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The Use of the Overstitch to Close Perforations and Fistulas

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INTRODUCTION

Endoscopic suturing represents a highly versatile minimally invasive endoscopic surgical technique, with a wide range of applications throughout the gastrointestinal tract. Although several other platforms have been previously described, the Apollo Overstitch and Overstitch SX (Apollo Endosurgery Inc, Austin, TX) are currently the only commercially available endoscopic suturing platforms. This article reviews the use of the Overstitch endoscopic suturing system specifically in the management of gastrointestinal perforations, leaks, and fistulas.

PERFORATIONS, LEAKS, AND FISTULAS

Gastrointestinal perforations are defined as an acute full-thickness defect of the gastrointestinal tract.¹ Perforation can occur as a result of a full-thickness injury, or progression from a partial thickness injury. Spontaneous perforations can result from a variety of etiologies including Boerhaave syndrome, ulcers, malignancy, diverticulitis, radiation therapy, inflammatory bowel disease, and intestinal ischemia. Traumatic perforations can result from direct blunt or penetrating trauma, or from foreign body ingestion. Accidental perforations are an uncommon but feared complication of endoscopic procedures, primarily those that are therapeutic in nature, such as in endoscopic dilation and resection. Etiologies of perforations are listed in Box 1.

Leaks are defined as a disruption in surgical anastomosis or closure, resulting in the egress and accumulation of luminal contents.² Leaks most often occur in an acute postoperative setting from gastrointestinal surgical procedures including intestinal resections and bariatric

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procedures. However, leaks can also occur from infection, inflammation, or diseases that increase intestinal pressure such as bowel obstruction. In a chronic setting, leaks can progress into fistulas, defined as the abnormal communication between 2 epithelialized surfaces. Chronic fistulas can involve communication with various different adjacent structures (eg, enteroenteric, enterobronchial/tracheal, enterovaginal, enterovesical, enterocutaneous, enteroatmospheric).

Perforations and leaks can present acutely, with sudden onset of chest or abdominal pain depending on the location of the perforation.³ However, occasionally perforation can present in an indolent manner, presenting with sepsis, an abdominal mass, or fistula drainage. Fistulas will typically present with fevers, pain, and sequelae of fluid egress depending specifically on the location of the fistula (ie, diarrhea, cough, feculent vaginal or urinary discharge, cutaneous leakage).

APPROACH TO MANAGEMENT

The fundamental principles of perforation, leak, and fistula management include (1) identification of the site of disruption, (2) drainage of any leaked contents, and (3) controlling the flow of luminal contents with either diversion of luminal contents or closure of the disruption. Aside from management of the primary site of disruption, comprehensive management includes bowel rest, broad spectrum antibiotic therapy, fluid and electrolyte management, parenteral nutritional support, and drainage of any fluid collections and/or abscesses.^{4,5}

When attempting endoscopic closure of an acute perforation, a sterile angiocatheter or Veress needle, connected to a syringe with sterile normal saline solution, can be placed into either the thoracic or peritoneal cavity through the chest or abdominal wall, to avoid complications associated with tension pneumothorax or tension pneumoperitoneum.

Traditionally, perforations, leaks, and fistulas require surgical management, especially if there is associated extraluminal contamination. However, the advent of endoscopic tools and techniques have allowed for select patients to be managed endoscopically, with complex cases managed in a coordinated multidisciplinary effort involving surgery, interventional radiology, and endoscopy (Box 2).^{6,7}

The decision between an endoscopic or surgical approach is dependent on the size and chronicity of the disruption, its location and endoscopic accessibility, and the ability to drain or limit any associated contamination. Endoscopic management can be a viable option for the management of acute perforations, with defect closure and/or diversion through enteral stent placement (Box 3). However, the management of leaks and fistulas are typically more complex and may require multimodality management in conjunction with interventional radiology and surgery.

