Colorectal anastomosis: factors influencing success[1]

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Summary: Preservation of the anal sphincters is now consistent with adequate extirpation of the majority of rectal neoplasms. However, there is still a troublesome incidence of leakage through colorectal anastomoses. A number of different factors, working in combination, are responsible for this. Although most problems have been solved, and the mortality is low, the anastomotic leak rate described in the present series, and in the hands of most surgeons, remains high. Efficient suturing without tension, adequate filling and drainage of the presacral space, and antimicrobial prophylaxis effective enough to abolish abdominal wound sepsis, have been applied. The large vessel arterial blood supply to the suture line is good but the microcirculation of the left colon and rectum, upon which suture line healing ultimately depends, is suspect. Reduction of blood viscosity by deliberate lowering of the haemoglobin level before operation has been practised in the hope of improving the microcirculatory flow. The results so far are encouraging and suggest that the method is worth a continued trial.

Introduction
To preserve the anal sphincter after adequate and safe removal of a rectal neoplasm is the major challenge with which colorectal surgeons are most frequently faced at present. The majority of invasive large bowel growths are found in the lower sigmoid colon and upper rectum (Gillespie *et al.* 1979). Up to 1950, most malignant neoplasms within 15 cm of the anus were treated by total rectal excision. In terms of operative mortality and cure, the results achieved by this method have not been bettered. Where there has been progress has been in the avoidance for most patients with rectal cancer of a permanent colostomy. In the three years of the present study the ratio of abdominoperineal excisions to restorative resections of the rectum was about 1 to 6.

The reasons for former doubts about restorative excision were three. Most important was the dire consequence for the patient of suture line leakage, which occurred in a consistent proportion of cases. The very active antimicrobial agents now available have greatly reduced this risk but have not abolished suture line leakage. The other doubts concerned the adequacy of the excision of malignant tissue and the fear that malignant cells would be implanted in the suture line. Most surgeons now discount these last two fears. For example, Nicholls *et al.* (1979) showed that for Dukes B and C tumours of average malignancy there was, in terms of five year survival, no difference between restorative and total excision; while Rosenberg (1979) studied malignant implantation in a number of different ways and concluded that, if the rectal stump was well irrigated at operation, it was a very rare event.

The present study
The peculiar problems of the operation are all connected with leakage from the colorectal anastomosis and are influenced by four factors: the shape of the pelvis; the virulently infective nature of the colonic contents; suturing technique; and the blood supply to the cut bowel ends. These factors operate independently but simultaneously and with varying individual influence. They should, ideally, be investigated separately, each by a randomized prospective trial; but this would need a very large number of cases and probably involve many surgeons – a great cause of statistical error. An ethical problem also arises. Some techniques which may influence the integrity of the anastomosis also influence the outcome in other ways. An example is antimicrobial prophylaxis which, if adequate, has been found to eliminate

abdominal wound sepsis. It would be very questionable moral behaviour to withhold this from some patients in order to study its effect upon suture line integrity, since it is almost inconceivable that it would be harmful in this respect. At worst the effect would be neutral.

Leakage from the suture line, studied radiologically, has been reported to occur in from 6% to 35% of anastomoses. All investigators have found that low anastomoses, that is those made between the colon and the extraperitoneal rectum, leak more often than high ones when the anastomosed rectum has a serous peritoneal coat covering the anterior half of its circumference (Table 1). For low anastomoses, many surgeons shelter behind the protection afforded by a proximal colostomy made as a routine part of the operation.

