Advantages of ICG-guided laparoscopic resection in complicated diverticulitis: A narrative literature review

By Nikolay Yordanov Yordanov

WORD COUNT	4478	TIME SUBMITTED	29-DEC-2024 09:32PM
		PAPER ID	113771195

AMALTEA MEDICAL PUBLISHING HOUSE

https://medscience.center/journals/

TYPE OF ARTICLE: Narrative Literature Review

Advantages of ICG-guided laparoscopic resection in complicated diverticulitis: A narrative literature review

Nikolay Y. Yordanov
Faculty of Medicine, Medical University - Sofia, Sofia, Bulgaria

ORCID ID: 0009-0003-2416-7040

Corresponding author:
Nikolay Y. Yordanov
E-mail: nikiyordanov99@gmail.com

ABSTRACT

More than 10% of cases of acute diverticulitis may require surgical intervention. Despite the high morbidity and mortality rates, the Hartmann's operation has been considered the "gold standard" in the treatment of complicated diverticulosis with peritonitis for many years. Contemporary treatment recommendations define laparoscopy as the method of choice for Hinchey stages II and III, allowing laparoscopic resection with primary anastomosis, as well as laparoscopy with drainage. The inflammatory syndrome causes disruption of microcirculation, and affects the trophicity of the intestinal wall, ultimately leading to compromise of the anastomosis. The use of indocyanine green (ICG) angiography allows for the assessment of circulation and prevention of severe complications. The use of ICG for visualization of the ureters also reduces the risk of iatrogenic lesions.

Keywords: diverticulitis, laparoscopy, resection, anastomosis, ICG

Abbreviations:
AL - anastomotic leak
ICG - indocyanine green

INTRODUCTION

Colonic diverticulosis is more common in the elderly, with only 5% diagnosed in patients in their 30s and over 60% occurring in elderly patients in their 80s [1]. Acute diverticulitis occurs in 4%-25% of cases [2, 3], 8%-35% of which present with colonic perforation. Generalized peritonitis in colonic perforation (Hinchey stages 3 and 4) is a life-threatening condition requiring immediate surgical intervention [2, 3, 4, 5, 6]. Hartmann's procedure, which involves resection of the inflamed colon, closure of the rectal stump, and placement of a colostomy, is still the operation chosen by the majority of surgeons [7, 8, 9, 10]. However, this method is still associated with high morbidity and mortality rates, as well as severe psychological consequences for the patient due to the formation

of a colonic stoma. This is the reason why surgeons are increasingly looking for alternative methods that will ensure better results [11, 12].

Numerous prospective studies in the context of colorectal surgery have demonstrated the advantages of the laparoscopic method over the open method, such as reduced postoperative morbidity and mortality, reduced pain, better aesthetic results, and shorter hospital stays [13, 14]. For this reason, laparoscopic surgery is considered the method of choice for the elective treatment of diverticulosis and its complications [1, 15, 16, 17]. More than 10 years ago, there were conflicting opinions regarding the use of laparoscopy in complicated diverticulitis with perforation and feculent peritonitis, evident from reports of the European Association of Endoscopic Surgeons [18] and the American Society of Colon and Rectal Surgeons [19]. Due to insufficient data on the advantages in emergency surgery, the laparoscopic method was considered unsuitable for the treatment of complicated diverticulitis.

Nowadays, with the routine use of minimally invasive methods in the treatment of benign and malignant diseases, the experience and skills of most surgeons have increased, which has facilitated the applicability of laparoscopy in emergency cases of diverticulosis [20, 21]. Practically all operations related to the acute stage of this disease can be performed laparoscopically. The first description of performing a laparoscopic Hartmann's procedure dates back 20 years already [22]. It is characterized by lower morbidity and postoperative mortality compared with the open method. Similarly, sigmoidectomy with primary anastomosis, with or without a protective ileostomy, is routinely performed for complicated diverticulitis [23].

Local inflammation from diverticulitis leads to disturbance in the microcirculation of the intestinal wall. Adequate microcirculation supplies oxygen and nutrients, which are crucial for the healing of the intestinal anastomosis. One of the most important factors determining the success rate of an intestinal anastomosis is the viability of its edges. Most surgeons use the in-vivo method, i.e. they observe the intestinal wall and edges (color, bleeding, peristalsis) to assess circulation [24]. However, in most cases, it has been found that the observation method has little informative value regarding the vitality of the intestinal edges [25]. For this reason, it is necessary to use instrumental methods to observe and assess circulation by direct visualization of the vessels [26] such as the laser Doppler method and Indocyanine green (ICG) angiography. ICG is increasingly used to assess intestinal wall trophicity in colorectal surgery [27], gastric resections, sentinel lymph node biopsy [28], and hepatobiliary surgery [29]. In addition, cystoscopic injection of ICG for ureteral imaging allows rapid and safe detection of intraoperative iatrogenic lesions during minimally invasive treatment of complicated diverticulosis [30]. This reduces the need for intraoperative ureteral stenting.

