A Flexible Unkinkable Cannula and its Obstruction by Dicalcium Orthophosphate Concretions

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SUMMARY

Chronic cannulation of an abdominal viscus or pouch is aided by the use of a cannula which does not leak or kink. Existing cannulae have been modified to achieve this. An unusual complication was encountered in jejunal cannulae after 1 - 3 months; large concretions of dicalcium orthophosphate precipitated on the inner cannula flange, completely blocking the lumen. Concretions were derived from the food, precipitation being aided by physico-chemical factors in the jejunum.

S. Afr. Med. J., **48**, 1879 (1974).

Experimental cannulation of the small bowel may be complicated by leakage or obstruction. The former problem should be prevented by adequate surgical technique and the use of suitable cannulae, and the latter is relatively rare. In this paper, modifications of existing cannulae which help to prevent leakage and obstruction are described. Blockage of these cannulae by dicalcium orthophosphate concretions occurred in a particular experimental model, a complication which, to the best of our knowledge, has not been recorded previously.

MODIFICATIONS IN CANNULA DESIGN

The Gregory cannula has been used successfully for many years to obtain secretions from experimental animals.[1] An important principle is that the cannula does not rotate and permits sealing around the internal end. Leakage, however, does sometimes occur, and attempts have been made to modify the Gregory cannula to avoid this frustrating complication. Condon and Harkins[2] designed a cannula to prevent pressure necrosis of gastric pouches after having found that about 20% of previous cannulae leaked. This cannula transferred the weight of collected secretions from the sensitive gastric mucosa to the tough anterior abdominal wall. Itoh, Shinohara and Honda[3] modified the traditional Gregory cannula by introducing a flexible silicone rubber segment to the middle of the cannula. In this way they avoided disturbing the internal end of the cannula when the long exteriorised end was moved as a lever. The natural reaction of the tissues around the cannula was thus undisturbed. We have introduced a further modification when kinking of the silicone rubber tube poses a problem.

The cannula has features of all three types already described. The basic unit is a Gregory-type cannula with the internal part made of synthetic nylon (Polypenco Nylotron 66; Fluorocarbon Resins (Pty) Ltd, Cape Town), and the external part of stainless steel (Figs 1 and 2). A perforated washer is inserted between these two materials (equivalent to the Condon and Harkins modification); the perforations enable the washer to be sutured to the abdominal wall if desired. The acrylic resin shaft is interrupted by a flexible siliconised rubber segment. A single thickness of siliconised rubber was found to kink very easily and obstruct the cannula (Fig. 3). This difficulty was overcome by introducing a smaller segment of siliconised rubber inside the outer tube. The cannula was therefore still flexible, but did not kink and maintained a patent lumen. The length of the flexible segment was varied according to need, and the outer larger rubber segment tied over the synthetic nylon with non-absorbable suture material. This flexible segment can be introduced into an existing Gregory cannula by dividing the shaft near its internal end.

A bite block is fixed to the exterior of the cannula for the first postoperative week. A thread can be turned in the exterior end of the steel shaft so that the cannula can be sealed with a screw cap if necessary (e.g. for chronic fistulae of the small bowel).

PRESENTATION OF CONCRETIONS

Mongrel dogs were surgically prepared with 3 cannulae inserted into the jejunum (10, 20, and 50 cm distal to the duodenojejunal flexure) and 1 into the ileum (10 cm proximal to the ileocaecal valve). The dogs were given subcutaneous fluids for 3 days postoperatively, and then fed proprietary dog cubes containing protein (minimum) 20%; fat (minimum) 4%; fibre (maximum) 5%; calcium (maximum) 1,55%; phosphate (maximum) 1,3% (calcium: phosphate ratio 1:1); methionine 0,34%; sulphaminoacids 0,64%; lysine 1,0%; tryptophan 0,18%; arginine 1,2%; and salt 1,0%, with added fat and water-soluble vitamins

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Date received: 11 April 1974.
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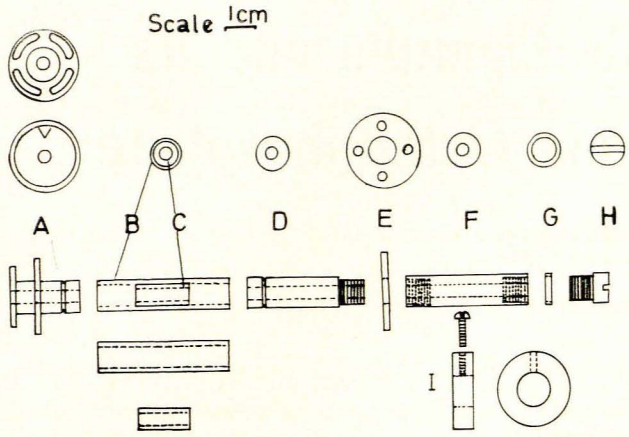

Fig. 1. Component parts of cannula: A — acrylic resin internal end; B — outer silicone rubber tube; C — inner silicone rubber tube; D — acrylic resin portion of shaft; E — perforated washer; F — stainless steel shaft; G — washer (acrylic resin); H — end screw; I — bite block.

