The Small Intestine

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The small intestine includes the duodenum, the jejunum, and the ileum. The duodenum is intimate with the pancreas, has no distinct mesentery in the usual sense of the term, and is divided anatomically into four parts. The first portion (D1) is short and more-or-less horizontal, arising immediately distal to the pylorus, and is sometimes referred to as the *duodenal bulb* due to its shape. It receives the effluent from the stomach. D2 is the vertical portion of the C-loop of the duodenum as it wraps around the head of the pancreas. It is where the *ampulla of Vater* (the *major papilla*) is located, through which the common bile and pancreatic ducts empty their contents into the intestine. There is also sometimes a minor papilla where the duct of Santorini empties. D2 is the most delicate and important portion of the intestine to be treated with meticulous care and only when absolutely necessary, but it is also the site of a busy embryologic crossroads where duodenal atresia, duodenal webs, or annular pancreas is to be found. D3 is horizontal and hugs the lower border of the body and tail of the pancreas. D4 is the short and relatively mobile portion that transitions at the ligament of Treitz into the jejunum. The duodenum is generally more delicate and surgically less forgiving than the jejunum or ileum.

The jejunum encompasses the initial 40% or so of the small intestine proper and differs from the ileum in subtle ways. It has a generally thicker wall whose serosal surface sometimes appears corrugated with fine gyri and lacteals, the mucosa is rougher with deeper with more numerous circular folds, and its mesentery is generally longer with a much less complex array of branching vessels (*vasa recta*) than the ileum. The transition to ileum can be subtle. The ileum has a narrower caliber and thinner walls, more fat and a more complex array of branching vessels in its mesentery. It is also where the occasional omphalo-mesenteric (vitelline) duct remnant or Meckel diverticulum is to be found. The terminal ileum is the last 20–30 cm or so before it joins the cecum and is recognized by a thin wisp of fatty tissue on its antimesenteric border (*ligament of Treves*) along its final 3–4 cm. The terminal ileum is also known for having a rich collection of lymphoid tissue within its walls, perhaps accounting for why it is more likely to be affected by infection (acute ileitis), Crohn's disease, and lymphoma.

Most of the lesions and disorders affecting the duodenum, jejunum, and ileum are addressed in other chapters. The purpose here is to discuss the unusual and often forgotten conditions of the small intestine and to highlight some of the basic principles of intestinal resection and repair.

Duodenum

The duodenum is rightfully one of the most feared organs a surgeon must deal with—it is relatively immobile, contains the ampulla of Vater, is intimate with the pancreas (another fearsome organ), and through it flows a very high volume of chyme and secretions. But the duodenum of most children is, like most of their tissues, more to be respected than feared—it will tolerate manipulation and sutures, can be mobilized and opened when necessary, and if the repair is sound, a drain does not always need to be placed. Nevertheless, it will not allow the surgeon to cut corners or violate, even in the slightest, any of the basic principles of safe surgery.

Mobilizing the duodenum (*Kocher's maneuver*) is to divide the areolar attachments of the lateral and posterior aspects of the C-loop of the duodenum, exposing the anterior aspect of the inferior vena cava and renal vessels and the posterior aspect of the head of the pancreas and portal vein confluence in the process. It is a crucial early step of a right nephrectomy or pancreaticoduodenectomy (Whipple procedure). For access to the ampulla during sphincterotomy, an incision is made in the lateral or anterolateral aspect of the duodenum. Classically this is made longitudinally and then closed transversely to avoid narrowing the lumen, though

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this is not always necessary or even prudent, such as when the duodenotomy is long and closing it transversely contorts the duodenum or creates undue tension. If the tissue is healthy and under little tension after a meticulous closure, a drain is not mandatory.

The blood supply of the second portion is generally of little practical import, but every surgeon knows that the *gastroduodenal artery* arises from the common hepatic artery and passes behind the duodenum where a posterior peptic ulcer can cause erosion and major upper gastrointestinal bleeding, and that it branches into the anterior and posterior *superior* pancreaticoduodenal arteries (as well as the *right gastroepiploic artery*). The anterior and posterior *inferior* pancreaticoduodenal arteries arise from a proximal branch of the superior mesenteric artery.

After penetrating (gun shot wound) or iatrogenic (blown stump) injury to D1 or D2, it is sometimes impossible to affect a durable closure without the risk of obstruction or leak. One option is to bring up a Roux limb of jejunum and create a duodenojejunostomy. Another is to place a large balloon catheter (Foley catheter) through a purse-string suture placed around the edge of the defect and bring it out through a separate stab incision to create a controlled fistula that can usually be removed 6 weeks later after a stable tract has formed. One or two closed-suction drains should usually be placed in the vicinity as well. Some advocate performing pyloric exclusion with a suture closure or even stapling across the pylorus, but this is probably overkill in most children, even those with complex duodenal injuries. Roux-en-Y gastrojejunostomy is also rarely indicated. As with any operation in this area, the ampulla must be clearly identified and protected from injury due to careless cautery or an errant stitch. Gentle compression of the gallbladder will usually cause the discharge of yellow bile from the ampulla, which helps betray its location. Extensive duodenal deserosalization or full-thickness tissue loss can be vexing. Options include Roux-en-Y duodenojejunostomy, a serosal patch (bringing up a loop or Roux of jejunum and tacking it to the duodenum such that the serosa of the loop covers and smothers the injury) or placing a Foley catheter and purse-string suture to create a controlled fistula.