ENDOSCOPIC SUTURING

Multiple endoscopic suturing devices have been described and developed over the past 2 decades, including the Bard EndoCinch (C.R. Bard, Murray Hill, NJ), the T-Bar (Cook

Medical, Bloomington, IN), and the Eagle Claw (Olympus America, Center Valley, PA) devices. The original devices were developed in support of natural orifice transluminal endoscopic surgery defect closures; however, each device had limitations that prevented further widespread use. The current Apollo Overstitch system was first developed in 2009, with a study from Moran and colleagues⁸ demonstrating its use in placing full-thickness sutures for gastrotomy closure in a porcine model with satisfactory tissue apposition. Currently, the Overstitch is the only endoscopic suturing platform commercially available in the United States, with increasing applications such as in defect closure following endoscopic resection or peroral endoscopic myotomy (POEM), enteral stent fixation, and multiple bariatric endoscopy applications, in addition to the closure of perforations, leaks, and fistulas.⁹

The Overstitch system itself is a disposable single-use endoscopic suturing device (Fig. 1).¹⁰ It is designed for use by a single operator, and allows full-thickness placement of either permanent (2–0 and 3–0 polypropylene) or absorbable (2–0 and 3–0 polydioxanone) sutures. The original Overstitch device requires a double-channel therapeutic endoscope. However, the newly introduced Overstitch SX device can be mounted alongside a single-channel endoscope and is compatible with more than 20 current single-channel flexible endoscopes and 4 platforms (Olympus, Pentax Medical, Fujifilm, and Storz) according to its manufacturer.

The main device is mounted on the tip of the double-channel therapeutic endoscope (Overstitch) or alongside a single-channel endoscope (Overstitch SX). The device contains a needle driver, which moves in an arclike fashion, and an anchor exchange catheter. The device is connected to a large handle, which is attached near the endoscope controls. The suture is first mounted onto the anchor exchange catheter and passed through the operating channel. The anchor is then transferred to the needle driver, and suturing is performed by transferring the anchor back and forth between the needle driver and the anchor exchange catheter. Tissue approximation can be facilitated with the use of a separate tissue helix, which is a corkscrewlike device that allows tissue grasping and retraction. When suturing is complete, a release button on the anchor exchange catheter releases the anchor. The suture is threaded onto a cinch device, which is then passed through the operating channel to both secure and cut the suture. In this fashion, the Overstitch device allows interrupted or continuous sutures to be placed without needing to remove the device (Fig. 2). The device itself can be reloaded multiple times with new needles without removing the endoscope.

ENDOSCOPIC SUTURING OF PERFORATIONS

Owing to the infrequency of iatrogenic perforations outside the setting of endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD) defect closure, and the relatively recent advent of endoscopic suturing, there is a paucity of literature evaluating the efficacy and outcomes of endoscopic suturing for perforations (Fig. 3), with existing literature confined to case studies, small case series, and animal studies. Indeed, in a Dutch systematic review of the existing literature published in 2015, which included 466 acute perforations across 24 different studies (21 retrospective, 3 prospective), perforations were closed using either standard endoclips, over the scope clips, or metal stents, and no cases

involving endoscopic suturing were included.¹¹ As with the Dutch systematic review, most existing large series of endoscopic suturing for defect closure relate to closure of partial thickness defects due to EMR/ESD,¹² rather than acute full-thickness perforations.

The potential application of endoscopic suturing in the management of perforation was first described using previously available suturing platforms. Pham and colleagues¹³ in 2006 described an animal study using the Eagle Claw prototype suturing device, considered to be the precursor of the currently available Overstitch device. In their study of 10 colonic perforations in 10 pigs, 8 perforations were successfully closed. Two perforations could not be closed due to device-related issues, resulting in worsening pneumoperitoneum and hemodynamic instability, and the animals were euthanized immediately. Of the 8 perforations that were closed, all of the pigs recovered well without any sepsis or peritonitis. On necropsy after 1 week, 7 out of 8 pigs had an intact perforation closure with no peritonitis or abscess formation; however, 1 pig demonstrated dehiscence of the perforation site. The results of the study demonstrated the feasibility of the prototype suturing device in closure of acute colonic perforations in a porcine model.

