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Biofragmentable anastomosis ring for laparoscopic bowel surgery

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Abstract. Laparoscopic surgery is now being applied for colonic resection, and one of the key challenges is fashioning a sound anastomosis. The biofragmentable anastomosis ring, a modern version of the Murphy Button, has been utilized in a series of experiments to develop and evaluate laparoscopic anatomotic techniques. A series of purpose-built devices were used to fashion left and right simulated colectomies as well as for a variety of other anastomoses. Survival animal experiments were performed and demonstrate the feasibility of this technique.

Key words: Laparoscopy — Anastomosis technique — Colon resection — Gastroenterostomy — Cholecystojejunostomy

The benefits to patients of performing general surgical procedures under laparoscopic guidance include reduced pain, earlier discharge from hospital, quicker return to normal activities, and improved cosmetic result. In the attempt to adapt open bowel techniques for the endoscopic approach, a major challenge has been to construct a sound anastomosis in a reasonable time frame. This paper details the construction of devices to perform a variety of intestinal anastomoses with the Valtrac Biofragmentable Anastomosis Ring (BAR) (Davis & Geck, Danbury, CT) and characterizes the techniques with early experimental results.

Material and methods

The BAR is a two-piece ring constructed of polyglycolic acid and mixed with barium sulfate to render it radio-opaque [10]. It fragments and passes out of the bowel in 12–22 days (mean 18.2 days) [9]. The design incorporates a locking mechanism such that when both sides of the BAR are squeezed together, the device is closely apposed and locked (Fig. 1). Two sizes were utilized for these experiments, the 25 mm for the transanal (TA) and the 28 mm mounted on the endoscope (EN). The TA device consisted of a curved, circular plastic device, on the distal end of which was mounted both ends of the BAR (Fig. 2). By squeezing on the handle of the instrument, the part of the BAR at the tip is brought down to abut on the more distal part of the BAR, allowing for the device to lock. By turning the screw on the TA, the BAR is then released from the instrument, allowing the TA to be withdrawn from the anus after effecting a colorectal anastomosis. The EN consists of a standard oblique-viewing 60-cm flexible endoscope on the distal end of which is mounted a delivery mechanism for the BAR. This is fired and released with the aid of a metal cable passed through the instrument channel of the endoscope (Fig. 3).

In all cases, the BAR was positioned using an especially constructed purse-string instrument (PSI). This consists of a 12-mm shaft with a distal articulating arm. Once introduced into the abdomen through a 12-mm cannula, the instrument is angulated and clamped onto the bowel and a plastic sheath is inserted which contains two long flexible needles with 2/0 or 3/0 monofilament absorbable sutures attached to the detachable tips. These needles are prescored 1 cm from their tip, and after the points have penetrated the bowel they are snapped off with a grasper introduced through another cannula (Fig. 4). By withdrawing the needles and attached thread through this cannula and pulling out the long shafts of the needles, the purse-string is completed. When ready to tie, extracorporeal knots are thrown and pushed into position with a knot-pushing rod.

Sections of resected bowel were removed transanally with a specially constructed device. This consists of a plastic sigmoidoscope, divided lengthwise, to the inside of which is glued a plastic bag. This is passed per anus and provides for an extracorporeal continuation of the pneumoperitoneum and prevents the specimen from coming into contact with the mucosa of the anorectum (Fig. 5).

After confirming the efficacy of both the TA and EN instruments on foam tubes, animal experiments were commenced. For the low colorectal technique, using both the TA and EA instruments, large mongrel dogs (40–60 lb) were used. The telescope was positioned via a cannula placed to the right of the right rectus muscle and cephalic and anterior traction was applied to the colon via a cannula in the left upper quadrant. The dog was placed in the head-down, left-side-up position to allow the small bowel to fall away from the pelvis. A window was made in the colonic mesentery, vessels were doubly clipped below, singly above, and then divided through a cannula placed in the right lower quadrant (Fig. 6). The PSI was introduced via a cannula positioned (Fig. 7) in the right upper quadrant. After the proximal purse-string was positioned the bowel below the purse-string (i.e., on the specimen to be extracted) was occluded with a Roeder knot. The bowel was then divided below the PSI flush with the jaws, thus completing the proximal purse-string. Next the distal

