INTESTINAL CANNULATION OF CATTLE AND SHEEP WITH A T-SHAPED CANNULA DESIGNED FOR TOTAL DIGESTA COLLECTION WITHOUT EXTERNALIZING DIGESTA FLOW

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Summary

An intestinal cannula was prepared that was designed to have the advantages of a reentrant cannula without permanently exteriorizing digesta flow or adding significantly to the resistance of digesta flow. The cannula was fabricated in the shape of a T from a Teflon fluorocarbon polymer. Total passage of digesta through the lumen of the cannula was accomplished by suturing a support boot around the outside of the intestine at the cannulation site. The support boot prevented the intestine from stretching away from the cannula. Digesta leakage around the barrel of the cannula was eliminated by a special peritoneal ring attached to the cannula in a position that interrupted the continuity of the tubular scar tissue that formed from the intestine alongside the barrel to the skin. The cannula was supported by an outer ring held in place by a simple stainless steel retaining ring. The low external profile of the cannula minimized mechanical disturbance of the cannula and cannula site. Diet consumption and growth rates were normal, and no blockage was encountered in either the duodenal or the ileal cannula with a wide variety of diets, indicating that the cannula added no significant resistance to digesta flow. Total digesta collection or simultaneous collection and addition were easily accomplished with special collection gates. The cannula preparation has a long functional life; in one case, the cannula remained functional for more than 2½ years.

(Key Words: Intestinal Cannula, Ruminants, Cattle, Sheep, Duodenum, Ileum.)

Introduction

Intestinal cannulas have proven to be valuable tools in the study of ruminant digestive function. The capability to sample intestinal digesta from strategic positions in the intestinal tract permits the generation of data unobtainable by other methods. Phillipson (1952) used intestinal cannulas in his early studies of the physiology of digestion in ruminants. One of the most useful preparations, the reentrant cannula described in detail by Markowitz *et al.* (1964) for dogs, had the advantage of permitting total collection of intestinal digesta. Numerous researchers have used the reentrant cannula in sheep and cattle. A popular and widely used reentrant cannula was that developed by Ash (1962), which was made from a molded plastisol.

Reentrant cannulas have several drawbacks. The surgical introduction of the reentrant cannula requires transection of the intestine. The digestive flow is permanently shunted to the outside of the body through one cannula and then reenters through another. The reentrant cannula interrupts the normal motility of the intestine (Wenham, 1979) because of the transection of the intestine and the added resistance to flow of digesta caused by the cannula assembly. Blockage of flow can occur, particularly with certain diets (Phillipson, 1952; Conner *et al.*, 1957; Easter and Tanksley, 1973; Phillips *et al.*, 1978). Another important drawback of many cannula preparations, particularly the reentrant cannula preparation, is the vulnerability of the external portion of

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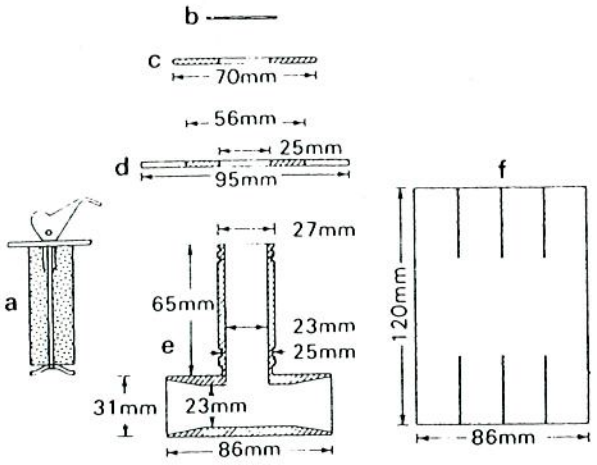


Figure 1. Cannula and associated components: (a) cam-activated neoprene plug for closing the cannula; (b) stainless steel retaining ring; (c) outer support ring; (d) inner peritoneal ring made to spread over the barrel (four cuts with a sharp blade around the diameter of the hole in the ring to allow it to open wider) and snap into the 25-mm groove in the barrel of cannula; (e) intestinal cannula; (f) cannula support boot.

the cannula to mechanical disturbance in the normal activity of the animal (Ash, 1962; Brown *et al.*, 1968). For these and other reasons, intestinally cannulated preparations generally require special handling facilities and special care, and they have a relatively short functional period (Phillipson, 1952; Ash, 1962; Brown *et al.*, 1968; Phillips *et al.*, 1978).

