Aseptic Colon Resection by an Invagination Technique

Experimental Study on Dogs

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A new aseptic colon resection by an invagination technique is presented. The bowel to be resected is invaginated down into the healthy intestine, and the anastomosis is sutured in one layer of continuous suture before transection by a diathermy wire, placed in the intestinal lumen via the anus. Sections of bowel that cannot be invaginated, *e.g.*, because of a tumor, are first removed by transection between pairs of cable ties, which close the lumen. Twenty dogs were operated on without receiving prophylactic antibiotics. In 10, the intestine was transected between cable ties. An imprint, taken from the anastomosis and subcutis, was cultured. The bacterial count at the anastomosis exceeded 100 in only three cases; in the subcutis, this was the case in one dog. One wound infection developed. Serial barium enemas at 1, 2, 3, and 4 weeks revealed no anastomotic leakage. One early death because of a total anastomotic dehiscence was encountered, and two dogs were killed because of wound dehiscence and anastomotic stricture, respectively. It is concluded that, in dogs, the method is easily and safely performed, but further experimental studies are needed. [Key words: Aseptic colon resection; Colon; Dog; Technique]

Jørgensen LS, Raundahl U, Knudsen LL, Aksglæde K, Søgaard P. Aseptic colon resection by an invagination technique: experimental study on dogs. Dis Colon Rectum 1991;34:594–599.

Conventional techniques for colon resection require an opening to the lumen and thus carry a great risk of bacterial contamination, even when all possible precautions are directed against this. After introduction of prophylactic antibiotics, the infectious complications in connection with colon resection have decreased from 45–51 percent[1,2] to 5–10 percent.[3-7] However, the use of antibiotics may be complicated by anaphylactic reactions and development of resistance. Besides, the costs are not negligible.

To abolish the need for prophylactic antibiotics in connection with resection of the large bowel, we have developed a new aseptic technique which, at the same time, simplifies performance of the anastomosis. The colon segment to be resected is invaginated down into the healthy intestine, and the anastomosis is sutured in one seromuscular layer of continuous absorbable suture. Then, the invaginated intestine is detached by activating a diathermy wire which is advanced through the intestine via the anus and placed around the invaginated intestine close to the anastomosis.

Figure 1 details the technique. An instrument consisting of a modified diathermy wire and a pull-out device is positioned in the intestine. The pull-out device is fixed to the middle of the segment with a ligature (Fig. 1B), and the bowel is invaginated down through the diathermy wire by traction on the pull-out device (Fig. 1C), which is supported by a stiffening cable.

If a tumor obstructs the lumen, thus preventing the bowel from being invaginated (Fig. 1D), this piece of intestine must be removed before the invagination can take place. If two plastic cable ties (Panduit®; Panduit Corp., Tinley Park, IL) are placed on each margin of the tumor occluding the lumen before division, flush with the cable ties, no contamination should occur (Fig. 1E). The two closed ends of intestine can then be united, *e.g.*, with a ligature (Fig. 1F), and the pull-out device fixed to the bowel, followed by invagination through the modified diathermy wire (Fig. 1G).

After having placed stay sutures at the mesenteric and antimesenteric borders, the anastomosis is su-