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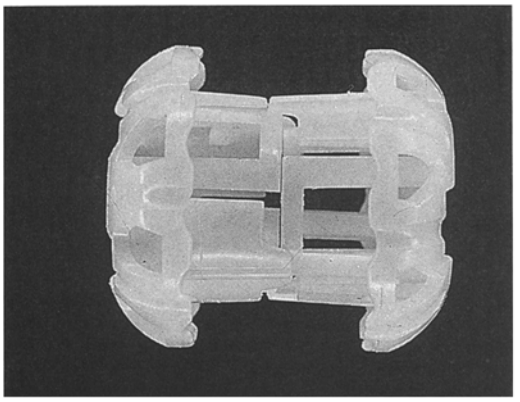

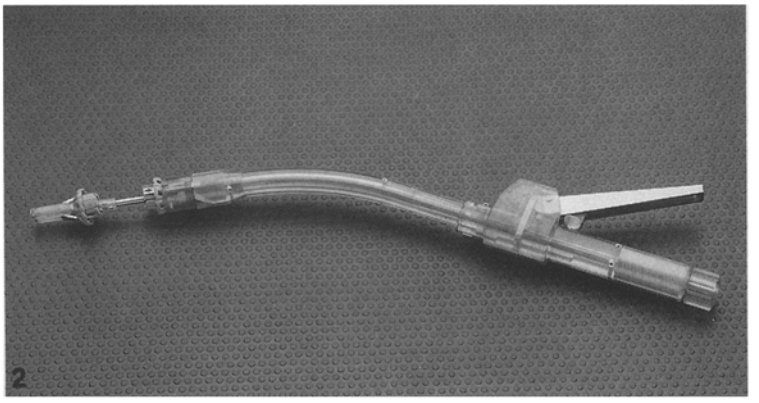

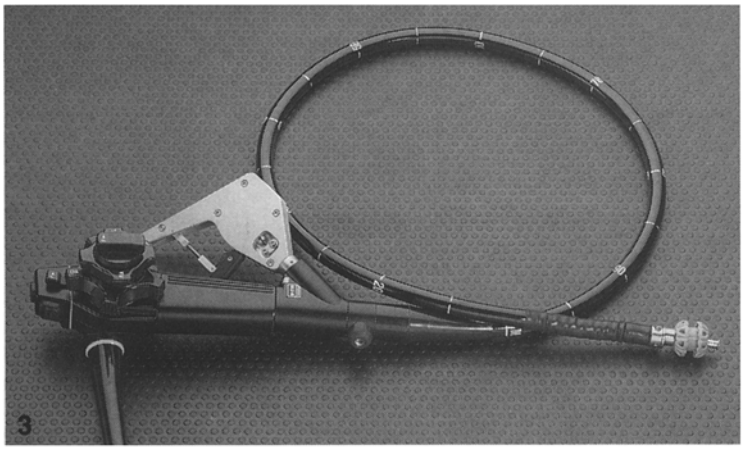

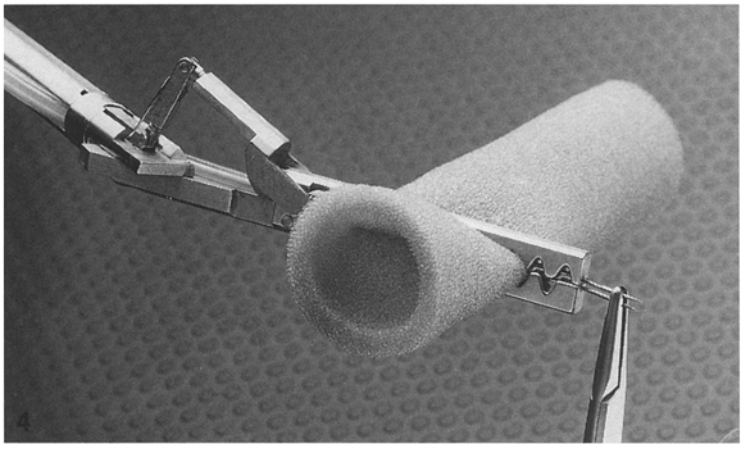

Fig. 1. The two halves of the BAR, which, when compressed, fashion a sutureless serosa-to-serosa anastomosis.

Fig. 2. The transanal application device (TA) with BAR attached; the screw on the handle releases the device.

Fig. 3. The flexible endoscope with the BAR firing mechanism on the distal end (EN). A wire passed through the endoscope instrument channel inserts into a handle which, when squeezed, brings the BAR together.

Fig. 4. The purse-string instrument (PSI) is shown here applied across a foam tube and the needles have been inserted. A grasper brought in from the opposite side grips the needles at the prescored point and breaks them. This is the fashion in which the PSI is used on the bowel.

resection margin was chosen and the PSI was applied here, and, as before, the distal resection margin above the PSI was closed off with a looped suture. The distal bowel was then divided just above the PSI (Fig. 8). After this instrument had been removed the modified sigmoidoscope was placed transanally and opened, and the specimen was extracted.

