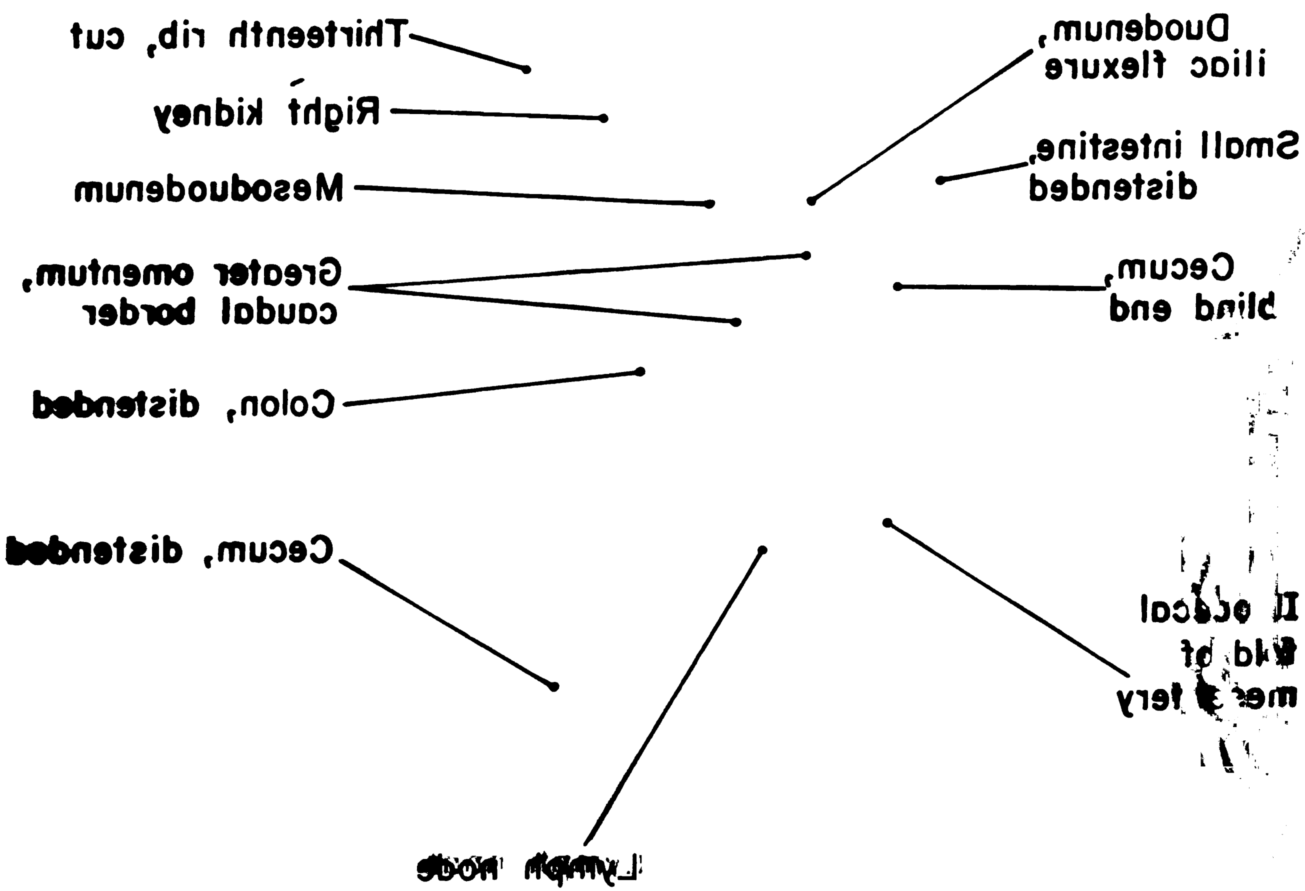


Plate IX. Cecum rotated back to normal, dorso-medial view


Thirteenth rib, cut
Right kidney
Mesoduodenum
Greater omentum, caudal border
Colon, distended
Cecum, distended
Lymph node
Duodenum, iliac flexure
Small intestine, distended
Cecum, blind end

