17 Fundamentals of Gastrointestinal Anastomoses

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17.1 Introduction

The creation of a gastrointestinal anastomosis is a fundamental skill essential to general surgery. As surgical techniques have evolved over the centuries, key concepts critical to the success of an anastomosis hold true. This chapter will detail the history of gastrointestinal anastomoses, will provide general principles for creation of a viable and successful anastomosis, and will review key technical considerations and current controversies.

17.2 Historical Perspective

Writings on gastrointestinal wound healing date as far back as the early nineteenth century. In 1812 Benjamin Travers affirmed, “the union of a divided bowel requires the contact of the cut extremities in their entire circumference…the species of suture employed is of secondary importance if it secures the contact” [1, 2]. A decade later, the French surgeon Antoine Lembert further specified the importance of serosal apposition with mucosal inversion [1, 2]. It took until the late nineteenth century for William Stewart Halsted to identify the submucosa as the strongest layer of the intestinal wall [1–3]. Through most of the twentieth century, it became standard practice to perform a two-layer, inverting anastomosis.

Controversy arose in the 1960s and 1970s when studies on canine models found everted anastomoses to have increased edema and tensile strength in the first 21 days after surgery [4]. This was quickly refuted by several animal studies which strongly recommended against mucosal eversion after finding inverted anastomoses to have superior strength and decreased adhesion formation [5–7].

Further debate arose in 1966 with the introduction of automatic stapling devices. Ravitch et al. were the first to report on the benefits of the “Ligating-Dividing-Stapling Instrument,” citing versatility, dependability, and a decrease in bowel wall trauma [8]. Initial randomized controlled trials (RCTs) comparing stapled versus hand-sewn gastrointestinal anastomoses found no difference in the rate of anastomotic leak, morbidity, or mortality [9]. Since these early RCTs, newer studies have found there are differences depending on the specific situation and location within the gastrointestinal tract.

In 1993, Choy et al. published a large RCT demonstrating that stapled ileocolonic anastomoses after elective right hemicolectomy had decreased

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fecal contamination and a trend toward a decreased anastomotic leak rate [10]. This was later supported by a 2011 Cochrane report comparing 441 stapled versus 684 hand-sewn anastomoses. Stapled ileocolonic anastomoses had a significantly lower rate of anastomotic leak, particularly in patients with malignancy [11]. Studies of trauma patients after penetrating bowel injury have found lower leak rates with hand-sewn anastomoses [12, 13].

Data regarding colorectal anastomoses has been mixed [9]. A 2001 meta-analysis included nine trials studying 1233 patients randomized to a hand-sewn versus stapled colorectal anastomosis [14]. The authors found a higher incidence of anastomotic strictures in the stapled group; however, the overall, radiological, and clinical leak rates were similar. As such, current guidelines recommend the surgeon use their clinical judgment in deciding which type of technique to use.

17.3 Physiology of Wound Healing and Anatomy of the Intestinal Wall

In order to understand the basic principles guiding the construction of a gastrointestinal anastomosis, it is important to understand the basic physiology of gastrointestinal wound healing and anatomy of the intestinal wall.

Creation of an enterotomy leads to initial hemostatic vasoconstriction followed by secondary vasodilation and increased capillary permeability, mediated by kinins. This results in edema and swelling at the tissue ends [15, 16]. The appearance of granulation tissue in the anastomosis commences the proliferative phase of healing during which collagen undergoes lysis and synthesis [15, 17, 18]. Studies in rabbits have shown that between days three and five of healing, there is an abundance of undifferentiated mesenchymal cells in the healing muscle layers along with capillary invasion. These cells transform into smooth muscle cells and phagocytic histiocytes. This transformation is thought to be responsible for the establishment of smooth muscle tissue [15, 19].

The serosa consists of a thin layer of connective tissue covering the muscularis externa. It is covered on its outer aspect by the mesothelial lining of the peritoneal cavity. Good serosal apposition is necessary to minimize the risk of leakage [4, 15, 20, 21] and is best achieved by using an inverting type of suture technique. Extraperitoneal segments of the GI tract without a serosal covering lack this component of anastomotic protection and are at a higher risk of complications, as seen in the esophagus and lower third of the rectum [15, 22].

