Introduction

There are numerous reasons for research scientists expending the substantial effort required surgically to establish and maintain permanent digestive cannulae in experimental animals. The overall objectives are to obtain information concerning the function and response of the digestive system to different conditions. The ultimate aim in such experiments is to utilize the knowledge gained to increase production of the milking cow. Except in unique situations these data are applied to “normal” conscious animals. The confidence in interpretation of these data and in their extrapolation to applied situations will be greatly facilitated if the data are from subjects whose condition is as close to the physiological norm as possible. This requirement alone implies that acute experiments on whole animals or in vitro experiments on isolated animal tissues can present problems in the application of results to field conditions. For example, general anesthetics produce profound changes in such physiological parameters as blood flow, motility of the digestive tract, and activity of various endocrine and exocrine glands. All of these functions profoundly affect performance of the digestive tract. Furthermore, it is extremely difficult to reproduce adequately these conditions under in vitro situations. This is not to say that acute and in vitro experiments are not extremely valuable. In many instances they allow the collection of data which is impossible with conscious animals. However, in studying various functions of the digestive tract, it is essential that all data collected on acute preparations or from in vitro experiments be tested on “normal” conscious animals.

Historical

The first recorded use of a fistula in the digestive tract was, interestingly enough, in man. This was the now famous case of Alexis St. Martin, a Canadian voyageur, who received a shotgun wound which left a fistulous opening into the stomach after the wound healed (13). Between 1825 and 1833, Dr. W. Beaumont, a U.S. army surgeon, observed the secretion of gastric juices, status of the empty stomach, gastric motility, and rate of gastric emptying through Mr. St. Martin’s fistula. The first gastric fistula produced experimentally was by Bassow in dogs in 1842, (13). These experiments were expanded and improved upon by the outstanding work of Pavlov in the mid 1800’s. The first use of gastric fistulas in ruminants was by Colin (4) in the latter part of the 19th century. Significant contributions to understanding the physiological function of the rumen by various fistulation techniques have been made by numerous investigators (2, 3, 5, 7, 8, 11, 14).

Schalk and Amadon (12) published a monograph of their research into rumen physiology using rumen fistulae in calves and mature dairy cattle. The results of these classical investigations into the physiology of the rumen laid the ground work for investigations by others to follow with more satisfactory types of fistulas and fistula plugs.

Between 1928 and 1971 there have been innumerable refinements in gastric fistulation techniques and particularly in various types of cannulae or fistula plugs. A review of the advantages and disadvantages of many of these techniques is in a publication of Mendel (9).

Cannulas

The objective of techniques for preparing animals with permanent digestive cannulas is to achieve minimal disturbance in the physiological functions of the animal. This requirement stipulates that discomfort to the animal due to the fistula should be reduced to an absolute minimum, both for humane reasons and to ensure the validity of the resulting data. This factor is of prime importance in selection of the material for construction of the cannula or fistula plug. The material must be pliable yet resilient and strong enough to seal the fistula to reduce leakage of the digestive tract contents, to maintain anaerobic conditions within the gastrointestinal tract, and to withstand the abuse which is inevitable in work
with unrestrained, conscious animals. Many people have attempted to use rubber products to achieve these objectives.

**Pneumatic fistula.** An example of this approach is a pneumatic rumen fistula plug for closing large diameter rumen fistulas in cattle (9). This fistula plug was constructed of natural gum rubber with a sophisticated stainless steel mold. Uncured gum rubber was placed in the stainless steel mold; the mold then was bolted together to achieve the desired pressure and heated to a high temperature for several hours to cure the rubber. The resulting fistula plug was very flexible yet resilient enough to withstand the abuse encountered in conscious, unrestrained animals. This fistula plug could be inflated with air through a tire valve stem to prevent leakage of rumen contents from the fistula. This feature was extremely useful for studying bloat where high intrarumen pressures may occur.

The pneumatic fistula plug achieved great progress towards minimal animal discomfort and leakage, yet offered maximal user convenience. One of the drawbacks of this fistula plug was the expensive mold required for construction of the plug. This disadvantage was somewhat alleviated by changing the material for construction of the fistula plug from natural gum rubber to a chemical cure rubber product known as Compound 888, manufactured by Dunlop Rubber Co. Compound 888 can be cured by painting the surface of the uncured rubber with carbon bisulfide and allowing the rubber to cure. Compound 888 can be molded into different shapes simple molds constructed from wire screen and can be bonded to other rubber materials such as various types of commercially available rubber tubing. Compound 888 has been used in construction of large diameter rumen fistula plugs for sheep (18). This fistula plug was essentially the same as that constructed from natural gum rubber (9) except a complicated mold was not required during construction. Since only simple molds are required to work with compound 888, plug design can easily be modified to fit the particular requirements of the surgical preparation and the experiment.