Other studies focused on competing endoscopic suturing-based tissue approximation systems. Sumiyama and colleagues¹⁴ in 2007 described an animal study using a T-tag-based tissue approximation system. In their study of 12 gastric perforations in 6 pigs, all perforations were successfully closed and follow-up endoscopy and necropsy after 1 week demonstrated that the tissue anchors remained intact with firmly held sutures and sealed perforation. Raju and colleagues¹⁵ in 2007 described an animal study comparing a similar full-thickness tissue approximation device versus a multi-clip applicator in closing 10 colon perforations. In their study, endoscopic closure of 4-cm-long colon perforations was successful in 9 out of 10 animals, with 1 failed closure using the multi-clip applicator. Successful closure prevented clinical peritonitis in 3 out of 4 animals in the suture closure group, and necropsy at 2 weeks showed mild peritonitis in 2 out of 4 animals; none developed fecal peritonitis.

Since the introduction of the Overstitch device, endoscopic suturing for perforations using the Overstitch device has mostly been limited to case studies or case series. In the esophagus, various groups have reported successful endoscopic suture repair of perforation during POEM for management of achalasia.^{16,17} Henderson and colleagues¹⁸ reported 3 cases of esophageal perforation in a 2014 case series, in which one patient had perforation due to Boerhaave syndrome, a second patient had perforation following unsuccessful endoscopic food disimpaction, and a third patient had perforation following transesophageal echocardiography. All 3 cases were successfully managed with endoscopic suturing with the Overstitch device. Maselli and colleagues¹⁹ in 2017 reported 2 cases of successful endoscopic suture repair of esophageal perforations after failed attempts at surgical sutured closure. More recently, various groups have reported video case reports of successful suture repair of Boerhaave syndrome,²⁰ esophageal perforation from Savary dilation,²¹ and type 1 duodenal perforation from duodenal stricture dilation.²²

Occasionally, perforation closure may require diversion and/or management of leaked luminal contents. Diversion in the foregut can be accomplished with placement of a fully

covered self-expanding metal stent, which can then be sutured in place to prevent migration.²³ Several groups have additionally reported direct abdominal exploration with washout of leaked luminal contents. Kumar and Thompson²⁴ reported 2 cases of perforation (1 gastric perforation and 1 gastrojejunal anastomotic perforation) in a 2014 case series, in which both cases were managed with endoscopic abdominal exploration through the perforation site to guide placement of an angiocatheter, inspect for any signs of injury that may warrant surgical management, and remove leaked luminal contents. Both perforations were then successfully repaired with endoscopic suturing with the Overstitch device, with confirmation of closure with an upper gastrointestinal (GI) series and discharge 1 day later. Moyer and colleagues²⁵ reported a recent series of 7 cases of endoscopic defect repair, which comprised of 4 perforations (1 esophageal perforation, 2 gastric perforations, and 1 duodenal perforation) and 3 postsurgical anastomotic leaks. In all cases, there was evidence of extraluminal contamination. The cases were then managed with transluminal washout, debridement, and either endoscopic sutured repair of the defect and/or endoscopic suturing of a fully covered self-expanding metal stent. Technical success was achieved in 100%, and overall clinical success in 86% due to 1 death from severe comorbid disease.

Several large retrospective case series have been published on endoscopic suturing for perforations. Kantsevoy and colleagues²⁶ in 2016 reported a series of 21 patients with iatrogenic colonic perforations from 2009 to 2014, of which 5 patients underwent closure with standard endoclips and 16 patients underwent closure with the Overstitch suturing device. The vast majority of the perforations were due to EMR/ESD; however, 2 were from screening colonoscopy and 1 was from colonic dilation. All 5 patients who underwent closure with endoclips subsequently had worsening abdominal pain. Four of those 5 patients required laparoscopy, which showed inadequate closure, thus requiring colon resection with ileocolonic anastomosis. One of those 5 patients underwent immediate rescue colonoscopy with endoscopic suturing, which was successful. On the other hand, only 2 patients who underwent closure with suturing subsequently had worsening abdominal pain, and laparoscopy confirmed complete and adequate closure. The results of the study demonstrated the apparent superiority of endoscopic suturing over standard endoclips for the management of colonic perforations, which are due to the ability of the Overstitch device to achieve full-thickness “surgical-quality” suturing and thus create an airtight closure. Stavropoulos and colleagues⁹ in 2015 reported a large case series that included endoscopic suturing in 22 ESD defects, 24 endoscopic full-thickness resection defects, and 16 accidental perforations, all of which were successful with 2 minor adverse events. Similarly, Sharaiha and colleagues²³ in 2016 reported a multicenter case series on endoscopic suturing that included 47 cases for stent anchorage, 40 fistulas, 15 anastomotic leaks, and 20 perforations, and reported 93% clinical success in the management of perforations using endoscopic suturing.