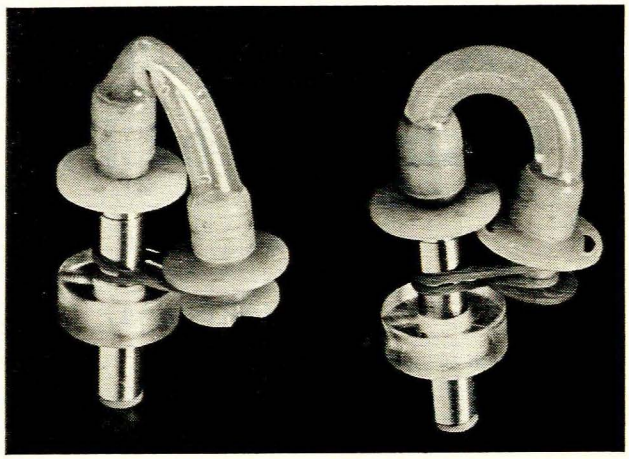

Fig. 3. Left: **Flexible part of cannula bent to show kinking found with single section siliconised rubber.** Right: **Flexible part of cannula bent but no kinking produced with double silicone rubber segment.**

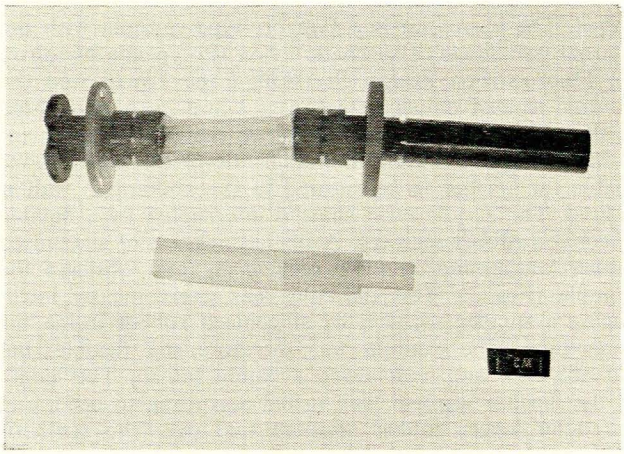

Fig. 2. Assembled cannula. Constituent parts of flexible segment are shown below cannula.

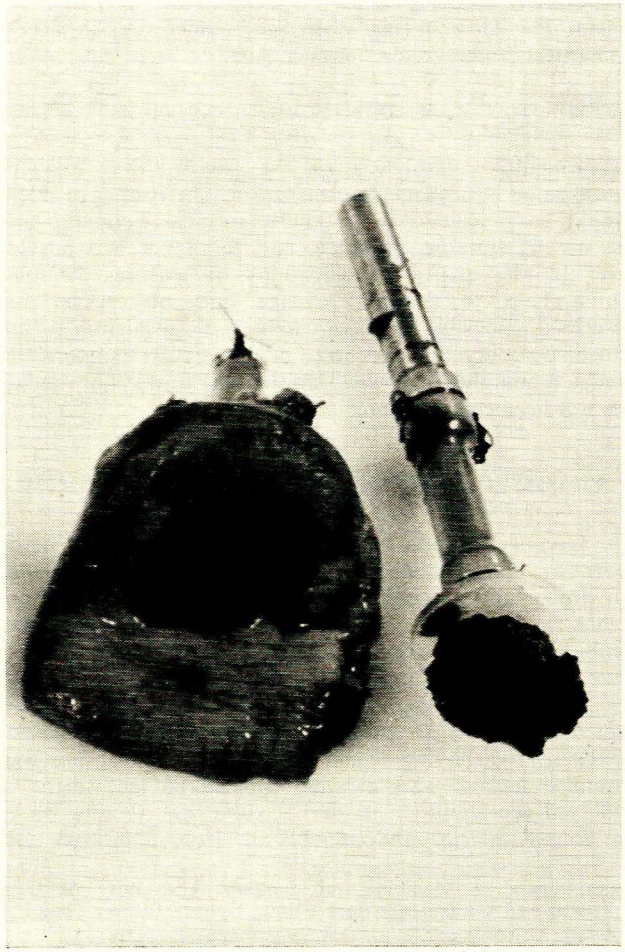

Fig. 4. Cannulae removed from experimental animal showing concretions obstructing opening into lumen. Part of the gut wall has been left around the cannula on the left.

and trace elements. Water was given *ad libitum*. Experiments began at least 2 weeks after surgery and consisted of perfusing an electrolyte solution isotonic to plasma (Na 140, K 5, Cl 110, and HCO_3 35 mEq/litre, and polyethylene glycol, molecular weight 4 000, 50 g/litre) into the most proximal cannula at 7 ml/min and withdrawing aliquots of secretions plus perfusate from the more distal cannulae. Each experiment lasted a maximum of 4 hours. Animals were fasted for 18 hours before each of the studies, which were not performed more frequently than once in 72 hours.

