A SILICONE ESOPHAGEAL CANNULA; ITS SURGICAL INSTALLATION AND USE IN RESEARCH WITH GRAZING CATTLE, SHEEP OR GOATS

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Summary

Esophageal cannulae were constructed of silicone and steel to provide soft flexible surfaces in the lumen of the esophagus of cattle, sheep or goats. Removable and embedded stainless steel braces provided strategic rigidity to the cannula in situ and allowed the cannula to be rapidly disassembled or assembled for removal or insertion into the fistula. Surgical procedures for establishment and postoperative care of fistulae in cattle and sheep are described. Results of eight grazing experiments with tame pastures indicate that these cannulae, together with rumen cannulae, did not alter output and composition of feces as compared with similar animals not cannulated.

(Key Words: Esophageal Cannula, Esophageal Fistula, Intake, Digestibility.)

Introduction

Ruminants with esophageal fistulae provide valuable capabilities in grazing research (Corbett, 1978). A number of different closure devices and cannulae have been devised to maintain the fistula and allow for ease of sampling consumed forage (Torrell, 1954; McManus et al., 1962; Van Dyne and Torrell, 1964; Veteto et al., 1972; Breen and Hunter, 1976; Corbett, 1978). Such devices have generally been constructed of rigid materials that irritate the lumen of the esophagus and are relatively heavy. The present paper describes a lightweight esophageal cannula constructed primarily of silicone, outlines surgical procedures for establishing fistulae in cattle and sheep and provides data relating to its operation and valid use in grazing research.

Experimental Procedure

Cannulae. The current design of cannulae for cattle and for sheep or goats is pictured in figure 1. Both models are constructed of the same materials with only minor differences other than size. Each complete assembly consists of a silicone cannula, two L-shaped stainless steel braces, a closure plug fabricated from polycarbonate tubing with one end filled with an epoxy resin and a clamp to hold the parts together once assembled in the fistula.

The cannula was molded from a room temperature vulcanizing (RTV) two-part molding silicone (Dow-Corning RTV-J[5]) of high tear resistance (>16 kg/cm) and desired hardness (durometer 65, shore A). A reinforcing strip (2.5 x 2 cm) of fiberglass cloth was embedded into the silicone of the gutter of the cannula during molding and before vulcanizing. The silicone cured at room temperature in 24 h or at 100 C for 1 h before demolding.

The braces were cut from high tensile strength stainless steel (410), angles and curves pressed out and hardened by heating to 550 C and immediately quenching in oil. Stresses were then relieved by reheating to 600 C and surface oxidation products were removed by sand-blasting.

A closure plug (44 x 130 mm length for cattle and 25 mm OD x 95 mm long for sheep or goat models) was fabricated from 1 mm thick wall polycarbonate (Lexan[6]) tubing and closed with 2 mm of an epoxy resin[7] deposited

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[5] Available at Hisco, 3710 Dacoma St., Houston, TX 77092 or SSI, P.O. Box 50323, Tulsa, OK 74150.
[6] Trade name for polycarbonate.
[7] Epoxy Plastic Mastic #8088, Crown Industrial Products Co., Hebron, IL 60034.

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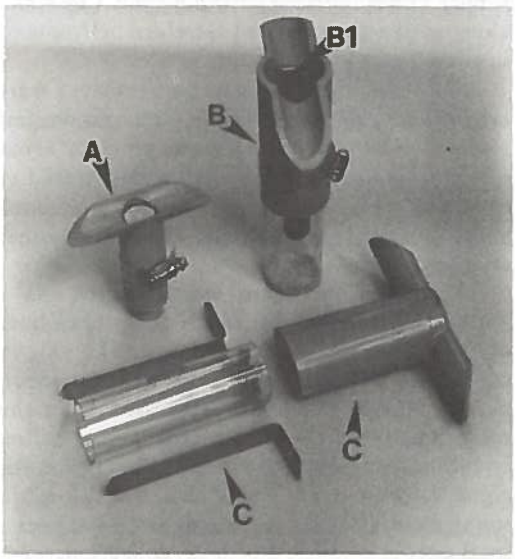

Figure 1. A. Silicone cannula for sheep or goats with closure plug in normal closed position. B. Cannula for cattle with closure plug in masticate collection position revealing steel braces in situ (B1). C. Cannula for cattle disassembled to show steel braces and closure plug.

in one end. This durable, lightweight closure plug closed the barrel of the cannula nearly flush with the lumen of the esophagus (figure 1), served also to properly align and restrain the two steel braces, and provided rigidity to the internal orifice of the cannula and its gutter.

