Recognition and Management of Colonic Perforation following Endoscopy

Earl V. Thompson, MD¹ Jonathan R. Snyder, MD¹

¹ Division of Colon and Rectal Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio

Clin Colon Rectal Surg 2019;32:183–189.

Address for correspondence Earl V. Thompson, MD, Division of Colon and Rectal Surgery, University of Cincinnati College of Medicine, 2123 Auburn Avenue # 524, Cincinnati, OH 45219 (e-mail: thompeo@ucmail.uc.edu).

Abstract

Although rare, perforation can be a devastating complication of colonoscopy. Incidence ranges from 0.012 to 0.65% during diagnostic procedures and is higher in therapeutic procedures. Early diagnosis and management are of paramount importance to decrease morbidity. Diagnostic imaging after colonoscopy can reveal extraintestinal air, but overall clinical status including leukocytosis, fever, pain, and peritonitis is equally important to determine management. With the expanding availability of complex endoscopic interventions, an increasing number of perforations are recognized during colonoscopy or immediately afterward based on high degree of suspicion. Colonoscopic management of these early perforations may be feasible and avoid the morbidity of surgery. Patients who require surgery may be managed with laparoscopic or open surgical techniques. Surgical management may consist of primary repair of the injury, resection with anastomosis, or resection with ostomy. Mechanical bowel preparation before endoscopy decreases fecal contamination after perforation, often obviating the need for ostomy creation.

Keywords

- colonoscopy
- perforation
- colon perforation

All complications are unwelcome, but few are less welcome than endoscopic perforation secondary to colonoscopy. This is perhaps due to the perception of faulty technique or the threat of medical–legal repercussion. In either case, it is fortunately a relatively rare event, occurring in as few as 0.012% of diagnostic colonoscopies.¹ However, as the population continues to grow and age, the sheer number of colonoscopies being performed is steadily on the rise, and most surgeons can expect to face the management of colonoscopic perforation at some point in their career. To minimize the morbidity of this sometimes devastating complication, early recognition and appropriate management are paramount. In addition, most legal case reviews for colonoscopic perforation are motivated by a perceived delay in diagnosis. The treatment is not always emergency laparotomy as the degree of containment (or lack thereof) and the patient's clinical status are the key elements to consider in management. Moreover, immediate recognition yields the opportunity for endoscopic repair and, when

surgery is required, minimally invasive techniques and repair, rather than resection, are often successful.

Incidence

The incidence of colonoscopic perforation during diagnostic studies ranges from 0.012 to 0.65%. Intuitively, the risk for perforation is higher (0.07–2.1%) during therapeutic colonoscopies, including those involving standard polypectomy and endoscopic mucosal resection.^{1–5} The National Health Service colon cancer screening program quality assurance guidelines in the United Kingdom suggest that perforation should occur in less than 1 in 500 therapeutic cases and less than 1 in 1,000 screening cases.⁶ As our endoscopic techniques become more advanced, with the use of endoscopic mucosal resection and thermal ablation, we may need to develop an increased sensitivity and more thorough algorithm for management of endoscopic perforations.

Risk factors for perforation, often combined with aggressive advancement or angulation of the colonoscope, include anatomic and physiologic factors, such as fixation or tortuosity of the colon secondary to fibrotic/phlegmonous changes due to diverticular disease, inflammatory bowel disease, previous surgery or radiation therapy, and ischemic colitis. In addition, elderly patients with poor tissue tensile strength and those on chronic corticosteroid therapy are at increased risk for mechanical disruption of the bowel wall during forceful maneuvering. Retroflexion of the scope in the rectum has been cited as a cause for rectal perforation.⁷ There is some evidence that sedation with propofol, versus conventional moderate sedation, confers an increased risk for perforation during therapeutic but not diagnostic colonoscopies.⁸ Presumably, the lack of patient feedback otherwise experienced with lighter sedation may numb both the patient and endoscopist to impending mechanical trauma.

Specific anatomic locations within the colon are particularly prone to perforation. The cecum and ascending colon are more vulnerable due to their thin walls, and both the cecum and rectum have been injured in the course of retroflexion.⁷ The sigmoid colon and transverse colon, due to their redundancy and tortuosity, are at increased risk for perforation due to looping of the scope in these locations and shear forces thus delivered to the colon wall.

