Int Surg 2024;**108:**84–88
DOI: 10.9738/INTSURG-D-23-00018.1

Case Report

Successful Intestinal Blood Flow Evaluation Using Indocyanine Green Fluorescent Imaging in a Case of Small Intestine Strangulation

Yusuke Matsune, Takeshi Aoki, Yoshihiko Tashiro

Department of Surgery, Division of Gastroenterological and General Surgery, Showa University, Tokyo, Japan

Introduction: The assessment of intestinal blood flow using indocyanine green (ICG) fluorescence imaging is useful in ischemic bowel disease because it renders blood flow visible. Strangulated small intestine is a common postoperative complication requiring massive bowel resection, which can cause short bowel obstruction (SBO), a malabsorptive condition. Here, we report a successful case of preserving an ischemic intestinal segment while avoiding SBO based on the gap between the macroscopic findings and the ICG fluorescence imaging assessment.

Case presentation: A 46-year-old Japanese female patient who underwent an abdominal total hysterectomy and bilateral salpingo-oophorectomy with para-aortic lymphadenectomy due to small round cells of the left ovary received a diagnosis of strangulated small intestine 1 month postoperatively. Macroscopic examination during the laparotomy revealed a strangulated small intestine with severe edema and dark red discoloration. However, this part of the bowel was preserved during surgery because the two-time administration of ICG solution revealed adequate perfusion.

Conclusion: This report reveals the effectiveness of ICG fluorescence imaging in intraoperative intestinal perfusion and its role in avoiding unnecessary massive resections. Combining these modalities may be effective for intraoperative bowel assessment; however, more accurate criteria and algorithms for evaluating blood flow and bowel perfusion should be established.

Key words: Strangulated small intestine – Indocyanine green fluorescence – Short bowel syndrome

Strangulation ileus is a form of small bowel obstruction (SBO), which is a common acute bowel syndrome that can cause bowel ischemia, requiring emergency surgery.[1,2] Careful assessment, including irreversible discoloration and the absence of peristalsis or visible pulsation of the bowel wall,

Corresponding author: Takeshi Aoki, MD, PhD, Department of Surgery, Division of Gastroenterological and General Surgery, Showa University, 1-5-8 Hatanodai, Shinagawa, Tokyo 142-8666, Japan.
Tel.: +81 03 3784 8000; Fax: +81 03 3784 5835; E-mail: takejp@med.showa-u.ac.jp

is required to evaluate the degree of intestinal necrosis.[3] Recently, indocyanine green (ICG) fluorescence imaging has been used for the objective intra-operative evaluation of intestinal ischemia and SBO.[4–8] Therefore, a precise assessment of resection is required to prevent massive resection and its associated complications. However, ICG fluorescence imaging is unavailable at all centers and cannot be used for patients allergic to iodine. Therefore, we report a successful case of ischemic intestine preservation using ICG fluorescent imaging and Doppler ultrasound more than 24 hours after onset.

Case Presentation

A 46-year-old Japanese female patient presented to our hospital with several days of abdominal pain, fever, and nausea. The patient was received a diagnosis of small round cells of the left ovary and underwent an abdominal total hysterectomy and bilateral salpingo-oophorectomy with para-aortic lymphadenectomy 1 month before admission. Physical examination revealed rebound tenderness in the upper abdomen, with a median surgical scar extending from the upper abdomen to the upper pubis and on the upper part of the pubic bone. Laboratory results indicated increased white blood cell count (16,400/μL) and C-reactive protein level (0.90 mg/dL). Blood gas analysis revealed decreased bicarbonate (14.6 mmol/L) and increased lactate (2.50 mmol/L) levels, indicating mild inflammation and peripheral circulatory failure. Contrast-enhanced computed tomography revealed a dilated small intestine with poor contrast enhancement and a closed-loop obstruction with ascites (Fig. 1). The patient received a diagnosis of strangulation ileus with intestinal ischemia and subsequently underwent an emergency laparotomy (Video 1, available at https://figshare.com/s/5faaf2c3c998402d363b). Serous ascites were observed intraoperatively. The strangulated small intestine was found more than 2 m from the demarcation line and 15 cm distal to the ligament of Treitz. Macroscopic examination revealed a strangulated small intestine with severe edema and dark red discoloration. An internal hernia resulted in strangulation due to the adhesion of the transverse colon to the site of periaortic lymph node dissection during ovarian cancer surgery. We injected 1 mL of a 2.5 mg/mL ICG solution intravenously and observed fluorescence in the dark-red distal ileum using the SPY PHI system (0 minutes 1 second; Stryker Japan, Tokyo, Japan). ICG can bind to albumin, which prolongs its circulation in the intravascular compartment and influences its fluorescence. Specifically, ICG is a near–infrared light dye that emits fluorescence when exposed to irradiation of excitation wavelengths in the range of 750 to 810 nm.[9] Assessing the strangulated intestine and mesentery using fluorescence was initially challenging because of severe edema (Fig. 2). However, Doppler ultrasound imaging revealed blood flow in the marginal arteries and veins of the small intestine. A second 1-mL dose of the 2.5 mg/mL ICG solution was administered 20 minutes after the initial ICG fluorescence observation, and the same level of fluorescence in the strangulated bowel and mesentery as in the normal bowel was found 10 seconds after the second administration (0 minutes 38 seconds; Fig. 3). Therefore, we decided to preserve this part of the bowel because the assessment with ICG revealed adequate perfusion. Postoperatively, a mild elevation in serum markers was noted, suggestive of intestinal necrosis without complications, such as lactate. The patient resumed oral fluid intake on postoperative day (POD) 2, started eating on POD 3, and was discharged from the hospital on POD 11 without postoperative complications. Written informed consent was obtained from the patient for publication of this report.