Owing to publication bias, reported success rates of endoscopic suturing for repair of acute perforations are quite high. In an abstract from Bartell and colleagues²⁷ in 2018, which described a systematic review of patients who underwent endoscopic suturing for repair of acute perforations, the clinical success was reported to be greater than 98%. Although well-powered high quality studies are needed, prospective trials are unlikely to occur due to

ethical issues of enrolling participants who are under sedation, unable to provide informed consent, and faced with a life-threatening adverse event that demands emergent attention.²⁸

The optimal suturing approach for the closure of large perforations was studied in an ex vivo porcine model by Schulman and colleagues²⁹ in 2016. The study compared interrupted, running, horizontal mattress, and pursestring suturing patterns to close a 2-cm colon perforation, with subsequent measurement of mean pressure required to achieve air leakage. Their results demonstrated that a full-thickness running suture produced the most robust perforation closure, with highest leak pressure, and was completed in the shortest amount of time.

ENDOSCOPIC SUTURING OF LEAKS AND FISTULAS

Endoscopic suturing has been used in the management of leaks and fistulas, both in the acute and chronic setting (Fig. 4), with variable success. As with the endoscopic management of perforations, there is an overall paucity of literature evaluating the efficacy and outcomes of endoscopic suturing for leaks and fistulas, with existing literature confined to case studies, small case series, and animal studies. Given the challenging nature of endoscopic therapy for leaks and fistulas, endoscopic suturing is typically a component of a carefully selected multimodality approach that may also include argon plasma coagulation (APC), through the scope clips, over the scope clips, and glue.³⁰ Diversion of enteral contents with placement of a fully covered self-expanding metal stent (which can then be sutured in place to prevent migration) is often a necessary adjunct.²³ In addition, percutaneous drainage catheters placed by interventional radiology or surgery are commonly necessary to evacuate cavities and fluid collections.⁵ Although successful closure using endoscopic suturing has been described in the literature, fistula/leak recurrence may develop and additional therapy may be required, particularly among challenging chronic epithelialized fistulas, which may be exceptionally resistant to closure.

The overall experience with endoscopic suturing for fistula closure varies by the type of fistula involved. Gastrogastric fistulas, a known complication from Roux-en-Y gastric bypass, has thus far been the most commonly reported scenario for endoscopic sutured fistula closure. Spaun and colleagues³¹ in 2010 reported closure for 4 patients with 5 gastrogastric fistulas using the T-tag-based tissue apposition system. Although primary closure of the 5 fistulas was 100%, after 3 months only the smallest fistula (10 mm) remained closed, and after 6 months all fistulas had reopened, leading the investigators to conclude that permanent closure could not be achieved. In a much larger series, Fernandez-Esparrach and colleagues³² in 2010 reported closure for 95 patients with gastrogastric fistulas using either standard clips (24/95, 25%) or the Bard EndoCinch suturing system (71/95, 75%). Complete initial fistula closure was achieved in 95% of patients; however, 65% of fistulas reopened in an average of 177 days. In an average follow-up period of 395 days, it was noted that none of the fistulas with initial size greater than 20 mm remained closed, compared with 32% of the fistulas with initial size 10 mm that remained closed. The investigators therefore concluded that the best results for endoscopic fistula closure were seen with fistulas 10 mm in diameter. More recently, Wu and colleagues³³ in 2016 reported a patient with a 2-cm gastrogastric fistula that was successfully closed with the