The submucosa provides the GI tract with the majority of its tensile strength and is responsible for anchoring the sutures that hold an anastomosis together [15, 23]. The submucosa is composed of loosely interwoven collagenous, elastic, and nerve fibers in addition to blood and lymphatic vessels. This layer has a predominance of type I collagen [15, 24].

Intestinal mucosa is repaired by migration and hyperplasia of epithelial cells which cover the granulation tissue of the wound and seal the defect, creating a watertight barrier [15, 25]. This sealing can occur in as little as three days if the layers of the bowel wall are directly apposed. Any inversion or eversion of specifically the mucosa will delay this process [15, 26].

17.4 General Concepts and Considerations

17.4.1 Factors Determining Anastomotic Healing

Both local and systemic factors impact anastomotic wound healing. These are highlighted in Table 17.1.

The key local factors encouraging healing include adequate intrinsic blood supply and the avoidance of undue tension on the anastomosis [15, 27, 28]. These affect oxygen delivery to the tissue which is required for the hydroxylation of lysine and proline during collagen synthesis [15, 27, 29, 30]. During the explorative, resective, and reconstructive steps of any procedure, the surgeon must employ meticulous technique in order to avoid excessive or rough handling of tissues. Additionally, excessive effort aimed at mobiliz-

Table 17.1 Local and systemic factors affecting anastomotic healing [7, 10]

	Local	Systemic
Positive	Adequate blood supply Healthy tissue edges Seromuscular apposition	Adequate nutritional status Hemodynamic stability
Negative	Tension on the anastomosis Presence of infected or necrotic tissue Hematoma formation Radiation to involved bowel distal obstruction	Anemia/blood transfusion Liver/kidney failure Medications (immunosuppressant, NSAIDs, steroids) Sepsis

ing the limbs to bring together can damage the primary blood vessels and impact perfusion [15, 31, 32]. Conversely, inadequate mobilization can leave tension on the anastomosis, compromising microperfusion leading to inflammatory cell infiltrates [15, 33]. The effect of tension on the microcirculation at the anastomotic site is least tolerated in the colon [15, 34].

Systemically, the presence of hypotension, hypovolemia, or sepsis affects blood flow and subsequent oxygen delivery. Patient factors such as malnutrition, immunosuppression, and the use of certain medications (i.e., steroids, NSAIDs) can also impair wound healing.

17.4.2 Anastomotic Configuration

Gastrointestinal anastomoses are classically described by the alignment of lumens being anastomosed (end-to-end, end-to-side, side-to-side) and the relative direction of peristalsis in the two segments (isoperistaltic vs antiperistaltic). In deciding which configuration to choose, one must take into consideration the segments of bowel being anastomosed, size discrepancy between the two segments, and any tension that may exist across the anastomosis. Anastomosis to the "side" of a segment is useful in situations where there is a size discrepancy between two loops, such as a gastroenteric or ileocolonic anastomosis. A side-to-side configuration also creates a wider anastomosis, minimizing the risk of narrowing or stricturing. An isoperistaltic anastomosis is thought to promote emptying and is generally preferred; however, an antiperistaltic anastomosis may be considered if delayed emptying is desired (i.e., short gut).

17.4.3 Choice of Suture Material or Stapling Device

The choice of suture material is generally dependent on the location within the GI tract and the enteric layer being anastomosed [35]. Sutures are typically 2-0 or 3-0 gauge in caliber and connected to a narrow, *tapered* needle of similar size. Suture may be monofilament, braided, or barbed. When performing a two-layer anastomosis, the inner layer traditionally utilizes an absorbable suture material (i.e., polyglactin [Vicryl]). The outer seromuscular layer is composed of nonabsorbable suture such as silk or polyester (Ethibond). For single-layer intestinal anastomoses, a long-lasting absorbable suture (e.g., polydioxanone [PDS]) or a nonabsorbable suture may be used. In creating a bilioenteric anastomosis, an absorbable synthetic monofilament suture is preferred to prevent infection or stone formation.

If the surgeon opts for a stapled anastomosis, important considerations include choice of stapling device and staple height. For a more in-depth look at stapling devices, you may refer to Chapter 10. In general, linear cutting staplers are preferred for a side-to-side anastomosis, whereas circular staplers are useful for end-to-side or end-to-end anastomoses. Staplers are available in various lengths and diameters depending on intestinal location and use. Staple cartridges are color coded to correspond to the height of the staples [36]. For intestinal anastomoses, a cartridge with an open/closed stapled height of 3.5/1.5 mm is commonly used. For thicker tissues (i.e., gastric tissue) a 3.8/1.8 mm or 4.1/2.0 mm cartridge may be used.