While performing therapeutic procedures, consideration must be given to the type and size of a polyp as well as its location. Endoscopic resection of sessile polyps is more likely to endanger the full thickness of the bowel wall. The “lift technique,” whether employed with crystalloid, colloid, or in combination with a hemostatic element, will serve to increase the thickness of the colon wall, allowing for greater separation of the mucosa from the deeper layers, and thus safer polyp removal. Polypectomies performed in the cecum, due to its thin wall, are inherently at higher risk for full-thickness injury. While using electrocautery to facilitate removal and hemostasis, great care must be taken to avoid transmural thermal injury to the colon wall.

Classification

Minor mucosal damage or “scope trauma” is relatively commonplace during colonoscopic evaluation and, aside from self-limited bleeding, is typically of no clinical consequence. Barotrauma resulting in the diffuse fracturing of the mucosa is more commonly seen when insufflating a colon with proximal diversion or a Hartmann’s pouch.

Full-thickness injury to the colon is typically caused by pneumatic trauma, mechanical insult, or thermal injury. Aggressive overinsufflation, especially in a nondistensible segment of the colon, can lead to remote barotrauma and potential perforation. Again, this perforation is more commonly seen in the cecum, due to its thin wall and the relative closed-loop obstruction caused by a competent ileocecal valve. Mechanical laceration of the colon can occur with the use of the blind “slide-by” technique, particularly in areas of tortuosity or fixation. Forceful reduction of sigmoid loops and direct penetrating force by the tip of the scope can tear

through the colon wall. Thermal injury can occur with the use of a hot snare, hot forceps, or ablative techniques (e.g., argon plasma coagulation). Mechanical perforations can also occur with dilation of colonic strictures. Thermal injuries are not always readily evident, endoscopically or clinically, as the serosa may remain intact initially, but may suffer subsequent degradation and ultimately fail in the hours or days following a procedure. The phenomenon of “postpolypectomy syndrome” is caused by a thermal serositis and sometimes microscopic failure of the colon wall when using heat to perform a polypectomy. Other names given to this phenomenon include “transmural burn syndrome” and “postpolypectomy coagulation syndrome.” Risk factors for the development of postpolypectomy syndrome, in addition to the use of cautery with polypectomy, include hypertension and polyp size greater than 2 cm.⁹

Diagnosis

Development of pneumoperitoneum secondary to colonoscopic perforation typically occurs immediately or within hours following the procedure. Prompt diagnosis and intervention will minimize the sequelae from this event. The identification of an epiploic appendage, mesenteric fat, or adjacent organ during the procedure establishes the diagnosis quickly. Other immediate indicators of perforation include sudden inability to maintain insufflation of the colon, or sudden increase in patient discomfort and abdominal distension. Colonoscopic findings of a poorly prepped colon will clue the endoscopist in a higher risk for fecal peritonitis in the event of a perforation. Conversely, a well-prepped colon is less likely to induce the same clinical response.

In many cases, however, the injury is not readily evident, particularly when the injury is remote and due to barotrauma from overinsufflation. In such cases, adjunctive studies are required as symptoms develop following the procedure. Abdominal plain films or an upright chest X-ray is often adequate to identify subdiaphragmatic free air or retroperitoneal gas. However, it is important to understand that the finding of extracolonic air following colonoscopy does not itself mandate immediate treatment. The clinical status of the patient must be taken into account.

Although often unnecessary to make the diagnosis of perforation, computed tomography (CT) of the abdomen is even more sensitive in the detection of extracolonic air and far more sensitive in the detection of adjacent fluid collection, fecal contamination, or abscess formation. While not required in the detection of pneumoperitoneum, administration of oral contrast may serve to help the practitioner delineate between a contained or sealed perforation and one with free extravasation of bowel contents. This may be more useful in the setting of a delayed presentation in a clinically borderline patient.

The findings of fever, leukocytosis, localized pain, and CT evidence of localized bowel thickening and/or a small degree of extraluminal air are consistent with postpolypectomy syndrome. These patients tend to present in the days following the procedure due to the progressive nature of the

Fig. 1 Algorithm for management of colonoscopic perforation. In centers with advanced endoscopic and laparoscopic options available, perforation during colonoscopy does not mandate immediate laparotomy. For those patients initially suitable for nonoperative management, close monitoring is necessary as abdominal infection can worsen. For the patient with peritonitis or signs of systemic infection, surgery is required.

thermal injury. This clinical picture can change, however, and attention must be paid toward detecting increasingly diffuse pain or hemodynamic instability.