Ivan (1974) described an intestinal cannula preparation for pigs that functioned in much the same way as a reentrant cannula but required only a single modified T-shaped cannula. The cannula was designed to be fitted with a special collection plug that allowed simultaneous collection and addition, and another plug that allowed the digesta to pass straight through. Ivan (1977), using sheep, improved the cannulation further by suturing an arterial graft (polyester) around the outside of the intestine at the site of the cannula to prevent the intestine from stretching away from the cannula. Ivan and Johnston (1979) recently reported the development of a cannula with a built-in sampling and maintenance valve.

This report describes a rigid cannula made from Teflon fluorocarbon polymer and designed to minimize resistance to digesta flow, allow total collection of digesta, be relatively maintenance free, remain functional for long periods of time and be resistant to mechanical disturbances.

Materials and Methods

Intestinal Cannula. The intestinal cannula was made in the form of a T from a block of fluorocarbon polymer[3] (figure 1). Although three sizes of cannulas were made for each species, only the external diameter of the crosspiece of the T was varied. The variations were provided to allow for possible differences in the intestinal size, but little variation was encountered and only the intermediate size was used for each species. For steers, crosspiece external diameters of 27, 31 and 35 mm were made on 27-mm barrels. For sheep, the crosspiece external diameters were 16, 17 and 18 mm on 16-mm barrels. By maintaining the same internal diameter for the crosspiece and the barrel at their intersection, it was possible to make collection gates that totally sealed the passage and diverted the flow of digesta. An inner peritoneal ring (figure 1d) was made to press over the barrel of the cannula and snap into a specially machined groove. A ring of foamed poly(fluoroformal) was sutured to the outside edge of the ring. An outer support ring (figure 1c) was made to support the

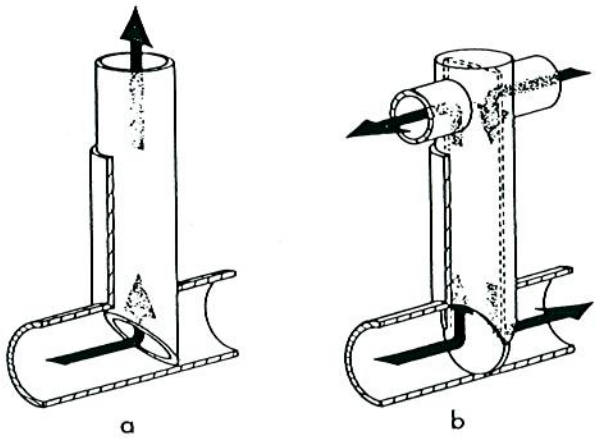


Figure 2. Cannula collection gates. (a) Total collection is accomplished by inserting a stainless steel tube (23 mm OD), with a carefully machined 45° angle, into the barrel of the cannula sealing the passage and completely diverting the flow. (b) Simultaneous collection and addition are accomplished with a collection gate with a dividing septum.

[3] Teflon, E. I. Du Pont de Nemours & Co., Wilmington, DE.