17.5 Technical Considerations: Review of Specific Anastomoses

Fundamental to the success of any intestinal anastomosis is the adherence to a few key principles, aimed to minimize the risk of leak or disruption [2]. First, the surgeon must employ good surgical technique, minimizing trauma to the tissues through gentle handling with atraumatic instruments. All sutures should incorporate the submucosa, which is the strength layer of the small intestine. Care should be taken to approximate the mucosa while preventing it from extruding from the suture line. Sutures should be placed 2–3 mm apart in order to create a watertight, airtight, leakproof closure. Finally, all segments of bowel being joined must have healthy blood supply with adequate hemostasis and avoidance of tension on the anastomosis. As it applies to any anastomosis, be it gastrointestinal or vascular, one key tenet is that no distal stricture or obstruction should exist; otherwise, the anastomosis healing and lifespan are doomed.

With these general concepts in mind, we will highlight the technical aspects of creating a few common anastomoses.

17.5.1 Hand-Sewn Gastrojejunostomy

This section will review a hand-sewn end-to-side isoperistaltic gastrojejunostomy in both a double-layer and single-layer fashion. It is important to note that this technique can be adapted to construct an enteroenteric, ileocolonic, or colocolonic anastomosis.

17.5.1.1 Double-Layer Hand-Sewn Gastrojejunostomy

The cut end of each enteric segment is brought together and aligned in an isoperistaltic orientation. The cut ends are secured by a staple line, non-crushing bowel clamp, or a series of Babcock clamps. For the purposes of this chapter, we will assume the cut end is secured by a staple line. Stay sutures are placed at the proximal and distal ends of the anastomosis, 5 mm from the staple line, incorporating a seromuscular bite using 3-0 silk. These sutures are left untied and are secured with a small clamp.

The posterior outer layer is created first using interrupted seromuscular (Lembert) stitches of 3-0 silk (Fig. 17.1). On the jejunal side, bites should be taken along the posterior wall, 5 mm away from the antimesenteric border. On the gastric side, bites should be taken on the posterior wall, ending 5 mm away from the staple line. Stitches should be placed 3–4 mm apart. Care should be taken to take good seromuscular bites, avoiding full thickness bites incorporating the mucosa. Sutures can be tied sequentially or once all stitches have been placed. All knots are then cut with the exception of the most proximal and distal knots, which serve to maintain traction.

With the posterior outer layer complete, the gastric staple line is excised, and a jejunal enterotomy is made to expose the mucosa. The posterior inner layer is then created using 3-0 absorbable braided sutures in a running locking fashion (Fig. 17.2). Two separate full thickness sutures are placed starting at the midpoint of the anastomosis. Each suture is tied down and then tied to the tail of the other. Full thickness running locking bites should be taken, advancing 5 mm with each bite while remaining 2–3 mm above the posterior Lembert stitches. Once at the apices, the same sutures are used to "turn the corner" as you transition to the anterior inner layer. A full thickness bite is taken from the gastric lumen toward the corner stitch on the gastric side (in to out). The next bite is then taken from the corner stitch on the jejunal side into the jejunal lumen (out to in). Once back in the lumen, the next stitch crosses over to the gastric side. This continues around the corners, advancing only a few millimeters until you reach the anterior layer.

The anterior inner layer is constructed using a "Connell" stitch, passing the suture from outside in, then inside out on one side, then crossing directly across and passing from outside in to inside out on the other side (Fig. 17.3). (Common saying for the Connell Stitch: "Go into the bar, then out of the bar, cross the street and go into the next bar, go out of the bar, cross the street, etc.") The bites should incorporate a relatively larger bite of serosa and smaller bites of mucosa to ensure good inversion of the mucosa and aposition of the serosa. Once the two sutures meet at the midpoint of the anterior wall of the anastomosis, they are tied together to complete the anterior inner layer. As this step is completed, it is important for the assistant to keep constant tension on this running suture.