Overstitch suturing device, using a single polydioxanone suture in a figure-of-8 configuration, and that remained closed on 6-month follow-up. Additional abstracts have also reported successful use of the Overstitch suturing device in closure of gastrogastic fistulas,³⁴ including a matched-cohort study, which demonstrated the superiority of the full-thickness Overstitch suturing device compared with a superficial suction-based suturing system.³⁵

Aside from gastrogastic fistulas, closures of various other enteric fistulas have been reported using the Overstitch system. Kantsevov and Thuluvath³⁶ reported a chronic gastrocutaneous fistula from prior gastrostomy tube that had been resistant to prior closure attempts with clips and glue. The fistula was successfully closed using 3 separate sutures deployed using the Overstitch system, without further drainage at 1-month follow-up. Several other case reports have described successful gastrocutaneous fistula closure using the Overstitch device.^{37,38} Catalano and colleagues³⁹ reported successful closure of 6 various enteric fistulas, including an esophagomediastinal fistula, 3 gastrocutaneous fistulas, and 2 esophagobronchial fistulas; the esophagobronchial fistulas notably required 3 to 4 sessions for complete closure. Stavropoulos and colleagues⁹ reported successful closure of 2 leaks and 12 fistulas (9 from gastric sleeves, 2 from Roux-en-Y gastric bypass, and 1 post-gastrostomy tube removal), and demonstrated 100% closure among the 2 leaks and 83% closure among the 12 fistulas. In the multicenter case series reported by Sharaiha and colleagues,²³ among 40 fistulas and 15 anastomotic leaks, the clinical success rate was 80% and 27%, respectively.

Additional case reports have described the use of the Overstitch device to successfully close a persistent esophagopleural fistula from Boerhaave syndrome,⁴⁰ a gastropleural fistula from a deformed sleeve gastrectomy,⁴¹ a cholecystoduodenal fistula,⁴² a gastropulmonary fistula following esophagectomy,⁴³ and a malignant gastroduodenal fistula from primary gastric lymphoma.⁴⁴

In cases in which the fistula tract has epithelialized, it is important to attempt to de-epithelialize the fistula tract before endoscopic closure. De-epithelialization is traditionally achieved using either APC along the perimeter of the fistula, or mechanical abrasion of the fistula tract and perimeter using a brush. Abidi and Thompson⁴⁵ in 2016 described a novel technique involving a modified ESD technique to fully resect a gastrogastic fistula tract, followed by sutured closure using the Overstitch device. Pang and colleagues⁴⁶ in 2018 described a similar technique in the closure of a chronic tracheoesophageal fistula, which involved multiple small snare mucosal resections around the fistula opening on the esophageal side, followed by successful sutured closure using the Overstitch device.

The largest existing multicenter series describing the use of endoscopic suturing in the management of gastrointestinal fistulas was reported by Mukewar and colleagues⁴⁷ in 2016. The series included 56 patients from 3 hospitals, and comprised a wide variety of gastrointestinal fistulas, including gastrogastic fistulas, enteroperitoneal fistulas, enterovaginal fistulas, enterobronchial fistulas, enterocutaneous fistulas, and leaks. Gastrogastic fistulas were the most common etiology (51.8%), and 28.6% patients had undergone prior failed attempts at closure. Although immediate success was achieved using

endoscopic suturing in all patients (100%), durable closure was observed in only 22.4% at 12 months, with a 17.1% ongoing closure rate of gastrogastic fistulas and 31.4% closure rate of other fistulas. Of the original 56 patients, 13 patients (30.2%) were able to achieve closure without the need for additional therapies, whereas 17 patients required additional attempts, of which successful closure was attained in only 4 out of 17 patients. The remaining patients either were lost to follow-up or had unsuccessful attempts at fistula closure. One patient with an enteroperitoneal fistula underwent 5 attempts at fistula closure, all of which were ultimately unsuccessful. Although the study overall demonstrates the feasibility of endoscopic suturing for fistula closure, the relatively low rate of durable closure highlights the fundamental challenges of fistula closure.