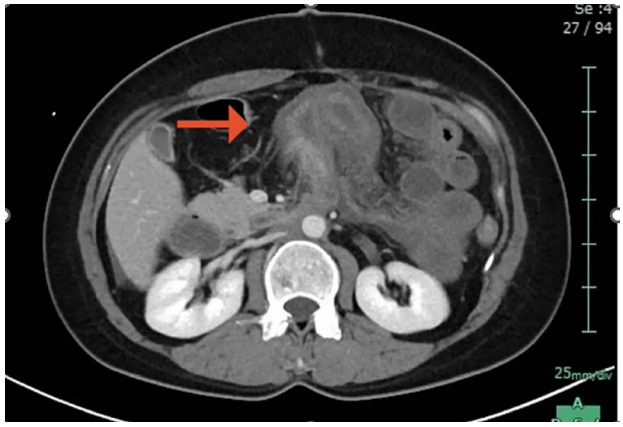

Fig. 1 Contrast-enhanced computed tomography (CT) revealed a dilated small intestine with poor contrast enhancement and a closed-loop obstruction with ascites.

Discussion

We successfully treated a 46-year-old Japanese female patient with a strangulated small intestine, avoiding unnecessary resections of an ischemic intestinal segment. Strangulation resulted from an internal hernia caused by severe adhesion following ovarian cancer surgery. Approximately 70 cm of the

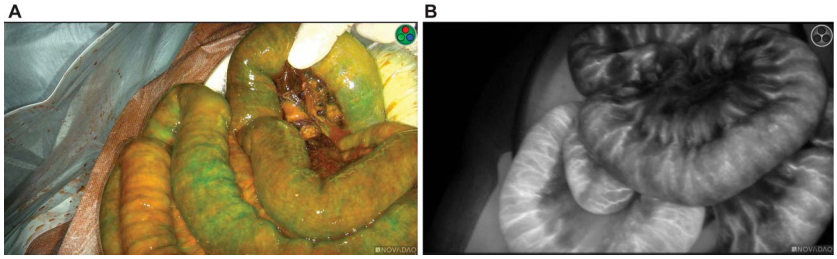

Fig. 2 A 1-mL dose of a 2.5 mg/mL indocyanine green solution is injected intravenously. (A) Overlay mode. (B) SPY mode.

strangulated segment was involved in the hernia band. The potential strengths of this report are that it highlights the benefits of using the ICG system to objectively assess bowel perfusion intraoperatively, thereby avoiding massive bowel resection. The patient was discharged from the hospital without the need for a nasogastric tube or the presence of postoperative complications, including postparalytic ileus. In addition, the gap between the macroscopic findings and evaluations after the two-time administrations of ICG showed the effectiveness of this procedure.

The ICG fluorescence method uses near-infrared light to identify ICG bound to lipoproteins in blood and observe blood perfusion.[10] Specifically, the ICG fluorescence imaging technique using a near-infrared camera was established in the 1970s and was used in cardiac surgery for several years before its application in the field of digestive surgery.[11] Compared with clinical evaluation alone, intraoperative ICG angiography was reported to be useful and accurate for evaluating bowel perfusion and survival in an experimental model of animals with mesenteric ischemia.[12,13] Recently, several studies have found that this technique can be useful for objective intra-operative evaluation of intestinal ischemia and SBO.[4–8] Furthermore, the consensus guideline on acute mesenteric ischemia indicates that ICG can be used in elective surgical settings.[14] However, the use of ICG in emergency settings is not well established in the guidelines. Moreover, it cannot be used for patients allergic to iodine.