The anterior outer layer is constructed using 3-0 silk Lembert sutures traversing the length of the anastomosis. Seromuscular bites should be taken 3–4 mm apart and then tied. Once the anastomosis is complete, it should be examined and palpated to ensure patency and integrity.

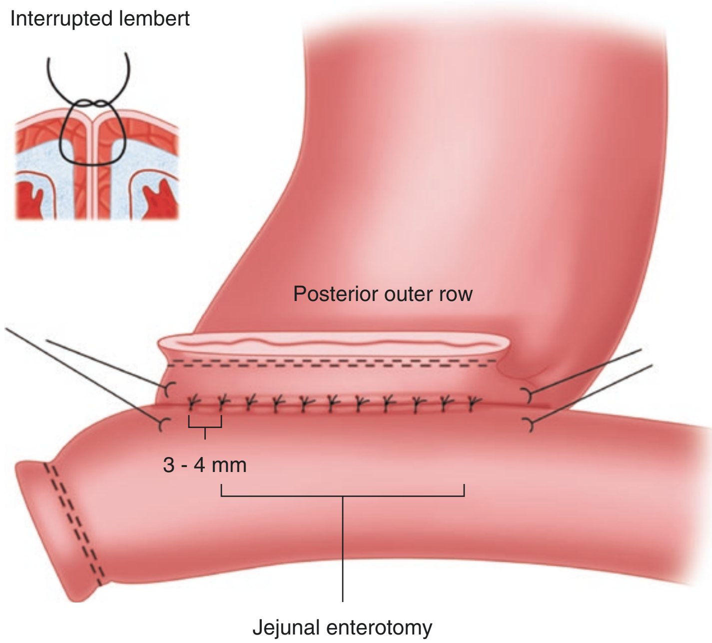

Fig. 17.1 Hand-sewn two-layer gastrojejunostomy: the posterior row is composed of interrupted Lembert sutures (inset) using 3-0 silk. Stitches should be placed 3–4 mm apart, taking good seromuscular bites. Once all knots have been tied, the gastric staple line is excised, and a jejunal enterotomy is made using surgical energy

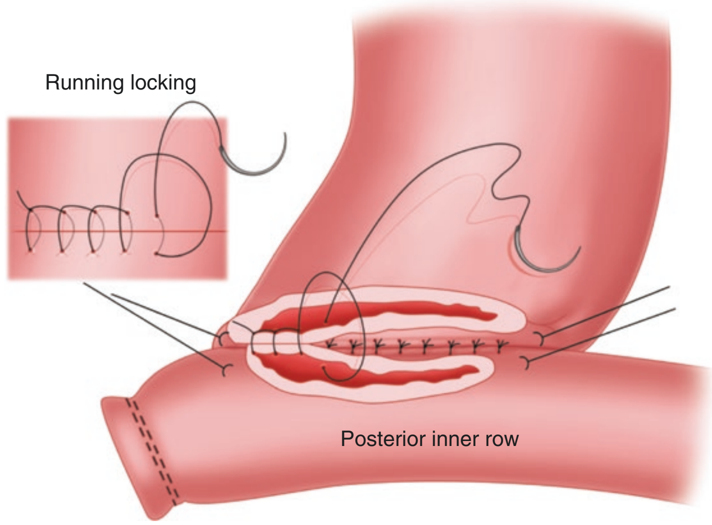

Fig. 17.2 Hand-sewn two-layer gastrojejunostomy: the posterior inner row is performed using 3-0 Vicryl in a running locking fashion. Bites should remain 2–3 mm above the posterior Lembert suture while advancing 5 mm with each bite

