Intraoperative Near Infrared Fluorescence Imaging in Robotic Low Anterior Resection: Three Case Reports

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The recent introduction of an intraoperative near infrared fluorescence (INIF) imaging system installed on the da Vinci Si® robotic system has enabled surgeons to identify intravascular NIF signals in real time. This technology is useful in identifying hidden vessels and assessing blood supply to bowel segments. In this study, we report 3 cases of patients with rectal cancer who underwent robotic low anterior resection (LAR) with INIF imaging for the first time in Asia. In September 2012, robotic-assisted rectal resection with INIF imaging was performed on three consecutive rectal cancer patients. LAR was performed in 2 cases, and abdominoperineal resection was performed in the third case. INIF imaging was used to identify the left colic branch of the inferior mesenteric artery and to assess blood supply to the distal rectum. We evaluated the utility of INIF imaging in performing robotic-assisted colorectal procedures. Our preliminary results suggest that this technique is safe and effective, and that INIF imaging may be a useful tool to colorectal surgeons.

Key Words: Robotics, fluorescence, indocyanine green, rectal neoplasms

INTRODUCTION

Since the first robot-assisted laparoscopic colorectal procedures were reported in 2002, this minimally invasive technique has been applied to many complex surgical cases in the field of colorectal oncology.[1,2] The development of medical imaging modalities such as three-dimensional CT, perfusion MRI and fluorodeoxyglucose (FDG) PET scans has allowed for preoperative imaging that characterizes surgical anatomy, as well as tissue perfusion, to more precisely guide the surgical approach. Although conventional techniques allow us to assess perfusion of the target area preoperatively, it is seldom useful since vessels that are ligated during the surgery will alter blood flow to the targeted organs; moreover, during gastrointestinal cancer surgery, it is often difficult to identify the critical vessels and lymph nodes and to assess physiologic information such as perfusion of the bowel. Therefore, improving the identification of vascular structures and assessment of perfusion of bowel segments in real time during surgery could be useful to surgeons and may improve patient outcomes.

Intraoperative near infrared fluorescence (INIF) imaging uses laser technology to

activate an intravenously delivered agent, indocyanine green (ICG), which rapidly binds to plasma proteins. This allows ICG to remain predominantly in the vasculature and provide visualization of vascular structures. A recently introduced INIF imaging system (Firefly™, Intuitive Surgical Inc., Sunnyvale, CA, USA) installed on the da Vinci Si® robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA) allows surgeons to identify intravascular NIF signals in real time. This technology can be used to identify hidden vessels, assess blood supply to bowel segments, and locate sentinel lymph nodes. The utility of ICG with INIF in safely performing robotic-assisted colorectal surgery has yet to be established however. In this study, we report 3 cases in which rectal cancer patients underwent robotic LAR with INIF imaging for the first time in Asia.

CASE REPORT

All patients successfully underwent robotic-assisted rectal resection using INIF imaging without complications associated with ICG dye administration, as measured by changes in vital signs, serum creatinine and liver function tests. Patient demographics and perioperative clinical outcomes are summarized in Table 1. Two women and one man were included in this study, with a mean age of 66 years (range, 52-75). The mean tumor distance from the anal verge was 11 cm (range 4-18). Operative times (skin-to-skin) ranged from 281-337 minutes, with a mean of 304 minutes. The mean postoperative hospital stay was 10 days (range, 5-17 days). The postoperative pathologic diagnoses were adenocarcinoma in 2 patients and obstructing urothelial carcinoma of the rectum originating from the urinary bladder in the third patient. Low anterior resection was performed in 2 cases, and abdominoperineal resection was done in one case in which the rectal carcinoma was in close proximity to the anal sphincter. No mortality was associated with the operative procedure.

During the surgery, INIF imaging allowed the surgeon to identify the left colic branch of the IMA within the mesenteric tissue in all 3 cases (Fig. 1). The da Vinci Si® robotic system was equipped with an LED illuminator as the visible light source, as well as a laser that emitted a near infrared wavelength of light. After changing the usual visual system to the fluorescent mode, a fluorescence response in the mesenteric blood vessels and tissue was visible within 50 seconds of the injection of the fluorescent dye. In the 2 LAR cases, INIF imaging demarcated the ischemic zone in the distal rectum, which helped the surgeon to define the distal resection margin (Fig. 2). Two of the patients recovered without complications, and one experienced a postoperative ileus that resolved with conservative management.