MATERIALS AND METHODS

A literature search was performed in PubMed and Cochrane databases for case series and comparative studies published in the last 15 years. The following medical subject headings (MeSH) were searched for English titles and abstracts: diverticulitis; acute; emergent; laparoscopy; lavage; drainage; peritonitis; purulent; stercoral; fecal; complicated; perforation; Hinchey; Hartmann; Indocyanine green. The "related articles" function was used to broaden the search. A manual search of the reference lists was also performed to identify additional relevant studies.

DISCUSSION

Sigmoid diverticulosis is uncommon in patients younger than 45 years, as its incidence increases from 5% to 70% in the eighth decade of life. The disease remains asymptomatic in 80% of patients. After an acute episode, the chance of recurrence is 30%. The success rate of conservative treatment decreases from 70% for the first attack to 6% for the third [1].

Parks et al. have reported an increase in the mortality rate from 3% for the first attack to 7,7% for recurrence [31]. For this reason, current recommendations provide guidance for early treatment of uncomplicated diverticulosis, especially in younger patients. Primary resection and anastomosis with or without protective colo- or ileostomy are considered the safest options for all stages of complicated diverticulitis [32, 33, 34].

Two multicenter studies [35, 36] have shown that laparoscopic sigmoidectomy with primary anastomosis for diverticular disease is feasible and safe, especially in elective surgery, whereas complicated diverticulitis and fistula cases are more likely to be associated with complications. The routine use of minimally invasive techniques in coloproctology has increasingly demonstrated their advantages in reducing intraoperative complications and improving both short- and long-term outcomes. Limiting factors are reported less frequently, even in emergency situations [37]. A study encompassing over 124,000 patients, using data from a national inpatient sample from 2002 to 2007, compared the complication rates, morbidity, and mortality between laparoscopic and open elective surgery for diverticulitis. The study demonstrated that laparoscopic surgery is associated with lower rates of complications, morbidity, and mortality, establishing the minimally invasive approach as the preferred method [38]. A similar comparison, conducted by the SIGMA randomized controlled trial, showed that laparoscopic sigmoid resection had a 15.4% longer operative time, but was associated with a shorter hospital stay [39], improved postoperative quality of life, and a 27% reduction in major morbidity at 6 months [40]. The primary goal of treatment for acute diverticulitis is to resect the bowel segment affected by diverticulosis to achieve disease control. The proximal resection line should be at the level of the descending colon and should be free of inflammatory process. Proximal diverticulosis does not require resection unless the colon is inflamed. The distal margin should be the upper part of the rectum to reduce the risk of recurrence. After colonic resection, there are two main options: creation of a terminal colostomy (Hartmann's procedure) or creation of a primary anastomosis with or without a protective stoma. Two randomized controlled trials provide guidance in making this decision. The first trial randomized 62 patients into two groups. The first group underwent a Hartmann's procedure, and the second group underwent primary anastomosis with a protective ileostomy [41]. Overall complications were comparable, but with a reduction in hospital stay, intraoperative time, and costs in the primary anastomosis group. In addition, when analyzing safety, significantly more serious complications were reported with Hartmann's resection than with primary anastomosis (20% vs. 0%). The DIVERTI trial was a multicenter, randomized trial that included 102 patients in which one group underwent Hartmann's surgery and the other group underwent resection with primary anastomosis and protective ileostomy [42]. The study observed comparable morbidity and mortality in the two groups, but a higher 18-month stoma closure rate in the primary anastomosis group (Hartmann's surgery: 65% vs. primary anastomosis: 95%). These studies suggest that in cases of complicated diverticulitis with perforation, performing a primary anastomosis with a protective ileostomy leads to a reduction in postoperative morbidity and mortality, and a shorter recovery of intestinal passage.

Current Uses of ICG in the Setting of Colonic Resection for Diverticulosis

Assessment of Bowel Perfusion

Anastomotic leak (AL) remains one of the most serious complications after colonic resection. The incidence of AL varies depending on the type of surgery, with an incidence of up to 19% [43]. To prevent AL, a well-vascularized and tension-free anastomosis is necessary. ICG angiography provides an objective intraoperative assessment of anastomotic perfusion.