The TA was then positioned in the anus. After the rectal purse-string had been tied around the distal part of the BAR (Fig. 9), the proximal bowel was brought down, the purse-string was tied over the proximal half of the BAR, the TA was closed, and the anastomosis was completed (Fig. 10). The pelvis was then filled with saline and the anastomosis was checked by occluding the bowel above the anastomosis with a Glassman-type clamp, insufflating air through the rectum, and looking for bubbles.

In another group of dogs a section of proximal large bowel was excised to mimic a right colon resection. As before, once the purse-strings had been positioned the bowel was excised, but in this circumstance it was withdrawn through the large cannula (12 mm). The anastomosis was effected using the BAR positioned on the tip of the EN device.

The same technique was applied when a low colorectal anastomosis was fashioned using the BAR delivered by the EN.

To test the possibility of creating a gastroenterostomy, a porcine model was used. The EN was introduced through the esophagus and into the stomach. When the tip of the endoscope could be seen to abut on the anterior wall of the stomach on the greater curvature, a site was selected and the purse-string was applied by tenting up part of the stomach wall. A small portion of the tissue held in the PSI was excised, thereby creating a hole in the stomach through which the EN was introduced; the mobility provided by the hand controls of the endoscope proved extremely useful here. The purse-string was tied around the proximal (intragastric) portion of the BAR. As the small bowel in the pig is not large enough, a piece of colon was selected, a purse-string was applied as above, tissue was excised, and the BAR anastomosis was completed. This animal was sacrificed immediately postoperatively.

Fig. 5. The tissue extraction device consists of a split plastic sigmoidoscope into which is glued a plastic specimen bag.

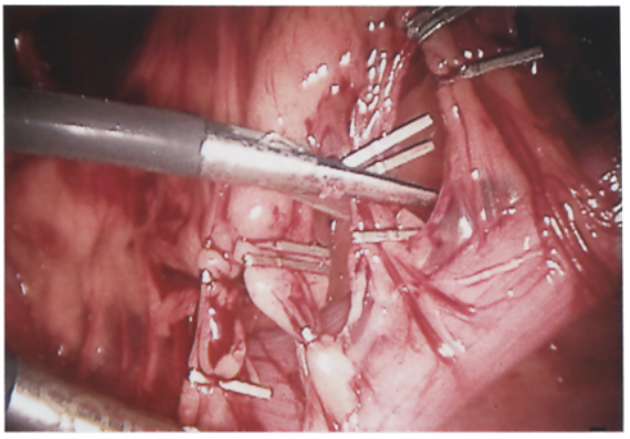

Fig. 6. The canine mesenteric vessels have been singly clipped above, doubly below, and are being divided.

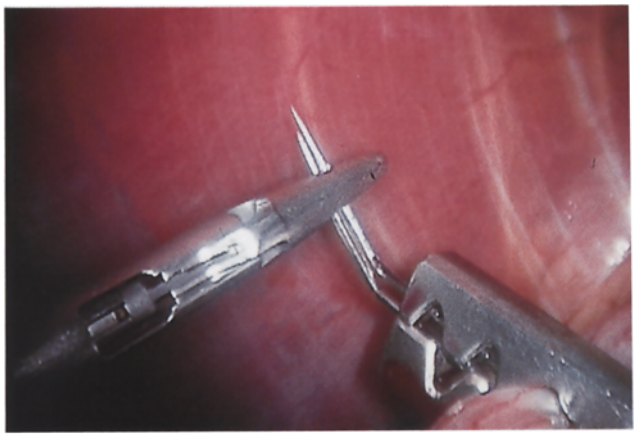

Fig. 7. The PSI has been applied across the bowel, the needles have been inserted, and a grasper is breaking the pre-fractured ends. This will allow the purse-string suture to be drawn out the cannula through which the grasper was introduced for an extracorporeal knot to be fashioned.

To develop the technique of cholecystoenterostomy, the EN was passed through the canine esophagus and into the duodenum. As in the gastroenterostomy, a site was selected and the purse-string was applied by tenting up the wall of the duodenum. This piece of tissue was excised and the BAR was brought through. After this purse-string had been secured, the gallbladder was grasped and the purse-string was positioned at the fundus of that organ. After the gallbladder had been incised and bile had been aspirated a duodenocholecystostomy was fashioned. This dog was sacrificed at the end of the procedure.