Here, we report a successful case of ischemic intestine preservation using ICG fluorescent imaging in emergency settings. Assessing perfusion of the intestinal mucosa is challenging using white light alone, and the patterns of ischemia and necrosis vary among patients.[15] Short bowel syndrome is a malabsorptive condition most commonly caused by massive resection of the small intestine and is associated with poor quality of life.[16,17] Therefore, extensive resections should be carefully considered. Small bowel length of less than 100 cm is highly predictive of permanent intestinal failure in adult patients.[18] However, if massive resection had been performed on our patient, she might have required total parental nutrition for the rest of her life.

The intestine can reportedly survive a 75% reduction in blood flow for approximately 12 hours without significant injury.[17] However, irreversible bowel damage occurs within 6 hours of complete vascular occlusion.[17] In this case, the onset of the patient's symptoms was several days before the operation. Macroscopic findings showed a strangulated small intestine with severe edema and dark red discoloration. However, Doppler ultrasound imaging revealed blood flow in the marginal arteries and veins of the small intestine. The level of fluorescence in the strangulated bowel and mesentery was similar to that in

Fig. 3 A second 1-mL intravenous injection of a 2.5 mg/mL indocyanine green solution is administered 20 minutes after the initial ICG fluorescence observation. (A) Overlay mode. (B) SPY mode.

the normal bowel 10 seconds after the administration of a second 1-mL dose of the 2.5 mg/mL ICG solution.

This report has some limitations. We have not yet reached a consensus on the timing and total dose of ICG required for evaluating intestinal blood flow. Therefore, further quantitative evaluation of the ICG injection method, including the dosage and timing, is needed to assess its use in blood flow assessments. In addition, Bulkley *et al*[15] evaluated the pattern of staining and predicted the viability of ischemic intestinal segments based on fluorescence patterns. Evaluating the staining pattern is also effective for more practical algorithms of this examination. Although ICG injection is beneficial for objective evaluation of the bowel segment when macroscopic findings are doubtful, the risk of reperfusion syndrome should be considered. Reperfusion of the ischemic intestine can cause microvascular and parenchymal cell injury due to the formation of superoxide radicals.[19,20] ICG fluorescence imaging may also be unavailable across all centers because it requires special equipment. Furthermore, ICG is contraindicated for patients allergic to iodine and cannot be used when the patient's condition is poor or when they cannot tolerate prolonged exposure in an emergency setting.

Although the macroscopic findings showed a strangulated bowel with severe edema and dark-red discoloration, we revealed the effectiveness of ICG fluorescence imaging in measuring intestinal perfusion intraoperatively to avoid unnecessary resections. Unnecessary resections should not be performed because extensive resection can trigger postoperative complications and anastomotic failure. Notably, Doppler ultrasonography and palpation are economical, noninvasive, and safe alternatives for measuring blood flow.[14] In this case, we initially evaluated the blood flow using palpation and Doppler ultrasound imaging. Subsequently, we intravenously injected the ICG solution.

Although combining these modalities may be effective for intraoperative bowel assessment, we need to investigate the dose and timing of injecting the ICG solution in combination with evaluation based on Doppler ultrasonography and physical findings. Therefore, evaluation of the modalities and further studies are needed to establish more accurate criteria and algorithms for evaluating blood flow and bowel perfusion.

Acknowledgments

We would like to thank Editage (www.editage.com) for English language editing and journal submission support. The authors have authorized the submission of this manuscript through Editage.

