The creation of a join between two bowel ends is an operative procedure that is of central importance in the practice of a general surgeon. Despite the potentially disastrous consequences that can arise from leakage of an intestinal anastomosis, joining bowel segments is one of the procedures that junior surgeons often perform in the emergency setting. With proper supervision and appreciation of fundamental concerns, however, there is little difference between the outcomes of anastomoses performed by trainees and those performed by established surgeons.1

To minimize the risk of potential complications, it is imperative to adhere to several well-established principles.2 The main ones relate to the creation of a tension-free join with good apposition of the bowel edges in the presence of an excellent blood supply.2 The importance of surgical technique is underscored by the wide variations of anastomotic leakage rates among surgeons.3

The frequency of anastomotic leakage ranges from 1 to 24%.4–6 The rate of leakage is generally considered to be higher for elective rectal anastomoses (12 to 19%) than for colonic anastomoses (11%).7–9 The consequences of postoperative dehiscence are dire and include peritonitis, bloodstream infection, further surgery, creation of a defunctioning stoma and death. A threefold rise in mortality was seen (from 7% to 22%) in the St. Mary’s Large Bowel Cancer Project, when anastomotic leakage occurred.7 Also other problems encountered include a significant increase in hospital stay, and there is a proportion of patients who do not go on to have their stomas reversed.4

This chapter is divided into three broad sections. The first discusses factors that influence intestinal anastomotic healing. The second analyzes different technical options for creating anastomoses. The third and final section concentrates on the operative techniques that are currently used in constructing intestinal anastomoses.

Intestinal Healing

The process of intestinal anastomotic healing mimics that of wound healing elsewhere in the body in that it can be arbitrarily divided into an acute inflammatory (lag) phase, a proliferative phase, and, finally, a remodeling or maturation phase. Collagen is the single most important molecule for determining intestinal wall strength, which makes its metabolism of particular interest for understanding anastomotic healing. During the proliferative stage, fibroblasts become the predominant cell type, playing an important role in laying down collagen in the extracellular space. At the epithelial level, the crypts undergo division to cover the defect on the luminal surface of the bowel. The density of collagen synthesis is in a constant state of dynamic equilibrium, which is dependent on the balance between the rate of synthesis and that of collagenolysis. After surgery, degradation of mature collagen begins in the first 24 hours and predominates for the first 4 days. This is caused by the upregulation of matrix metalloproteinases (MMPs), which are an important class of enzymes involved in collagen metabolism.10

Metalloproteinases (MMPs) are an important class that increases in the early postoperative period. In an animal model where bacterial peritonitis was induced, increased MMP levels were seen on postoperative day 3, coinciding with a fall in the bursting pressure.10 However, no increase in anastomotic dehiscence was found in comparison with the control group. By postoperative day 7, collagen synthesis becomes the dominant force, particularly proximal to the anastomosis. After 5 to 6 weeks, there is no significant increase in the amount of collagen in a healing wound or anastomosis, though turnover and thus synthesis are extensive. The strength of the scar continues to increase for many months after injury.

The cross-linking between collagen fibers and their orientation are the major factors that determine the tensile strength of tissues. Bursting pressure is used as a quantitative measure to grade the strength of an anastomosis in vivo. This pressure has been found to increase rapidly in the early postoperative period, reaching 60% of the strength of the surrounding bowel by 3 to 4 days and 100% by 1 week.12,13 The submucosal layer is, in fact, where the tensile strength of the bowel lies, as a consequence of its high content of collagen fibers [see Figure 1]. Therefore, in constructing a hand-sewn intestinal anastomosis, it is imperative that this layer is included when extramucosal bites are taken. Collagen synthetic capacity is relatively uniform throughout the large bowel but less so in the small intestine: synthesis is significantly higher in the proximal and distal small intestine than in the midjejunum. Overall collagen synthetic capacity is somewhat less in the small intestine. Although no significant difference has been found between the strength of ileal anastomoses and that of colonic anastomoses at 4 days, colonic collagen formation is much greater in the first 48 hours.14 It is noteworthy that the synthetic response is not restricted to the anastomotic site but appears to be generalized to a significant extent.15 The presence of the visceral peritoneum on the bowel wall also has an influence on the ease with which two bowel ends can be joined. This effect is highlighted by the increased technical difficulty of joining extraperitoneal bowel ends, for example the thoracic esophagus and the rectum.
Dehiscence has been linked adversely with increasing age.\textsuperscript{16,17} This connection may be secondary to a number of factors, including the presence of comorbid conditions, malnutrition, and vitamin deficiency. A study employing an in vivo model of severe protein malnutrition, which can occur in advanced cancer, demonstrated a reduction in tissue collagen, as well as in the bursting pressure of colonic anastomoses.\textsuperscript{18} However, the introduction of parenteral nutrition has not been shown to enhance anastomotic healing.\textsuperscript{18} Several factors that are known to inhibit collagen synthesis, such as vitamin C deficiency, zinc deficiency, jaundice, and uremia, have a detrimental effect on tissue healing.\textsuperscript{16} A critical stage in collagen formation is the hydroxylation of proline to produce hydroxyproline; this process is believed to be important for maintaining the three-dimensional triple-helix conformation of mature collagen, which gives the molecule its structural strength. The amount of collagen found in a tissue is indirectly determined by measuring the amount of hydroxyproline, though no significant statistical correlation between hydroxyproline content and objective measurements of anastomotic strength has ever been demonstrated.\textsuperscript{19} Vitamin C deficiency results in impaired hydroxylation of proline and the accumulation of proline-rich, hydroxyproline-poor molecules in intracellular vacuoles.

In high doses, corticosteroids have been associated with poor healing. One study employing therapeutic doses, however, reported no difference in leakage rates was found between control subjects and those treated with steroids.\textsuperscript{17}

**Local Factors**

Blood flow is a critical factor in tissue healing. The increased vascularity of the bowel wall is the reason why gastric and small bowel anastomoses heal more rapidly than anastomoses involving the esophagus or the large bowel. In preparing the bowel ends for anastomosis, it is imperative that the mesentery be prepared carefully and not dissected too far.