Suture lines and anastomoses near the ligament of Treitz tend to kink, leak, or stricture. They frequently require revision. This is presumably due to a tenuous blood supply and the unusual local anatomic configuration that causes the bowel to twist on itself. An anastomosis in this location can be hand-sewn or stapled but should be generous, under no tension, and immediately revised on the spot if there is any question of viability or patency. It is acceptable to extend the anastomosis onto the distal third portion of the duodenum if necessary. It is important to create the anastomosis such that the lines of tension are well-suited to the eventual lie of the bowel in situ, rather than how it looks when delivered into the field—it might look perfect up in the air but then become twisted like a balloon animal when dropped back in the abdomen.

Upper GI contrast studies in children with abdominal pain or weight loss will sometimes show a duodenum that appears redundant or inverted (*duodenum inversum*). Whether these anatomic variants are a cause of symptoms—or even fixable at operation—is unclear. Although in most cases they are likely simply an incidental finding, one might reasonably offer the patient desperate for relief a laparoscopic look-see in case there are bands or adhesions that can be lysed and to ensure the absence of a *forme fruste* of malrotation, which is an indication for Ladd's procedure.

Rarely treated surgically anymore, duodenal mural hematomas from blunt trauma might sometimes need to be evacuated due to obstruction, usually done by splitting the serosa, evacuating the clot, controlling residual bleeding vessels, repairing a full-thickness injury if found, and closing the serosa loosely with fine absorbable sutures. It is harrowing but almost never necessary anymore.

Jejunum

The jejunum is the normally quiet and steady region of the digestive system, where dangerous or important events rarely occur. Small-bowel intussusception occasionally occurs here, most often near the tip of a naso- or gastro-jejunal feeding tube. The pathophysiology of this phenomenon is not entirely clear, but surgery is rarely indicated and removing the tube is usually the best treatment. In the past, it was common as a resident to be quizzed about the phenomenon of early postoperative small-bowel obstruction due to small-bowel intussusception, supposedly especially common after retroperitoneal operations like nephrectomy or pancreatectomy. These seem to occur much less commonly now, perhaps due to the popularity and proven benefit of enhanced recovery protocols that emphasize early diet advancement and avoiding opiates and nasogastric tubes.

We are occasionally asked to place a jejunostomy tube for feeding access in a patient with severe reflux or gastroparesis. This can be done safely laparoscopically in much the same way as gastrostomy tube placement. For a time, it was fashionable to use a very short Roux-en-Y to create a short diverticulum where the balloon from a jejunostomy tube would not obstruct the lumen, which unfortunately carries a high risk of volvulus and is no longer recommended. Modern buttons have smaller balloons and are well tolerated in this location.

The jejunum is not accessible by upper or lower GI endoscopy, though a polyp or arteriovenous malformation can sometimes be seen by video-capsule endoscopy. Exploring

the jejunum for a small luminal lesion requires palpation, easily done through a small periumbilical laparotomy incision. Peutz-Jeghers syndrome is caused by an autosomal dominant genetic mutation and usually recognized by the presence of freckles of the buccal mucosa, gingiva, or lower lip. It is associated with polyps (benign hamartomas) of the stomach and bowel that usually only come to clinical attention when they cause bleeding or intussusception. As adults, these patients are also at increased risk of cancer in the GI tract, pancreas, gonads, and cervix.

Jejunostomy after bowel resection for necrotizing enterocolitis or jejunal atresia produces a high volume of caustic effluent that frequently results in fluid and electrolyte imbalance and excoriated peristomal skin. The concept of refeeding the effluent through a mucous fistula is ingenious but in practice is usually tedious, risky (catheter-related bowel perforation), and messy. Unless one has an evidence- and experience-based protocol and can do it consistently well, it might not be worth the risks. A better option might be to close the stoma early, within 3–4 weeks, assuming the baby is stable and able to tolerate another laparotomy.

Patients with Crohn's disease sometimes develop fibrotic enteric strictures. If there are only one or two, resection with primary anastomosis is probably best. But sometimes there are 5–10 scattered throughout the small bowel, making resection unwise or the unavoidable loss of a few centimeters of normal bowel with each resection untenable. This is when stricturoplasty makes more sense. For simple stricturoplasty of a short stricture, the bowel is opened longitudinally along its antimesenteric border, splitting the ring of scar. This is extended it for at least 1–2 cm proximal and distal onto the normal bowel. The enterotomy is closed transversely in a single layer with interrupted full-thickness absorbable sutures, which usually heals well; leaks are surprisingly rare. A long stricture not amenable to bowel resection can be opened using Finney's technique (folding the bowel into a hairpin shape and creating a long side-to-side anastomosis), which is less than ideal and probably best avoided. The same goes for simple bypass of a diseased segment that is purposely left in situ. When there are multiple short strictures all in a row, Michelassi's operation (a long isoperistaltic stricturoplasty) is an elegant and effective option: the bowel is divided midway along the length to be repaired and the proximal and distal limbs brought parallel to each other in isoperistaltic fashion. A long hand-sewn side-to-side anastomosis is then created, preferably in two layers. With any of these techniques, the long-term implications of leaving segments of inflamed or damaged bowel in a young person are unknown.