Table 1. *Comparison of radiological leak rates following colorectal anastomosis*

Reference	Suture method	Leakage from anastomosis		
		High	Low	Total
Matheson & Irving (1975)	Hand	2/37 (5%)	1/15 (7%)	3/52 (6%)
Everett (1975)	Hand	11/67 (16%)	8/25 (32%)	19/92 (20%)
Goligher *et al.* (1977)	Hand	23/84 (27%)	25/51 (49%)	48/135 (35%)
Tagart (present series)	Hand	6/23 (26%)	11/28 (39%)	17/51 (33%)
Goligher *et al.* (1979)	Stapler	0/38 (0%)	6/24 (25%)	6/62 (10%)
Dorricott *et al.* (1981)	Stapler			10/50 (20%)
Tagart (present series)	Stapler	3/13 (23%)	4/16 (25%)	8/29 (28%)

Shape of the pelvis
The anastomosis lies in the presacral space which is deep and has a rigid, curved posterior wall. Blood and exudate accumulate here very easily and, if this collection becomes infected, the resulting abscess points naturally forward through, and disrupts, the suture line. The result of this was that most suture line failures occurred posteriorly. Since the problem has been overcome suture line failures have not ceased but have been found, by digital and sigmoidoscopic examination, to occur anywhere on the circumference of the anastomosis.

Colonic contents and infection
Forty per cent of the dry weight of faeces consists of bacteria, and 97% of these are obligatory anaerobes (Moore 1976). Without antimicrobial prophylaxis, a 50% abdominal wound infection rate can be expected (e.g. Feathers *et al.* 1977). In the early part of the present investigation metronidazole alone was used for prophylaxis, but the wound infection rate remained high. The reason for this lies in the finding of Marks *et al.* (1978) that on the rectal mucosa itself, where presumably the oxygen tension is highest, and where the type of organism matters, half the organisms are aerobes and half anaerobes. The addition to metronidazole of a wide spectrum, non-toxic cephalosporin, cefuroxime, had a spectacular effect on the wound infection rate which fell to zero. At first it seemed that the effect on the anastomosis of the metronidazole-cefuroxime combination would be equally good, for only two radiological leaks occurred in 21 consecutive cases (Figure 1). Unfortunately this improvement was not maintained, suggesting that the main importance of antimicrobial prophylaxis is in mitigating the consequences of suture line leakage, not in preventing it.

I have relied completely on plasma-carried antimicrobials. There has been no attempt to sterilize the faeces because that may be dangerous; but it seems only sensible to try to empty the colon of its very large bacterial content before operation. At first whole gut irrigation (Hewitt *et al.* 1973) was used, but this was popular neither with patients nor nurses. Following Australian reports I have gone over to the use of mannitol which is almost always effective, even in partly obstructed cases. In the event of occasional failure, the peroperative colonic irrigation technique of Dudley *et al.* (1980) is a useful fall-back.
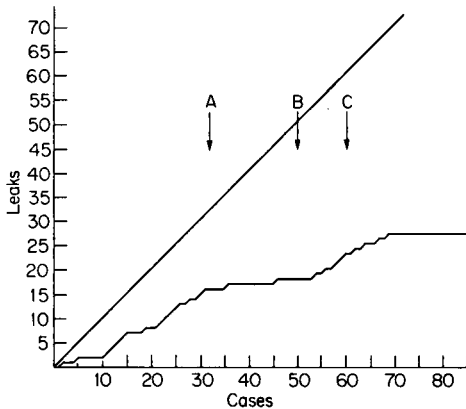
Figure 1. Order of occurrence of radiological leaks following colorectal anastomosis in 85 cases. Arrows: A, efficient antimicrobial prophylaxis from here on; B, stapler used for anastomosis from here on; C, measured haemodilution from here on

Suturing techniques

The general use of anastomotic stapling devices has diverted attention from the previous arguments about details of suturing technique. Staplers undoubtedly make the operation quicker and easier; they are particularly useful in the case of low anastomoses, where they probably extend the scope of the operation in the hands of most surgeons. However, Overy *et al.* (1980) have reported that the Russian stapler did not alter the radiological leak rate and Table 1 suggests that, although individual surgeons have improved their results with the stapler, the results overall are only slightly better than with hand suturing.

A stapler makes a very good and consistent anastomosis and its use largely eliminates the variation caused by the differing skills of surgeons. However, the amazingly good, and never bettered, results reported in 1975 by Matheson & Irving at Aberdeen were achieved using hand suturing.