**Table 1** Principles of Successful Intestinal Anastomosis

| Well-nourished patient with no systemic illness |
| No fecal contamination, either within gut or in surrounding peritoneal cavity |
| Adequate exposure and access |
| Well-vascularized tissues |
| Absence of tension at anastomosis |
| Meticulous technique |

**Figure 1** Shown are the tissue layers of the jejunum. Most of the bowel wall’s strength is provided by the submucosa.
from the bowel edge. Mesenteric compromise, secondary to overly enthusiastic dissection or inappropriate suturing, may result in a reduction of perianastomotic blood flow. The avoidance of tension at the anastomosis is also critical; this is achieved through the appropriate mobilization of the splenic flexure. Other factors that influence blood flow at the site of anastomoses are hypovolemia and the viscosity of the blood.\(^{20}\) Radiation may damage the microcirculation and thereby predispose to poor healing.\(^{17}\)

**Technical Options for Fashioning Anastomoses**

Over the past 160 years, numerous different materials have been used to join one bowel end to another, including substances such as catgut and stainless steel. Newer materials include monofilaments and absorbable sutures. In the past 30 years, stapling devices have been embraced enthusiastically by the surgical community. The main attraction of these devices lies in their ability to create a robust anastomosis in a relatively short space of time. Their main drawback, as with any technologically advanced device, is their cost. More important, there continues to be some controversy regarding which of the two methods of creating an anastomosis yields better clinical outcomes.\(^{21}\) Accordingly, the following sections review the relative merits of hand-sewn and stapled anastomoses.

**Suturing: Technical Issues**

**Choice of Suture Material**

Apart from inert substances, most foreign materials will evoke an inflammatory reaction in the human body. Surgical sutures are no exception. Studies that have examined the relative abilities of different suture materials to elicit such a reaction have found that silk has a potent ability to cause a cellular infiltrate at the site of the anastomosis that may persist as long as 6 weeks after implantation.\(^{22}\) Substances such as polypropylene (Prolene), catgut, and polyglycolic acid (Dexon) evoked a milder response.\(^{22,23}\) There is little difference between absorbable and nonabsorbable sutures with respect to the strength of the anastomosis.

The ideal suture material is one that elicits little or no inflammation while maintaining the strength of the anastomosis during the lag phase of healing. This ideal substance has yet to be discovered, but the newer generation of sutures, which include monofilament sutures and coated braided sutures, represent a substantial advance beyond silk and other multifilament materials.

**Continuous versus Interrupted Sutures**

Both continuous and interrupted sutures are commonly used in fashioning intestinal anastomoses [see Figure 2]. Retrospective reviews have not shown interrupted sutures to have any advantage over continuous sutures in a single-layer anastomosis.\(^{24-26}\) Oxygen tension and blood flow, as discussed previously, are critical factors in anastomotic healing. Animal studies indicated that perianastomotic tissue oxygen tension was significantly lower with continuous sutures than with interrupted sutures.\(^{27}\) This finding was correlated with an increased anastomotic complication rate and impaired collagen synthesis and healing with continuous sutures in a rat model.\(^{28}\) A prospective, randomized trial compared the continuous single-layer technique for intestinal anastomosis (in the small bowel and colon) with the two-layer interrupted technique. No significant difference was seen in the leakage rate (3.1% for the single-layer technique versus 1.5% for the two-layer). The added advantages of reduced operating times and cost were observed. In a case series review that included 3,027 patients who had single-layer anastomoses done with continuous sutures, fistula rates ranged from 0 to 6.8% (mean fistula rate, 1.7%), which demonstrated that this suture technique could be safely performed.\(^{29}\)

**Single-Layer versus Double-Layer Anastomoses**

The technique of double-layer anastomosis, originating from work done by Travers and Lembert,\(^{29}\) has been used traditionally for more than 100 years. A double-layer anastomosis consists of an inner layer of continuous or interrupted absorbable suture and outer layer of interrupted absorbable or nonabsorbable suture [see Figure 3]. The technique of single-layer anastomosis was championed because of potential advantages such as reduced operating time and lower cost. The main issue to consider, however, is safety. A
randomized trial comparing the single- and double-layer techniques of anastomosis found no evidence that there was an increased risk of leak with the single-layer approach. However, the study groups (65 and 67 patients) were too small for any significant difference to be detected; the authors stated that a multicenter trial comprising at least 1,500 patients would be required to establish whether any such difference existed. Furthermore, a 2006 meta-analysis that addressed this issue by analyzing six trials with data from 670 patients (299 in the single-layer group, 371 in the double-layer group) concluded that there was no evidence that two-layer anastomoses yielded a lower rate of postoperative leakage than single-layer anastomoses.

STAPLING: TECHNICAL ISSUES

Choice of Stapler

Surgical stapling devices were first introduced by Hültl in 1908; however, they did not gain popularity at that time and for some time afterward because the early instruments were cumbersome and unreliable. The development of reliable, disposable instruments over the past 30 years has changed surgical practice dramatically. With modern devices, technical failures are rare, the staple lines are of more consistent quality, and anastomoses in difficult locations are easier to construct.

Three different types of stapler are commonly used for fashioned intestinal anastomoses. The transverse anastomosis (TA) stapler is the simplest of these. This device places two staggered rows of B-shaped staples across the bowel but does not cut it: the bowel must then be divided in a separate step. The gastrointestinal anastomosis (GIA) stapler places two double staggered rows of staples and simultaneously cuts between the double rows. The circular, or end-to-end anastomosis (EEA), stapler places a double row of staples in a circle and then cuts out the tissue within the circle of staples with a built-in cylindrical knife. All of these staplers are available in a range of lengths or diameters. Staplers may be used to create functional or true anatomic end-to-end anastomoses as well as side-to-side anastomoses. The original staplers were all designed for use in open procedures, but there are now a number of instruments (mostly of the GIA type) available for use in laparoscopic procedures. The staples themselves are all made of titanium, which causes little tissue reaction. They are not magnetic and do not cause subsequent difficulties with magnetic resonance imaging (MRI).