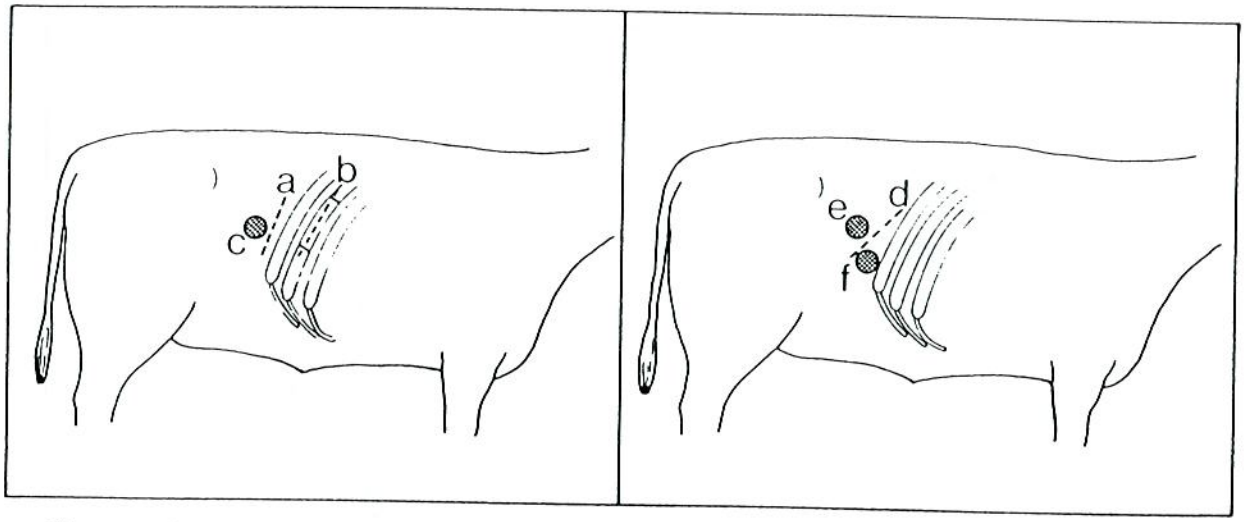


Figure 3. Sites of the (a) paracostal and (b) transcostal laparotomies and the (c) cannula esteriorization site used for single duodenal cannulations with steers, and the (d) paracostal laparotomy and the exteriorization sites for the (e) terminal ileal and (f) proximal duodenal cannulations.

cannula on the outside of the animal and was secured with a stainless steel retaining ring[4] (figure 1b). A support boot of foamed poly-(fluoroformal) was sutured around the outside of the intestine at the site of the cannula (figure 1f). The cannula was sealed with a special closure, or plug (figure 1a). The plug utilized a cam lever to compress and expand a cylindrical section of neoprene rubber and thereby seal the cannula.

For the collection of digesta, a collection gate was made from a stainless steel tube with an outside diameter that matched the inside diameter of the cannula barrel, with the end cut at an accurate 45° angle (figure 2a). The gate completely closed off the flow of digesta passing through the crosspiece and diverted it up the barrel to the collection vessel. For simultaneous collection and addition, a collection tube was designed with a central divider, or septum (figure 2b).

Surgery. Dorset-Hampshire crossbred sheep that weighed between 30 and 50 kg and Angus and Hereford steers that weighed about 200 kg were used. Both the sheep and the cattle were fasted for 24 hr before surgery. For some steers, xylazine[5] was used as a preanesthetic. Halothane was used to induce anesthesia in cattle and sheep since both tolerated the mask. When sufficient depth of anesthesia had been achieved with the mask, a cuffed endotracheal tube was inserted and anesthesia was maintained with halothane, by means of a closed-circuit inhalation anesthetic unit[6]. A specially designed, long-bladed laryngoscope was prepared to facilitate intubation of the steers.

Surgery was performed with the animals in the left lateral recumbency. The operating table was positioned to raise the thorax to a position above the head the abdomen (Komarek *et al.*, 1960; Hecker, 1974), and standard aseptic surgical procedures were used. Atropine was administered to inhibit salivation, improve respiration and inhibit the gastointestinal musculature. Either a paracostal (figure 3a) or a transcostal (figure 3b) laparotomy was used to gain entrance to the peritoneal cavity. Cannulas were placed in the proximal duodenum and, in some steers, both the proximal duodenum and terminal ileum.

The dual cannulation required a paracostal laparotomy angled posteriorly and ventrally to reach both the proximal duodenum and the terminal ileum with a single opening approach (figure 3c). The duodenal cannula was placed 4 to 6 cm from the pyloric sphincter, and the ileal cannula was placed about the same distance from the ileo-cecal junction. After the peritoneal cavity and exposed organs were packed off with sterile towels to prevent their contamination and the intestine was gently tied off with gauze, a longitudinal

[4] Truarch retaining ring No. 510C-106H Waldes Kohinoor, Inc., Long Island City, NY.
[5] Rompun, Haver-Lockhart, Shawnee, KS.
[6] VML-5 Fraser Sweatman, Inc., Lancaster, NY.

