Chapter 9
Minimally Invasive Small Bowel Surgery

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Introduction

Minimally invasive surgery has been growing in favor over the past several decades, and it has been proven to be safe and feasible for organs beyond just the gallbladder, particularly the small intestine [1]. While the laparoscopic approach has been accepted as the standard of care for cholecystectomy, a consensus has not been reached for surgery of the small intestinal tract [2]. Some of the benefits demonstrated for laparoscopic surgery compared to open surgery include reduced postoperative complications (including wound infections), decreased incidence of hernias, improved cosmetic results, improved postoperative recovery, decreased intraoperative and postoperative pain, quicker return of bowel function, shorter length of stay, faster return to normal activity and diet, improved social and sexual interaction, and decreased rate of adhesive small bowel obstruction [2–5]. These procedures are similar to those performed during open surgery but require the surgeon to translate the same principles to a confined space, often maneuvering longer instruments in technically challenging angles. The indications for these procedures are similar to the open approach, including both benign and malignant processes, and are being performed in elective, urgent, and even trauma settings [6, 7].

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The evolution of minimally invasive techniques for small bowel surgery started with the success of the laparoscopic approach to disease processes of the appendix and colon. The first laparoscopic appendectomy was performed by Kurt Semm in 1983 [4]. Laparoscopic techniques were then applied to colon surgery with the first laparoscopic right hemicolectomy performed by Moises Jacobs in June of 1990 in Miami, Florida. Subsequently, the first entirely laparoscopic right hemicolectomy with an intracorporeal ileocolonic anastomosis was performed on July 26, 1991, by Joseph Uddo [8]. Further contributions included the first reported successful laparoscopic adhesiolysis in 1991 by Bastug et al. [9]. Over the next three decades, the minimally invasive approach to small bowel surgery was applied more broadly with the use of laparoscopy for many other benign diseases, including Crohn's disease, Meckel's diverticulum, superior mesenteric artery (SMA) syndrome, intussusception, gallstone ileus, foreign body removal, and almost any other disease entity in which open surgery has been indicated [1, 10–12]. Likewise, laparoscopy has also been utilized safely in the management of many malignancies requiring surgical intervention, including gastrointestinal stromal tumors (GIST), neuroendocrine tumors (NET), lymphoma, lipoma, schwannoma, sarcoma, adenocarcinoma, and other tumors found in the small intestine as well as for the identification of metastatic disease with diagnostic laparoscopy [1, 13–16]. Additionally, laparoscopy can be useful for diagnosing the etiology of abdominal pain of unknown origin [17]. With the advent of robotic surgery, surgeons are increasingly performing small intestinal surgery robotically; however, the studies examining the safety of robotic small bowel surgery are limited to some case series and reports [18].

Preoperative Considerations

When anticipating a minimally invasive approach to small bowel surgery, many of the same principles should be adhered to as in an open case. These include a full history and physical examination, including a review of systems. Appropriate laboratory testing, including CBC, BMP, hepatic function panel, coagulation panel, lactate, and/or arterial blood gas, may be useful in assessing the patient and narrowing down the differential diagnoses further. Imaging with x-ray, ultrasound, cross-sectional imaging, and/or other studies can be useful, particularly when planning for a minimally invasive approach. These studies can help assess the appropriateness of approaching the case in a minimally invasive fashion and provide a road map for the surgeon in regard to the anatomy. The details of the diagnostic work-up of each of these disease processes are beyond the scope of this chapter and can be reviewed in other texts.

Indications and Outcomes in Laparoscopic Small Bowel Surgery

With the increased training and comfort in advanced laparoscopic techniques among surgeons, the use of laparoscopy for small intestine pathology has been growing

[19]. To follow is a more detailed review of the progression of minimally invasive techniques for a variety of small bowel disorders.