In a functional end-to-end anastomosis, two cut ends of bowel (either open or stapled closed) are placed side by side with their blind ends beside each other. If the bowel ends are closed, an enterotomy must be made in each loop of bowel to allow insertion of the stapler. A cutting linear (i.e., GIA) stapler is then used to fuse the two bowel walls into a single septum with two double staggered rows of staples and to create a lumen between the two bowel segments by dividing this septum between the rows. A noncutting linear (i.e., TA) stapler is then used to close the defect at the apex of the anastomosis where the GIA stapler was inserted. An alternative, and cheaper, method of closing the defect is to use a continuous suture. The cut and stapled edges of the bowel should be inspected for adequacy of hemostasis before the apex is closed. Some authors suggest cauterizing these edges to ensure hemostasis; however, given that electrical current may be conducted along the metallic staple line to the rest of the bowel, it is probably easier and safer simply to underpin bleeding vessels with a fine absorbable suture. It is also important to offset the two inverted staple lines before closing the apex.

True anatomic end-to-end stapled anastomoses may be fashioned with a linear stapler by triangulating the two cut ends and then firing the stapler three times in intersecting vectors to achieve complete closure [see Figure 4]. The potential drawback of this approach is that the staple lines are all everted. It is often easier to join two cut ends of bowel with an EEA stapler, which creates a directly apposed, inverted, stapled end-to-end anastomosis. However, circular staplers can be more difficult to use at times because of the need to invert a complete circle of full-thickness bowel wall. In addition—at least at locations other than the anus—they typically require closure of an adjacent enterotomy.

Staple Height

TA and GIA staplers are available with a variety of inserts containing several different types of staples. These inserts
vary with respect to width, the height (or depth) of the closed staple, and the distance between the staples in the rows. They are designed for use in specific tissues, and it is important to choose the correct stapler insert for a given application. In particular, inserts designed for closing blood vessels should not be used on the bowel, and vice versa. With TA and EEA staplers, it is possible to vary the depth of the closed staples by altering the distance between the staples and the anvil as the instrument is closed. The safe range of closure is usually indicated by a colored or shaded area on the shaft of the instrument. Thus, if full closure would cause excessive crushing of the intervening tissues, the stapler need not be closed to its maximum extent. A 1987 comparison of anastomotic techniques that used blood flow to the divided tissues as a measure of outcome found that the best blood flow to the healing site was provided by stapled anastomoses in which the staple height was adjusted to the thickness of the bowel wall. The next best blood flow was provided by double-layer stapled and sutured anastomoses, followed by double-layer sutured anastomoses and tightly stapled anastomoses, in that order.

**Single-Stapled versus Double-Stapled Anastomoses**

To accomplish many of these anastomoses, intersecting staple lines are created. Initially, some concern was expressed about the security of these areas and about the ability of the blade in the cutting staplers to divide a double staggered row of staples. Animal studies, however, demonstrated that even though nearly all (> 90%) of the staple lines that were subsequently transected by a second staple line contained

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**Figure 4** (a) The bowel ends are triangulated with three traction sutures. (b) A noncutting linear stapler (TA) is placed between two of the sutures. (c) The stapler is closed and the excess tissue excised. (d) The bowel is rotated, and steps b and c are repeated twice more to close the remaining two sides of the triangle.
bent or cut staples, the integrity of the anastomosis was not compromised in any way, nor was healing adversely affected.\textsuperscript{34,35}

**Hand-Sewn Versus Stapled Anastomoses**

Titanium staples are ideal for tissue apposition at anastomotic sites because they provoke only a minimal inflammatory response and provide immediate strength to the cut surfaces during the weakest phase of healing. Initially, tissue eversion at the stapled anastomosis was a major concern, given that everted handsewn anastomoses had previously been shown to be inferior to inverted ones; however, the greater support and improved blood supply to the healing tissues associated with stapling tend to counteract the negative effects of eversion. In fact, one study found that bursting strength for canine colonic end-to-end anastomoses was six times greater when the procedure was performed with a hand-stapler than when it was done with interrupted Dacron sutures.\textsuperscript{36}

In 1993, a randomized multicenter trial studied 440 patients who had either hand-sewn or stapled anastomoses after ileocolic resection for cancer.\textsuperscript{37} The patients were assessed both clinically and by imaging for the presence of a leak (consisting of a contrast enema at about 10 days after the operation). The overall leakage rate in the hand-sewn group was 8.3\%, which compared unfavorably with the 2.8\% rate in the stapled group. A possible explanation for the higher rate in the hand-sewn group might have been surgical inexperience with the variety of suture techniques used in the study (end-to-end and end-to-side with either continuous or interrupted sutures). In a study from the West of Scotland and Highland Anastomosis Study Group that included data on 732 patients at 5 centers, the rate of radiologically proven leakage was significantly higher in the sutured group (14.4\% versus 7.4\%); however, no difference was seen with respect to clinical leaks, morbidity, or postoperative mortality.\textsuperscript{38} A 1998 meta-analysis comparing the hand-sewn and stapled techniques of intestinal anastomosis addressed 13 trials published from 1980 to 1995.\textsuperscript{39} For colorectal anastomoses, no significant differences were seen in mortality, total leakage rate, clinical leakage rate, radiologic leakage rate, tumor recurrence rate, or incidence of wound sepsis. Strictures and technical problems, however, were more common in the stapled group. A subsequent meta-analysis that reviewed data from 955 patients with ileocolic anastomoses reported a significant reduction in the overall leakage rate and the clinical leakage rate when stapling was employed.\textsuperscript{40}