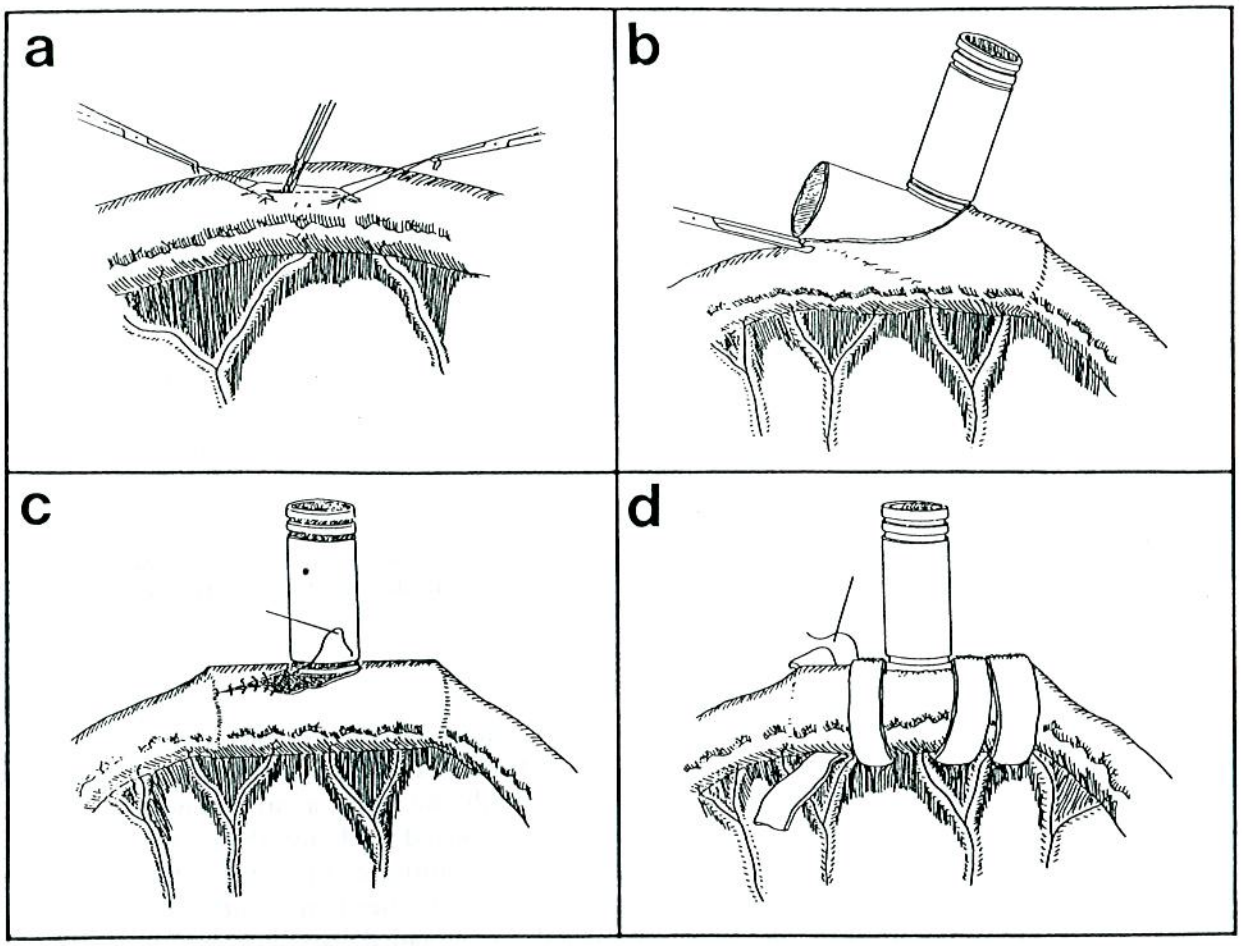


Figure 4. (a) A longitudinal intestinal incision is made by electrocautery for cannula introduction. (b) The cannula is inserted into the intestine with an Allis forceps, which stretches the intestine over the cannula. (c) A Connell intestinal suture is used to close the incision and is followed by purse-string sutures to invert the incision around the barrel of the cannula and form a tight fit. (d) The mesentery is parted for each segment of the boot brought around the intestine and sewn to the corresponding segment from the other side.