**Modifications.** A modification of this rumen fistula plug was developed to eliminate the problem of irritation of the rumen fistula in experiments where frequent removal of the fistula plug is required. The center of the rumen fistula plug was left open and the sleeve of a rubber veterinary obstetrical glove was bonded into the center of the plug (6). This allowed access to the rumen through the sleeve of the obstetrical glove. To close the fistula a simple knot was tied in the sleeve of the obstetrical glove. One disadvantage of this type of fistula plug was its lack of durability. Therefore, if the fistula was not in use for extended periods, the regular fistula plug with the closed center was inserted into the rumen fistula.

Both the gum rubber and compound 888 rumen fistula plugs require a large diameter rumen fistula. Certain types of experiments may not require large diameter rumen fistulae in which case the Jarrett rumen cannula can be used (17). This cannula is constructed of rubber and has a 2.5 cm internal diameter.

The Jarrett cannula also can be used to close omasal fistula in sheep (15). The barrel of the Jarrett cannula was extended with compound 888 to make the cannula long enough to pass through the rib cage of the sheep into the omasum. This type of extension would probably allow the Jarrett cannula to be used as a rumen cannula in cattle as well. The Jarrett cannula can also be used to close abomasal fistulas in sheep (17).

Compound 888 also has been utilized in the construction of an esophageal cannula (18). This cannula was used for saliva collection and for temporary rumen isolation procedures in sheep (6). Esophageal cannulas of larger diameter have been constructed of stainless steel (20) and plastics (16). These esophageal cannulas were useful in collecting forage samples during grazing (1).

**Plastic materials.** Other types of materials have been used for the construction of cannula and fistula plugs. One of the more successful of these is a polyvinylchloride plastic called plastisol. A very useful gastro-intestinal re-entrant cannula was constructed from plastisol by Ash (1). This type of cannula exteriorizes the route of passage of the intestinal contents with a shunt constructed of plastisol. The shunt carries the intestinal contents outside the abdominal wall, through the plastisol cannula, back through the abdominal wall, and into the intestine. The cannula can be inserted into almost any area of the small intestine and allows sampling of the gut contents at the particular site of insertion.

Yarns and Putnam (10) utilized plastisol to construct a 9.4 cm diameter rumen cannula for cattle. Plastisol is light, flexible and durable. Cannulae are constructed by pouring the plastisol into a pre-heated mold, then curing
the plastisol by heating for several minutes in an oven.
Polyethylene has been used to construct various types of gastric cannulae. An example is a caecal cannula for use in pigs (10). Generally, polyethylene has the disadvantage of being less flexible than rubber or plastisol and more difficult to mold into smooth shapes. Polyethylene tubing can be inserted into various areas of the digestive tract and are useful for the injection of various substances into isolated areas of the gastrointestinal tract. However, it is extremely difficult to withdraw samples from the gastrointestinal tract through the tubing.

Metal cannulae. Stainless steel also has been used for various gastric cannulae. It has the disadvantage of being extremely expensive and completely inflexible. In addition, stainless steel is very heavy and may tend to distort and stretch the fistula leading to a variety of difficulties with the preparation.

These examples of different materials for the construction of digestive cannulas illustrate how the proper choice of materials and type of cannula or fistula plug can help produce a chronic animal preparation which will yield valid experimental data. Many other factors, beginning with proper surgical technique and ending with proper post-operative care, contribute to the success of the preparation. I have chosen to discuss the importance of cannulae construction but should stress that chronically prepared animals require constant care and attention to prevent such things as maggot infestation, ulceration of the fistula, and development of general systemic infection. A very valuable animal with an ideally functioning fistula can be completely lost by lack of postsurgical care. This factor alone points out very strongly that highly qualified personnel should care for animals with chronic fistulas in the digestive tract. This will increase the validity of the data and ensure an absolute minimum of discomfort to the animals.

References
(14) Stalfaro, H. 1926. Contributions to the knowledge of the physiology of the stomachs in ruminants. Archive fur Wissenschaftlich und Praktische Tierheilkunde, 54:519.