Several cohort studies have demonstrated a reduced incidence of AL with the use of intraoperative ICG assessment of anastomotic perfusion, although the results were not always statistically significant [44, 45, 46]. The first randomized controlled trial (RCT) assessing the utilization of ICG angiography in this context was published in 2020 by De Nardi et al. [47]. The trial comprised 252 patients. Although the authors concluded that ICG is safe and does not increase intraoperative time, it failed to show significantly lower rates of AL (5% in the ICG group vs. 9% in the control group). Another RCT published by Alekseev et al. [48] depicted the rates of AL in two groups of patients who underwent bowel resection with low anastomosis (4–8 cm from the anal verge) performed with the usage of circular mechanical stapler. The AL rates were significantly lower in the group in which ICG angiography was utilized (AL rate= 14.5%), compared to the group in which this method was not implemented (AL rate= 25.7%). Two recent meta-analyses [49, 50] concluded that intraoperative use of ICG for perfusion assessment is associated with a significantly lower risk of AL. The current literature reports that assessment of anastomotic perfusion with ICG angiography may lead to a reduction in AL. One of the main disadvantages of this otherwise objective method is that subjective factors such as camera distance and visualization time after injection are present in the evaluation of results. Therefore, further studies are needed to standardize the method.

The reduction in AL with ICG angiography has led to its introduction as a routine tool for assessing the blood supply to the bowel wall.

(Figure 1.)

Intraoperative assessment of ureteral anatomy

Iatrogenic injury to the ureters is one of the complications seen during colonic resection for diverticulosis. The left ureter is closely associated with the mesocolon of the descending colon and is at high risk of injury. The highest rates of ureteral injury are seen in operations involving this anatomical region, such as low anterior resection, abdominoperineal resection, and sigmoidectomy [51, 52]. The right ureter is also at risk during lateral mobilization of the right colon, because it is located in the retroperitoneum, lateral to the cecum [53].

A retrospective study conducted in the United States of America has examined patients undergoing colorectal surgery and reported the overall incidence of ureteral injury to be 0.28%. The incidence was found to be significantly higher in patients with stage 3-4 carcinoma, malnutrition, steroid use, etc. The highest risk is in rectal carcinoma (7.1/1000), followed by Crohn's disease and diverticulosis (2.9/1000) [54].

Iatrogenic lesions most often require reoperation to correct the trauma and to prevent intra-abdominal urine leakage, which causes extensive inflammation. There are numerous reports in the literature on the use of the ICG method for intraoperative identification of the ureters [55, 56, 57, 58, 59, 60]. This method consists of injecting ICG into the lumen of each ureter cystoscopically. Although the exact amount varies among studies, most recommend applying 2.5-5 mg/ml in each ureter, which is visualized in green during surgery. This facilitates their identification, especially

in minimally invasive surgery with local inflammation from complicated diverticulosis. Until recently, stenting and dye imaging of the ureters was routinely used to visualize them to prevent trauma. A recent meta-analysis concluded that the use of ICG for ureteral imaging is a safe and effective procedure that can be used intraoperatively, associated with less trauma and without prolonged intraoperative time [61].
(Figure 2.)

CONCLUSION

The use of ICG in the laparoscopic treatment of complicated diverticulosis is undoubtedly beneficial. Perfusion assessment with ICG appears to reduce AL. Its use for identification of the ureters is a fast and efficient method for their visualization and leads to a reduced rate of iatrogenic injuries requiring reoperations, which increase postoperative morbidity and mortality. From all of the above, it can be concluded that laparoscopic surgery in the treatment of complicated diverticulitis has significant advantages over the open method, and in particular Hartmann's operation. The use of ICG brings additional advantages to the success of the treatment, with reducing the rate of serious complications.

Conflict of interest: none declared
Financial support: none declared

Author's contributions:

Nikolay Y. Yordanov is the only author of this review of the literature. His contributions include: the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article and revising it critically.