This study was supported with grants from Fonden til Laegevidenskabens Fremme, Kraeftens Bekaempelse, Sygekassernes Helsefond, and Aarhus Universitets Forskningsfond.
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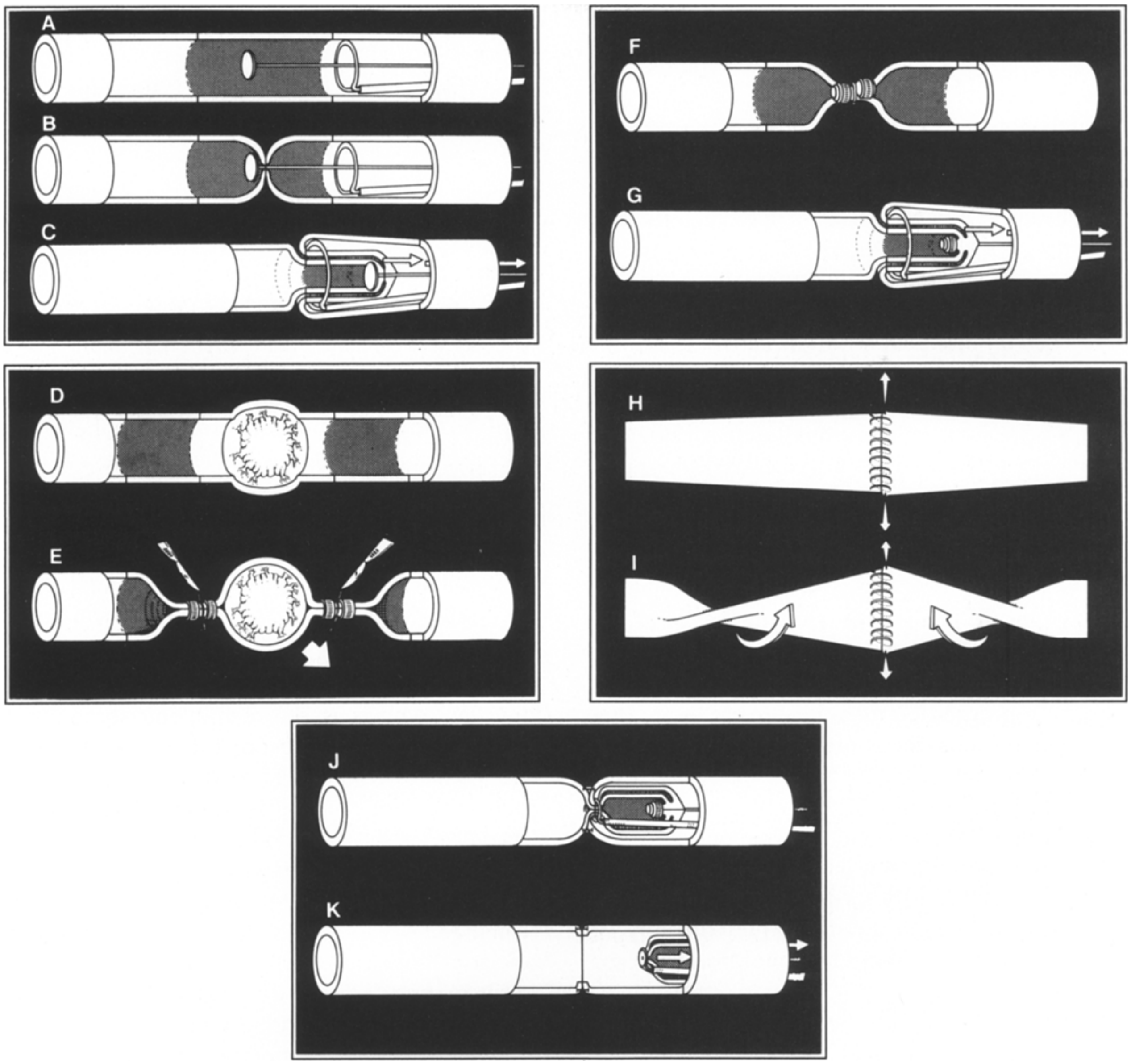

Figure 1. A to C. Aseptic resection of a segment of colon which can be invaginated. The instrument is positioned at the resection site (hatched area to be resected), and the pull-out device is ligated to the middle of the segment. By traction, the intestine is invaginated down through the modified diathermy wire. D and E. A tumor-infiltrated intestine cannot be invaginated but is removed after occluding the lumen on each side with cable ties. F and G. The two occluded ends are united with a ligature, and, after positioning of the pull-out device, the invagination is performed. H and I. Anterior row of a continuous seromuscular suture is performed after two stay sutures have been placed. The intestine is turned, and the posterior row is placed. J and K. The invaginated intestine is liberated by activating the diathermy, and it can be pulled out through the anus by traction on the pull-out device.

tured starting at the mesenteric border and progressing toward the antimesenteric stay suture (Fig. 1H). The intestine is turned (Fig. 1I), and the second side of the anastomosis is sutured. Then, the invaginated bowel is liberated by activating the diathermy, and it can be pulled out via the anus (Fig. 1J and K).

The aim of the present study was to investigate whether the method is technically practicable, whether it is truly aseptic, with and without transectioning of the bowel between cable ties, and whether complications such as infections and anastomotic complications occur within the 1st month after surgery.

MATERIALS AND METHODS

Twenty Labrador dogs, aged 4–15 months (median, 8 months), were divided into two groups of 10 each. In the first group, the intestine was not transected before suturing the anastomosis (Fig. 1A–C). In the second group, the bowel was transected between a pair of cable ties and secured with the Panduit® GS2B installation tool before invagination. The ends were then united with a ligature (Fig. 1F), and the pull-out device was fixed to the bowel, which was then invaginated through the modified diathermy wire (Fig. 1G). From this point, the operation was identical in the two groups, with suturing of the anastomosis using one layer of seromuscular continuous atraumatic Dexon 3-0 suture, followed by division of the intestine by the diathermy wire (Fig. 1H–K).