DISCUSSION

Indocyanine green (ICG) is a fluorescent dye that absorbs near infrared wavelengths of light. ICG emits an infrared signal when excited by laser light *in situ*, which can be detected with an NIRF camera. ICG has a half-life of 2-5 minutes and is excreted mainly though the biliary system, making it impossible to visualize the ureters. The maximum dosage of ICG is 2 mg/kg, and it must be given within 6 hours of reconstitution. Since gaining approval for its use from the FDA in 1959, adverse reactions to ICG have been rarely reported (0.004%).[3]

The indications for use of INIF imaging include visual assessment of blood vessels, blood flow, and tissue perfusion. By integrating INIF imaging into the da Vinci Si® robotic system, a 1080i 3-dimensional high definition stereoscopic fluorescence capable camera attached to an endoscope enables infrared vision and detection of fluorescence ICG by the da Vinci computer core. By switching between normal white light and fluorescence imaging modes, the surgeon can perform minimally invasive surgery using standard endoscopic visibility without leaving the console. This allows the surgeon to view high resolution near infrared images of blood flow in the microvasculature, as well as tissue

Table 1. Summary of the Patients Undergoing Robotic Assisted Rectal Resection Using INIF Imaging

Patient no.	Age	Sex	Distance from anal verge (cm)	Preoperative chemoradiation	Surgical procedure	ICG dose (mg/mL)	Operative time (min)	Histology	Complication
1	72	M	18	No	LAR	2.5	281	Adenocarcinoma	No
2	52	F	11	Yes	LAR	5	294	Adenocarcinoma	No
3	75	M	4	No	APR	2.5	337	Urothelial carcinoma	Ileus

ICG, indocyanine green; APR, abdominoperineal resection; LAR, low anterior resection; INIF, intraoperative near infrared fluorescence.
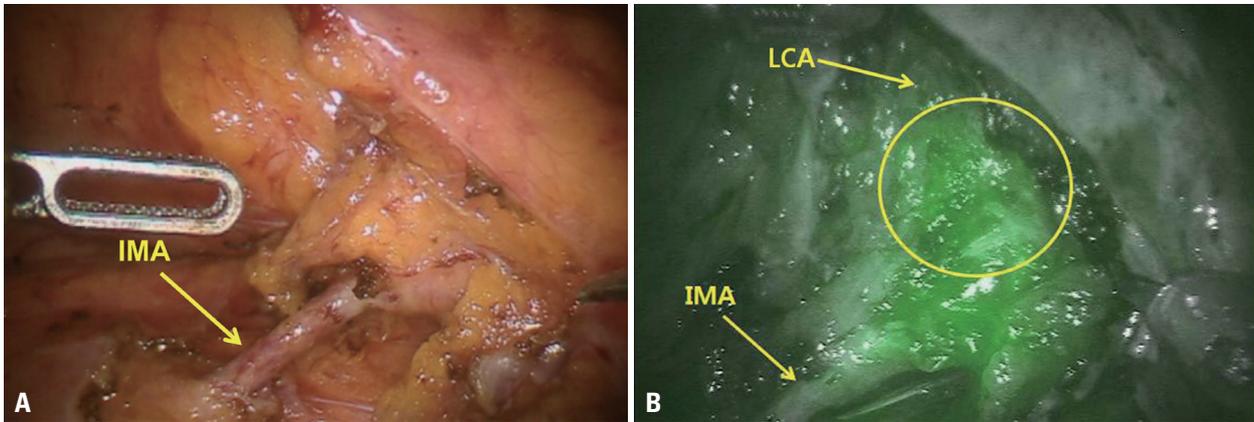
Fig. 1. White light imaging (A) and INIF imaging (B) of dissection around the root of the IMA. Yellow circle demarcates left colic branch from IMA hidden in mesenteric tissue. LCA, left colic artery; IMA, inferior mesenteric artery; INIF, intraoperative near infrared fluorescence.
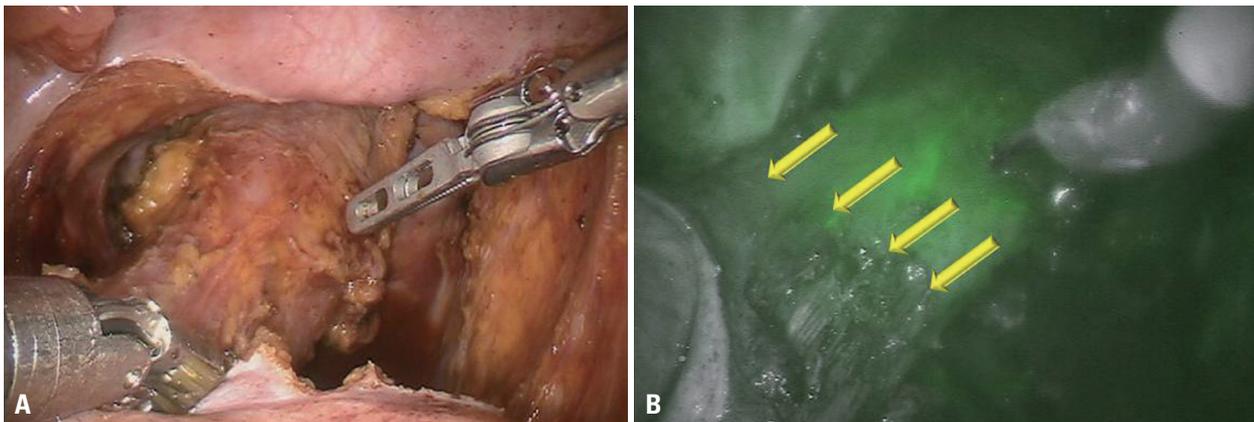