Between 4 and 12 weeks after surgery, difficulty was experienced in maintaining the patency of the 3 proximal cannulae in 2 dogs. Initially the lumen could be cleared by blowing water through the cannulae with a syringe, and later a soft plastic probe was sometimes successful in restoring patency. A gritty, granular material was usually recovered from the lumen. The ileal cannula was

not affected in either dog. Eventually all 3 jejunal cannulae became completely obstructed and the dogs were sacrificed.

At autopsy, large stony-hard, greeny-brown concretions were found firmly adherent to the synthetic nylon base of each jejunal cannula (Fig. 4). The concretions were 2 - 3 cm in diameter and 0,7-1 cm thick. Some were rounded and some slightly elliptical along the length of the bowel. The larger concretions almost obstructed the bowel lumen.

ANALYSIS OF CONCRETIONS

The concretions were analysed and their composition is given in Table I. Correcting for the presence of free moisture and proteinaceous matter, the results calculated in respect of the phosphate of calcium, which was the most significant inorganic component, were calcium 23,31%, ash 72,72% and phosphorus 18,54%. The molar proportion Ca : P or Ca : PO_4 was approximately 1,0. Theoretically considering dicalcium orthophosphate ($CaHPO_4.2H_2O$) which changes to calcium pyrophosphate upon ashing ($2CaHPO_4.2H_2O \longrightarrow Ca_2P_2O_7 + 5H_2O$), the analysis of the dicalcium orthophosphate was as follows:

	Calculated %	*Found* %
Ca	23,28	23,31
P	18,02	18,54
Ash	73,84	72,72

It was therefore apparent that the concretions were essentially dicalcium orthophosphate with a small amount of proteinaceous matter and free moisture. This compound was present in the feed and was found to be soluble in acidic solution, to have a very low solubility in neutral solution, and to be almost insoluble in alkaline solution.

TABLE I. COMPOSITION OF CONCRETIONS

Moisture content	**2,06%**	**(mass/mass)**
Ash content	**69,90%**	
Phosphorus content	**17,82%**	**(54,58% as PO_4)**
Calcium content	**22,40%**	**(31,34% as CaO)**
Nitrogen content	**0,24%**	**(equivalent to 1,84% protein)**

DISCUSSION

Modification of the existing forms of cannulae have minimised a previously high incidence of leaks at the site of entry into a viscus or pouch. Obstruction as a result of kinking of the flexible segment has been eliminated. However, in the particular model described above, precipitation of dicalcium orthophosphate on the inner flange of the cannula led to intractable blocking.

It is suggested that if the jejunal pH were greater than 7,0, any dicalcium orthophosphate present in that part of the bowel would be precipitated, and that any foreign material would be a possible site for collection of the seeded precipitate. Although the synthetic nylon of the type used in this cannula is virtually inert, the very small charge present[4] and its action as a foreign body would act as a focus for the deposition of the concretion. We have noticed a fine precipitate on the steel cannulae previously used in our laboratory; this, together with the rarity of the complication, would suggest that composition of the cannula is not the most important factor in the deposition of this material.

Other variables that predispose to concretion formation could be: (*a*) food composition—an excess of calcium phosphate in the diet might raise the salt concentration above the critical level for solubility; (*b*) dehydration—if the animals have insufficient oral fluid intake, similar results may occur; (*c*) jejunal pH—this is usually between 6 and 7,[5,6] but in conditions where acid is continuously diverted to the exterior (e.g. chronic gastric fistula studies), the small bowel pH may rise and render the dicalcium orthophosphate insoluble. Similarly, perfusion of alkaline solutions into the upper small bowel for prolonged periods may have the same result. It is not known which factor was applicable to our 2 dogs.

The total absence of concretions in the ileum is of interest, since this would appear to be a likely site of occurrence due to the alkaline pH of 7 - 8 normally present at this site.[5,6] It is likely that most of the salt had been absorbed or precipitated in the proximal bowel, leaving little or none for precipitation on the ileal cannula.

Similarly, concretions have never occurred in Thiry-Vella loops of small bowel (jejunum and ileum) or in gastric pouches, and the continued use of these cannulae in these sites is fully justified. It is concluded that the deposition of dicalcium orthophosphate is determined by dietary constituents and the particular physicochemical factors present in the proximal small bowel.

We wish to thank Mr D. Stewart, of the Department of Bioengineering, Groote Schuur Hospital, who constructed the cannulae, and Mr N. Greenblau, of Consulting Testing Laboratories, Cape Town, who analysed the concretions. Financial assistance was provided by the South African Medical Research Council and by a grant from the University of Cape Town Staff Research.

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