The diathermy instrument was specially designed and gradually improved until the final design at Operation 14 (Dog 18). An Aesculap® tm 400 surgical unit (Aesculap-Werke AG, Tuttlingen, Germany) served as the power supply.

Surgical preparation included a clear liquid diet for 24 hours and a bowel preparation consisting of two bisacodyl tablets in the morning and afternoon the day before surgery, followed by two bisacodyl suppositories 2–3 hours before surgery.

No antibiotics were given before or after surgery. Using general anesthesia the dogs were operated on through a midline incision. Approximately 10 cm of the distal part of the left colon was resected in both groups.

It was noted whether the emptying of the left colon was good or bad, and, just before closing the peritoneum, an imprint was taken by applying a strip of sterile blotting paper (Whatman® No. 1, 1.3 × 5.5 cm; Whatman, Maidstone, United Kingdom) to the anastomosis. The strip covered approximately half the circumference. The imprint was transferred to a 5 percent horse blood agar plate and an anaerobic agar plate. Cultivation was done at 35°C in 5 percent CO_2 and anaerobic atmosphere, respectively. A similar imprint was made from the subcutis.

The wound was closed with a continuous Dexon 1-0 suture in the fascial layer, continuous monofile nylon 3-0 in the subcutis, and nylon 3-0 knots in the skin. No wound dressing was applied.

One, two, three, and four weeks after surgery, a barium enema under fluoroscopic control was performed under methohexital anesthesia. Two bisacodyl suppositories were given beforehand. Immediately after the last barium enema, the animals were killed and a postmortem examination was done with reference to adhesions and signs of intraperitoneal abscess.

RESULTS

Tables 1 and 2 show results of the cultures from the anastomosis and subcutis in Groups 1 and 2, respectively. In the majority of cases, there were no or only a few bacteria. The bacterial count at the anastomosis exceeded 100 in only three cases (Dogs 6, 8, and 15). In Dog 15 it was related to some technical problems during the operation, with a gap in the anastomosis which was eventually closed. In only one case did the bacterial count in the subcutis exceed 100. This was also in a case (Dog 12) with an accidental, small leakage which was eventually closed. Three cases (Dogs 12, 15, and 17) had such accidental, minimal openings to the lumen of the bowel.

The complications are detailed in Table 3. The dogs with wound dehiscence and stenosis were killed, and the one with anastomotic dehiscence was found dead.

Barium Enema

No leakage was encountered, and the four examinations showed good passage of contrast through the anastomosis in all but five cases. These were as follows.

Dog 8. The anastomosis could not be visualized because of feces at the third and fourth examinations. The stools were normal from 5 days after surgery, and the autopsy after 4 weeks revealed an anastomosis which allowed passage of a thumb.

Dog 13. None of the examinations was sufficient because of feces. Normal stools were passed from the day after surgery, and an anastomosis which allowed passage of an index finger was found at autopsy.

Dog 16. There was no passage of contrast at either of the two examinations. Normal stools were passed 3 days after surgery, but, after 6–7 days, they became scarce and watery. At autopsy 14 days after surgery, the stenosis was confirmed.

Dogs 19 and 23. There was insufficient bowel emptying at the second examination (Dog 19) and first and second examinations (Dog 23). The dogs had normal stools from 2 to 3 days after surgery, and capacious anastomoses were found at autopsy.

Table 1.
Group 1: No Transection of Colon Before Performing Anastomosis*

No.	Bowel Emptying	Bacteriology Anastomosis		Bacteriology Subcutis	
5	Bad	Nonhemolytic streptococci	10	Nonhemolytic streptococci	1
		Escherichia coli	4		
7	Bad	*Staphylococcus aureus*	2	*Staphylococcus aureus*	6
		Hemolytic streptococci	1	*Pasteurella*	15
		Clostridia	2		
		Diphtheroids	1		
8	Good	Nonhemolytic streptococci	300	*Staphylococcus albus*	4
		Diphtheroids	200		
9	Good	Bacteroides	3	Nonhemolytic streptococci	1
10	Bad	Nonhemolytic streptococci	30		0
		Bacteroides	3		
		Diphtheroids	13		
		Clostridia	6		
12	Good	Bacteroides	6	*Enterococcus faecalis*	130
				Acinetobacter	2
				E. coli	11
15	Bad	*E. coli*	2	*E. coli*	1
		Bacteroides	Many†	Bacteroides	30
		Clostridia	Many†	Clostridia	30
				Nonhemolytic streptococci	1
18	Bad		0		0
20	Bad		0		0
22	Good	Bacillus	6		0

* Quality of bowel emptying and number of bacteria per imprint (approximately 7 cm^2) on the anastomosis and in the subcutis.