The differences between reports remain and this suggests that other factors are operating. In the present series the early cases were anastomosed by hand using a two-layer technique with 00 chromic catgut – the outer layer interrupted, the inner layer continuous. When an American stapler became available it was used in most cases. Tables 1 and 2 and Figure 1 show that, in my hands, although the stapler may make the operation easier and quicker, it has not altered the results as regards suture line leakage.

Table 2. Comparison of clinical leak rates following colorectal anastomosis

Reference	Suture method	Leakage from anastomosis		
		High	Low	Total
Matheson & Irving (1975)	Hand	1/37 (3%)	0/15 (0%)	1/52 (2%)
Everett (1975)	Hand	2/57 (3%)	2/35 (6%)	4/92 (5%)
Goligher *et al.* (1977)	Hand	1/84 (1%)	8/51 (16%)	9/135 (7%)
Tagart (present series)	Hand, unprotected	1/23 (4%)	4/26 (15%)	5/49 (10%)
Goligher *et al.* (1979)	Stapler	0/38 (0%)	2/24 (8%)	2/64 (3%)
Dorricott *et al.* (1981)	Stapler			3/50 (6%)
Leicester & Heald (1980)	Stapler, unprotected	0/24 (0%)	15/61 (25%)	15/84 (18%)
Tagart (present series)	Stapler, unprotected	3/15 (20%)	2/12 (16%)	5/27 (18%)

Blood supply

The large vessel supply to both sides of the anastomosis is good and seldom fails. Only once in the present series did this happen when the one vessel supplying the colonic side thrombosed causing gangrene of the left colon. The microcirculation of the left colon, the main function of which is storage rather than secretion or absorption, is however more suspect. Ischaemic colitis is almost confined to the left colon, and when encountered it is usual to find the large arteries pulsating normally.

In the case of a patient with radiation necrosis of both bladder and rectum, who had to have a double diversion, the right-sided ureterocaecocolostomy gave no trouble; but on the left side, the terminal colostomy sloughed for about 5 mm due, probably, to microcirculatory failure. Microcirculatory failure is, I suggest, the remaining factor which determines whether suture line leakage occurs, once other probable influences, pelvic drainage, adequate suturing without tension, and infection, have been controlled.

Bailey *et al.* (1979) reported a very significant difference between the high preoperative haemoglobin levels of successes and the low haemoglobin levels of failures in diabetic digital amputations. They attributed this association to the fact that a high haemoglobin concentration, although increasing the oxygen-carrying capacity of the blood, in fact reduces the delivery of oxygen to the tissues because the higher viscosity results in decreased microcirculatory flow and probably, as well, an increased tendency to intracapillary thrombosis. In 1970 Gruber, of Basel, reported that canine experiments had shown that oxygen delivery to the tissues was maximal at a haematocrit reading of 35% (equivalent in man to a haemoglobin level of about 11.0 g), decreasing quite sharply on either side of this figure (Figure 2). Finally, Whitaker *et al.* (1970) showed that the only factor, out of 31 studied, which was related significantly to colorectal anastomotic failure was that the patient had received a peroperative transfusion of more than 2 units of blood. This rather inexplicable association could well be connected with blood viscosity.

When a preliminary statistical survey in the present series suggested that there was a correlation between suture line integrity and low postoperative haemoglobin levels (estimated
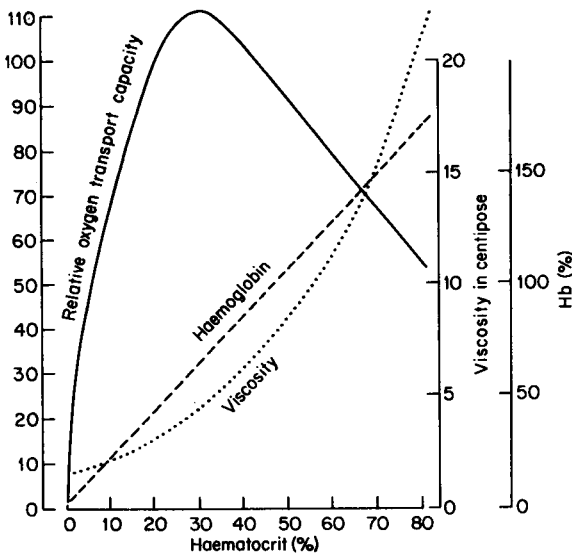