In the group of dogs who underwent colonic anastomosis the abdominal wounds were closed with 0 polyglyconate to the fascia

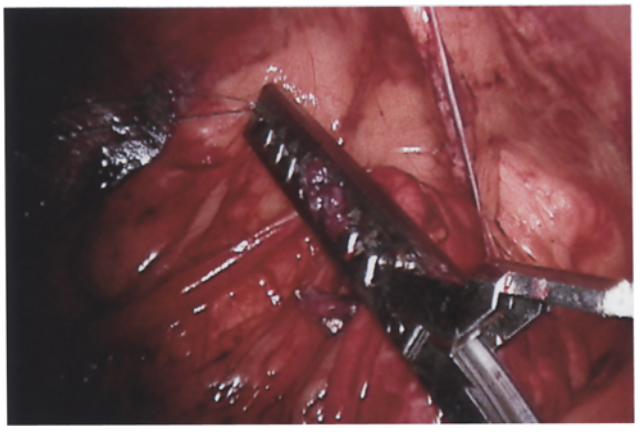

Fig. 8. The specimen has been sealed with Roeder knots above and below; the PSI occludes the rectum. After the bowel has been divided, the PSI is removed, the tissue extraction device is inserted, and the specimen is withdrawn.

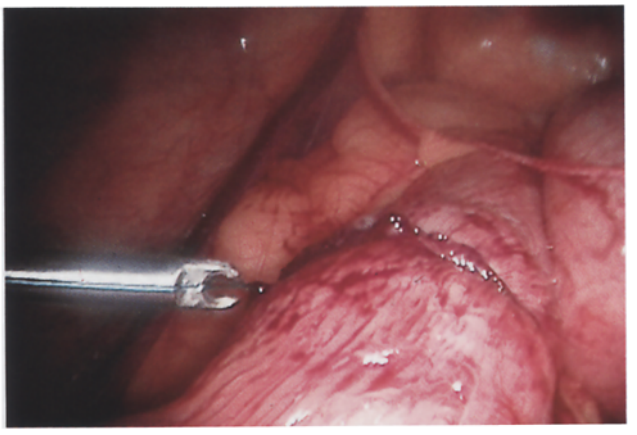

Fig. 9. The TA is introduced and the purse-string is tied on the distal side.

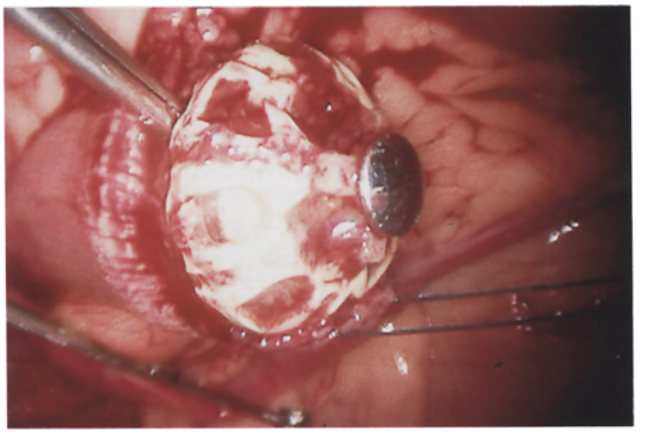

Fig. 10. The proximal purse-string is secured with an extracorporeal knot that is pushed into position. The TA (or EN) is fired, completing the anastomosis.

Table 1. Evaluation of resected animals

Procedure	Purse-string		Postoperative complications	10-day leak test	Day of BAR fragmentation	6-week result
	Proximal	Distal				
EN colocolonic	2/0	2/0	None	−ve	16	1. Good physical condition 2. Well-healed anastomosis 3. Slight stricture
EN colocolonic	3/0	3/0	None	−ve	15	1. Good physical condition 2. Moderately dense adhesions 3. Diffuse serosal scar 4. Thick congested mucosal ridge
EN colocolonic	3/0	3/0	None	−ve	<15	1. Good physical condition 1. Loose omental & bladder adhesions to anastomosis 3. Raised serosal scar 4. Mucosa healing normally
TA colorectal	3/0	3/0	BAR not locked	−ve	13	1. Good physical condition 2. Filmy omental adhesions 3. Diffuse serosal scar 4. Mucosa healed normally 5. One purse-string present
TA colorectal	3/0	2/0	BAR completely open	−ve	13	1. Good physical condition 2. Loose omental adhesions 3. Diffuse scar 4. Slight stricture

and 4/0 polyglyconate to the skin. The animals were recovered and commenced on fluids ad libitum. Normal diet was commenced at 2 days and the animals underwent gastrograffin enemas at 10–12 days postoperatively. In addition, they underwent daily X-rays to follow the fragmentation of the BAR. Prior to sacrifice at 6 weeks, a barium enema was performed to evaluate any stenosis at the anastomosis. At autopsy, firstly, the area of the anastomosis was inspected for any adhesions and these were graded. The anastomosis was removed and sections obtained for histological examination.