incision was made in the antimesenteric side of the intestine. Electrocautery was used to minimize hemorrhaging (figure 4a).

Digesta were removed by aspiration. The incision was only long enough to allow insertion of the cannula (figure 4b) and was closed with 00 chromic gut by a Connell intestinal suture (figure 4c). A Murphy purse-string suture (size 00 Vetafil)[7] was sewn in the intestine around the barrel of the cannula and pulled taut to invert the incision. A second purse-string suture was then sewn to complete the inversion. The mesentery was parted and the support boot slipped under the intestine at the site of the cannula. Instead of the usual single attachment, the mesentery was attached to the proximal duodenum and terminal ileum along two lines on each side of the intestine. The mesentery was parted in four nonvascular areas, and each of the four segments of the boot, four on each side, was brought through the mesentery, around the intestine and sutured together (figure 4d).

Next, the peritoneal ring was slipped over the barrel of the cannula and down into a specially machined groove (figure 5). The expansion of the hole in the ring was facilitated by four radial cuts 3 mm long, starting from the inner diameter of the Teflon inner segment. The insertion cone (Komarek, 1981) was then attached to the top of the barrel of the cannula (figure 5).

A small stab incision was made in the skin of sheep, and a circular skin incision was made in steers (a 17-mm circle of skin was removed)

[7] Vetafil Bengen imported by S. Jackson, Inc., Washington, DC.



Figure 5. Insertion cone is attached to the cannula after positioning of the peritoneal ring.

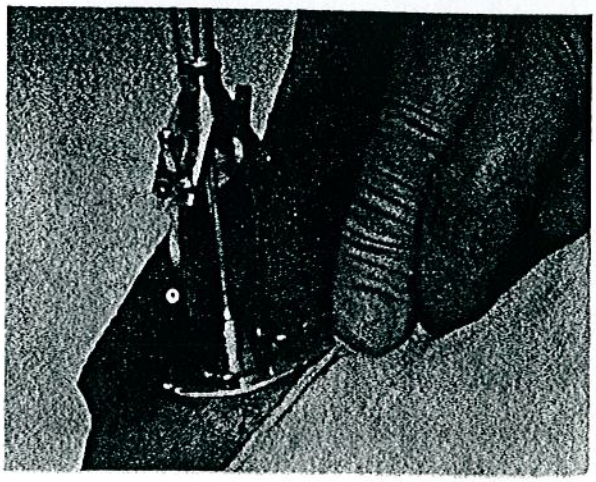


Figure 6. The skin is stretched over the cone by the force applied by the presser feet and calipers, together with the upward thrust of the drawing rod.

for the insertion of the cannula barrel. The sites of the incisions are illustrated in figure 3. A stab incision was then made through the muscle layers and peritoneum while the abdominal wall was lifted away from the visera. Before the scalpel was removed, the lower segment of the drawing rod from the insertion instrument was passed down alongside the scalpel into the peritoneal cavity. After the rod was attached to the cone on the inside and to the rest of the instrument on the outside of the animal, the cannula barrel was inserted into the abdominal wall (figure 6). The instrument stretched the skin and other tissues over the cone and onto the barrel of the cannula (Komarek, 1981).

The outer ring was then slipped over the top of the barrel and held in place with a retaining ring inserted into a groove machined in the top of the cannula (figures 7 and 8). The cannula was sealed with an expansion plug that filled the barrel of the cannula and eliminated dead space where digesta could lodge. The opening incision was then closed and the suture line treated with a mixture of penicillin and dehydrostreptomycin[8]. The antibiotic mixture was administered IM immediately after surgery (.050 ml/kg body weight) and daily (.025 ml/kg body weight) for 5 days thereafter. Feed and water were not restricted and were commonly consumed within 3 to 6 hr after surgery.