The cannula assembly may be clamped with a stainless steel clamp (as for the larger cow model, figure 1) or with a solid plastic cable tie applied with an appropriate tensioning tool[8]. The cable tie has the advantage of a lower profile and presents less opportunity for being snagged.

Surgical Procedures in Cattle. Feed was withheld for 2 to 3 d and water for 12 to 18 h before surgery to minimize excessive regurgitation during surgery. Xylazine (Rompum[9]) was administered im at a dosage rate of .22 mg/kg. The animal was then restrained on a surgical table with the head slightly extended, and the table tilted at a 45 degree angle.

The surgical region was closely clipped with a no. 40 Oster clipper blade and scrubbed using either a hexachlorophene-based soap or iodine preparation. The esophageal cannula was immersed in benzalkonium chloride (Roccal[10]) for 24 h before surgery.

The surgical site was the left jugular furrow, just ventral to the jugular vein. A local anesthetic was injected sc around the site. A 25 to 30 cm incision was then made in the skin ventral to the jugular vein. The esophagus was exposed by blunt dissection and the jugular vein identified and reflected dorsally. A 20 to 25 cm blunt incision was made in the sternomastoideus muscle following the muscle fibers. The deep fascia was blunt dissected and the left carotid artery and esophagus identified. The esophagus was separated from the fascial attachments and exteriorized using sterile umbilical tape with attached forceps. A 5 to 7 cm incision was made in the esophagus, the cannula was inserted and an oversewing purse-string suture pattern was made using no. 1 chromic catgut. The incised esophagus was drawn around the cannula, sutures tied, the umbilical tape retainers removed and the esophagus returned to its natural position. A fixed dosage antibiotic (Penicillin, 200 mg/ml and Streptomycin, 250 mg/ml) preparation was used to flush the area of the incision site. The divided sections of the sternomastoideus muscle were brought back into apposition using interrupted catgut sutures. Elliptical sections of skin were removed on both sides of the incision so that the exteriorized cannula protruded and the skin incision did not fold up around the cannula. The skin incision was then closed with interrupted mattress sutures using a nonabsorbable material (Vetafil®).

Postoperative care included daily washing with water followed by 5% H_2O_2. Nitrofuran spray was then applied along with fly control. This postoperative procedure was followed for 7 to 10 d with appropriate systemic antibiotic therapy. The animals were not allowed any roughage for this period and were fed a pelleted diet to avoid regurgitation.

Surgical Procedure in Sheep and Goats. Surgical techniques for establishment of fistulae were a modification of the procedure described by Cook (1958). Approximately 2 wk before surgery, animals were adjusted to a pelleted

[8]Cole Palmer catalog no. K-6830-00; 7425 N. Oak Park Ave., Chicago IL 60648.

[9]Bayvet, a division of Cutter Laboratories. Cutter Animal Health, Bayvet Div. Mills Laboratories, Inc., Box 390 Shawnee, KS 66201.

[10]National Laboratories, a division of Sterling Drugs. Montvaile, NJ 07645.

diet. Feed and water were withheld for 24 h immediately before surgery. Each animal was tranquilized with xylazine[9] administered im at a dosage of .22 mg/kg. An injection of atropine (110 mg/100 kg body weight) was also administered to reduce excess salivation. The animal was placed on an operating table and restrained by confinement of all limbs. The surgical area was clipped and disinfected and the head slightly lowered to allow fluids to drain from the nose and mouth. A flexible tube (approximately 1.3 cm diameter) was passed through the mouth and approximately two-thirds of the way in the cardia. This was used to locate the esophagus and in making the skin incision and blunt dissection.

The initial skin incision (approximately 7.6 cm in length) was located as near as possible to the ventral midline of the neck and about midway between the jaw and shoulder. The esophagus was exposed by blunt dissection. An incision (approximately 1.3 cm in length) was made through the esophageal wall and into the lumen. Two forceps were clamped on the lateral sides of the esophagus at the point of the incision and the plastic hose removed. A "split-T" esophageal cannula similar to that reported by McManus et al. (1962) and Denney (1981), but molded of polyvinylchloride[11] (PVC), was used to stretch the incision by inserting the "gutters" of the two halves into the incision and then closing the two halves together to form the normal "T" position. This stretched the esophageal orifice to a diameter just sufficient to allow insertion of the silicone cannula into the lumen of the esophagus. The skin incision was closed with plain 00 surgical gut.

Animals were fed a pelleted diet for 1 wk post surgery and injected with 5 ml of the antibiotic mixture already described on alternate days. After 1 wk the animals were placed on pasture.