Figure 2. Relative oxygen transport capacity in relation to haemoglobin or haematocrit and to viscosity. Oxygen transport capacity is highest at about 30% (Hint 1968) haematocrit. (Reproduced from Gruber 1970, by kind permission)

on the second day), it was thought worthwhile to reduce the haemoglobin level, before operation, of those patients in whom it was unacceptably high.

Procedure

The patient is admitted to hospital a few days before operation. Measured haemodilution is started at once if necessary. One unit (500 ml) of blood is withdrawn – a unit at a time – for every gram or part of a gram of haemoglobin above 13.0 g. At first 11.0 g was taken as the critical level, but this often led to unacceptably low postoperative levels, making transfusion necessary. Unfortunately, the effect of bleeding on the haemoglobin level is somewhat unpredictable and there is no constant relationship between the amount of blood withdrawn and the subsequent reduction in haemoglobin level. There is also an experimental error in the haemoglobin estimations of about 1 g either way. Surprisingly, what does seem reasonably constant is a drop in haemoglobin of about 2 g during the course of the operation. This is not necessarily a reflection of blood loss but may be the result of intravenous hydration.

On the day before operation the intestine is cleared. Maxolon 10 mg is given intramuscularly, and an intravenous infusion is set up. 500 ml of 20% mannitol is then given by mouth. This produces profuse diarrhoea lasting for about 8 hours. Lost fluid is replaced intravenously using Hartmann's solution, 1 litre in 6 hours. For the 2 preoperative and 6 postoperative days only clear, mixed fluids are given by mouth.

The operation is standard. The bowel preparation is effective in most cases but if the colon is at all loaded, the on-table irrigation technique of Dudley *et al.* (1980) is used. The rectal stump is irrigated before division of the bowel with one litre of 1% noxythiolin solution. Full mobilization of the left colon with high ligation of the inferior mesenteric pedicle is carried out if necessary. In all cases care is taken to fill the presacral space with redundant colon. The presacral space is drained with a 'Drevac' suction apparatus usually of 18F bore. If the splenic flexure has been mobilized the left flank is often drained as well. The muscles, fascia and peritoneum of the anterior abdominal wall are closed in one layer with continuous monofilament nylon.

During and after operation blood volume is maintained as far as possible with clear fluids. Only when loss is demonstrably large is blood given. Daily haemoglobin checks are made and blood given on the basis of one unit for every gram of haemoglobin below 11.0 g. Keeping the patient well-hydrated is very important. Gilmour *et al* (1980) showed that, in the dog, a loss in blood volume of 10%, while producing only small changes in blood pressure and cardiac output, reduced colonic blood flow and oxygen availability by 28%. The worst possible clinical combination is inadequate volume replacement using only blood.

The presacral drain is removed on the sixth or seventh postoperative day. During the second postoperative week, sigmoidoscopy and a limited barium enema are carried out. This is not clinically necessary in the absence of signs of suture line leakage and some would call it mere casuistry; but for an honest assessment of the different factors which influence healing of the suture line, the variables deriving from differing patient reactions and, more important, different standards of clinical assessment should, if possible, be eliminated.

Antimicrobial measures: Cefuroxime and metronidazole are given intravenously during the operation and 8-hourly afterwards, so long as the intravenous infusion is maintained. Once flatus is passed and the patient is able to take fluids by mouth, the medication is changed to oral metronidazole and cephradine until and including the sixth postoperative day.