Results and Discussion

Five sheep and six steers were operated on and all were successfully cannulated. Two steers were cannulated in both the proximal duodenum and the terminal ileum. Recovery from surgery was rapid, and normal levels of dietary consumption were resumed within a week.

The cannula evidently offered little or no significant resistance to digesta flow as judged by consumption rates, lack of blockage and growth rates. No blockage was encountered with a wide variety of diets (diets included alfalfa hay, cottonseed hulls, corn silage and cracked corn plus urea and soybean meal protein supplements). Diet consumption levels of up to 10 kg dry matter/day were observed.

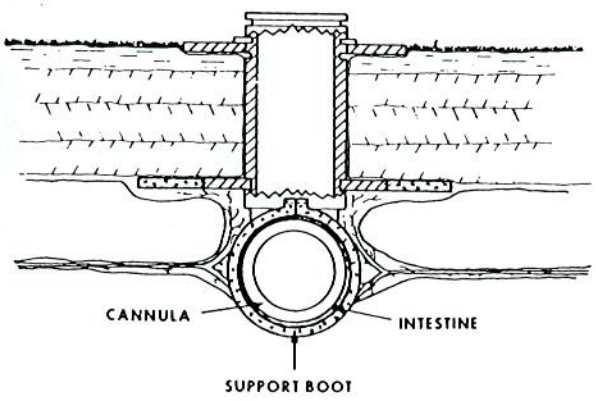


Figure 7. Side and cross-sectional views of the cannula healed in place in the animal, with the relative position of the cannula crosspiece, intestine and support boot shown.

[8] Combiotic, 200,000 units of procaine penicillin G and 250 mg dehydrostreptomycin/ml, Pfizer Inc., New York.

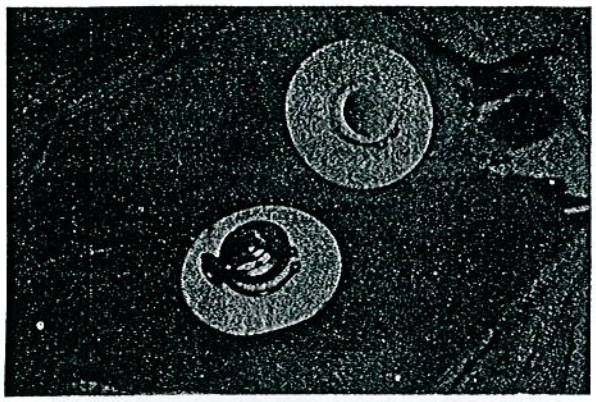


Figure 8. Proximal duodenal and terminal ileal cannulas in position before closing.

The cannulated animals grew rapidly (about 1.2 kg/day in some experiments) and compared favorable in feed consumption and size to noncannulated animals from the same group. The additional resistance to the flow of chyme imparted by two intestinal cannulas was apparently minor, because the dual-cannulated Angus steer was the most rapid-growing steer. One of the cannulated steers grew to four times his original size after cannulation.

In sheep, epithelization of the scar tissue around the neck or barrel of the cannula occurred rapidly, and little or no exudate was produced. No digesta leakage was noticed in either sheep or cattle over a 2-year period. In cattle, the epithelization process was much slower, and, for a period of about 1 year, a white exudate consisting chiefly of leucocytes (no infection was detected) was observed, after which it disappeared. An attempt to harden the scar tissue and stop the exudate by treating the area with a weak solution of formaldehyde was unsuccessful.

Access to the proximal duodenum was possible with both the paracostal and transcostal laparotomies, but with both approaches it was difficult to move the duodenum into a position in which cannulation was convenient. The terminal ileum was easily brought into the operating field for surgical manipulations.