REFERENCES

1. Andersen JC, Bundgaard L, Elbrond H, Laurberg S, Walker LR, Stovring J, Danish Surgical S. Danish national guidelines for treatment of diverticular disease. Dan Med J. 2012. p. C4453. PMID: 22549495.
2. Parks TG. Natural history of diverticular disease of the colon. A review of 521 cases. Br Med J. 1969. p. 639–42. doi: 10.1136/bmj.4.5684.639. PMID: 5359917. PMCID: PMC1630185.
3. Shahedi K, Fuller G, Bolus R, Cohen E, Vu M, Shah R, Agarwal N, Kaneshiro M, Atia M, Sheen V, Kurzbard N, van Oijen MG, Yen L, Hodgkins P, Erder MH, Spiegel B. Long-term risk of acute diverticulitis among patients with incidental diverticulosis found during colonoscopy. Clin Gastroenterol Hepatol. 2013. p. 1609–13. doi: 10.1016/j.cgh.2013.06.020. PMID: 23856358. PMCID: PMC5731451.
4. Li D, Baxter NN, McLeod RS, Moineddin R, Wilton AS, Nathens AB. Evolving practice patterns in the management of acute colonic diverticulitis: a population-based analysis. Dis Colon Rectum. 2014. p. 1397–405. doi: 10.1097/DCR.0000000000000224. PMID: 25380006.
5. Hinchey EJ, Schaal PG, Richards GK. Treatment of perforated diverticular disease of the colon. Adv Surg. 1978. p. 85–109. PMID: 735943.
6. Krukowski ZH, Matheson NA. Emergency surgery for diverticular disease complicated by generalized and faecal peritonitis: a review. Br J Surg. 1984. p. 921–7. doi: 10.1002/bjs.1800711202. PMID: 6388723.
7. Salem L, Anaya DA, Flum DR. Temporal changes in the management of diverticulitis. J Surg Res. 2005. p. 318–23. doi: 10.1016/j.jss.2004.11.005. PMID: 15820264.
8. Kronborg O. Treatment of perforated sigmoid diverticulitis: a prospective randomized trial. Br J Surg. 1993. p. 505–7. doi: 10.1002/bjs.1800800434. PMID: 8495323.
9. Khan AL, Ah-See AK, Crofts TJ, Heys SD, Eremin O. Surgical management of the septic complications of diverticular disease. Ann R Coll Surg Engl. 1995. p. 16–20. PMID: 7717637 PMCID: PMC2502524.
10. Kohler L, Sauerland S, Neugebauer E. Diagnosis and treatment of diverticular disease: results of a consensus development conference. The Scientific Committee of the European Association for Endoscopic Surgery. Surg Endosc. 1999. p. 430–6. doi: 10.1007/s004649901007. PMID: 10094765.
11. Salem L, Anaya DA, Roberts KE, Flum DR. Hartmann's colectomy and reversal in diverticulitis: a population-level assessment. Dis Colon Rectum. 2005. p. 988–95. doi: 10.1007/s10350-004-0871-x. PMID: 15785895.
12. Seah DW, Ibrahim S, Tay KH. Hartmann procedure: is it still relevant today? ANZ J Surg. 2005. p. 436–40. 10.1111/j.1445-2197.2005.03367.x. PMID: 15943733.
13. Schwenk W, Haase O, Neudecker J, Muller JM. Short term benefits for laparoscopic colorectal resection. Cochrane Database Syst Rev. 2005. p. CD003145. doi: 10.1002/14651858.CD003145.pub2. PMID: 16034888. PMCID: PMC8693724.
14. Braga M, Vignali A, Gianotti L, Zuliani W, Radaelli G, Gruarin P, Dellabona P, Di Carlo V. Laparoscopic versus open colorectal surgery: a randomized trial on short-term outcome. Ann Surg. 2002. p. 759–66; disscussion 767. doi: 10.1097/01.SLA.0000036269.60340.AE. PMID: 12454514. PMCID: PMC1422642.
15. Grozdev K, Khayat N, Arabadzhiev A, Angelov K. Technique of totally laparoscopic treatment of diverticular colovesical fistula with transanal colorectal anastomosis and urinary

bladder repair. Comptes rendus de l'Acade'mie bulgare des Sciences. 2021. p. 1836–1843. doi: 10.7546/CRABS.2021.12.15.

16. Fozard JB, Armitage NC, Schofield JB, Jones OM, Association of Coloproctology of Great B, Ireland. ACPGBI position statement on elective resection for diverticulitis. Colorectal Dis. 2011. p. 1–11. doi: 10.1111/j.1463-1318.2010.02531.x. PMID: 21366820.

17. Dapri G, Grilli A, Arabadzhiev A, Bascombe NA, Grozdev K. Transanal and transabdominal laparoscopic Hartmann's reversal with rectal stump fistula management - a video vignette. Colorectal Dis. 2020. p. 227–228. doi: 10.1111/codi.14865. PMID: 31562828.

18. Sauerland S, Agresta F, Bergamaschi R, Borzellino G, Budzynski A, Champault G, Fingerhut A, Isla A, Johansson M, Lundorff P, Navez B, Saad S, Neugebauer EA. Laparoscopy for abdominal emergencies: evidence-based guidelines of the European Association for Endoscopic Surgery. Surg Endosc. 2006. p. 14–29. doi: 10.1007/s00464-005-0564-0. PMID: 16247571.