Colostomy: This was not made routinely. In most cases where a pre-existing transverse colostomy was present it was closed at the time of the resection. Further details about colostomy are given in the section on results.

Antithrombotic precautions: The greatest danger to life in the operation is from cardiopulmonary complications, and all measures favoured by the particular surgeon against deep venous thrombosis should be energetically pursued.

Results
The present series consisted of 80 consecutive unselected cases (46 female, 34 male) treated over a period of about 3 years. In that period improvements in antimicrobial agents and in suturing technique have been the cause of changes in treatment. An attempt has been made to assess the effect of these measures of suture line integrity, and the preliminary results of an effort to improve the microcirculation at the suture line by reducing blood viscosity are reported. Some of the operations were quite extensive, involving removal, in continuity with the rectum, of the uterus or the caecum or part of the bladder, small intestine or transverse colon.

The age distribution is shown in Figure 3. In comparing results age is important, since it is the main factor influencing mortality. Table 3 details the indications for operation.
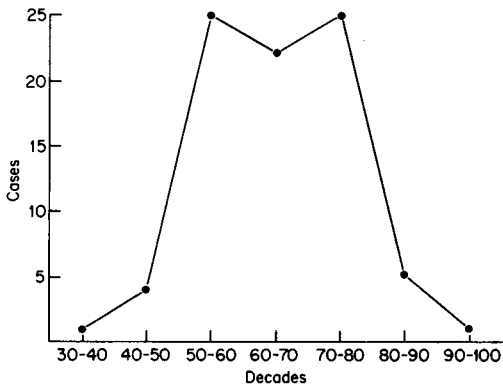

Figure 3. Age distribution of 83 cases with colorectal anastomoses

In each case the distance of the lesion from the anal skin was measured at sigmoidoscopy. The five highest distances were 20, 20, 20, 23, 25 cm and the five lowest were 4, 7, 8, 8, 8 cm (median 13 cm). The distance between the suture line and the anal skin was also measured at sigmoidoscopy, the five highest distances being 14, 14, 14, 15, 15 cm, and the five lowest being 4, 4, 4, 5, 5 cm (median 10 cm). There were 36 high and 44 low anastomoses. Colo-anal anastomoses are not included in this series.

Table 4 gives details of colostomies. In 4 cases out of 80 the anastomosis was protected by proximal colostomy, either because of anxiety about the patient's general condition or because of special difficulty with the anastomosis. Of patients with unprotected anastomoses, 1 in 10 had an emergency colostomy carried out around the seventh day because the signs suggested that there was a danger of spreading peritonitis from suture line leakage. Some of these could possibly have been avoided but the nil mortality from peritonitis or septicaemia justifies the cautious approach.

Four out of 80 patients died (5%). They were aged 76, 78, 88 and 90 years respectively. The deaths occurred in the second or third postoperative week; 3 were due to pneumonia, and the fourth was proved at autopsy to be due to a pulmonary embolism. The mortality rate for patients over 75 years was 4 out of 18 (22%). Below 75 years there was no mortality.

Table 3. Indications for colorectal anastomosis in 80 cases

	No. of cases
Resection for neoplasm	61
Resection for inflamatory disease	8
Resection for inflammatory vesicocolic fistula	4
Resection for malignant vesicocolic fistula	1
Resection for neoplasm of rectum secondary to ovarian primary growth	2
Reconnection following Hartmann's procedure	4

Table 4. *Colostomies in patients with colorectal anastomoses*

	No. of cases
Preoperative colostomy (including 4 Hartmann's)	10
Preoperative colostomy closed at time of anastomosis	8
Preoperative colostomy	2
Postoperative colostomy for leak (unprotected anastomosis)	8/76

Suture line leakage

Clinical leaks (Table 2, Figure 4) can be discussed meaningfully if only those cases with anastomoses unprotected by a proximal colostomy are considered. The incidence is quite low. Although leaks occur more often in low than in high anastomoses, high leaks, within the peritoneal cavity, are more dangerous than when the anastomosis is tucked away deep in the pelvis. For this reason emergency colostomies, necessary in 10% of cases, were distributed equally between high and low anastomoses.