Small Bowel Obstruction

Small bowel obstruction is a disease process that is often managed non-operatively, but when operative intervention is required, surgeons traditionally approach this process with an open surgical procedure. The default to an open operation is often due to the concern for inadequate intra-abdominal working space to visualize the pathology secondary to dilated loops of small bowel as well as the concern for possible injury to dilated and friable loops of small bowel. The laparoscopic approach to lysis of adhesions was first described for the treatment of chronic pelvic pain and infertility by gynecologists in the 1970s [20]. This technique was first applied to small bowel obstructions by Bastug et al. in 1991 for a patient with an obstruction secondary to a solitary adhesive band [9]. Many subsequent studies have been conducted on the successful use of minimally invasive surgery for small bowel obstructions. However, no prospective randomized trials comparing laparoscopic to open adhesiolysis exist to date, and certainly no consensus statement exists on the gold standard approach to small bowel obstruction. Despite this paucity of data, according to a large review of the American College of Surgeons National Surgical Quality Improvement Program data, a trend exists nationally toward an increase in the adoption of laparoscopic adhesiolysis by 1.6% per year, increasing from 17.2% in 2006 to 28.7% in 2013 [2]. With this increasing trend, high-volume centers have shorter postoperative length of stay with a minimally invasive approach, even when adjusted for case complexity [19]. Despite the increasing trend and acceptance of minimally invasive adhesiolysis as a safe and feasible approach, the use of the minimally invasive techniques for operative management of small bowel obstruction has been demonstrated to be underutilized [21].

Crohn's Disease

Minimally invasive surgery has also been explored in the setting of Crohn's disease involving the small intestine. Despite the proven benefits of laparoscopy compared to open surgery in small and large intestinal surgery, surgeons have been apprehensive to apply these techniques to patients with Crohn's disease due to the disease process itself. Some of these reservations stem from the concern of inability to identify all occult segments of diseased bowel; lack of tactile sense to identify proximal strictures; possibility of reduced immune response induced by laparoscopy, resulting in earlier recurrence; and the difficulty of operating on friable, inflamed bowel and mesentery, which can possibly be complicated further by dense adhesions, fistulas, and abscesses. These concerns of applying minimally invasive techniques to the surgical management of Crohn's disease were

the premise of a Cochrane review in 2011, comparing the use of laparoscopic surgery to open surgery for Crohn's disease and addressing the safety and feasibility of the laparoscopic approach to this disease process. The review focused on the most common procedures performed for Crohn's disease of the small bowel, including ileocecectomy, small bowel resection, and stricturoplasty. Two randomized control trials were included in the review, demonstrating laparoscopic surgery to be associated with a reduced number of wound infections and decreased reoperation rates for non-disease-related complications, but these differences were not statistically significant. Furthermore, no statistically significant difference was noted in the compared outcomes between laparoscopic and open surgery for Crohn's disease. Ultimately, the authors concluded that the minimally invasive approach to small bowel Crohn's disease was safe with no significant difference in perioperative outcomes or long-term reoperation rates, both disease and non-disease related [5].

Small Bowel Tumors

Minimally invasive surgery has been proven to be comparable to open surgery by oncologic standards for many malignancies, including pancreas, gastric, and colorectal cancer. Conversely, the data comparing minimally invasive surgery to open surgery for neoplasms of the small intestinal tract are scarce [22–25]. Several studies have demonstrated laparoscopic surgery to be safe and oncologically equivalent to open surgery in the setting of small bowel GIST and small bowel NET, particularly when an R0 resection (microscopically and macroscopically negative margins) is achieved for both malignancies and an adequate lymphadenectomy is achieved in the setting of small bowel NET [14, 15, 26, 27].

In the setting of small bowel NET, thorough exploration of the entire small bowel either laparoscopically or open from the ligament of Treitz to ileocecal valve is essential in ensuring no lesions are missed. Controversy still exits for the role of laparoscopy in small bowel NET given the often small size of the primary small bowel NET and the known possibility of having multiple small bowel NET. For smaller NET of the small intestine, endoscopy can assist in identifying the lesion and its location [27]. A few studies have been performed specifically examining the role of laparoscopy for small intestine carcinoid. The only retrospective study on the topic was reported by Reissman et al. in 2014, demonstrating 20 patients with midgut carcinoid tumor who underwent laparoscopic resection en bloc with resection of the corresponding mesenteric root mass suffered no major morbidities. Two patients (10%) experienced minor morbidity, consisting of a wound infection and prolonged ileus. None of the 20 patients required conversion to an open operation. This study demonstrated laparoscopic resection of midgut carcinoid tumors to be a safe, feasible, and oncologically sound surgical approach to these tumors [28]. However, additional studies are necessary prior to accepting a minimally invasive approach to small bowel NET as the gold standard.