Although Overstitch has been well described for fistulas, endoscopic suturing can also be applied to acute leaks and dehiscence. Belfiori and colleagues⁴⁸ in 2017 described using the Overstitch device to close a large anastomotic dehiscence 1 week following left colectomy for colon cancer. The perimeter of the leak was first cauterized with APC, and subsequently running sutures were placed using the Overstitch device in a distal-to-proximal technique, attempting to create a full-thickness suture repair. A minimal residual leak was noted 1 week later, and a second round of endoscopic sutured repair was performed with the Overstitch device. This ultimately resulted in a successful and durable closure at 6-month follow-up. Although successful, it is important to note that an abdominal surgical drain had remained in place for removal of soiled contents that had leaked into the peritoneum.

Irrespective of the method of endoscopic closure for fistulas and leaks, successful closure of fistulas and leaks requires adequate drainage of any leaked luminal contents. This is typically achieved using either surgical drainage or percutaneous drainage placed by an interventional radiologist. However, recently internal drainage techniques have also been described using either endoscopic stents placed into adjacent fluid collections,^{49,50} or endoscopic vacuum therapy.^{51,52}

LIMITATIONS

Despite the advantages and robustness of endoscopic suturing, there remain multiple limitations to the Overstitch device. The current Overstitch device is limited to the Olympus double-channel therapeutic endoscope, whereas the Overstitch SX device is compatible with multiple platforms of single-channel endoscopes. However, neither device is compatible with colonoscopes. Both devices are characterized by their large size and limited field of view, and the Overstitch SX device appears to have an even more limited maneuverability when compared with the original Overstitch device due to its design. Because of these issues, the ability to suture defects and perforations in certain challenging locations remains limited to all but the most experienced operators. Difficult locations for endoscopic suturing includes the gastric fundus (because of poor angulation/maneuverability), duodenum (because of narrow space), and the right colon (because of incompatibility with colonoscopes).

In addition, despite its availability, the Overstitch device demands familiarity with the device for optimal results, especially with regard to the ability to place full-thickness sutures and

the ability to perform complex suturing patterns. Although different situations may require different approaches, endoscopic suturing for perforations is typically best performed in a right-to-left and distal-to-proximal progression, using a running suture pattern.²⁹ This allows a robust closure and also maintains clear visibility of the defect edges until the suturing has been completed. On the other hand, due to the circular shape of the defect, endoscopic suturing for fistulas may be best performed in a figure-of-8 pattern. This allows equal circumferential anisotropic compression from the suture toward the center of the defect.⁹ However, either of these complex suturing patterns can be prone to entanglement of the suture especially in the hands of an inexperienced operator, and any suture failure via tissue erosion or suture breakage would result in dehiscence of the entire closure. Similarly, accidental needle drop or breakage of the suture during cinching could result in failure of the entire closure.

SUMMARY

Endoscopic suturing represents an important technological advancement in the minimally invasive management of perforations, fistulas, and leaks. The currently available Overstitch platform is more complex than traditional through the scope and over the scope clips deployment, and requires additional training and experience to achieve proficiency. Despite this, with familiarity and mastery of the device, Overstitch allows for the capability to mimic a true full-thickness surgical closure in a minimally invasive endoscopic fashion. Although the present data suggest that endoscopic suturing is favorable in the management of perforations, it remains challenging and suboptimal in the long-term management of chronic fistulas. Further prospective comparative studies are needed to define the role of endoscopic suturing and determine its long-term outcomes in the management of perforations, fistulas, and leaks.

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KEY POINTS

- Fundamental principles of perforation, leak, and fistula management include identification of the site of disruption, drainage of any leaked contents, and controlling the flow of luminal contents with either diversion or closure.
- Endoscopic suturing may be superior to endoclips in the management of perforations, due to the ability of the Overstitch device to achieve full-thickness “surgical-quality” suturing and create an airtight closure.
- A full-thickness running suture pattern (compared with interrupted, horizontal mattress, and pursestring patterns) produces the most robust perforation closure, with highest leak pressure, and can be completed faster than other suturing patterns.
- Although successful closure of leaks and fistulas using endoscopic suturing has been described in the literature, recurrence is common and additional therapy with a multimodality approach is often required.
- In cases involving chronic fistula tracts, de-epithelialization of the fistula tract before endoscopic closure can be achieved using argon plasma coagulation, an endoscopic brush, or with endoscopic resection of the fistula edges and/or fistula tract.