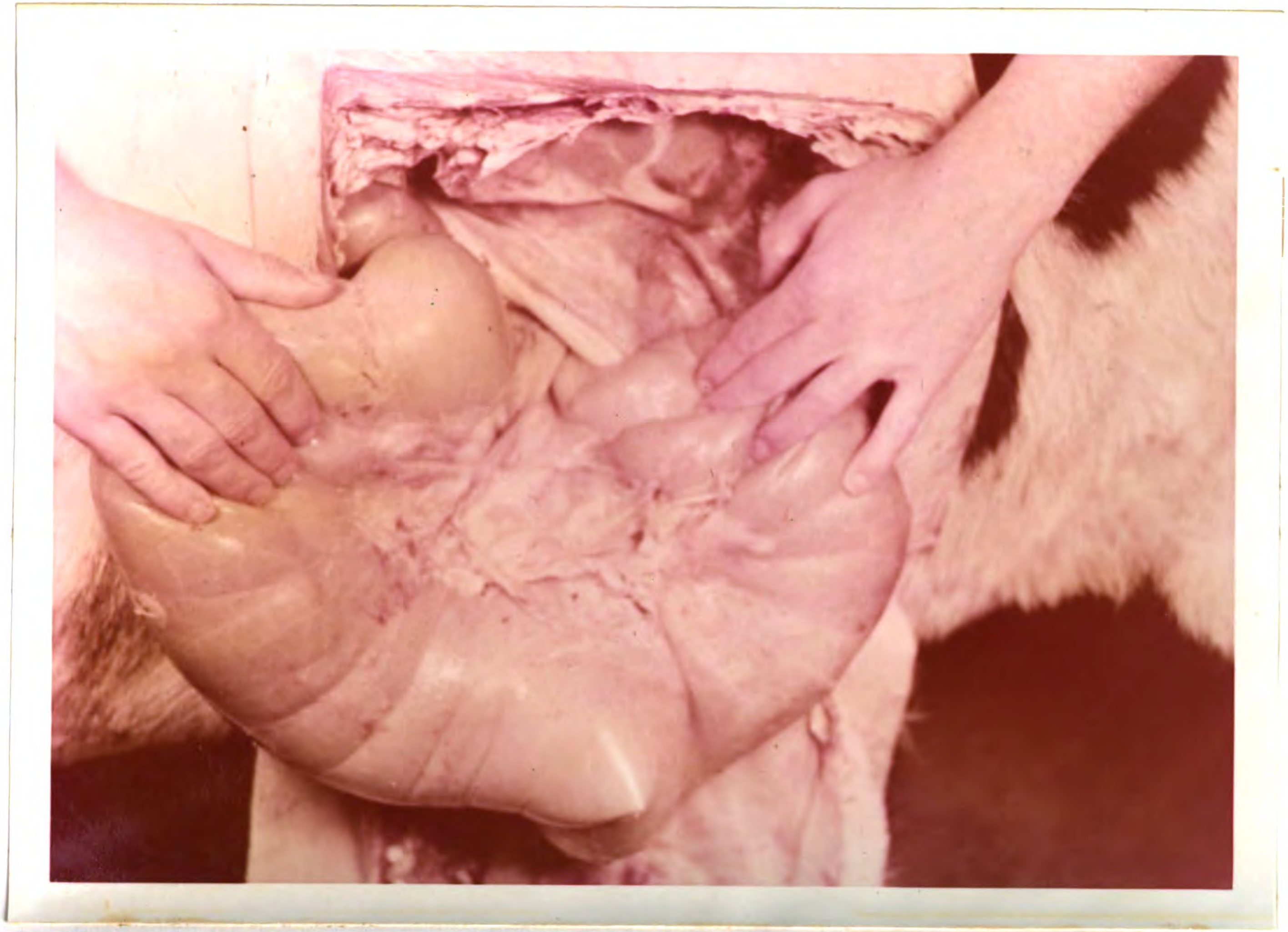


Plate IX. Cecum rotated back to normal, dorso-medial view

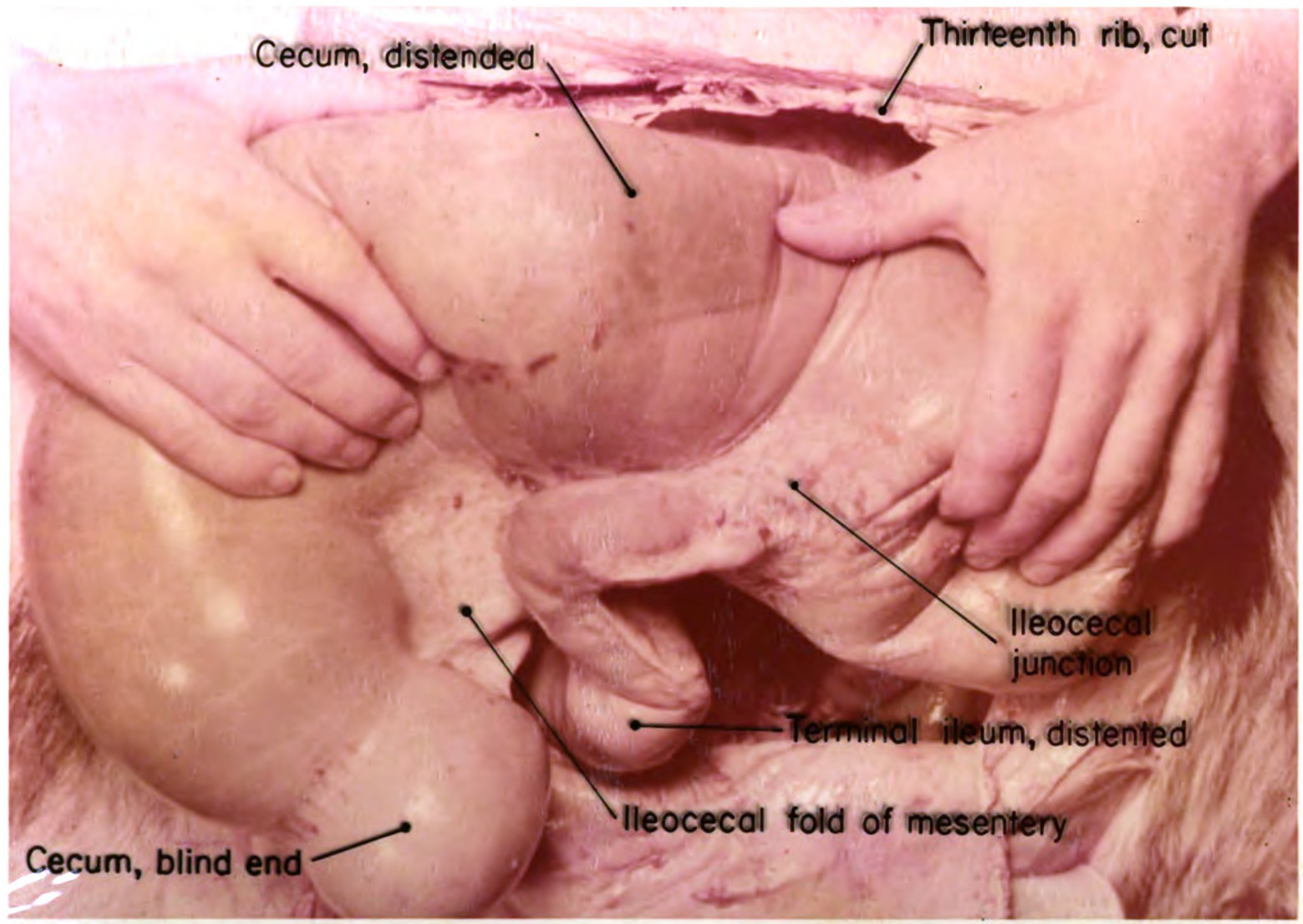