Even when the anastomosis had to heal under adverse conditions (e.g., carcinomatosis, malnutrition, previous chemotherapy or radiation therapy, bowel obstruction, anemia, or leukopenia), no significant differences have been demonstrated between stapled and hand-sewn anastomoses. Stapling has, however, been shown to shorten operating time, especially for low pelvic anastomoses. Cancer recurrence rates at the site of the anastomosis have been reported to be higher or lower depending on the technique used. Certainly, suture materials engender a more pronounced cellular proliferative response than titanium staples do, particularly with full-thickness sutures as opposed to seromuscular ones, and malignant cells have been shown to adhere to suture materials.\textsuperscript{41,42}

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**Unusual Techniques**

In 1892, Murphy introduced his button, which consisted of a two-part metal stud that was designed to hold the bowel edges in apposition without suturing until adhesion had occurred.\textsuperscript{43} Thereafter, the stud was voided via the rectum. Several modifications of this technique have been described since then, primarily focusing on the composition of the rings or stents. In particular, dissolvable polyglycolic acid systems have been developed. These so-called biofragmentable anastomotic rings leave a gap of 1.5, 2.0, or 2.5 mm between the bowel ends to prevent ischemia of the anastomotic line.

The use of adhesive agents such as methyl-2-cyanoacrylate to approximate the divided ends of intestinal segments has been studied as well.\textsuperscript{44} There was only a moderate inflammatory response at the wound, which persisted for 2 to 3 weeks. Leakage rates were high, however, and many technical problems remained (e.g., how to stabilize the bowel edges while they underwent adhesion). Fibrin glues have also been employed in this setting. Although these substances are not strong enough to hold two pieces of bowel in apposition, they have been used to coat a sutured bowel anastomosis in an effort to reduce the risk of anastomotic failure. To date, no controlled clinical trials have confirmed that this approach is worthwhile.

**Factors Contributing to Failure of Anastomoses**

**Type and Location of Anastomosis**

Since the introduction of stapling, there has been an increase in the number of extremely low anterior resections being performed routinely. The literature seems to suggest that rectal anastomoses are more prone to leakage than more proximal joins are.\textsuperscript{7,9} A retrospective review of risk factors in patients undergoing rectal resection for cancer found that low anastomoses, defined as being 5 cm or less from the anal verge, were associated with a 6.5-fold increased risk of leakage when compared to anastomoses that were more than 5 cm from the anal verge.\textsuperscript{45} Another study showed that the leakage rate was increased in patients undergoing low colorectal anterior resection in the absence of a proximal stoma (the leakage rate was 17\%, which fell to 6\% when a stoma was present).\textsuperscript{46} The technique of total mesorectal excision (TME), which is now standard for rectal cancer operations, has reduced the local recurrence rate to 5\% at 5 years.\textsuperscript{47} However, the incidence of anastomotic leakage in patients undergoing TME for low anterior resection is higher in the absence of a defunctioning stoma (25\% versus 8\%).\textsuperscript{48} The Rectal Cancer Trial on Defunctioning Stoma (a randomized multicenter trial) studied the outcomes of 234 patients undergoing low anterior resection with a defunctioning stoma.\textsuperscript{4} The overall leakage rate was 19.2\%; however, the rate in the group that had a stoma was only 10.3\%, compared with 28.0\% in the group that did not. Therefore, it is safe practice to cover a low anterior resection with a defunctioning stoma.

**Patient Preparation**

Patients who present in the emergency setting are usually compromised in terms of hydration status, typically as a consequence of sepsis, obstruction, or a combination of the two. Preoperative fluid optimization is always necessary and may
require the aid of intensivists. Before an elective procedure, the patient is assessed with regard to systemic diseases (e.g., cardiovascular, respiratory, or diabetes), and anemia is corrected. Adequate preoperative antibiotic prophylaxis has been shown to reduce the risk of postoperative infection in all types of bowel surgery and must be given at the start of the operation [see 1:1 Prevention of Postoperative Infection]. Some patients require additional steroids perioperatively [see 8:10 Endocrine Problems].

Mechanical bowel preparation (MBP) has been thought to be an essential component of colorectal surgery for more than 100 years.69,70 Emptying the bowel before elective operations on the colon was traditional until about 5 years ago, and indeed, this practice was recommended by the Association of Surgeons of Great Britain and Ireland (ASGBI) until relatively recently.51,52 The evidence for MBP was derived from observational studies showing that mechanical clearance of feces from the bowel was associated with reduced morbidity and mortality in colonic surgery.53 Proponents of MBP listed several advantages, such as reduction in intraluminal bacterial load, prevention of potential anastomotic disruption by fecal pellets and also easier handling of bowel.54 In recent years, however, there has been a shift in practice regarding the use of MBP.

A Swiss randomized clinical trial published in 2005 studied the effect of MBP on patients undergoing left-side colorectal resection with primary anastomosis.54 The anastomotic leakage rate proved to be lower in the group that did not receive MBP than in the group that did. Furthermore, the former group spent less time in hospital and exhibited less extra-abdominal morbidity (e.g., pneumonia and cardiac-related problems). These results seemed to agree with the findings of a Cochrane review.52 Two large randomized trials published in 2007 compared the outcomes of patients who underwent MBP (with either polyethylene glycol or sodium phosphate) and patients who did not.55,56 One recruited 1,431 patients undergoing elective colorectal surgery from 13 centers.55 Leakage was defined by the onset of significant symptoms and corroborated by means of imaging. The rate of leakage was 4.8% in the MBP group, which was not significantly different from the 5.4% rate in the non-MBP group. The other trial examined 1,343 patients from 21 centers and found no significant differences in outcomes (such as cardiovascul problems, general infections and surgical site infections) between the MBP group and the non-MBP group.56 However, in a a subsequent meta-analysis57 that examined data from 10 randomized trials conducted over the past 24 years, the rates of both anastomotic leakage and wound infection were significantly higher in the MBP group than in the non-MBP group (5.1 versus 2.6% and 8.2% versus 5.5%, respectively).57 Possible explanations of these findings include immune changes in the colonic mucosa that might impede wound repair.58 In view of the currently available evidence, some surgical institutions, including our own, have chosen to adopt a policy of employing fluid restriction and enemas rather than MBP before elective colorectal surgery.59