The jejunum is home to the rare ectopic pancreatic or adrenal rest, distinguishable by the characteristic color of the mother organ and having the appearance of an inconspicuous thickening of the bowel wall, rarely more than 1–2 cm in diameter. They are usually noted incidentally but can occasionally be the lead point of an intussusception. We usually excise them and primarily close the subsequent enterotomy, though in some cases they are probably safe to observe.

Ileum

The ileum is similar to the jejunum in terms of strictures, rests, and anastomotic hardiness. Pathology involving the terminal ileum or cecum often entails ileocecectomy, which in some situations might seem dramatic or dangerous but is actually safe and well-tolerated. Despite a recent resurgence in interest in developing a new way to create an end-to-end hand-sewn anastomosis, a stapled side-to-side ileocolostomy using a 75 mm gastrointestinal stapler works well and, even in the setting of inflammatory bowel disease or lymphoma, carries with it a very low risk of leak or stricture. After laparoscopically mobilizing the entire right colon, it can be performed easily through a 3–4 cm right-lower-quadrant muscle-sparing incision (Rockey-Davis) or even a periumbilical incision. If indicated, one should not hesitate to perform this straightforward bowel resection.

When ileitis or bowel wall thickening is found in the patient suspected of having acute appendicitis, it is usually best to perform a biopsy to rule out lymphoma or to confirm Crohn's disease, though the risk of leak or fistula is not zero. If the disease is severe or obstructing, ileocecectomy might be a reasonable consideration as, again, it is safe and well-tolerated, though the surgeon should expect criticism from well-meaning colleagues and Monday-morning quarterbacks for being too aggressive.

Having to create an anastomosis when there is a large size mismatch is always somewhat risky, especially when the ratio of proximal to distal is much greater than 2- or 3-to-1. The concern is that the bottleneck will act like a downstream obstruction and cause a leak. Meticulous technique is obviously paramount. A small mismatch is easily overcome with simple spatulation. A large mismatch might require creating an *end-to-back* configuration, in which the spatulation incision is longer than the diameter of the bowel and the two limbs end up nearly perpendicular to each other. A side-to-side functional end-to-end anastomosis is an option, even in infants now that high-quality narrow staplers are available. It is also reasonable to consider tapering the proximal end using longitudinal applications of a stapler. Finally, for ostomy closures some believe the caliber of the distal segment might enlarge with refeeding of stoma effluent into the mucous fistula, but this is little evidence to support this notion.

Bowel anastomoses involving the small intestine can be stapled or hand-sewn. The stapled side-to-side anastomosis using a long gastrointestinal stapler (or an endo-stapler in smaller children) has its critics but is time-tested and dependable. There is no need to reinforce the staple line with sutures, but the luminal staple lines should be examined for bleeding that occasionally requires an absorbable figure-of-eight. When the lumen is small or there is inadequate length for a side-to-side anastomosis (too close to the ileocecal valve or ligament of Treitz), a traditional hand-sewn anastomosis is a reasonable alternative. In infants, this is usually best performed with a single full-thickness interrupted layer of braided or monofilament absorbable suture. Every stitch must be perfect, especially in the corners. For older children and adolescents, a double-layer anastomosis (running inner braided absorbable, outer interrupted absorbable Lembert sutures) is preferred. Bowel clamps are unnecessary. Although laparoscopists have insisted for years that large mesenteric defects do not require closure, most mesenteric defects can and should be closed to prevent internal hernias. Contrary to dogma, this can be done safely with either running or interrupted sutures, but always in a way that preserves the blood supply to the anastomosis. Enterotomies should almost always be closed transversely so as to avoid narrowing the lumen. This can be done by hand or with two tangential staple lines placed at a slight angle to each other, but each also oriented perpendicular to the long axis of the bowel.

Serosal injuries of the small intestine can generally be left alone. If extensive, or if the bowel is extensively or circumferentially degloved, one must consider either resection with primary anastomosis or, if feasible, precise reapproximation of the serosal edges with fine absorbable sutures.

Summary

The duodenum is to be respected but not feared, but any surgical maneuver must be meticulous and well-thought-out, with careful attention to preserving blood supply and avoiding tension. The jejunum and ileum are, in many ways, the most forgiving of surgical structures but also demand attention to detail and dedication to the foundational principles of safe surgery. More important than the type of anastomosis, stapled or hand-sewn, is meticulous precision and avoiding short cuts.

Further Reading

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