Results

The main purpose of these experiments was to demonstrate the feasibility of applying purse-strings and completing anastomoses with the BAR in a number of settings which might have clinical significance. For this reason, several of the experiments were nonsurvival in nature. These demonstrated that a gastroenterostomy (stomach and colon) could be completed using this technique. Similarly, cholecystoenterostomy is a feasible procedure, although tension on the gallbladder in the canine model would almost certainly have led to a failed anastomosis—this animal had not previously been prepared as an obstructed bile duct model with gallbladder distention. Those animals undergoing successful proximal or distal colon resection were evaluated as discussed above (Table 1). Two TA and three EN procedures were available for assessment. These revealed no leaks, fragmentation of the BAR between 13 and 16 days, and good function of the BAR in all the EN cases. In the two procedures using the TA inserter the BAR failed to lock, but despite this, the anastomosis healed.

Discussion

There are a number of challenges inherent to laparoscopic bowel surgery. These include performing the operation in a reasonable time frame, ensuring adequate resection, maintaining a field free of intestinal contamination, withdrawing the specimen, and effecting a sound anastomosis [12]. The presence of the pneumoperitoneum seems to limit intestinal spillage after the bowel has been opened, and this is assisted greatly by careful positioning of occlusive bowel clamps. Until now, there have two techniques for withdrawing the specimen from the patient's abdomen: making an incision large enough for the specimen [6] or simply drawing it through the anal canal. The former is unappealing as it necessitates doing exactly what the laparoscopy aims to avoid—making a large incision. The latter is worrying, since if the colon resection were performed for malignancy there would be the potential to seed the anorectum with cancerous cells. The technique described here obviates the need for an incision and protects the distal bowel from malignant contamination.

A number of techniques of anastomosis have been performed laparoscopically and each has its own drawbacks. A purely sutured method requires an enormous expenditure of time, considerable surgical prowess, and is probably not a viable option. Use of mechanical stapling devices in the laparoscopic assisted, or totally intracorporeal methods is time consuming and expensive. The absence of a technique of applying purse-string sutures has necessitated the use of linear devices to supplement the actions of the end-to-end intraluminal staplers. The use of the BAR, which fashions a serosa-to-serosa anastomosis, is appealing from a physiological standpoint and also seems to be cost effective [2, 7–9]. The BAR has been extensively studied in open surgery and has been found to be a safe and efficient method of intraperitoneal sutureless bowel anastomosis [5]. Prospective, randomized trials between the BAR, sutured, and stapled anastomoses show similar return in bowel function, resumption of diet, and length of hospital stay. There were a higher

number of intraoperative difficulties with the BAR but these did not seem to have any adverse effects [1]. The BAR was found to help the surgeon to fashion a wide range of anastomoses in an expeditious fashion [3]. The BAR has also been used to create a sound anastomosis in the laparoscopically assisted colon resection scenario [13].

Laparoscopy has been demonstrated to be of value in patients with pancreatic cancer, for many with this disease are found at the time of surgery to have previously unsuspected metastases and may thereby avoid a laparotomy [4]. It would be appealing to be able to simply bypass the bile duct obstruction at the time of the laparoscopy and also to divert food with a gastroenterostomy. Such diversions have been performed using either sutures or staples [11], but, as above, this is time consuming and expensive. The acute experiments performed here demonstrate that gastroenterostomy and cholecystojejunostomy with the BAR may be performed.

It is certain that further development of these methods is needed and certain modifications are already being made. The purse-string device is being developed to include a simple knob that with each successive turn performs one of the functions currently necessitating a different maneuver (angulation, locking straightening). It became evident that purse-strings of 3/0 suture material were too fragile, but the holes in the plastic sleeve of the PSI were a little too tight to accommodate 2/0 sutures with ease. This can be easily modified.

The extraction device has been improved to include a firmer sprung ring at the top and a simpler method of opening up the intraabdominal portion of the tube.

The initial intention for the EN device utilizing an endoscope was to provide control of direction and vision to deliver the BAR to inaccessible sites. It became evident that using the side-viewing endoscope, an insufficient view (approximately 30° vision) was obtained to be of any great use and that laparoscopic guidance was probably all that was needed anyway. Therefore, a guidewire "pull" method is being devised. This will allow for placement of the BAR without the use of direct vision and will be the subject of a future communication.

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