Enemas are given to patients undergoing anterior resections to ensure that fecal matter does not impede the use of stapling devices. It is advisable for patients to stop eating solid food 24 hours before the operation. Many trials have confirmed the benefits of giving IV antibiotics over the perioperative period.60 However, there is some evidence to suggest that there is an increased risk of Clostridium difficile-associated diarrhea with the use of cephalosporin, penicillin, and clindamycin.60–62 Prophylaxis of thromboembolism [see 6:6 Venous Thromboembolism] is mandatory in all patients scheduled to undergo intestinal anastomosis. There is very little evidence in the literature to indicate that thromboembolism has any direct effect on anastomotic leakage rates. However, mesenteric venous thrombosis (MVT) accounts for one-tenth of acute mesenteric ischemic events.63 The extent of thromboses is variable, with the worst outcome being mesenteric infarction necessitating urgent repeat laparotomy. Inadequate prophylaxis may increase the risk that MVT will occur postoperatively, especially in patients with other risk factors (e.g., a hypercoagulable state, previous thrombosis, or a history of smoking).

Associated Diseases and Systemic Factors

Anemia, diabetes mellitus, previous irradiation or chemotherapy, malnutrition with hypoalbuminemia, and vitamin deficiencies are all associated with poor anastomotic healing. Some of these factors can be corrected preoperatively. Malnourished patients benefit from nutritional support delivered enterally or parenterally before and after operation [see 8:22 Nutritional Support]. Well-nourished patients appear not to derive similar benefits from such support.64

Resections for Crohn disease appear to carry a significant risk of anastomotic dehiscence (12% in one prospective study) even when macroscopically normal margins are obtained.65 With the lifetime risk of repeated resections, strictureplasty has therefore become an attractive alternative to resectional management of Crohn disease even in the presence of moderately long strictures, diseased tissue, or sites of previous anastomoses. This approach allows preservation of more of the length of the small intestine.

The glucocorticoid response to injury may attenuate physiologic responses to other mediators whose combined effects could be deleterious to the organism.66 In animal experiments, wound healing, as measured by the bursting pressure of an ileal anastomosis 1 week after operation, was optimal at a plasma corticosterone level that maintained maximal nitrogen balance and corresponded to the mean corticosterone level of normal animals.67 Both supranormal and subnormal cortisol levels resulted in significantly impaired wound healing, probably through different mechanisms. It is believed that slow protein turnover is responsible for delayed anastomotic healing in adrenalectomized animals, whereas negative nitrogen metabolic balance is responsible for increased protein breakdown and delayed healing in animals with excess glucocorticoid activity.67,68

Lifestyle factors have also been associated with an increased risk of leakage. A Danish prospective study of 333 consecutive patients undergoing colorectal resection collected lifestyle information by means of a questionnaire.69 The overall leakage rate was 15.9% (53 out of 333). Smoking was found to be associated with an increased risk of anastomotic leakage (relative risk 3.18), as was alcohol consumption exceeding 35 units a week (relative risk 7.18).

Controversial Issues in Intestinal Anastomosis

Inversion versus Eversion

The question of the importance of inversion (as described by Lembert in the early 1800s) versus eversion of the
anastomotic line has long been a controversial one. It has been argued that the traditional inverting methods ignore the basic principle of accurately opposing clean-cut tissues. In the late 19th century, Halsted proposed an interrupted extramucosal technique, which has since been assessed in retrospective and prospective reviews and found to have a low leakage rate (1.3% to 6.0%) in a wide variety of circumstances. A 1969 study reported greater anastomotic strength, less luminal narrowing, and less edema and inflammation with everted small intestinal anastomoses in dogs. Subsequent laboratory and clinical studies have not confirmed these findings and, in fact, have often yielded quite the opposite results: lower bursting pressure, slower healing, and more severe inflammation have all been associated with an everted suture line. A 1970 trial, however, conclusively demonstrated the importance of inverting the cut edges of bowel in colorectal surgery. In this study, the rate of fecal fistula formation was far higher in the group that had everted suture anastomoses (43%) than in the group with inverted suture anastomoses (8%).

Nasogastric Decompression

Routine nasogastric decompression in patients undergoing a procedure involving an intestinal anastomosis remains controversial. In retrospective and prospective, randomized, controlled trials, routine use of a nasogastric tube conferred no significant advantage in terms of reducing the risk of anastomotic leakage. In fact, there was a trend toward an increased incidence of respiratory tract infections after routine gastric decompression. Nonetheless, one study found that nearly 20% of patients required insertion of a gastric tube in the early postoperative period. If the choice is made not to place a nasogastric tube routinely, it is important to remain alert to the potential for gastric dilatation, which can develop suddenly and without warning.

Abdominal Drains

Fecal contamination from bowel surgery is a dreaded complication. Peritoneal drainage is of the subject of considerable controversy, with two basic schools of thought dominating. The first school accepts the possibility that drains may help with diagnosis by serving as an early warning system for either anastomotic leakage or bleeding and makes the point that evacuating blood and serous fluid will reduce the risk of abscesses. The other school is skeptical about the benefits, arguing that drains may irritate the peritoneum, thus increasing the production of serous fluid, and may provide a route whereby microbes can enter the peritoneal cavity. In addition, there is a potential risk that the drain may physically impede the movement of the omentum and adjacent organs and consequently may hinder the body’s innate ability to wall off any possible infection. Finally, it is thought that drains are at high risk for blockage.

Even before World War I, the old dictum “when in doubt, drain” was called into question by Yates, who wrote that the peritoneal cavity could not be effectively drained because of adhesions and rapid sealing of the drain tract. Six decades later, one study showed a dramatic increase in the incidence of anastomotic dehiscence (from 15% to 55%) after the placement of perianastomotic drains in dogs. This increase was associated with a significant increase in mortality. A 1999 study of pelvic drainage after a rectal or anal anastomosis showed that prophylactic drainage did not improve outcome or reduce complications. Yet another study reported the severe inflammatory reaction caused by drains at anastomoses.