Grazing Trials. Eight grazing trials were conducted over a period of 3 yr and involved pastures of Coastal Bermuda [Cynodon dactylon (L.) Pers.; trials 1,2,3,5 and 6], Common Bermuda (Cynodon dactylon, trials 9 and 10) or oats (Avena sativa, trial 11). Cannulated Brahman x Jersey females were used with similar noncannulated cattle in trials 1 to 6 and along with noncannulated Hereford heifers used in trials 9 to 11.

Times of intense grazing activity were established by observation and esophageal samples collected during these times to avoid selective grazing induced by fasting (Arnold et al., 1969; Sidahmed et al., 1977). Fistulated animals grazed within sight contact of other animals.

Esophageal masticate was collected via a mesh bag attached to 20-cm long open-bore polycarbonate tubing that replaced the plug in the barrel of the cannula for the collection period. Excess saliva was expressed from the masticate, which was then frozen and subsequently freeze-dried for chemical analysis. All animals were penned and fed a daily grain supplement (1 kg/d) containing $Er_2(NO_3)_3$ as a fecal output marker, and fecal collections were made while penned during a 6 d period. In Exp. 9 to 11, the cannulated animals were fitted with a mesh bag for collection of masticate during the .5 to 1.5 h after fecal collections. In Exp. 1 to 6, the cannulated animals were tethered for 2 d successively at each of three pasture sites in which grazing activity by the herd had been observed. The tethered animals were fed their grain supplement at this site at the same time as the penned noncannulated animals. Fecal samples were collected when the tethered animals were fed and bags were attached for collection of esophageal masticate.

The freeze-dried esophageal masticate was ground to pass a 1 mm sieve and subsequently analyzed for indigestible neutral detergent fiber (INDF). The INDF was analytically defined as the organic matter insoluble in the neutral detergent solvent after a 6 d in vitro fermentation by a modification of the procedure of Goering and Van Soest (1970). The concentration of INDF was expressed as a fraction of the organic matter (OM) of the masticate. This same method was used to determine INDF of dried (60 C) and ground fecal samples. Digestibility of organic matter (OMD) was calculated as:

$$OMD = 1 - \frac{\text{INDF, \% of esophageal masticate OM}}{\text{INDF, \% of fecal sample OM}}.$$

Estimates of daily fecal output (FO) were computed based on the daily dose of Er consumed and the concentration of ER in the fecal

[11] Plastisol CPD – 6104, GS Plastics Co., 5201 Grand Ave., Cleveland, OH 44125.

sample collected at that time (Pond and Ellis, 1981):

$$\text{FO, g OM /d} = \frac{\text{dose Er, g/d}}{\text{g Er/g fecal OM}}.$$

The Er content of fecal samples was determined by atomic absorption spectrophotometry using the 3 M HNO_3 leachate of the dry ash resulting from ashing at 500 C (Ellis et al., 1982).

Results and Discussion

Cattle. The present design was evolved (a) to be lightweight yet capable of closing a 5 cm fistula, (b) to have gutters with flexible edges and tips to minimize irritation to the esophagus, (c) to be strategically rigid for dependable retention in situ under extensive pasture and range conditions, but sufficiently flexible for easy field removal and reinsertion and (d) to provide for collection of extrusa without removal of the cannula.

The present cannula was surgically implanted in 16 Brahman x Jersey heifers (weighing 150 to 200 kg) over a 2 yr period. An annular fibrous ring developed cranially from the cannula in one calf. Food pockets developed sc during the first 2 wk in several animals. This latter problem was contained by continual clearing and flushing until the area closed by second intention healing. All other animals adapted to the cannulae during the subsequent 3 to 4 mo period during which they grazed cool season annual grasses such as small grains, ryegrass or warm season perennial grasses such as Bermuda grass. Difficulty in swallowing was observed in certain animals 3 to 4 mo post-surgery when all animals grazed more mature forages. In comparison with cannulae molded of PVC (McGilliard, 1982), the lighter silicone cannulae alleviated this problem in cattle and sheep.

Approximately 25% of the cattle failed to adapt to the present cannulae when grazing mature grasses for 2 to 4 mo and were eliminated. Animals that did not have blockage problems during this period rarely (1 of 12) had blockage problems during their subsequent 4 yr of use. This suggested the surgical position of the fistula was the primary cause of such blockage. However, more favorable locations have not been identified.