19. Rafferty J, Shellito P, Hyman NH, Buie WD, Standards Committee of American Society of C, Rectal S. Practice parameters for sigmoid diverticulitis. Dis Colon Rectum. 2006. p. 939–44. doi: 10.1007/s10350-006-0578-2. PMID: 16741596.

20. Turley RS, Barbas AS, Lidsky ME, Mantyh CR, Migaly J, Scarborough JE. Laparoscopic versus open Hartmann procedure for the emergency treatment of diverticulitis: a propensity-matched analysis. Dis Colon Rectum. 2013. p. 72–82. doi: 10.1097/DCR.0b013e3182749cf5. PMID: 23222283. PMCID: PMC4431891.

21. Dapri G, Cawich SO, Bascombe NA, Bobb AK, Arabadjiev A, Gomez-Galdon M. Simultaneous transanal endolaparoscopic resection of a large anal canal and low rectal polyps - a video vignette. Colorectal Dis. 2019. p. 976–977. doi: 10.1111/codi.14669. PMID: 31058407.

22. Anderson CA, Fowler DL, White S, Wintz N. Laparoscopic colostomy closure. Surg Laparosc Endosc. 1993. p. 69–72. PMID: 8258079.

23. Bretagnol F, Pautrat K, Mor C, Benchellal Z, Huten N, de Calan L. Emergency laparoscopic management of perforated sigmoid diverticulitis: a promising alternative to more radical procedures. J Am Coll Surg. 2008. p. 654–7. doi: 10.1016/j.jamcollsurg.2007.11.018. PMID: 18387470.

24. Dapri G, Bobb KA, Navarro EJB, Arabadzhiev A. Suprapubic single-incision laparoscopic right colectomy with complete mesocolic excision, lateral-to-medial approach and intracorporeal anastomoses. Int J Gastrointest Interv. 2019. p. 35–40. doi: 10.18528/ijgii180038.

25. Ong SY, Tan ZZX, Teo NZ, Ngu JCY. Surgical considerations for the "perfect" colorectal anastomosis. J Gastrointest Oncol. 2023. p. 2243–2248. doi: 10.21037/jgo-23-41. PMID: 37969832. PMCID: PMC10643590.

26. Varga A, Matrai AA, Fazekas LA, Al-Khafaji MQM, Vanyolos E, Deak A, Szentkereszty Z, Peto K, Nemeth N. Changes in microcirculation of small intestine end-to-end anastomoses in an experimental model. Microvasc Res. 2024. p. 104731. doi: 10.1016/j.mvr.2024.104731. PMID: 39134118.

27. Garoufalia Z, Wexner SD. Indocyanine Green Fluorescence Guided Surgery in Colorectal Surgery. J Clin Med. 2023. p. 494. doi: 10.3390/jcm12020494. PMID: 36675423. PMCID: PMC9865296.

28. Arabadzhiev A, Popov T, Sokolov M. Laparoscopic Gastrectomy with ICG Guided D2 Lymph Node Dissection – A Case Report and Review of the Literature. Acta Medica Bulgarica. 2022. p. 43–47. doi: 10.2478/amb-2022-0019.