Management

Management of endoscopic perforations continues to evolve as technology and knowledge advance. A general algorithm is shown in ►**Fig. 1**. Patients with peritonitis or signs of systemic infection require surgery. Early perforation in an otherwise well patient can be managed without surgery. The management of perforations recognized at the time of endoscopy and those created during advanced endoscopic procedures will also be reviewed in some depth as evolving technology allows a significant number of these perforations to be controlled endoscopically.

Endoscopy

Management of endoscopic perforation with endoscopically placed clips offers an appealing alternative to surgical inter-

vention. If the perforation can be successfully closed in a colon mechanically prepped and free of stool, minimal peritoneal contamination occurs and surgery may be avoided. Much of the data from this approach are derived from immediate closure of defects created by therapeutic procedures, but the technique has been applied to perforations recognized during or immediately after diagnostic procedures as well. Through-the-scope endoscopic clips offer the advantage of widespread availability but are limited to smaller defects. Larger over-the-scope clips have been shown to effectively close larger defects, but their availability is not as widespread and expertise with their use is consequently limited.

In a porcine study demonstrating the histological results of endoscopic clipping after colon perforation, Raju et al created 1 to 2 cm full-thickness perforations in the intraperitoneal colon in live, anesthetized animals. These perforations were then immediately closed using endoscopic clips. One animal was immediately euthanized and evaluation of the closure site revealed excellent apposition of the mucosa with serosa and muscularis remaining widely dehiscid. The

remaining four animals were treated with antibiotics and diet was advanced to regular 2 days after the procedure. None showed signs of infection or peritonitis and all were killed on day 7. Necropsy of these animals did not reveal signs fecal soiling of the peritoneal cavity or pericolic abscess. There were signs of healing on both macroscopic and histologic evaluation.¹⁰

Multiple small studies have shown the safety and efficacy in closure of iatrogenic perforations in humans using endoscopic clips. In one study by Kim et al, 27 perforations were diagnosed after 115,285 endoscopies. Twenty-four of these were noted by the endoscopist during the procedure and endoscopic clip placement was attempted in 16 of 24 patients. In 13 of these 16 patients, endoscopic clip placement was technically successful and none of those patients required surgical management. The authors note that the perforation was significantly smaller in patients who were successfully managed with endoscopic clipping (1.0 vs. 1.4 cm, $p < 0.04$) and that the average number of clips used was 5.6.¹¹ In another, similar, multi-institution observational study, 109 patients with perforation after colonoscopy were identified. Endoscopic clipping was attempted in 31 of these patients and conversion to surgery was required in 8 of 31 (25.8%). Again, larger perforation size was associated with failure of nonoperative management.¹² Magdeburg et al identified 30 perforations after colonoscopy out of 7,589 procedures performed at a single center over 34 months. Twenty-seven of these perforations were treated with endoscopic clipping and 25 of 27 were successfully managed without surgery.¹³ Another study identified 38 perforations out of 118,115 colonoscopies performed at a single center over 7 years. Endoscopic clip closure was attempted and technically successful in 22 patients and 21 of 22 did not require surgery.¹⁴

Cost analysis in a retrospective review of endoscopic perforations in a single center demonstrated a lower direct cost for equipment and procedures for perforations managed by endoscopic clipping compared with those who underwent surgery. In this study, 12 perforations were identified from a total of 7,136 colonoscopies performed over a 6-year period. Endoscopic clipping was attempted in seven patients whose perforation was identified at the time of the procedure and was successful at closing the perforation in five of seven patients. Direct health care costs for procedures and investigations were lower for the seven patients to whom endoscopic management was attempted. Length of stay (9 vs. 13 days) and total costs (US\$ 1,481.70 vs. 3,281.90) were also lower in the endoscopic clipping group, but this result did not reach statistical significance. As these investigators were unable to report the size of the perforation, there may be selection bias as previously discussed studies have demonstrated that smaller perforations are more amenable to endoscopic therapy and one would therefore predict lower costs. The authors also note that costs vary among countries, and their results may not be applicable in all areas.¹⁵