Figure 1 shows the incidence of radiological leaks as the series progressed. Efficient antimicrobial prophylaxis and measured haemodilution (MHD) both seemed to have some effect, that of MHD probably being the largest. High and low leaks were charted separately and the slopes for both were the same. In my hands the use of the stapler has not affected the leak rate.

Colo-anal anastomoses which lie 3 cm or less from the anal skin present special problems. The indications for the operation are few. I only have experience of three cases. In two, an attempted stapled anastomosis failed and the suture line had to be constructed per anum by hand. Two out of three leaked radiologically. Two out of three had a protecting colostomy.

Statistical correlations: The leak rates for low and high anastomoses have been analysed for correlation with the following variables: age, sex, systolic blood pressure, diastolic blood pressure, pulse pressure, preoperative haemoglobin level, postoperative haemoglobin level, hand suturing, stapling.
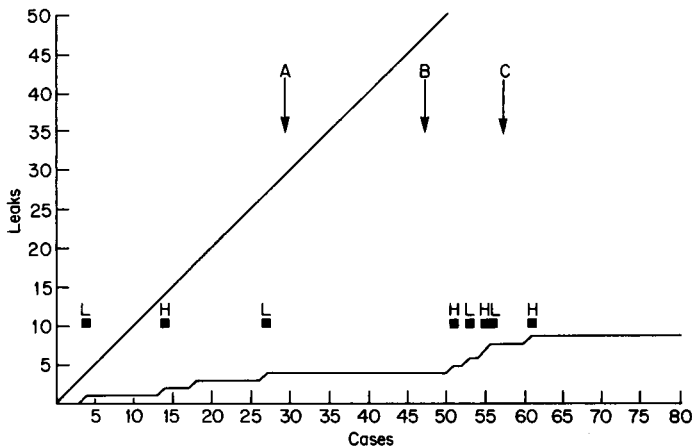

Figure 4. Clinical leaks and emergency colostomies following colorectal anastomosis in 80 cases. Arrows: A, effective antimicrobial prophylaxis from here on; B, stapler used for anastomosis from here on; C, measured haemodilution from here on. ■ =emergency colostomies for high (H) and low (L) cases

Some trends have emerged. For example, the mean haemoglobin levels of patients with leaking anastomoses were higher than those of the non-leakers, but the differences were not significant at a 5% level. One significant difference did emerge. Leaking low anastomoses in male patients were associated with a mean preoperative haemoglobin level of 14.6 g (9 cases) while non-leakers in the same group had a mean haemoglobin of 12.5 g (8 cases). An analysis of variance has shown that this difference would occur by chance less than 1 in 100 times ($P < 0.01$).

Discussion and conclusions

Can colorectal anastomosis be done safely in one stage without a protecting proximal colostomy? This was the most important question which the present investigation set out to answer. The answer is yes – with the method and precautions outlined in this report. This is a great advantage in obstructed cases which have been treated initially by a transverse colostomy. These patients can now be managed by a 2-stage procedure rather than in the conventional 3 stages, the transverse colostomy being closed at the time when the colorectal anastomosis is made. However, a surgeon with this policy may have to resign himself to making an emergency colostomy around the seventh day for 1 in 10 of his cases. The ideal would be to predict which cases are going to require this and to give these a prophylactic colostomy, but the experience from this series shows that this is very difficult.

The technical and microbiological problems of this procedure have been solved as far as is possible with present methods and equipment. The remaining problem is the inherent microcirculatory inadequacy of the left colon related, probably, to the fact that its normal function is storage rather than secretion or absorption. Measured haemodilution will, I think, go some way towards neutralizing the effect of this deficiency by increasing the blood flow through the rather sparse colonic microcirculation. It is, however, an imprecise and somewhat unpredictable method. Further progress may well depend on the use of agents which reduce blood viscosity directly, predictably and consistently.

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