29. Ishizawa T, Saiura A, Kokudo N. Clinical application of indocyanine green-fluorescence imaging during hepatectomy. Hepatobiliary Surg Nutr. 2016. p. 322–8. doi: 10.21037/hbsn.2015.10.01. PMID: 27500144. PMCID: PMC4960410.
30. Soriano CR, Cheng RR, Corman JM, Moonka R, Simianu VV, Kaplan JA. Feasibility of injected indocyanine green for ureteral identification during robotic left-sided colorectal resections. Am J Surg. 2022. p. 14–20. doi: 10.1016/j.amjsurg.2021.07.012. PMID: 34353619.
31. Parks TG. Natural history of diverticular disease of the colon. Clin Gastroenterol. 1975. p. 53–69. PMID: 1109820.
32. Burgel JS, Navarro F, Lemoine MC, Michel J, Carabalona JP, Fabre JM, Domergue J. [Elective laparoscopic colectomy for sigmoid diverticulitis. Prospective study of 56 cases]. Ann Chir. 2000. p. 231–7. doi: 10.1016/s0001-4001(00)00129-x. PMID: 10829501.
33. Collaborative EESA, Surgery NGHRU in. Evaluation of a quality improvement intervention to reduce anastomotic leak following right colectomy (EAGLE): pragmatic, batched stepped-wedge, cluster-randomized trial in 64 countries [Internet]. Br J Surg. 2024. doi: 10.1093/bjs/znad370. PMID: 38029386. PMCID: PMC10771257.
34. Popov Ts, Pavlov V, Arabadzhiev A, Momchilova M, Mehmed A, Sokolov M, Maslyankov S. Surgical Methods for Minimizing the Incidence of Paracolostomy Hernias. Scripta Scientifica Medica. 2023. p. 32–36. doi: 10.14748/ssm.v55i0.930.
35. Bouillot JL, Berthou JC, Champault G, Meyer C, Arnaud JP, Samama G, Collet D, Bressler P, Gainant A, Delaitre B. Elective laparoscopic colonic resection for diverticular disease: results of a multicenter study in 179 patients. Surg Endosc. 2002. p. 1320–3. doi: 10.1007/s00464-001-9236-x. PMID: 11984674.
36. Kockerling F, Schneider C, Reymond MA, Scheidbach H, Scheuerlein H, Konradt J, Bruch HP, Zornig C, Kohler L, Barlehner E, Kuthe A, Szinicz G, Richter HA, Hohenberger W. Laparoscopic resection of sigmoid diverticulitis. Results of a multicenter study. Laparoscopic Colorectal Surgery Study Group. Surg Endosc. 1999. p. 567–71. doi: 10.1007/s004649901042. PMID: 10347292.
37. Arabadzhiev A, Momchilova M, Petrova V, Popov Ts, Mehmed A, Maslyankov S, Sokolov M. Advantages and Limiting Factors in Laparoscopic Colorectal Surgery. Scripta Scientifica Medica. 2023. p. 26–31. doi: 10.14748/ssm.v55i0.9305.
38. Masoomi H, Buchberg B, Nguyen B, Tung V, Stamos MJ, Mills S. Outcomes of laparoscopic versus open colectomy in elective surgery for diverticulitis. World J Surg. 2011. p. 2143–8. doi: 10.1007/s00268-011-1117-4. PMID: 21732208.
39. Klarenbeek BR, Veenhof AA, Bergamaschi R, van der Peet DL, van den Broek WT, de Lange ES, Bemelman WA, Heres P, Lacy AM, Engel AF, Cuesta MA. Laparoscopic sigmoid resection for diverticulitis decreases major morbidity rates: a randomized control trial: short-term results of the Sigma Trial. Ann Surg. 2009. p. 39–44. doi: 10.1097/SLA.0b013e31818e416a. PMID: 19106674.
40. Klarenbeek BR, Bergamaschi R, Veenhof AA, van der Peet DL, van den Broek WT, de Lange ES, Bemelman WA, Heres P, Lacy AM, Cuesta MA. Laparoscopic versus open sigmoid resection for diverticular disease: follow-up assessment of the randomized control Sigma trial. Surg Endosc. 2011. p. 1121–6. doi: 10.1007/s00464-010-1327-0. PMID: 20872022.
41. Oberkofler CE, Rickenbacher A, Raptis DA, Lehmann K, Villiger P, Buchli C, Grieder F, Gelpke H, Decurtins M, Tempia-Caliera AA, Demartines N, Hahnloser D, Clavien PA,

Breitenstein S. 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. p. 819–26; discussion 826-7. doi: 10.1097/SLA.0b013e31827324ba. PMID: 23095627.

42. Bridoux V, Regimbeau JM, Ouaissi M, Mathonnet M, Mauvais F, Houivet E, Schwarz L, Mege D, Sielezneff I, Sabbagh C, Tuech JJ. Hartmann's Procedure or Primary Anastomosis for Generalized Peritonitis due to Perforated Diverticulitis: A Prospective Multicenter Randomized Trial (DIVERTI). J Am Coll Surg. 2017. p. 798–805. doi: 10.1016/j.jamcollsurg.2017.09.004. PMID: 28943323.

43. Ellis CT, Maykel JA. Defining Anastomotic Leak and the Clinical Relevance of Leaks. Clin Colon Rectal Surg. 2021. p. 359–365. doi: 10.1055/s-0041-1735265. PMID: 34853555. PMCID: PMC8610631.

44. Bencurik V, Skrovina M, Martinek L, Bartos J, Machackova M, Dosoudil M, Stepanova E, Pribylova L, Bris R, Vomackova K. Intraoperative fluorescence angiography and risk factors of anastomotic leakage in mini-invasive low rectal resections. Surg Endosc. 2021. p. 5015–5023. doi: 10.1007/s00464-020-07982-x. PMID: 32970211.