Plate X. Cecum rotated back to normal, ventro-lateral view

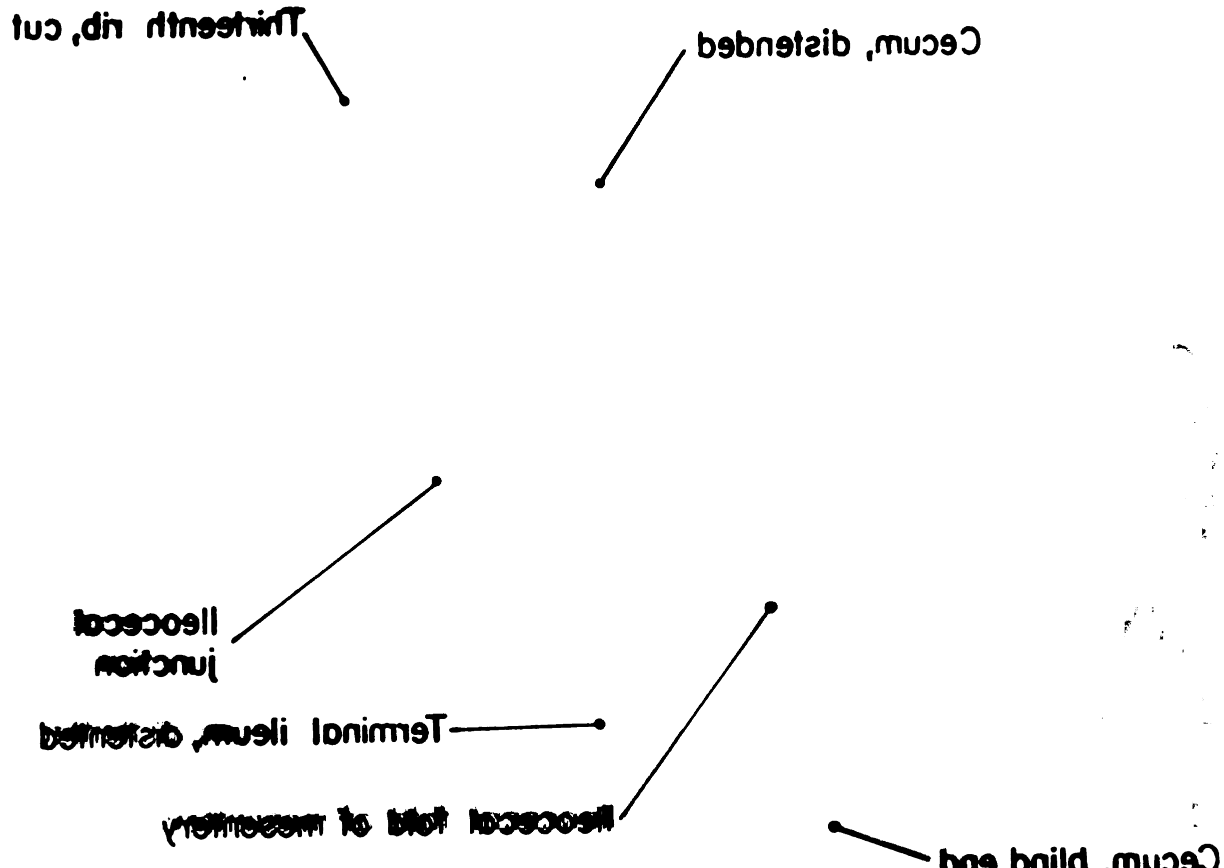

Thirteenth rib, cut
Cecum, distended
Ileocecal junction
Terminal ileum, distended
Ileocecal fold of mesentery
Cecum, blind end