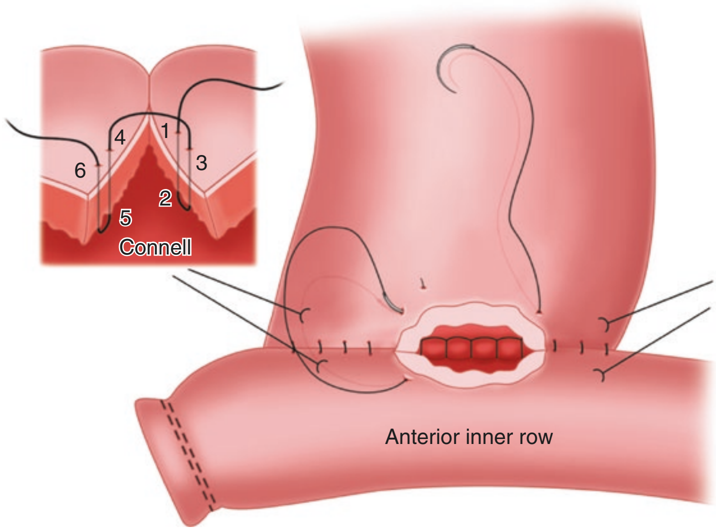

Fig. 17.3 Hand-sewn two-layer gastrojejunostomy: the anterior inner row is constructed using a Connell stitch, passing the suture from outside in and then inside out on one side, then crossing directly across, and passing from outside in to inside out on the other side (inset). The bites should incorporate a larger bite of serosa and smaller bite of mucosa to ensure good inversion of the mucosa, as well as aposition of the serosa

17.5.1.2 Single-Layer Hand-Sewn Gastrojejunostomy

The single-layer anastomosis begins similar to the double-layer anastomosis by bringing both the cut end of the jejunum to the cut end of the stomach. While generally a slowly absorbable suture is utilized, the techniques that have been described for a single-layer anastomosis can employ multiple different knots: some of these advocate the use of running near full thickness sutures (avoiding mucosa), some employ the use of interrupted vertical mattress inverting sutures (Gambee stitch), and others support the use of the Halstead stitch (editor's note: some of these basic stitches can be found in Chap. 3).

With any suturing technique utilized, the same general concepts apply: the cut ends are aligned with interrupted sutures, and the posterior wall is the first one created (in a running or interrupted fashion); when using a running suture, generally three quarters of the anastomosis are sutured together prior to switching to a series of interrupted sutures to complete the final millimeters of the anterior wall.

17.5.2 Linearly Stapled Enteroenterostomy

A linear stapler is commonly used to create a side-to-side, functional end-to-end enteroenterostomy. To begin, the cut ends of the segments being anastomosed are placed side by side. If the cut ends are stapled off, a small enterotomy is made proximally along the antimesenteric border of each segment (Fig. 17.4). Alternatively, the corner of each staple line can be cut off at the antimesenteric border. One fork of the automatic stapling device is placed through each enterotomy. The two forks are then connected and the intestinal lumens manipulated to ensure good antimesenteric to antimesenteric apposition (Fig. 17.4). If creating an enterocolonic anastomosis, the stapler should be aligned along the tinea as opposed to the true antimesenteric border. The stapling device is then fired to create a single common channel. The staple line within the lumen should be inspected to ensure hemostasis. The common enterotomy is brought together with clamps to create a temporary linear closure. Here it is important to adjust the staple lines within the intestinal lumen so they are not directly crossing. A second firing of the linear stapler directly below the clamps permanently closes the enterotomy. The staple line should be inspected for bleeding.

While not necessary, some surgeons opt to further reinforce the staple line along the common enterotomy by "dunking" it with a series of Lembert sutures. The distal end of the interior staple line can also be reinforced with a single 3-0 silk Lembert stitch. This step—advocated by many—has also been heavily criticized for its paradoxical potential of weakening the staple line. Finally, the resulting mesenteric defect should be closed.

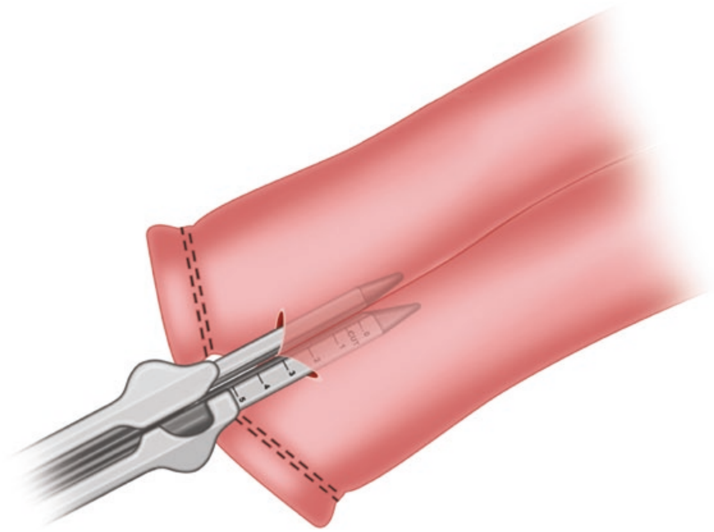

Fig. 17.4 Stapled enteroenterostomy: the two forks of the stapler are placed through enterotomies made along the respective antimesenteric borders. Before the stapling device is closed, the intestinal lumens should be manipulated to ensure good antimesenteric to antimesenteric apposition. The common enterotomy is approximated with clamps before being closed with a second firing of the stapler (not shown)