Box 1**Etiologies of perforations****Spontaneous Perforation**

Boerhaave syndrome (esophagus)

Diverticulitis

Inflammatory bowel disease

Intestinal ischemia

Malignancy

Perforated ulcer

Radiation therapy

Traumatic Perforation

Blunt trauma

Caustic injury

Foreign body ingestion

Penetrating trauma

Accidental Perforation

Endoscopy (EGD, colonoscopy, EUS, ERCP)

Endoscopic stricture management (dilation, bougienage, stricturotomy)

Endoscopic myotomy (POEM and related procedures)

Endoscopic resection (EMR, ESD, STER, EFTR)

Endoscopic treatment of gastrointestinal bleeding

Laparoscopic or open surgical injury

Other instrumentation (nasogastric tubes, Blakemore or Minnesota tubes, etc.)

Abbreviations: EFTR, endoscopic full-thickness resection; EGD, esophagogastroduodenoscopy; EMR, endoscopic mucosal resection; ERCP, endoscopic retrograde cholangiopancreatography; ESD, endoscopic submucosal dissection; EUS, endoscopic ultrasound; POEM, peroral endoscopic myotomy; STER, submucosal tunneling endoscopic resection.

Box 2**Approach to management of perforations, leaks, and fistulas****Clinical Management**

Nothing by mouth

Fluid resuscitation

Intravenous broad spectrum antibiotics

Radiographic evaluation (plain films or contrast computed tomography scan)

Nasogastric decompression

Abdominal or chest decompression if tension pneumothorax or tension pneumoperitoneum

Intervention

Endoscopic therapy

- Immediate or early postprocedure recognition
- Contained or small/limited leak

Percutaneous or surgical intervention

- Delayed recognition
- Uncontained or large leak
- Clinical peritonitis

Box 3**Endoscopic tools and adjuncts for management of perforations, leaks, and fistulas****Diversion**

Fully covered self-expanding metal stents

External Drainage

Percutaneous drainage (interventional radiology)

Surgical drainage

Internal Drainage

Endoscopic vacuum therapy

Transluminal pigtail plastic stents placed directly from lumen into fluid collections

De-Epithelialization (Fistulas)

Argon plasma coagulation of fistula edges

Endoscopic brushing of fistula tract

Endoscopic resection of fistula edges and/or fistula tract

Repair

Through the scope clips

Over the scope clips

Endoloop

Tissue sealants (eg, fibrin, cyanoacrylate)

Cardiac septal occlude

Endoscopic suturing (Overstitch)

Fig. 1.

Steps involved in endoscopic suturing. (A) Grasp tissue using tissue helix. (B) Retract tissue into the needle path. (C) Drive needle through the tissue. (D) Open needle arm to release tissue. (E) Repeat as indicated until suturing is complete. (F) Depress blue button to release needle. (G) Tighten and cinch. (H) Completed defect repair. (Courtesy of Apollo Endosurgery, Inc., Austin, TX; with permission.)

Fig. 2. Endoscopic suturing patterns. (A) Interrupted suture. (B) Running suture. (C) Figure-of-8 suture. (D) Pursestring suture.

Fig. 3.

Endoscopic sutured closure of a large perforation. (*A*) Initial view of a large perforated jejunal ulcer (arrows) within the proximal Roux limb in a patient with a history of Roux-en-Y gastric bypass surgery. (*B*) Endoscopic intraperitoneal exploration with washout and debridement of spilled luminal contents. (*C, D*) The perforation was closed using a single running suture. (*E*) Completed perforation closure.

Fig. 4. Endoscopic sutured closure of a chronic fistula. (A) Initial view of chronic gastrogastroic fistula (arrow) in a patient with a history of Roux-en-Y gastric bypass surgery. (B) An endoscopic fistulectomy is performed using a modified ESD technique to de-epithelialize the fistula tract. (C) The fistula was closed using 2 sets of running sutures in a layered fashion. (D) Completed fistula closure.