The 12 animals that survived their first season of grazing winter dormant pasture have, with the one exception, had no trouble consuming coarse chopped (5 cm length chop) corn silage or unchopped sorghum fodder. In the case of the corn silage, cob fragments as large as 3.5 x 3.5 cm and stalk fragments as large as 2.5 x 7 cm have been found in the masticate recovered from the esophageal fistula.

Results of eight grazing trials are summarized in table 1. An analysis of variance indicated no difference (P=.70) in chemical composition of masticate due to animal, tethering site or days in tethering site. The lack of a significant effect due to day in site indicated the quantity of forage within the tethered area was sufficient to avoid changes in diet composition due to selective grazing. The lack of significant differences in composition of diet selected among animals and pasture sites increases confidence that the diet of the cannulated animals represents the diet selected by other animals grazing within the same pasture.

The chemical composition of the feces and fecal output did not differ significantly (P=.40) between cannulated and noncannulated animals indicating the diets of these animals were qualitatively and quantitatively similar. The lack of significant difference in fecal output by cannulated and noncannulated animals provides evidence that the cannulation procedure did not impair forage intake.

Sheep and Goats. It was preferable to allow a 1 to 2 wk recovery period after surgery before collection of diets. All eight Angora goats adjusted quickly to the silicone cannulae and required a minimum amount of care for approximately 8 mo.

The fistulation and cannulae were not as successful in sheep as in goats. Pressure necrosis developed within 3 wk after the surgery. Generally, sheep and goats have had more problems associated with esophageal cannulation than cattle. This may be the result of less musculature around the esophagi of goats and sheep as compared with cattle. It was not uncommon for the entire cannula to be expelled from the esophagi of the sheep and goats. This problem was less with the silicone cannulae as compared with the more rigid cannulae made from PVC pipe (Taylor and Bryant, 1977). The silicone cannula was more flexible than plastic pipe and appeared to allow for greater movement of the striated muscles in the esophagus.

TABLE 1. OUTPUT AND INDIGESTIBLE FIBER (INDF) CONTENT OF FECES FROM ESOPHAGEAL AND RUMEN CANNULATED (CANN.) AS COMPARED WITH NONCANNULATED HEIFERS

Trial no.	No. of animals		Fecal output			INDF in feces			INDF	
	Cann.	Noncann.	Cann.	Noncann.	SE[a]	Cann.	Noncann.	SE	Esop.[b]	OMD[c]
			kg OM·100 kg BW^{-1} · d^{-1}			% of OM				
1	3	6	1.04	1.08	.11	65.4	64.7	1.0	30.7	53.1
2	3	8	.79	.89	.05	70.7	69.9	.8	30.7	56.6
3	6	10	.70	.77	.08	78.3	77.1	.6	49.2	37.2
5	4	15	.88	1.10	.18	74.3	73.5	1.3	35.9	51.7
6	7	12	1.14	1.09	.15	60.9	61.8	1.2	32.3	47.0
9	6	30	—NC[d]—			80.3	81.5	.7	30.1	62.5
10	6	30	—NC[d]—			85.0	86.1	.8	50.1	41.1
11	6	30	—NC[d]—			57.0	60.1	1.1	20.7	73.7

[a]SE = standard error of mean.

[b]Composition of extrusa from esophageal cannula.

[c]OMD = organic matter digestibility; computed from INDF content of esophageal extrusa and feces of cannulated animals.

[d]Not comparable groups of cattle; cannulated cattle were mature Brahman X Jersey, while noncannulated cattle were Angus and Hereford heifers 8 to 14 mo of age.

Compaction was a greater problem when animals were forced to consume coarse mature forage. Also, certain plant species cause more problems than others. Sacahuista (Nolina texana) and prickly pear (Opuntia macrorhiza) are examples of fibrous plants that readily caused compaction of ingesta around the cannula.

The silicone cannula appeared to allow a more complete ingesta recovery during collection periods and optimal functioning of the esophagus.

Collection Apparatus. Alternative collection methods have been used, depending upon the heterogeneity of the forage to be sampled, the size of particles in the masticate and the need to collect the associated saliva. On pure stand swards, collection of small samples (30 to 50 g DM) of masticate was made from the barrel of the in situ cannula for convenience. If total masticate plus accompanying saliva was to be collected (Acosta and Kothmann, 1978), a plastic bag replaced the mesh bag. Alternatively, the closure plug of polycarbonate tubing was reversed and served as a collection vessel. If more volume was required, a longer length of plugged tubing was used.

If the vegetation was heterogeneous or if considerable variety due to selective grazing was anticipated, a larger sample was collected. For this purpose an appropriate collection bag was attached to the animal's neck.

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