17.5.3 Circular Stapled Colorectal Anastomosis

A colorectal anastomosis can be created in an end-to-end or end-to-side fashion using a circular end-to-end anastomosis (EEA) stapler. This requires the patient to be positioned in lithotomy. Generally, the proximal colonic margin and distal rectal margin are divided first with a linear stapler.

The proximal (colonic) end of the anastomosis is prepared first. The linear staple line is cut off, and the lumen diameter is measured using a series of sequential dilators in order to select the appropriately sized stapling device. The anvil head is then placed within the lumen of the bowel. A single purse-string suture using 3-0 silk or polypropylene is placed along the cut end of bowel either freehand or using an automatic purse-stringing device (Fig. 17.5). The suture is tied around the anvil above the tying notch, securing the anvil in place. The tails of this suture should be kept very short.

The trans-anal portion of the anastomosis begins with gentle dilation of the anus, first manually, then with sequential dilators. This is performed by the assistant who is no longer within the sterile field. The shaft of the EEA stapler is placed through the anus and into the rectum. The surgeon helps to guide the EEA stapler to the very end of the rectal stump. When the face of the EEA stapler shaft is flush with the rectal staple line, the assistant turns the knob of the stapler in a counterclockwise fashion to extend the trocar through the rectal wall. The anvil's shaft is mated with the trocar until it snaps into place (Fig. 17.5). At this point, the surgeon should ensure that the colon and rectum are aligned without twisting of the mesentery. The EEA stapler is closed by turning the knob in a clockwise direction until the ends are perfectly apposed. A marker on the EEA device will guide the surgeon to ensure the anastomosis isn't too tight or too loose. The stapler is then fired and removed by turning the knob counterclockwise for three half-turns and then rotating the stapler itself counterclockwise for a half-turn to then remove it from the anus. The stapler should be inspected on the back table to ensure there are two intact "doughnuts," confirming that the stapler fired correctly. The anastomosis is then interrogated by instilling air in the rectum, while the pelvis is filled with saline, watching for air bubbles.

17.6 Current Controversies

17.6.1 Closure of Mesenteric Defects

It is well accepted that routine closure of mesenteric defects after Roux-en-Y gastric bypass surgery reduces the rate of internal hernia formation. This has been supported by both retrospective and prospective randomized controlled trials [37, 38]. To date, there is no consensus on the ideal method of primary closure. Surgeons use a variety of techniques including stapled closure and