Despite these findings, many surgeons elect to place an intra-abdominal drain in the pelvis after an anterior resection or a coloanal anastomosis because of the higher than usual risk that a fluid collection will develop. Drainage is rarely helpful, or indeed easy, after a gastric or small bowel anastomosis. Drains are indicated, however, after emergency operations for peritonitis or trauma in which it was necessary to close or anastomose damaged or inflamed bowel.

Operative Techniques for Selected Anastomoses

The following section covers the essential preliminary steps before a bowel anastomosis and then describes three generic operations involving the small and large bowel. These procedures illustrate many of the general principles previously discussed (see above).

Patient Positioning and Incision

Patients must be positioned on the operating table in a manner that is appropriate for the planned operation. Most abdominal operations are performed through a midline incision of adequate length with the patient supine. For pelvic procedures, the patient is placed in the lithotomy position to allow access to the abdomen and the anus; care must be taken to position the legs and feet in the stirrups correctly, without excessive flexion or abduction and with sufficient padding to prevent pressure ulceration, thrombosis, and neurapraxia. For esophageal procedures, the patient is positioned lying on the appropriate side, and the incision of choice is a lateral thoracotomy. Occasionally, the patient must be shifted to a different position during the course of an operation. Gravity can be useful for moving structures out of the way. Accordingly, it is often helpful to alter the axis of the operating table. For example, a 30° head-down or Trendelenburg position facilitates pelvic operations.

Exposure, Mobilization, and Dissection

Access is a critical determinant of the ease with which an operative procedure can be carried out. Accordingly, the incision must be made in such a way as to allow adequate exposure of the operating field. The lateral aspects of the field can be controlled by using a suitable retractor, which can be attached to the operating table. This measure allows more efficient use of operating assistants and space. Often, the colorectal surgeon is faced with operating in confined spaces, such as the pelvis. Therefore, it is important to be able to compartmentalize the abdomen. This can be achieved in a number of ways. The small bowel can be extremely difficult to handle and therefore is commonly packed away by placing wet gauze. The next stage involves bringing the bowel to the surface. In the absence of adhesions or tethering caused by disease, the small bowel is usually sufficiently mobile to allow the relevant segment to be brought out of the abdomen. Doing so makes the operation easier and allows the remainder of the bowel to be kept warm and tension free.
inside the abdominal cavity. Sometimes, the transverse colon and the sigmoid colon are mobile enough to be brought to the surface. More commonly, however, as with the other sections of the large bowel, the peritoneum must be divided along the lateral border of the colon and the retroperitoneal structures reflected posteriorly. Tension is rarely a problem with small bowel anastomoses, but with colonic or esophageal anastomoses, it is absolutely vital that the two ends of bowel to be joined lie together easily. For a large bowel anastomosis, this means that the splenic flexure or the hepatic flexure—or, sometimes, both—must be adequately mobilized.

Classically, the tissues around the bowel are divided with a scissors, whereas the mesentery is divided between clamps and tied with a suitable thread. Recognized tissue planes are separated by means of blunt dissection with either the fingers or a swab. Minor bleeding points are occluded with a coagulating electrocautery, though this approach is often relatively ineffective on mesenteric or omental vessels. The disadvantages of this dissection technique are that oozing from raw surfaces can be a nuisance and that the tissues beyond a tie are often bulky and leave dead tissue within the body that may act as a focus for infection and adhesions. Newer methods of dissection that make use of the ultrasonic scalpel or the bloodless bipolar electrocautery prevent these problems by coagulating a small section of tissue between the jaws of the instrument and simultaneously occluding all blood vessels up to a certain size within the tissues. Consequently, bleeding is reduced, fewer (or no) ties are needed, and only a small quantity of dead tissue results at each point. Becoming skilled in the use of these instruments often takes a little time, but the time is well spent, in that it is now possible to perform an intestinal resection without resort to a single tie.

**Bowel Resection**

The precise techniques involved in resecting specific bowel segments will not be discussed in great detail here. (Colonic resection, for example, is described elsewhere.) The following discussion outlines only the general principles.

**Preparation**

The segment of bowel to be removed must be isolated with an adequate resection margin. To this end, all surrounding adhesions are divided. Next, the mesentery is divided. The key consideration in this step is to preserve the blood supply to the two remaining ends of bowel while still achieving adequate excision of the diseased bowel. This is more easily accomplished in the small bowel than in the large bowel, thanks to the ample blood supply of the former; even so, transillumination of the mesentery and careful division of the vascular arcade are vital. In the colon, the surrounding fat and the appendices epiploicae should be cleared from the remaining bowel ends so that subsequent suture placement is straightforward.

Care should be taken to avoid two common problems. First, ties placed close to the bowel can bunch tissues excessively and thereby cause angulation or distortion of the free edge of the intestine, which can make the anastomosis difficult and threaten the blood supply. Second, because mesenteric vessels are usually tied very close to their ends, the arteries sometimes slip back beyond the ties. Such slippage results in a hematoma within the leaves of the mesentery, which can itself threaten the viability of the bowel. Generally, the bleeding vessel can be secured with a fine stitch; sometimes, however, a limited further bowel resection is the only safe course of action. Both of these problems can be avoided by using the ultrasonic scalpel or the bipolar coagulating electrocautery.

**Division of Bowel**

If staplers are not available, the bowel segment to be removed is isolated between noncrushing clamps placed across the intestinal lumen some distance away from the resection margin so as to limit the amount of bowel contents that can escape into the wound. Crushing clamps are then placed on the specimen side of the diseased segment at the point of the resection, and the bowel is divided with a knife just proximal and distal to the clamps. Thus, the lumen of the diseased segment is never open within the abdominal wound. Even so, the contents of the bowel between the open ends and the non-crushing clamps can leak into the wound. To minimize this problem, it is usual to isolate the working area with abdominal packs, which are sometimes soaked in an antiseptic (e.g., povidone-iodine).