Over-the-scope clips may allow closure of larger defects than smaller through-the-scope endoscopic clips. In an early porcine study, full-thickness colon perforations were created

using biopsy forceps in 10 animals and then closed using an over-the-scope clip (OTSC system, Ovesco Endoscopy AG, Tübingen, Germany). The animals were observed for 90 days before they were killed and evaluation of the colon. Nine of 10 animals survived the study period with no signs of illness. The 10th died of a cause unrelated to the study. Autopsy revealed no signs of peritoneal inflammation in any animal with the clip still preset in two of nine animals at 90 days.¹⁶ In a follow-up study, 18 mm colotomies were created using cautery and an esophageal dilation balloon in 24 pigs. The experimental animals were then randomized to closure with over-the-scope clip or surgical suture. The primary end point of this study was burst pressure of the repair measured *ex vivo* after the animals were killed. There was no significant difference between burst pressure of repair by over-the-scope clip and suture (62.8 and 67.4 mm Hg, respectively). The authors do report incorporation of adjacent small bowel in one over-the-scope closure.¹⁷

Human studies of over-the-scope clips for endoscopic perforation are few and consist primarily of retrospective data. They do suggest improved outcomes compared with through-the-scope clips. Khater et al evaluated a series of patients who suffered full-thickness perforations in both upper endoscopy and colonoscopy. Their study compared outcomes of patients treated before and after the availability of the over-the-scope clip at their center. In the period before introduction of over-the-scope clip, 62.5% of patients were referred immediately to surgery compared with none referred directly to surgery after the introduction of over-the-scope clips. Of 11 patients treated with over-the-scope clip, 2 went on to require surgery, 1 of these due to obstruction of the right ureter by the clip.¹⁸ Another prospective cohort study from 11 European centers identified 36 patients with perforation during endoscopy. Thirteen suffered perforation during colonoscopy, eight of whom were undergoing diagnostic colonoscopy. All were treated with over-the-scope clip and contrast studies demonstrated no leak in any of the patients after clip deployment. One of the 13 patients clinically deteriorated after endoscopy, underwent surgery which revealed a dislodged clip with persistent perforation, and died within 36 hours. All other patients recovered without surgery.¹⁹ The inclusion of a large number of patients who suffered perforation during diagnostic colonoscopy is interesting in that these perforations are often longer linear tears and may not respond well to nonoperative management.

The use of an endoscopic suturing device to treat iatrogenic colon perforations occurring during colonoscopy may offer similar advantages to endoscopic clipping with higher probability of nonoperative management. Published series are small but encouraging. Kantsevoy et al describe 21 patients in whom perforations were identified at the time of colonoscopy. The majority (19/21) were therapeutic procedures. Perforation size was estimated to range from 3 to 15 mm (mean size, 6.6 ± 3.9 mm). Endoscopic clips were used to close five of these perforations and an endoscopic suturing device (Overstitch; Apollo Endosurgery Inc, Austin, TX) was used to close the remaining 16. All five of the

perforations closed with clips were in the cecum or ascending colon and four of five went on to require laparoscopic colon resection. The fifth patient treated with endoscopic clipping of a perforation in the cecum awoke from the procedure with abdominal pain, the endoscopy was repeated, and the clips were successfully replaced with endoscopic suture. Of the 16 patients treated with endoscopic suturing alone, 2 required diagnostic laparoscopy for ongoing pain with no evidence of peritoneal contamination and no further intervention. The remaining 14 required no further intervention and were discharged home. These authors estimate that each patient treated with endoscopic suture instead of surgery recognizes a cost savings of \$7,529 to \$9,621.²⁰

Nonsurgical Management

Nonoperative management of colon perforation after endoscopy is safe and effective in properly selected patients. In the absence of peritonitis or systemic signs of infection, nonoperative management with bowel rest, antibiotics, and monitoring of the abdominal exam has been shown to be effective in many small studies over decades.^{21–24} Few studies have offered specific guidance on selection of patients in whom nonoperative management may be attempted. Won et al determined that patients treated nonoperatively had less severe abdominal pain and were afebrile. A majority (64.7%) of patients treated with surgery were febrile compared with none in the nonsurgical group, while all of the patients treated with surgery had severe abdominal pain.²⁵ Patients whose bowel preparation was judged insufficient have a higher probability of surgery after perforation. Also, patients whose perforation resulted from traction injury have a higher probability of undergoing surgery than those whose perforation was caused by therapeutic maneuvers or barotrauma.²⁶ Imaging studies showing uncontained leak of contrast should alert the clinician that nonoperative management is unlikely to be successful. Patients who worsen or fail to improve with nonoperative management require surgery.