Plate X. Cecum rotated back to normal, ventro-lateral view

Plate XI--A. Operative procedure, initial incision

Plate XI--B. Cecum exposed through the incision

Plate XII--A. Injecting the local anesthetic

Plate XII--B. Ligating blood vessels

Plate XIII--A. Applying the Payr clamp

Plate XIII--B. Undersewing the Payr clamp

Plate XIV--A. Oversewing the Payr clamp

Plate XIV--B. The inverted intestinal stump

Plate XV--A. The viscera replaced

Plate XV--B. Suturing the muscles and peritoneum

Plate XVI--A. Suturing the skin with a buried suture pattern

Plate XVI--B. The cecectomized steer on the day following surgery

Plate XVII. Steer in the digestion trial stall

Plate XVIII. Cectomized calf

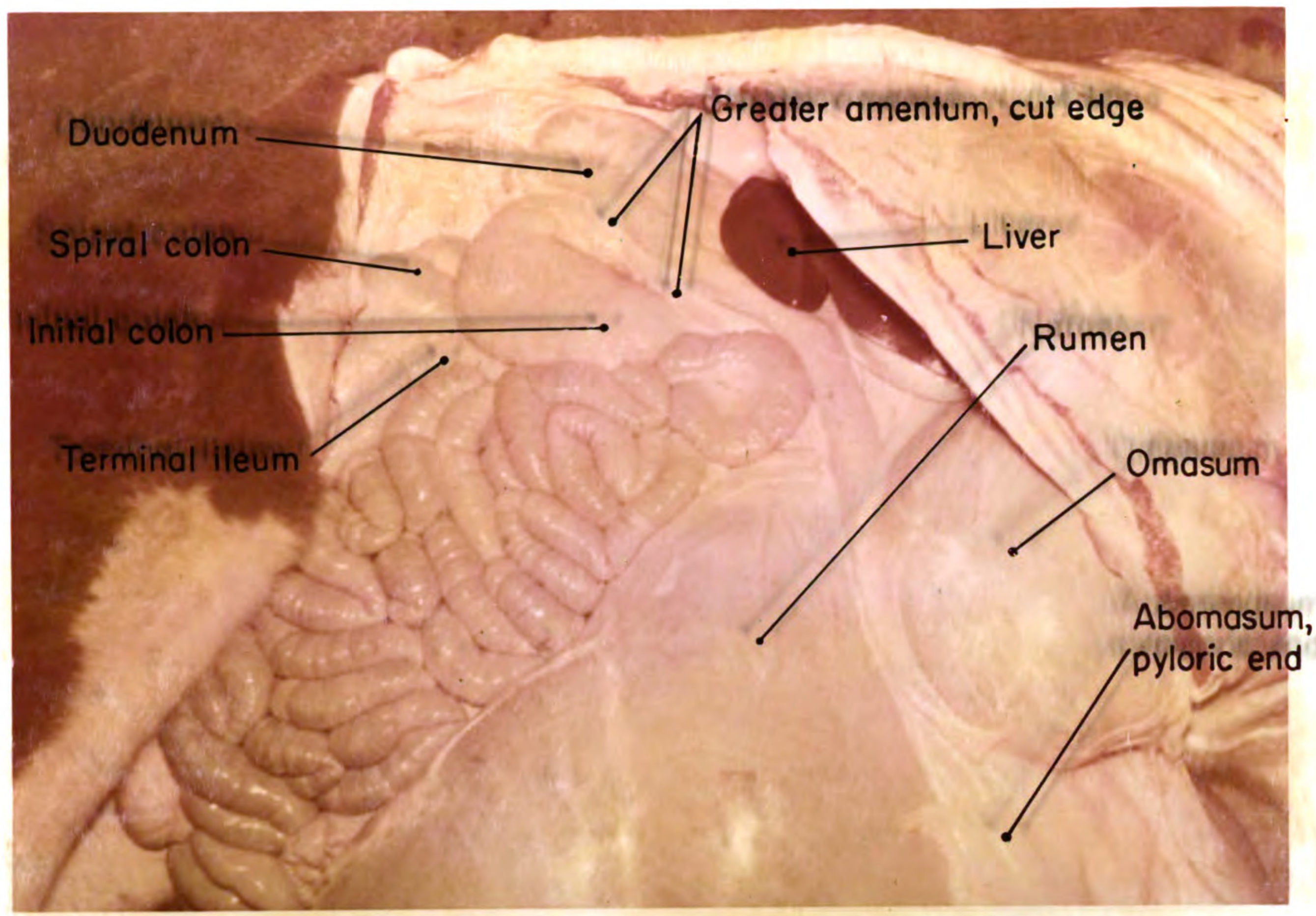
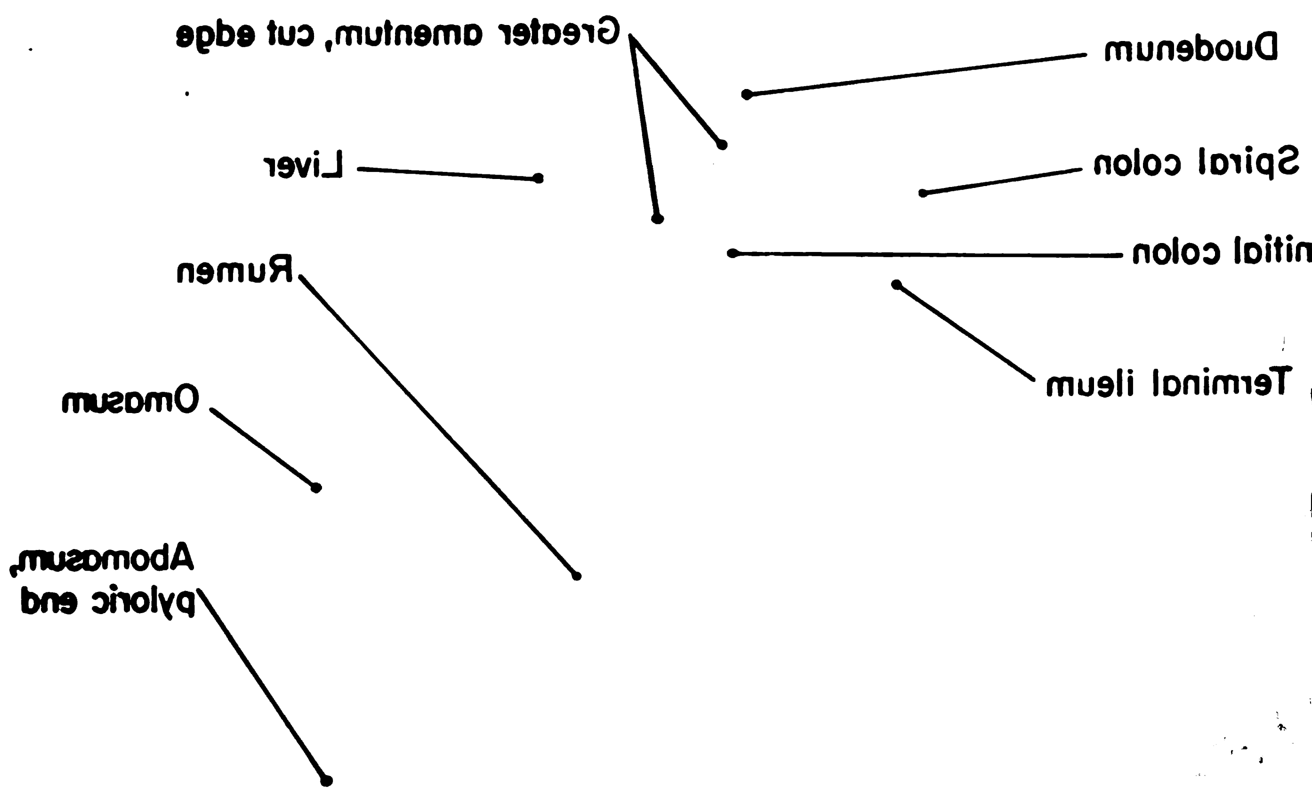


Plate XIX. The viscera of the cecectomized calf



Greater omentum, cut edge
Liver
Rumen
Omasum
Abomasum, pylori end
Duodenum
Spiral colon
Initial colon
Terminal ileum