45. Bonadio L, Iacuzzo C, Cosola D, Cipolat Mis T, Giudici F, Casagranda B, Biloslavo A, de Manzini N. Indocyanine green-enhanced fluorangiography (ICGf) in laparoscopic extraperitoneal rectal cancer resection. Updates Surg. 2020. p. 477–482. doi: 10.1007/s13304-020-00725-6. PMID: 32072407.

46. Dinallo AM, Kolarsick P, Boyan WP, Protyniak B, James A, Dressner RM, Arvanitis ML. Does routine use of indocyanine green fluorescence angiography prevent anastomotic leaks? A retrospective cohort analysis. Am J Surg. 2019. p. 136–139. doi: 10.1016/j.amjsurg.2018.10.027. PMID: 30360896.

47. De Nardi P, Elmore U, Maggi G, Maggiore R, Boni L, Cassinotti E, Fumagalli U, Gardani M, De Pascale S, Parise P, Vignali A, Rosati R. Intraoperative angiography with indocyanine green to assess anastomosis perfusion in patients undergoing laparoscopic colorectal resection: results of a multicenter randomized controlled trial. Surg Endosc. 2020. p. 53–60. doi: 10.1007/s00464-019-06730-0. PMID: 30903276.

48. Alekseev M, Rybakov E, Shelygin Y, Chernyshov S, Zarodnyuk I. A study investigating the perfusion of colorectal anastomoses using fluorescence angiography: results of the FLAG randomized trial. Colorectal Dis. 2020. p. 1147–1153. doi: 10.1111/codi.15037. PMID: 32189424.

49. Safiejko K, Tarkowski R, Kozlowski TP, Koselak M, Jachimiuk M, Tarasik A, Pruc M, Smereka J, Szarpak L. Safety and Efficacy of Indocyanine Green in Colorectal Cancer Surgery: A Systematic Review and Meta-Analysis of 11,047 Patients [Internet]. Cancers (Basel). 2022. doi: 10.3390/cancers14041036. PMID: 35205784. PMCID: PMC8869881.

50. Emile SH, Khan SM, Wexner SD. Impact of change in the surgical plan based on indocyanine green fluorescence angiography on the rates of colorectal anastomotic leak: a systematic review and meta-analysis. Surg Endosc. 2022. p. 2245–2257. doi: 10.1007/s00464-021-08973-2. PMID: 35024926.

51. Selzman AA, Spirnak JP. Iatrogenic ureteral injuries: a 20-year experience in treating 165 injuries. J Urol. 1996. p. 878–81. doi: 10.1016/s0022-5347(01)66332-8. PMID: 8583597.

52. Rose J, Schneider C, Yildirim C, Geers P, Scheidbach H, Kockerling F. Complications in laparoscopic colorectal surgery: results of a multicentre trial. Tech Coloproctol. 2004. p. s25-8. doi: 10.1007/s10151-004-0103-3. PMID: 15655633.

53. Cimpean S, Arabadzhiev A, Marie-Thérèse M, Dapri G. 3 Trocars Laparoscopic Right Hemicolectomy for Gunshot Wound. EC Gastroenterology and Digestive System. 2019. p. 138–142.

54. Halabi WJ, Jafari MD, Nguyen VQ, Carmichael JC, Mills S, Pigazzi A, Stamos MJ. Ureteral injuries in colorectal surgery: an analysis of trends, outcomes, and risk factors over a 10-year period in the United States. Dis Colon Rectum. 2014. p. 179–86. doi: 10.1097/DCR.0000000000000033. PMID: 24401879.

55. Kanabur P, Chai C, Taylor J. Use of Indocyanine Green for Intraoperative Ureteral Identification in Nonurologic Surgery. JAMA Surg. 2020. p. 520–521. doi: 10.1001/jamasurg.2020.0094. PMID: 32186665.

56. White LA, Joseph JP, Yang DY, Kelley SR, Mathis KL, Behm K, Viers BR. Intraureteral indocyanine green augments ureteral identification and avoidance during complex robotic-assisted colorectal surgery. Colorectal Dis. 2021. p. 718–723. doi: 10.1111/codi.15407. PMID: 33064915.

57. Hamada M, Matsumi Y, Sekimoto M, Kurokawa H, Kita M, Kinoshita H. Image Navigation Surgery With the Fluorescent Ureteral Catheter of Recurrent Tumors in the Pelvic Cavity. Dis Colon Rectum. 2022. p. e72–e76. doi: 10.1097/DCR.0000000000002144. PMID: 34990431.

58. Mandovra P, Kalikar V, Patankar RV. Real-Time Visualization of Ureters Using Indocyanine Green During Laparoscopic Surgeries: Can We Make Surgery Safer? Surg Innov. 2019. p. 464–468. doi: 10.1177/1553350619827152. PMID: 30734638.