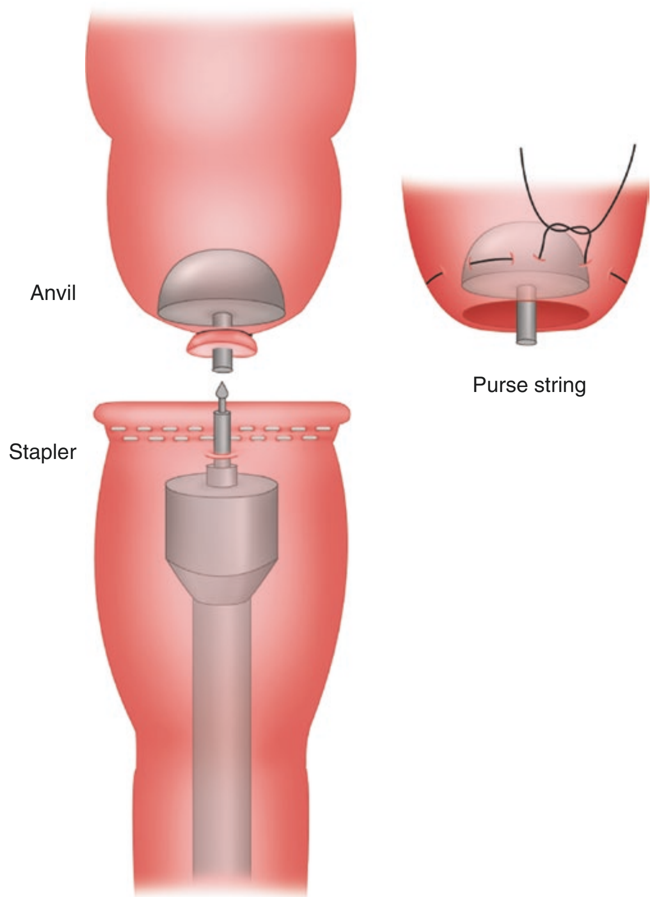

Fig. 17.5 Stapled end-to-end colorectal anastomosis: the anvil head is secured within the proximal colonic lumen using a purse-string (inset). This is then mated with the trocar, which is seen extending out of the stapler shaft and through the rectal wall

interrupted versus running closure using nonabsorbable or barbed suture [38, 39].

Routine closure of mesenteric defects during colon surgery is more controversial. In the era of laparoscopic surgery, routine closure has been limited by technical difficulty given the small surgical space, proximity to mesenteric blood supply and underlying ureter, and the increase in operative time [40]. On the other hand, leaving the defect open poses a risk of internal herniation and subsequent small bowel obstruction or strangulation. Unlike with laparoscopic Roux-en-Y gastric bypass, the incidence of symptomatic internal herniation after laparoscopic colon resection is relatively low. A retrospective review of 530 consecutive patients found a 0.8% incidence of internal herniation, recommending against routine closure of the mesenteric defect [41]. Larger, prospective randomized trials are needed.

17.6.2 Use of Barbed Suture

Unidirectional barbed suture has been used in general surgery for cruroplasty and for the closure of peritoneal defects created during gastrointestinal and hernia surgery [42, 43]. Barbed suture provides the surgeon with the ability to anchor the filament in a knotless manner and allows for tension to be evenly distributed across a wound as the barbs serve as fixation points [44]. The surgeon is thus able to operate independently with more technical ease.

Studies evaluating the use of barbed suture in creating gastrointestinal anastomoses have been more limited. Recent studies have compared the use of barbed suture to traditional interrupted sutures in creating or closing the gastrojejunostomy during laparoscopic Roux-en-Y gastric bypass [44–46]. All have found a significantly shorter suture time and decreased cost associated with barbed suture;

however, two of the studies reported a case of anastomotic leak with barbed suture. Larger randomized trials are needed in both laparoscopic and open cases before its use in gastrointestinal anastomoses can be more widely adopted.

17.6.3 Intraoperative Indocyanine Fluorescence Green Angiography

Adequate blood supply is the most critical factor impacting anastomotic healing. Several methods for objectively measuring blood perfusion have been proposed including pulse oximetry, Doppler ultrasound, spectrophotometry, and others [47, 48]. In the last decade, there has been an emergence of fluorescence angiography (FA) using indocyanine green and near-infrared light to assess bowel perfusion. This tool has demonstrated accuracy in assessing microperfusion and has been associated with improved outcomes in hepatobiliary, foregut, transplant, and plastic surgery [49–55].

Recent studies looking at anastomotic leaks in intestinal anastomoses have focused on colonic surgery. The 2015 PILLAR II study was a prospective, multicenter study looking at 139 patients who had a colonic anastomosis. The authors found that FA changed the operative plans in 11 (8%) patients, and while the whole cohort had two (1.4%) anastomotic leaks, there were no leaks in the 11 patients who had their operative plan changed as a result of FA [49]. A 2017 retrospective, case-matched study found that surgeons changed the planned anastomotic level of the colon in two of 42 patients in the FA group (4.7%). There were no anastomotic leaks in the FA group and two in the historical control group [47].

While fluorescence angiography may be a promising adjunct to aid in intraoperative perfusion assessment, randomized controlled trials are needed to truly establish its efficacy.

Take-Home Points

- Care should be taken to employ good surgical technique and to minimize tissue trauma through gentle handing with atraumatic instruments.
- The success of the anastomosis is dependent upon healthy blood supply with adequate hemostasis and avoidance of tension.
- All sutures should incorporate the submucosa (strength layer of the small intestine) and approximate the mucosa while preventing it from extruding from the suture line.
- The choice of suture material or staple is generally dependent on the location within the GI tract and the enteric layer being anastomosed.

Suggested Readings

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