Surgical Management

During any surgical treatment for endoscopic perforation, the surgeon should not discount the possibility of a second injury, proximal due to barotrauma or distal due to traction. The entire colon must be evaluated. Surgery with primary suture repair is the least invasive surgical management option for colonoscopic perforations. In properly selected patients, omitting fecal diversion or bowel anastomosis may decrease the risk of postoperative complications. Primary repair can be performed laparoscopically or through an open laparotomy incision. An early case-control series comparing laparoscopic primary repair to laparotomy with primary suture repair demonstrated lower complication rates and length of stay in the laparoscopic group. In this study by Bleier et al, 11 patients treated with laparoscopic repair were compared with 7 controls treated with laparotomy and

repair. With similar patient characteristics, the laparoscopic group was superior to the open group in incision length (12 vs. 120 mm, $p = 0.001$), length of stay (5 vs. 9 days, $p = 0.01$), and complication rate (2/11 vs. 5/7, $p = 0.01$). Both complications in the laparoscopic group were ileus. Complications in the open group were ileus, wound infection, and pneumonia. These authors recommend laparoscopy as an initial management modality, but also caution that open procedures may be required in unstable patients or when laparoscopy fails.²⁷

A recent meta-analysis of six studies confirms the findings of this single-institution series. In the meta-analysis, 161 patients were included, 90 of whom underwent initial laparoscopic management. Conversion to open surgery was required in nine patients. Primary outcomes favored laparoscopy over open surgery for overall complication rate (18.2 vs. 53.5%), mortality (1.11 vs. 4.22%), and reintervention (1.11 vs. 8.45%).²⁸ There will likely be some selection bias in these retrospective studies as hemodynamically unstable patients or those with extensive peritoneal contamination would be expected to undergo laparotomy more frequently.

Several factors are important in determination of the feasibility of laparoscopic primary repair. As defects created during diagnostic procedures are often larger linear lacerations compared with smaller injuries created during therapeutic procedures, it has been suggested that nonoperative management will be less often successful in managing injuries after diagnostic procedures. In one series, nonoperative management was attempted in 21 patients and was successful in 13 patients. Of the 13, 12 had undergone therapeutic colonoscopy and 1 diagnostic colonoscopy.²⁹ While the size of the defect is an important consideration, minimal abdominal fecal contamination or inflammation at the site of perforation is critical for repair without fecal diversion. Therefore, shorter delay from injury to repair is a relevant consideration.³⁰ Location of the injury on the mesenteric border or the colon may make identification during laparoscopy challenging, and the surgeon should therefore be prepared for intraoperative colonoscopy.

Laparotomy with repair, resection, or diversion is offered when the above measures do not succeed. Published studies in this area are limited, but management strategies can be extrapolated from extensive publications on management of traumatic injuries and diverticular disease with the caveat that perforation after mechanical bowel preparation will limit fecal contamination from endoscopic perforation. The liberal use of colostomy after penetrating trauma has been largely abandoned. In the absence of severe fecal contamination, colostomy offers no protection from abdominal complications compared with primary anastomosis.³¹ Similar outcomes have been noted in management of Hinchey III or IV perforated diverticulitis. Although most studies are retrospective, there does not appear to be an advantage for Hartmann's procedure over resection with primary anastomosis.³² Other studies have shown that the evolving strategy of resection, primary anastomosis, and proximal diverting ileostomy does not increase risk of postoperative

complications in patients with peritonitis from perforated diverticulitis.^{33–36}

Primary repair with suture or transverse stapling can be attempted for any endoscopic perforation so long as repair will not create a stricture and there is not excessive inflammation surrounding the site of injury. For right-sided perforations, primary repair should be attempted with resection and primary anastomosis as an alternative. Primary repair can also be safely attempted in left-sided perforations, with resection and primary anastomosis again as an alternative. In the face of significant contamination or inflammation, primary anastomosis can be protected with proximal diversion. End colostomy can be performed when necessary if a patient is hemodynamically unstable, contamination is too excessive to allow safe anastomosis, or underlying pathology (such as inflammatory bowel disease) renders anastomosis unwise. Consideration must be given to colon pathology prior to attempting any management as newly encountered malignancy or inflammatory bowel disease may necessitate surgery.