† Confluent growth.

Table 2.
Group 2: Transection of Colon Between Cable Ties Before Performing Anastomosis*

No.	Bowel Emptying	Bacteriology Anastomosis		Bacteriology Subcutis	
6	Good	Acinetobacter	8	*S. albus*	1
		Nonhemolytic streptococci	200		
		S. albus	4		
11	Good	*S. albus*	2		0
13	Good	*E. coli*	10	*E. coli*	1
		Bacteroides	20		
14	Good	*E. coli*	1		0
16	Good	Bacteroides	6		0
		E. coli	2		
17	Bad	*E. coli*	3	*E. coli*	2
		Bacteroides	20	Clostridia	10
19	Bad	*E. faecalis*	25	*E. faecalis*	3
		E. coli	32	*E. coli*	2
21	Good		0		0
23	Bad		0		0
24	Good	Nonhemolytic streptococci	5	*S. albus*	2
		Candida albicans	2	Anaerobic gram-positive rods	1

* Quality of bowel emptying and number of bacteria per imprint (approximately 7 cm^2) on the anastomosis and in the subcutis.

Table 3.
Complications

No.	Complication
6	Wound dehiscence with evisceration 7 days after surgery. Killed. Autopsy showed no signs of infection and no anastomotic leakage.
7	Wound abscess 5 days after surgery. Revision under general anesthesia and injection of 1 g of ampicillin in the wound. Specimen for culturing not collected.
11	Anastomotic dehiscence 2 days after surgery. Dead of peritonitis.
16	Stenosis of anastomosis. After 1 week with normal stools, signs of stricture developed. X-ray showed no passage through the anastomosis at 1 and 2 weeks. Dog was killed after 14 days. Autopsy showed a stenosis with dilatation proximal to the anastomosis. No adherences, abscess, or sign of leakage.
19	Two small 2-cm round elements at the edge of the wound. Incision under general anesthesia shows no pus, only a fleshy granulation tissue. *E. coli* and *S. aureus* were cultured from the elements.

Postmortem Examination

In the 17 surviving dogs, only slight omental adherences were seen in 14 cases. In two dogs, the anastomosis adhered to the small bowel and urinary bladder, but anastomotic leakage was not revealed on the four barium examinations. In one case, a missed towel was found encapsulated in omental and small bowel adherences, with no signs of anastomotic leakage and with four normal barium examinations.

DISCUSSION

The present study demonstrates that resection of dog colon by the invagination technique is possible. The invagination was easily performed with an instrument consisting of a pull-out device and a thin diathermy wire attached to a stiffening cable which keeps the thin wire in position. Before introduction of this instrument (from Operation 14), problems with controlling the position of the thin diathermy wire were embarrassing. The instrument can easily be felt through the intestinal wall, and endoscopic control of the procedure is unnecessary. Accidental burnings of healthy intestine were not encountered, and bleeding from the line of resection did not occur. A standard diathermy apparatus served as the power supply, and the intestine was easily transected with the modified diathermy wire.

A few bacteria were cultured from the anastomotic line in the majority of cases. In the nontransected-colon group, seven dogs had 10 or fewer bacteria. This was the case in six of the transected-colon dogs. More than 100 bacteria were encountered in only two nontransected-colon dogs and one transected-colon dog. After introduction of a simple instrument (from Operation 14), seven dogs were operated upon. From ⅔ of the dogs without transection of the intestine, no bacteria were cultured from either the anastomosis or the subcutis. In Group 2, the figure was ¾.

It should be emphasized that all animals received only a light bowel preparation and no antibiotics. In 9 of the 20 dogs, emptying of the bowel was insufficient as the bowel was filled with compact feces down to the anus. In spite of this, only one anastomotic leakage (a total dehiscence) and one wound abscess occurred. Both were in the early part of the series which started with Dog 5.