One advantage of using staplers for an anastomosis is that in most instances, division of the bowel can be accomplished without opening the lumen. A linear cutting stapler (e.g., GIA) transects the bowel and seals the two cut ends simultaneously. Unfortunately, in the pelvis, it is usually necessary to employ an angulated noncutting linear stapler (e.g., TA) so as to obtain as much length as possible distal to the lesion. The proximal rectum is then clamped with a crushing bowel clamp, and a long knife is used to transect the rectum above the staple line. Even so, there remains the potential for leakage of a small amount of fecal material, which must then be suctioned away.

**Simple Bowel Closure**

There are occasions where the bowel damage requires simple repair rather than a formal resection, as in the case of a perforated duodenal ulcer or an iatrogenic injury sustained during adhesiolyis. Such holes may be closed in a number of ways. Most surgeons would use a double layer of absorbable sutures. Special mention should be made of the technique of strictureplasty, which is employed for a number of benign small bowel strictures (especially those resulting from Crohn disease) as a means of avoiding small bowel resection and anastomoses. In this procedure, the bowel is opened longitudinally and closed transversely with a single layer of 2-0 polyglycolic acid sutures in a Connell stitch. Excellent functional results have been achieved with this technique despite its reputation for fistula formation, which is associated with Crohn disease.

**Single-Layer Sutured Extramucosal Side-to-Side Enterostomy**

A side-to-side anastomosis [see Figure 5] may be performed when no resection is done, as a bypass procedure (e.g., a gastroenterostomy); after a small bowel resection; when there is a discrepancy in the diameter of the two ends to be anastomosed (e.g., an ileocolic anastomosis after a right hemicolecotomy); or when the anatomy is such that the most
tension-free position for the anastomosis is with the two bowel segments parallel (as in a Finney strictureplasty).

Two stay sutures of 3-0 polyglycolic acid are placed approximately 8 cm apart on the inner aspect of the antimesenteric border. A 5 cm enterotomy is made on each loop with an electrocautery or a blade on the inner aspect of the antimesenteric border. If an electrocautery is used, care must be taken not to injure the mucosa of the posterior wall during this maneuver; placement of a hemostat into the enterotomy to lift the anterior wall usually prevents this problem. Hemostasis of the cut edges is ensured, and the remaining enteric contents are gently suctioned out. A swab soaked in povidone-iodine may be used at this point to cleanse the lumen of the bowel in the perianastomotic region.

A full-length seromuscular and submucosal stitch of 4-0 polyglycolic acid is placed and tied on the inside 4 to 5 cm from the blind end of the distal segment; this proximity is probably unnecessary. The proximal cut end of the intestine is similarly closed either with staples after division with a cutting linear stapler or with a crushing bowel clamp. This proximal end is brought into apposition with the side of the distal bowel segment at a point no farther than 2.5 to 5 cm from the blind end of the distal segment; this proximity to the cut end is important for prevention of the blind loop syndrome.

Stay sutures of 3-0 polyglycolic acid are placed between the serosa of the proximal limb, about 10 to 15 mm from the clamp, and the serosa of the distal limb. Interrupted seromuscular sutures of 3-0 polyglycolic acid are then placed between these stay sutures, spaced about three to six to the centimeter. These stitches may be tied sequentially or snapped and tied once they are all in place. It is crucial not to apply excessive tension, which could cut the seromuscular layer or render it ischemic. Suction is then readied. The staple line or crushed tissue on the proximal limb is cut off with a coagulating electrocautery or a knife; this maneuver opens the lumen of the proximal limb. All residual intestinal content is gently suctioned.

An enterotomy or colotomy is created on the distal limb opposite the open lumen of the proximal bowel. A full-thickness suture of 3-0 polyglycolic acid is inserted in the posterior wall at a point close to the far end of the enterotomy and run in an over-and-over stitch back toward the surgeon. The corner is rounded with the baseball stitch, and when the anterior wall is reached, the Connell stitch is used. A second full-length 3-0 suture is started at the same point on the posterior wall as the first, and the short ends of the two stay sutures are tied together and may simply be cut off. The remainder of the posterior wall is sewn away from the surgeon in the same manner as the portion already sewn, and the corners are approximated with the baseball stitch. The anterior wall is then completed with this second suture, either with the Connell stitch or with an over-and-over stitch with the assistant inverting the edges before applying tension to the previous stitch.

When the defect is completely closed, the two sutures are tied across the anastomotic line. The stay sutures are removed, and the anastomosis is carefully inspected. Often, there is no mesenteric defect to close in a side-to-side anastomosis, but if there is one, it should be approximated at this point with continuous or interrupted absorbable sutures, with care taken not to injure the vascular supply to the anastomosis.

**DOUBLE-LAYER SUTURED END-TO-SIDE ENTEROCOLOSTOMY**

In this procedure, the end of the ileum is joined to the side of the transverse colon [see Figure 6]. The distal colon is divided with a cutting staple so that a blind end is left. Some surgeons underpin or bury this staple line, though this practice is probably unnecessary. The proximal cut end of the intestine is similarly closed either with staples after division with a cutting linear stapler or with a crushing bowel clamp. This proximal end is brought into apposition with the side of the distal bowel segment at a point no farther than 2.5 to 5 cm from the blind end of the distal segment; this proximity to the cut end is important for prevention of the blind loop syndrome.

Stay sutures of 3-0 polyglycolic acid are placed between the serosa of the proximal limb, about 10 to 15 mm from the clamp, and the serosa of the distal limb. Interrupted seromuscular sutures of 3-0 polyglycolic acid are then placed between these stay sutures, spaced about three to six to the centimeter. These stitches may be tied sequentially or snapped and tied once they are all in place. It is crucial not to apply excessive tension, which could cut the seromuscular layer or render it ischemic. Suction is then readied. The staple line or crushed tissue on the proximal limb is cut off with a coagulating electrocautery or a knife; this maneuver opens the lumen of the proximal limb. All residual intestinal content is gently suctioned.