Conclusion

Management of perforation after colonoscopy relies on prompt recognition and careful evaluation of the patient's overall clinical situation. If the expertise exists for endoscopic closure of a recent perforation, this technique may minimize morbidity. Although some patients will require laparotomy with colon resection, many can be managed with laparoscopy and primary suture repair of the defect. Close communication between the endoscopist and surgeon can facilitate improved patient outcomes.

References

- Shi X, Shan Y, Yu E, et al. Lower rate of colonoscopic perforation: 110,785 patients of colonoscopy performed by colorectal surgeons in a large teaching hospital in China. *Surg Endosc* 2014;28(08):2309–2316
- Damore LJ II, Rantis PC, Vernava AM III, Longo WE. Colonoscopic perforations. Etiology, diagnosis, and management. *Dis Colon Rectum* 1996;39(11):1308–1314
- Jentschura D, Raute M, Winter J, Henkel T, Kraus M, Manegold BC. Complications in endoscopy of the lower gastrointestinal tract. Therapy and prognosis. *Surg Endosc* 1994;8(06):672–676
- Nelson RL, Abcarian H, Prasad ML. Iatrogenic perforation of the colon and rectum. *Dis Colon Rectum* 1982;25(04):305–308
- Crispin A, Birkner B, Munte A, Nusko G, Mansmann U. Process quality and incidence of acute complications in a series of more than 230,000 outpatient colonoscopies. *Endoscopy* 2009;41(12):1018–1025
- Rutter M, Chilton A. Quality Assurance Guidelines for Colonoscopy. Vol. 6. NHS Cancer Screening Programmes. Sheffield, UK: NHS BCSP Publication; 2011:24
- Quallick MR, Brown WR. Rectal perforation during colonoscopic retroflexion: a large, prospective experience in an academic center. *Gastrointest Endosc* 2009;69(04):960–963
- Adeyemo A, Bannazadeh M, Riggs T, Shellnut J, Barkel D, Wasvary H. Does sedation type affect colonoscopy perforation rates? *Dis Colon Rectum* 2014;57(01):110–114
- Lee SH, Kim KJ, Yang DH, et al. Postpolypectomy fever, a rare adverse event of polypectomy: nested case-control study. *Clin Endosc* 2014;47(03):236–241
- Raju GS, Pham B, Xiao SY, Brining D, Ahmed I. A pilot study of endoscopic closure of colonic perforations with endoclips in a swine model. *Gastrointest Endosc* 2005;62(05):791–795
- Kim JS, Kim BW, Kim JI, et al. Endoscopic clip closure versus surgery for the treatment of iatrogenic colon perforations developed during diagnostic colonoscopy: a review of 115,285 patients. *Surg Endosc* 2013;27(02):501–504
- An SB, Shin DW, Kim JY, Park SG, Lee BH, Kim JW. Decision-making in the management of colonoscopic perforation: a multi-centre retrospective study. *Surg Endosc* 2016;30(07):2914–2921
- Magdeburg R, Collet P, Post S, Kaehler G. Endoclippping of iatrogenic colonic perforation to avoid surgery. *Surg Endosc* 2008;22(06):1500–1504
- Yang DH, Byeon JS, Lee KH, et al. Is endoscopic closure with clips effective for both diagnostic and therapeutic colonoscopy-associated bowel perforation? *Surg Endosc* 2010;24(05):1177–1185
- Chan WK, Roslani AC, Law CW, Goh KL, Mahadeva S. Clinical outcomes and direct costings of endoluminal clipping compared to surgery in the management of iatrogenic colonic perforation. *J Dig Dis* 2013;14(12):670–675
- Schurr MO, Hartmann C, Ho CN, Fleisch C, Kirschniak A. An over-the-scope clip (OTSC) system for closure of iatrogenic colon perforations: results of an experimental survival study in pigs. *Endoscopy* 2008;40(07):584–588
- von Renteln D, Schmidt A, Vassiliou MC, Rudolph HU, Gieselmann M, Caca K. Endoscopic closure of large colonic perforations using an over-the-scope clip: a randomized controlled porcine study. *Endoscopy* 2009;41(06):481–486
- Khater S, Rahmi G, Perrod G, et al. Over-the-scope clip (OTSC) reduces surgery rate in the management of iatrogenic gastrointestinal perforations. *Endosc Int Open* 2017;5(05):E389–E394
- Voermans RP, Le Moine O, von Renteln D, et al; CLIPPER Study Group. Efficacy of endoscopic closure of acute perforations of the gastrointestinal tract. *Clin Gastroenterol Hepatol* 2012;10(06):603–608
- Kantsevov SV, Bitner M, Hajiyeva G, et al. Endoscopic management of colonic perforations: clips versus suturing closure (with videos). *Gastrointest Endosc* 2016;84(03):487–493
- Carpio G, Albu E, Gumbs MA, Gerst PH. Management of colonic perforation after colonoscopy. Report of three cases. *Dis Colon Rectum* 1989;32(07):624–626
- Farley DR, Bannon MP, Zietlow SP, Pemberton JH, Ilstrup DM, Larson DR. Management of colonoscopic perforations. *Mayo Clin Proc* 1997;72(08):729–733
- Araghizadeh FY, Timmcke AE, Opelka FG, Hicks TC, Beck DE. Colonoscopic perforations. *Dis Colon Rectum* 2001;44(05):713–716
- Shin DK, Shin SY, Park CY, et al. Optimal methods for the management of iatrogenic colonoscopic perforation. *Clin Endosc* 2016;49(03):282–288
- Won DY, Lee IK, Lee YS, et al. The indications for nonsurgical management in patients with colorectal perforation after colonoscopy. *Am Surg* 2012;78(05):550–554
- Castellví J, Pi F, Sueiras A, et al. Colonoscopic perforation: useful parameters for early diagnosis and conservative treatment. *Int J Colorectal Dis* 2011;26(09):1183–1190
- Bleier JI, Moon V, Feingold D, et al. Initial repair of iatrogenic colon perforation using laparoscopic methods. *Surg Endosc* 2008;22(03):646–649
- Martínez-Pérez A, de'Angelis N, Brunetti F, et al. Laparoscopic vs. open surgery for the treatment of iatrogenic colonoscopic perforations: a systematic review and meta-analysis. *World J Emerg Surg* 2017;12:8–017
- Orsoni P, Berdah S, Verrier C, et al. Colonic perforation due to colonoscopy: a retrospective study of 48 cases. *Endoscopy* 1997;29(03):160–164
- Hansen AJ, Tessier DJ, Anderson ML, Schlinkert RT. Laparoscopic repair of colonoscopic perforations: indications and guidelines. *J Gastrointest Surg* 2007;11(05):655–659