59. Ryu S, Hara K, Kitagawa T, Okamoto A, Marukuchi R, Ito R, Nakabayashi Y. Fluorescence vessel and ureter navigation during laparoscopic lateral lymph node dissection. Langenbecks Arch Surg. 2022. p. 305–312. doi: 10.1007/s00423-021-02286-7. PMID: 34378079

60. V. R. Satish VN, Acharya A, Ramachandran S, Narasimhan M, Ardhanari R. Fluorescent ureterography with indocyanine green in laparoscopic colorectal surgery: A safe method to prevent intraoperative ureteric injury. J Minim Access Surg. 2022. p. 320–323. doi: 10.4103/jmas.jmas_183_21. PMID: 35046172. PMCID: PMC8973486.

61. Garoufalia Z, Wexner S. Ureter identification utilizing indocyanine green (ICG) imaging in colorectal surgery: a systematic review of the literature. Mini-invasive Surg. 2022. p. 51. doi: 10.20517/2574-1225.2022.60.

FIGURES

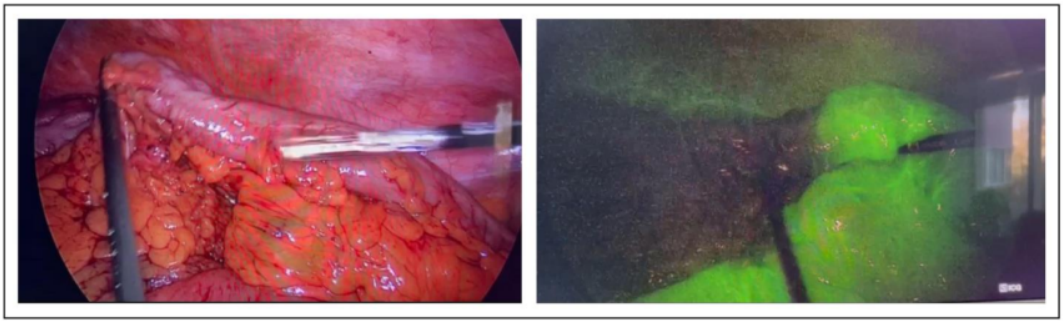

Figure 1. Assessment of bowel perfusion during laparoscopic resection of the colon. Photographs from the author's personal archive.

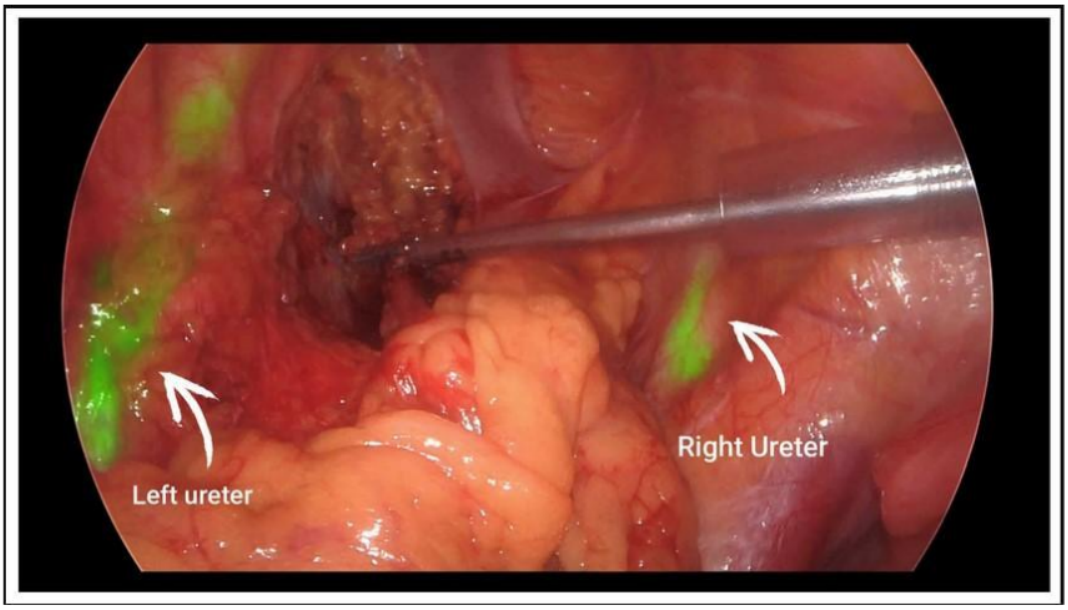

Figure 2. Intraoperative visualization of the ureters using the ICG method. [27]