As for appendiceal carcinoids, these tumors are often resected incidentally when surgery is performed for presumed appendicitis or during a gynecologic procedure, both of which are commonly performed via a laparoscopic technique. As with primary midgut carcinoid, laparoscopic resection of appendiceal carcinoid tumor is not currently the gold standard; however, it is widely accepted by most surgeons [27]. More extensive surgery, such as a right hemicolectomy, may be necessary based on the size of the lesion, proximity to the base of the appendix, nodal involvement, and other factors. Minimally invasive approaches to appendiceal tumors will be covered later in this chapter as well.

Case reports and series have also been published supporting minimally invasive surgical approaches to adenocarcinoma of the small bowel as well as metastatic lesions to the small bowel; however, further studies are necessary to better define this indication [15, 29, 30].

Meckel's Diverticulum

Meckel's diverticulum, resulting from an obliteration defect of the omphalomesenteric duct, is one of the most common gastrointestinal malformations, present in 2–4% of the population [31, 32]. Symptomatic Meckel's diverticulum generally presents as a gastrointestinal bleed due to ectopic gastric mucosa in younger patients and more acutely in the adult population, complicated by inflammation, obstruction, perforation, ulceration, and hemorrhage. The treatment for Meckel's diverticulum is surgical, typically consisting of a diverticulectomy, wedge resection of the diverticulum containing the heterotopic mucosa (usually gastric or pancreatic), or segmental resection of the small intestine and primary anastomosis. Traditionally, these procedures have been performed with a laparotomy incision; however, laparoscopy is being utilized more often. A meta-analysis reporting on 35 cases by Abul Hosn et al. and several other studies and case reports have demonstrated safety and efficacy with a laparoscopic approach to this disease process, even in the pediatric setting [31, 33, 34]. Nonetheless, more formal studies have not been conducted to form a consensus statement on the best surgical approach to Meckel's diverticulum.

Appendicitis

Over the past 15 years, laparoscopic appendectomy has been accepted as improving diagnostic accuracy and decreasing wound infection rates over open appendectomy. According to the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines, laparoscopic appendectomy is safe and effective for treating uncomplicated appendicitis and may be used as an alternative to an open appendectomy. Despite longer operative times laparoscopically, several randomized control

studies demonstrated laparoscopic appendectomy to be associated with shorter hospital stay and possibly quicker return to work, supporting laparoscopic appendectomy as an alternative to open appendectomy in the SAGES guidelines. Furthermore, meta-analyses demonstrated open appendectomy resulted in increased pain, longer length of stay, and increased wound infection rate compared to laparoscopic appendectomy.

For patients with complicated or perforated appendicitis, no randomized controlled trials have been performed comparing open appendectomy to laparoscopic appendectomy. However, multiple studies have verified that the laparoscopic technique is feasible and safe in the setting of perforated appendicitis. Many of the reports had variable complication rates between the two approaches but generally demonstrated a lower wound infection rate, shorter length of stay, and decreased morbidity and mortality for laparoscopic appendectomy compared to open appendectomy [35].

Appendiceal Neoplasms

Appendiceal neoplasms encompass a wide range of disease processes, ranging from benign to malignant and including leiomyomas, neuromas, lipomas, carcinoids, mucinous neoplasms, and adenocarcinoma. The role of surgery varies based on the underlying disease process and the histology of the neoplasm. While there is no consensus statement for the minimally invasive approach to appendiceal neoplasms, some retrospective studies have demonstrated a minimally invasive approach resulted in slightly higher rates of margin positivity but had similar 5-year survival rates compared to open appendectomy [36].

Appendiceal carcinoid tumors, a specific type of appendiceal neoplasm, can be managed with either an appendectomy or a right hemicolectomy, based on the size of the lesion, proximity to the base of the appendix, nodal involvement, and other such factors. Since many of these tumors present as presumed appendicitis, appendiceal carcinoid tumors are often resected with a laparoscopic appendectomy prior to diagnosis [37]. Many retrospective reviews, including the review by Park et al., demonstrate the safety and feasibility of a minimally invasive approach for appendiceal tumors. This is particularly notable in the setting of appendiceal mucinous neoplasms given the potential for mucinous spillage and increased risk of pseudomyxoma peritonea for a ruptured lesion [38]. As for appendiceal adenocarcinoma, these neoplasms typically behave as colon cancers, requiring a right hemicolectomy for adequate lymph node harvest to appropriately stage the tumor. In a study of 94 patients with primary appendiceal adenocarcinoma, 12 patients (38%) were upstaged based upon the final pathology following a right hemicolectomy compared to the pathology following an appendectomy [39]. As in colon cancer, a right hemicolectomy can be performed safely and effectively using a minimally invasively approach.