An enterotomy or colotomy is created on the distal limb opposite the open lumen of the proximal bowel. A full-thickness suture of 3-0 polyglycolic acid is inserted in the posterior wall at a point close to the far end of the enterotomy and run in an over-and-over stitch back toward the surgeon. The corner is rounded with the baseball stitch, and when the anterior wall is reached, the Connell stitch is used. A second full-length 3-0 suture is started at the same point on the posterior wall as the first, and the short ends of the two stay sutures are tied together and cut. This second suture is then run away from the surgeon to complete the posterior wall, and the anterior wall is completed with the Connell stitch. The two sutures are then tied across the anastomotic line.

A second series of interrupted seromuscular stitches is then placed anteriorly in the same fashion as the seromuscular stitches placed in the posterior wall. It is important not to narrow either lumen excessively by imbricating too much of the bowel wall into this second layer. The lumen of the
anastomosis is palpated to confirm patency, and the mesenteric defect is closed if possible with either continuous or interrupted absorbable sutures. The integrity of the join can be tested by injecting 20 mL of saline into the lumen of the bowel, which is then placed under gentle pressure by simultaneously finger-clamping the bowel a couple of centimeters distal to the anastomosis and a couple of centimeters proximally.

**Figure 6** Double-layer sutured end-to-side enterocolostomy. *(a)* The proximal bowel end is stapled, interrupted Lembert stitches are used to form the posterior outer layer, and a colotomy is made. *(b)* Two continuous sutures are used to form the inner layer of the anastomosis; the posterior portion is done with the over-and-over stitch, the anterior with the Connell stitch. *(c)* Interrupted Lembert stitches are used to form the anterior outer layer.

Once the surgeon is satisfied that the bowel is sufficiently mobilized, a noncrushing bowel clamp is placed on the colon 10 to 15 cm proximal to the margin, and the crushing clamp is removed. At this stage, it is usual to create an 8 to 10 cm colonic J pouch; this measure typically yields a substantially
improved functional outcome, especially in the early postoperative period in older patients. A whip-stitch (or purse-string suture) of 2-0 polypropylene is placed around the colotomy, and the anvil from the appropriately sized curved EEA stapler is inserted into the open end and secured in place by tying the suture. The proximal bowel clamp is removed. The assistant—who may also, if desired, gently wash out the rectal stump with a dilute povidone-iodine solution—performs a digital rectal examination.

The stapler, with its trocar attachment in place, is then inserted into the anus under the careful guidance of the surgeon. The pointed shaft is brought out through or adjacent to the linear staple line, and the sharp point is removed. The peg from the anvil in the proximal colon is snapped into the protruding shaft of the stapler, and the two edges are slowly brought together. The colonic mesentery must not be twisted, and the ends must come together without any tension whatsoever. The stapler is fired. In some types of stapling guns, a crunching sound is heard. The anvil is then loosened the appropriate amount, and the entire mechanism is withdrawn through the anus. Finally, the proximal and distal rings of tissue, which remain on the stapler, are carefully inspected to confirm circumferential closure of the staple line.

The pelvis is then filled with body-temperature saline, and a Toomey or bladder syringe is used to insufflate the neorectum with air. The surgeon watches for bubbling in the pelvis as a sign of leakage from the anastomosis. If there is a leak, additional soluble sutures must be placed to close the defect and another air test performed. A rectal tube may then be inserted by the assistant or may be placed at the end of the procedure. When the anastomosis is very low or there is some concern about healing, a drain may be placed in the pelvis behind the staple line; however, as noted, this practice has not been shown to be beneficial and may in fact impair healing.

Figure 7 Double-stapled end-to-end coloanal anastomosis. (a) The C-EEA stapler comes with both a standard anvil (left) and a trocar attachment (right). A more recent version of these staplers comes with a trocar in the body rather than in the head of the device. (b) The rectal stump is closed with an angled linear noncutting stapler. A purse-string suture is placed around the colotomy, and the anvil of the stapler is placed in the open end and secured. (c) The stapler, with the sharp trocar attachment in place, is inserted into the anus, and the trocar is made to pierce the rectal stump at or near the staple line, after which the trocar is removed. (d) The anvil in the proximal colon is joined with the stapler in the rectal stump, and the two edges are slowly brought together. (e) The stapler is fired and then gently withdrawn.
As noted (see above), a 1998 meta-analysis by Macrae demonstrated an association between stapled anastomoses and an increased incidence of colorectal anastomotic strictures, in comparison with hand-sewn anastomoses.39 The cause of this association remains uncertain. Most of these patients were asymptomatic and in those who required treatment, simple dilatation was sufficient to rectify the problem. A 2007 Cochrane review did not find the risk of anastomotic strictures to be increased in patients undergoing ileocolic resection with a linear cutting stapler.40

Conclusion

Any anastomosis, no matter how technically sound on creation, may fail. The limiting factor may be the tissue or the resulting inflammatory sequelae that follow closure of the abdominal wall. Therefore, as for ultralow anterior resections, it is important to recognize any potential risk factors and take the measures necessary to prevent any harm that may ensue if leakage results. This may mean giving the patient a temporary stoma. Even if fecal diversion has been carried out, it is important to keep watching closely for any signs of failure and to take prompt action if such signs appear.

Anastomtic failure rates have improved over the past two centuries, and postoperative morbidity and mortality have decreased accordingly. These beneficial developments can be attributed to a combination of factors, such as better appreciation of the principles of healing, improved anesthesia, appropriate antibiotic prophylaxis, and enhanced postoperative monitoring. Currently, with the emergence of laparoscopic colorectal surgery, it is essential that the surgeon continues to practice the same principles of creating a join—good apposition of the edges, without tension and with an optimal blood supply—just as for open colorectal surgery.

References

Acknowledgment

Figures 1 through 7 adapted from Tom Moore. Portions of this chapter are based on previous iterations written for *ACS Surgery* by Zane Cohen, MD, Barry Sullivan, MD, and Julian Britton. The authors wish to thank Drs. Cohen, Sullivan, and Britton.