In humans, elective resection of the large bowel in the absence of prophylactic antibiotics results in infectious complications in 45–51 percent even when maximal efforts are carried out to empty the bowel mechanically,[1,2] but it can be reduced to 5–10 percent with an appropriate antibiotic prophylaxis directed against both aerobic and anaerobic microorganisms.[3–7]

Figures for the frequency of anastomotic leakage vary depending on whether or not barium enema is done as a routine. In the work by Goligher *et al.*,[8] who routinely studied the anastomoses clinically as well as by barium enema, a 67 percent leakage rate was found in anastomoses performed on unprepared bowel above the level of the pelvic peritoneal floor, *i.e.*, on peritoneum-covered bowel. With some kind of bowel preparation, with or without antibiotics, it was 26 percent. Clark *et al.*[9] compared the leakage frequency in large bowel anastomoses sewn with Dexon and catgut in the neomycin-prepared bowel and found an overall leakage rate of 39 percent on barium enema examination. When considering Dexon anastomoses on peritoneum-covered intestine, the leakage rate was 3/21 = 14 percent. In studies where x-ray is not done routinely, the leakage frequency is reported to be 5–30 percent,[2,3,6] but it includes low anterior resections which carry a higher risk of leakage because of the non-peritoneum-covered anastomosis.

Of course, our study on young healthy dogs cannot, without caution, be compared with these human studies. However, studies have been conducted with large bowel anastomoses in dogs. Oka *et al.*[10] made EEA anastomoses 13 cm from the anus on dogs that were restricted from solid food for two days and were given parenteral penicillin G and streptomycin for three days. A leakage rate on 19/34 (56 percent) was discovered, 14 of which were found on barium enema. Five of the 34 dogs died of peritonitis. The 13-cm distance from the anal verge corresponds with our experiments.

Aseptic resection of the large bowel has been attempted before, especially before the era of antibiotic prophylaxis,[11,12] but did not gain general popularity, probably because of technical problems. The method presented in this paper is easy, quick, and safe to perform without antibiotic prophylaxis. It could be advantageous in reducing costs to antibiotics as well as improving antibiotic hygiene. However, further experimental studies are needed to evaluate this new technique in animals, as well as in humans, before it can be recommended for routine use in the clinical situation.

ACKNOWLEDGMENTS

We are indebted to Reh-Hosp Aps. and James Polack A/S for providing us with equipment.

REFERENCES

1. Keighley MR, Crapp AR, Burdon DW, Cooke WT, Alexander-Williams J. Prophylaxis against anaerobic sepsis in bowel surgery. Br J Surg 1976;63:538–41.
2. Eykyn SJ, Jackson BT, Lockhart-Mummery HE, Phillips I. Prophylactic peroperative intravenous metronidazole in elective colorectal surgery. Lancet 1979;2:761–4.
3. Marti M-C, Auckenthaler R. Antibiotic prophylaxis in large bowel surgery: results of a controlled clinical trial. Surgery 1983;93:190–6.
4. Bergman L, Solhaug JH. Single-dose chemoprophylaxis in elective colorectal surgery. Ann Surg 1987;205:77–81.
5. Hinchey EJ, Richards GK, Prentis J. Metronidazole as a prophylactic agent in wound infection after colon surgery. Surgery 1983;93:197–200.
6. Gierckský K-E, Danielsen S, Garberg O, *et al.* A single dose tinidazole and doxycycline prophylaxis in elective surgery of colon and rectum: a prospective controlled clinical multicenter study. Ann Surg 1982;195:227–31.
7. The Norwegian Study Group for Colorectal Surgery. Should antimicrobial prophylaxis in colorectal surgery include agents effective against both anaerobic and aerobic microorganisms? A double-blind, multicenter study. Surgery 1985;97:402–7.
8. Goligher JC, Graham NG, De Dombal FT. Anastomotic dehiscence after anterior resection of rectum and sigmoid. Br J Surg 1970;57:109–18.
9. Clark CG, Harris J, Elmasri S, Wyllie JH. Polyglycolic-acid sutures and catgut in colonic anastomoses. Lancet 1972;2:1006–7.
10. Oka H, Harrison RC, Burhenne HJ. Effect of a biologic glue on the leakage rate of experimental rectal anastomoses. Am J Surg 1982;143:561–4.
11. Pringle S. Aseptic resection of the intestine. Br J Surg 1924;12:238–43.
12. Fraser J, Dott NM. Aseptic intestinal anastomosis: with special reference to colectomy. Br J Surg 1924;11:439–54.