The cannulation was designed to encourage adhesions and tissue infiltration in several important areas (figure 7). The intestinal support boot provided a structural base, after tissue infiltration, that did not allow the intestine to stretch away from the cannula and thus ensured total digesta flow through the lumen of the cannula. The peritoneal ring, with its semirigid Teflon center and foamed polymer outer ring (figure 7), broke the continuity of the tubular scar tissue that developed from the intestine to the outside of the animal. This barrier encouraged healing around the peritoneal ring, which prevented digesta leakage.

Autopsy of one steer 1 year after surgery indicated that the cannula was firmly healed in the abdominal wall and duodenum (figure 9). The poly(fluroformal) foam evidently had been absorbed and replaced by a line of fibrous tissue. The fibrous tissue had sufficient elasticity over a period of time to stretch away from the cannula and allow some bypass of digesta. This did not occur in most steers until 2 years after surgery. Presumably, a nonabsorbable support boot (made, for example, of polyester) would not be absorbed and would hold the intestine in position for even longer periods. One steer maintained digesta passage through the cannula for over 2¾ years after surgery, and, when the animal was sacrificed, the cannula was still functional (figure 10).

The cannula insertion device described in the preceding article (Komarek, 1981) saved considerable time during surgery and produced a tightly fitting cannulated preparation. The size of the circular incision in the skin was chosen so that the cone would stretch the skin to its limits without tearing the skin. This contributed to the leak-free performance of the cannula.

Only one cannula diameter was used for each species (17 mm OD for sheep and 31 mm OD for steers). Larger animals could obviously use larger cannulas, but the elasticity of the



Figure 9. The abomasum and proximal duodenum after autopsy, with the cannula embedded in the abdominal wall and the intestines and abomasum attached.

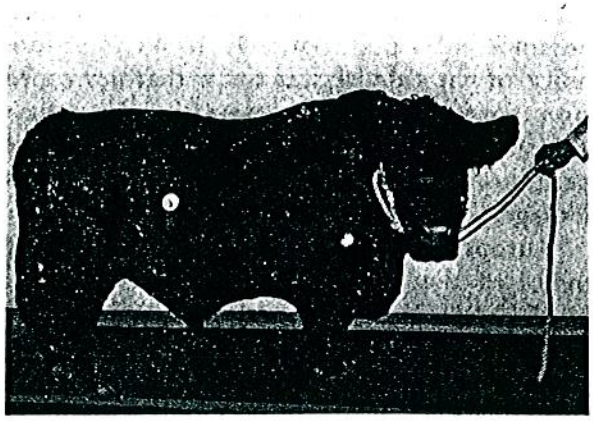


Figure 10. Angus steer, Chester, 2½ years after a proximal duodenal cannulation. He increased in size four times after the cannula was inserted, and the cannula remained completely functional.

intestine makes any one of a range of diameters suitable. The cannulas used in these operations generally stretched the intestines to about four-fifths of their capacity.

A major advantage of this cannula over the reentrant cannula was that it eliminated transection of the bowel and externalization of digesta flow. Wenham (1979) reported that the reentrant cannula caused gross abnormalities of propulsion and flow. Because of the transection, many peristaltic contractions terminated at the cannula. Digesta did not easily traverse the reentrant assembly and were commonly delayed or reversed. This is a particularly difficult problem when a reentrant cannula is placed in the terminal ileum (Easter and Tanksley, 1973), where digesta with a higher portion of solids must pass through the device. MacRae and Wilson (1977) found that the reentrant cannula affected digestive efficiency and resulted in reduced wool growth rates. Another major disadvantage of externalizing digesta flow is the vulnerability of the external connecting tubing and the problem of dehydration if the tubing is accidentally disconnected (Ash, 1962).

The cannula discussed in this paper has other advantages over the reentrant cannula. It has a relatively simple tubular design and is easily machined. It is fabricated from a tissue-inert fluorocarbon polymer that is rigid enough to allow the use of an expandable plug with a close-fitting external profile not subject to mechanical disturbances (the animal could regularly lie on the cannula without disturbing it). In the trials reported herein, the cannulas did not leak any digesta and had a long functional life. The cannulas provided convenient collection of digesta: total digesta collections were accomplished simply by inserting the collection gate.

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