- 31 Demetriades D, Murray JA, Chan L, et al; Committee on Multicenter Clinical Trials. American Association for the Surgery of Trauma. Penetrating colon injuries requiring resection: diversion or primary anastomosis? An AAST prospective multicenter study. *J Trauma* 2001;50(05):765–775
- 32 Abbas S. Resection and primary anastomosis in acute complicated diverticulitis, a systematic review of the literature. *Int J Colorectal Dis* 2007;22(04):351–357
- 33 Gawlick U, Nirula R. Resection and primary anastomosis with proximal diversion instead of Hartmann's: evolving the management of diverticulitis using NSQIP data. *J Trauma Acute Care Surg* 2012;72(04):807–814, quiz 1124
- 34 Oberkofler CE, Rickenbacher A, Raptis DA, et al. A multicenter randomized clinical trial of primary anastomosis or Hartmann's procedure for perforated left colonic diverticulitis with purulent or fecal peritonitis. *Ann Surg* 2012;256(05):819–826, discussion 826–827
- 35 Tadlock MD, Karamanos E, Skiada D, et al. Emergency surgery for acute diverticulitis: which operation? A National Surgical Quality Improvement Program study. *J Trauma Acute Care Surg* 2013;74(06):1385–1391, quiz 1610
- 36 Bridoux V, Regimbeau JM, Ouaisi M, et al. Hartmann's procedure or primary anastomosis for generalized peritonitis due to perforated diverticulitis: a prospective multicenter randomized trial (DIVERTI). *J Am Coll Surg* 2017;225(06):798–805