References

1. Lee MJ, Sayers AE, Wilson TR, Acheson AG, Anderson ID, Fearnhead NS *et al*. Current management of small bowel obstruction in the UK: results from the National Audit of Small Bowel Obstruction clinical practice survey. *Colorectal Dis* 2018; **20**(7):623–630
2. Bizer LS, Liebling RW, Delany HM, Gliedman ML. Small bowel obstruction: the role of nonoperative treatment in simple intestinal obstruction and predictive criteria for strangulation obstruction. *Surgery* 1981;**89**(4):407–413
3. Di Saverio S, Gori A, Chisari E, Wheeler J, Lim R. Laparoscopic management of adhesive small bowel obstruction with strangulation: when to resect and how to distinguish reversible from nonreversible bowel ischaemia–a video vignette. *Colorectal Dis* 2019;**21**(6):727–729
4. Karampinis I, Keese M, Jakob J, Stasiunaitis V, Gerken A, Attenberger U *et al*. Indocyanine green tissue angiography can reduce extended bowel resections in acute mesenteric ischemia. *J Gastrointest Surg* 2018;**22**(12):2117–2124
5. Ryu S, Yoshida M, Ohdaira H, Tsutsui N, Suzuki N, Ito E *et al*. Intestinal blood flow assessment by indocyanine green fluorescence imaging in a patient with the incarcerated umbilical hernia: report of a case. *Ann Med Surg (Lond)* 2016;**8**:40–42
6. Irie T, Matsutani T, Hagiwara N, Nomura T, Fujita I, Kanazawa Y *et al*. Successful treatment of non-occlusive mesenteric ischemia with indocyanine green fluorescence and open-abdomen management. *Clin J Gastroenterol* 2017;**10**(6):514–518
7. Nohara K, Takemura N, Ito K, Oikawa R, Yagi S, Wake H *et al*. Bowel perfusion demonstrated using indocyanine green fluorescence imaging in two cases of strangulated ileus. *Clin J Gastroenterol* 2022;**15**(5):886–889
8. Daskalopoulou D, Kankam J, Plambeck J, Ambe PC, Zarras K. Intraoperative real-time fluorescence angiography with indocyanine green for evaluation of intestinal viability during surgery for an incarcerated obturator hernia: a case report. *Patient Saf Surg* 2018;**12**:24
9. Landsman ML, Kwant G, Mook GA, Zijlstra WG. Light-absorbing properties, stability, and spectral stabilization of indocyanine green. *J Appl Physiol* 1976;**40**(4):575–583
10. Rübben A, Eren S, Krein R, Younossi H, Böhler U, Wienert V. Infrared videoangiofluorography of the skin with indocyanine green–rat random cutaneous flap model and results in man. *Microvasc Res* 1994;**47**(2):240–251
11. Landsman ML, Kwant G, Mook GA, Zijlstra WG. Light-absorbing properties, stability, and spectral stabilization of indocyanine green. *J Appl Physiol* 1976;**40**(4):575–583
12. Iinuma Y, Hirayama Y, Yokoyama N, Otani T, Nitta K, Hashidate H *et al*. Intraoperative near infrared indocyanine green fluorescence angiography (NIR-ICG AG) can predict

delayed small bowel stricture after ischemic intestinal injury: report of a case. *J Pediatr Surg* 2013;**48**(5):1123–1128
13. Diana M, Noll E, Diemunsch P, Dallemagne B, Benahmed MA, Agnus V *et al*. Enhanced-reality video fluorescence: a real-time assessment of intestinal viability. *Ann Surg* 2014; **259**(4):700–707
14. Bala M, Catena F, Kashuk J, De Simone B, Gomes CA, Weber D *et al*. Acute mesenteric ischemia: updated guidelines of the World Society of Emergency Surgery. *World J Emerg Surg* 2022;**17**(1):54
15. Bulkley GB, Zuidema GD, Hamilton SR, O'Mara CS, Klacsmann PG, Horn SD. Intraoperative determination of small intestinal viability following ischemic injury: a prospective, controlled trial of two adjuvant methods (Doppler and fluorescein) compared with standard clinical judgment. *Ann Surg* 1981;**193**(5):628–637
16. O'Keefe SJ, Buchman AL, Fishbein TM, Jeejeebhoy KN, Jeppesen PB, Shaffer J. Short bowel syndrome and intestinal failure: consensus definitions and overview. *Clin Gastroenterol Hepatol* 2006;**4**(1):6–10
17. Tilsed JV, Casamassima A, Kurihara H, Mariani D, Martinez I, Pereira J *et al*. ESTES guidelines: acute mesenteric ischaemia. *Eur J Trauma Emerg Surg* 2016;**42**(2):253–270
18. Messing B, Crenn P, Beau P, Boutron-Ruault MC, Rambaud JC, Matuchansky C. Long-term survival and parenteral nutrition dependence in adult patients with the short bowel syndrome. *Gastroenterology* 1999;**117**(5):1043–1050
19. Zimmerman BJ, Granger DN. Reperfusion injury. *Surg Clin North Am* 1992;**72**(1):65–83
20. Granger DN, Rutili G, McCord JM. Superoxide radicals in feline intestinal ischemia. *Gastroenterology* 1981;**81**(1):22–29