Fig. 2. In contrast to standard white light imaging (A), margin (yellow arrows) between fluorescent normal and ischemic rectum was readily apparent (B).

perfusion, in real time during robotic surgical procedures.

INIF imaging has been used in several other surgical specialties for this purpose. During kidney surgery, it is used to accurately identify the renal vasculature and to differentiate renal tumors from the surrounding normal parenchyma. Additionally, Wagner, et al. reported that during right robotic thymectomy, fluorescence imaging facilitated identification of the contralateral phrenic nerve by fluorescing the pericardiophrenic vessels.[4-6] We propose that NIRF imaging can also be selectively used in colorectal procedures. INIF imaging using ICG offers a potentially more reliable and less time consuming method for identification of the inferior mesenteric branches during low ligation. Because intraoperative identification of the bowel resection margins is not always easily accomplished, the ability to assess blood flow to the distal rectum may aid in creating safe anastomoses and improving patient outcomes.

With increased patient volume and experience with this technique, INIF imaging could be incorporated into several robotic-assisted colorectal procedures including sentinel lymph node detection in rectal cancer patients and identifi-

cation of the neurovascular bundle arising from the pelvic plexus. Further studies are needed to determine if this technique will help improve patient outcomes after robotic-assisted colorectal procedures.

In conclusion, we evaluated the utility of INIF imaging in performing robotic-assisted colorectal procedures. Our preliminary results suggest that this technique is safe and effective, and that INIF imaging may be useful to colorectal surgeons.

REFERENCES

1. Weber PA, Merola S, Wasielewski A, Ballantyne GH. Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease. Dis Colon Rectum 2002;45:1689-94.
2. Ballantyne GH. Robotic surgery, telerobotic surgery, telepresence, and telementoring. Review of early clinical results. Surg Endosc 2002;16:1389-402.
3. Speich R, Saesseli B, Hoffmann U, Neftel KA, Reichen J. Anaphylactoid reactions after indocyanine-green administration. Ann Intern Med 1988;109:345-6.
4. Tobis S, Knopf J, Silvers C, Yao J, Rashid H, Wu G, et al. Near

infrared fluorescence imaging with robotic assisted laparoscopic partial nephrectomy: initial clinical experience for renal cortical tumors. J Urol 2011;186:47-52.

5. Krane LS, Manny TB, Hemal AK. Is near infrared fluorescence imaging using indocyanine green dye useful in robotic partial nephrectomy: a prospective comparative study of 94 patients. Urolo-gy 2012;80:110-6.

6. Wagner OJ, Louie BE, Vallières E, Aye RW, Farivar AS. Near-in-frared fluorescence imaging can help identify the contralateral phrenic nerve during robotic thymectomy. Ann Thorac Surg 2012; 94:622-5.