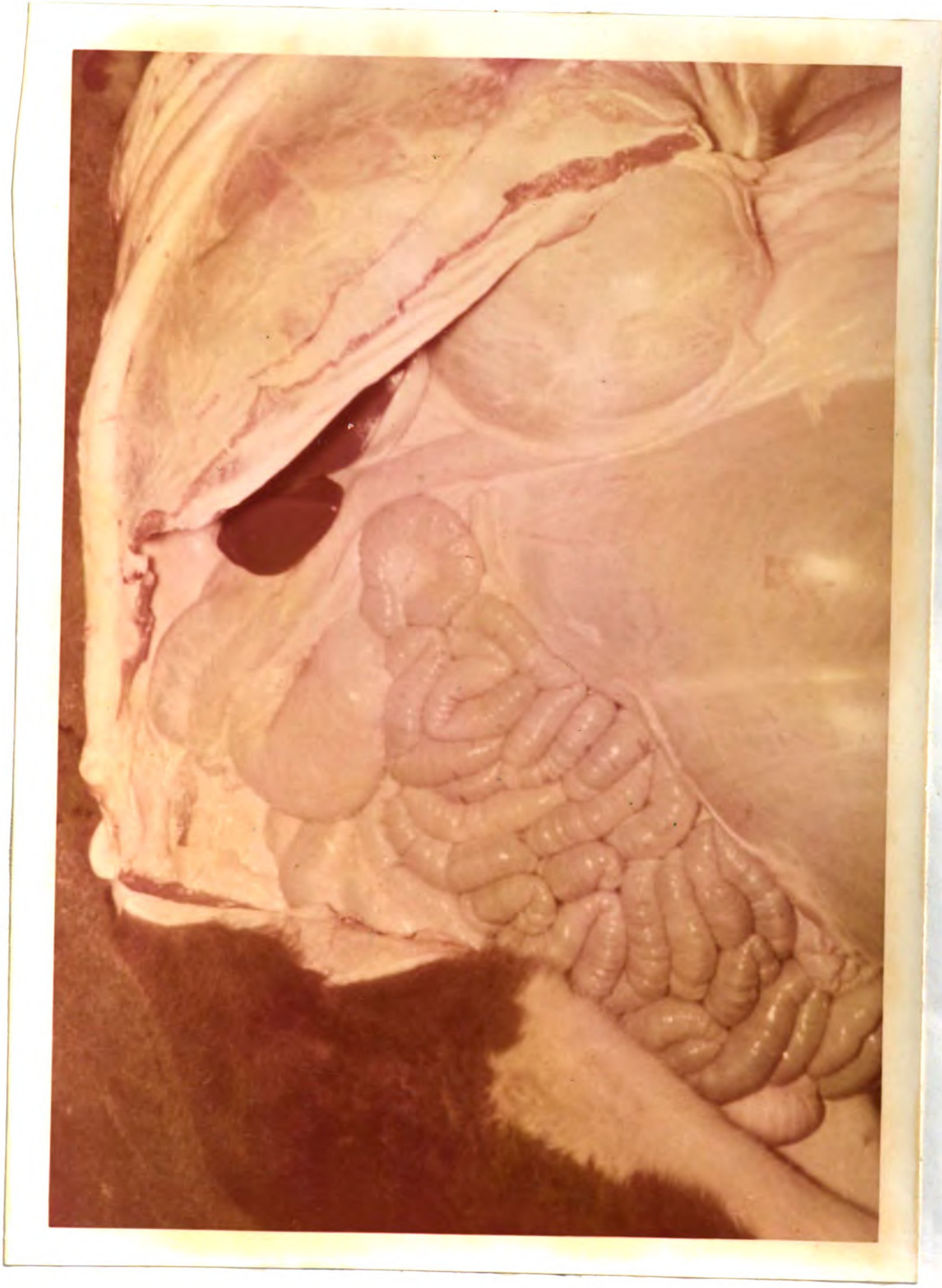


Plate XIX. The viscera of the cecectomized calf

Plate XX. Intestinal capacity equipment

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