Less Common Applications

Minimally invasive techniques have been applied to more complicated surgical processes previously thought to not be amenable to this technique, such as gastrointestinal bleeds [40]. At times, this technique can be aided by the use of double-balloon enteroscopy [41]. The minimally invasive technique has also been utilized successfully in identifying and removing foreign bodies, at times requiring small bowel resection with primary anastomosis [42, 43]. Some case reports have also been published on the laparoscopic approach to gallstone ileus, in which a laparoscopic enterotomy with stone extraction is performed safely [44, 45]. Similarly, only case reports and a small case series consisting of three patients with intussusception were successfully managed with laparoscopic-assisted small bowel resection as reported by Siow and Mahendran [46].

Robotic Surgery

As seen in other organs, many of the same principles used to manage and treat surgical problems afflicting the small bowel can be applied with a robotic approach to the same disease process. While the robot has improved optics and more precise movements, it lacks the haptic feedback afforded by the laparoscopic and open approach. Although no consensus statement has been currently made regarding the safety, feasibility, and use of robotic surgery for small bowel surgery, many case reports and case series are emerging to suggest robotic surgery as an acceptable alternative to open surgery. As more and more surgeons overcome the learning curve for robotic surgery, studies will need to be performed more formally to assess the safety of this technique in small bowel surgery.

Limitations and Contraindications of Minimally Invasive Surgery

While not considered contraindications, caution should be taken in the setting of technically challenging situations, such as prior laparotomy, obesity, and adhesions to name a few. The severity of disease can also contribute to a higher rate of conversion from a minimally invasive approach to an open approach, including massively dilated loops of small bowel, enterocutaneous fistula, large inflammatory masses, extensive inflammation, and difficulty safely identifying the anatomy [1, 47]. Other relative contraindications include hypotension, septic shock, and inability to establish pneumoperitoneum. Emergency operations performed laparoscopically have also been associated with higher rates of conversion to an open procedure but are not prohibitive to a minimally invasive approach, which at times can be beneficial

to the patient [1, 7]. Experience can also contribute to the surgeon's ability to complete an operation in a minimally invasive fashion [48, 49].

Postoperative Complications

While generally beneficial to the patient, a minimally invasive approach to small bowel surgery can have several potential complications. Complications have been associated with simply entering the abdomen with either a Veress needle or trocar insertion, including injury to major retroperitoneal vessels and/or bowel, abdominal wall hematoma, wound infection, fascial dehiscence, and herniation. In order to perform an operation utilizing a minimally invasive approach, pneumoperitoneum must be achieved. However, pneumoperitoneum results in its own complications, including respiratory acidosis from the carbon dioxide used to insufflate the abdomen, which then gets absorbed in the body. In addition, pneumoperitoneum results in decreased cardiac output by up to 30% secondary to decreased stroke volume during laparoscopic surgery. There is also an increase in systemic vascular resistance. Consequently, people with poor cardiac performance may require invasive cardiac monitoring to ensure they can tolerate insufflating the abdomen fully [50].

Enterotomies and serosal injuries can occur during minimally invasive surgery for any indication secondary to tearing the bowel during adhesiolysis; manipulating the bowel, especially if the bowel is particularly friable; inadequately visualizing the tips of the instruments; and from thermal injuries secondary to electrocautery [1]. If diagnosed at the time of initial operation, these injuries should be addressed and repaired immediately. Other complications associated with minimally invasive small bowel surgery are inherent to the particular procedure being performed and similar to the complications observed when the procedure is performed with an open approach, such as an anastomotic leak, bleeding, intra-abdominal abscess, wound infection, pulmonary embolism, pneumonia, pleural effusion, atelectasis, acute respiratory distress syndrome, acute coronary syndrome, myocardial infarction, deep vein thrombosis, adhesions requiring re-intervention, and incisional hernias to name of few [51]. The rates of complication vary depending on each of the aforementioned scenarios.

Conclusions

Minimally invasive surgery is a safe, feasible, and efficacious approach to the management of surgical disease processes of the small intestine. Precluding certain situations where it is contraindicated, a minimally invasive approach to small bowel surgery is recommended in the hands of a skilled surgeon experienced in minimally invasive techniques.

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