HHS Public Access

Author manuscript

Innovations (Phila). Author manuscript; available in PMC 2017 July 24.

Published in final edited form as:

Innovations (Phila). 2014 ; 9(5): 391–393. doi:10.1097/IMI.0000000000000091.

Intraoperative Near-Infrared Fluorescence Imaging as an Adjunct to Robotic Assisted Minimally Invasive Esophagectomy

Inderpal S. Sarkaria, MD, **Manjit S. Bains, MD**, **David J. Finley, MD**, **Prasad S. Adusumilli, MD**, **James Huang, MD**, **Valerie W. Rusch, MD**, **David R. Jones, MD**, and **Nabil P. Rizk, MD**

Thoracic Service, Department of Surgery, Memorial Sloan-Kettering Cancer Center, New York, NY

SUMMARY

During esophagectomy, identification and preservation of the right gastroepiploic vascular arcade are critical and may be challenging with minimally invasive approaches. We assessed the use of near-infrared fluorescence imaging fluorescence angiography (NIFI-FA) during robotic assisted minimally invasive esophagectomy (RAMIE) as an aid to visualize the gastric vasculature with mobilization. After intravenous administration of 10 mg of indocyanine green (ICG), a robotic platform with near-infrared optical fluorescence capability was used to examine the gastric vasculature in patients undergoing RAMIE. Thirty of 42 patients (71%) undergoing RAMIE were assessed NIFI-FA during mobilization of the greater gastric curve and fundus; 11 were excluded because the system was not available and 1 because of documented allergy to iodinated contrast. The median time from ICG administration to detectable fluorescence was 37.5 seconds (range, 20–105 seconds). NIFI-FA identified or confirmed termination of the vascular arcade in all 30 cases. Subjectively, NIFI-FA often identified otherwise unvisualized small transverse vessels between the termination of the vascular arcade and the first short gastric artery, as well as between the short gastric arteries. Identification and/or confirmation of the vascular arcade position during mobilization of the greater curve/omentum were also aided by NIFI-FA. While there are limitations to the current technology, NIFI-FA may be a useful adjunct to confirm and identify the position of gastroepiploic vessels, allow for safer and more confident dissections during gastric mobilization, and potentially decrease serious intraoperative vascular misadventures.

Keywords

Robotic Surgery; Esophagectomy; Esophageal Cancer; Fluorescence Imaging; Angiography

INTRODUCTION

Owing to its association with quicker recovery, less postoperative morbidity, improved quality of life, and equivalent oncologic outcomes compared with open surgery, the use of

Corresponding Author: Inderpal (Netu) S. Sarkaria, MD, FACS, Thoracic Service, Department of Surgery, Memorial Sloan-Kettering Cancer Center, 1275 York Avenue, New York, NY 10065, sarkarii@mskcc.org, Office: 646-888-3265; Fax: 646-422-0915.

Conflicts of Interest: All authors declare no conflicts of interest.

Presented at: 2013 International Society for Minimally Invasive Cardiothoracic Surgery Annual Scientific Meeting, June 12–15, 2013, Prague, Czech Republic.

minimally invasive esophagectomy (MIE) as an approach for resection has increased.[1–3] However, these operations, including robotic assisted minimally invasive esophagectomy (RAMIE), are complex and technically demanding.[4, 5]

When these operations are performed with laparoscopy, safe mobilization of the stomach represents one of the more challenging aspects, in part because of loss of tactile feedback, difficult visualization related to field-of-view limitations, and the frequency of increased adiposity obscuring the vasculature in high body mass index patients. Concern over these aspects may constitute the primary reason for conversion to open procedures or for the preference for “hybrid” approaches requiring “mini” laparotomy for “hand-assistance.”[6] Techniques allowing for more confident visualization are warranted to improve safety and accuracy of dissection, to minimize operative errors, to decrease operative times, and to potentially decrease costs.

Intraoperative fluorescence angiography (FA) using near-infrared imaging (NIFI) allows for real-time visualization of vascular structures and/or assessment of organ perfusion after administration of indocyanine green (ICG), a well-established fluorescent dye for intravenous injection, with a high safety index, that is used most commonly to determine cardiac output, hepatic function, and blood flow, as well as in ophthalmic angiography. Owing to its small content of sodium iodide, its primary contraindication is in patients with allergies to iodinated contrast agents. NIFI-FA platforms have been developed and are commercially available for open, standard laparoscopic, and robotic systems. In this study, we describe a novel use for NIFI-FA as an adjunct to accurately identify the gastric vasculature and aid in safe mobilization of the stomach during minimally invasive esophagectomy.

PATIENTS AND METHODS

This was a prospective, observational, uncontrolled study of all consecutive patients undergoing RAMIE at a single institution during the study period. The RAMIE procedure performed by our group has been described previously.[5] Because of the already established use of ICG in operative patients at our center, an institutional review board waiver of consent was granted. Patients with an established or reported allergy to iodinated contrast dye were excluded from the study.

Prior to surgical mobilization of the gastric fundus and greater curve, 10 milligrams of ICG (4 mL of 2. 5 mg/mL aqueous solution) were administered via a single peripheral venous injection by the anesthesiologist, as a single dose, just before NIFI-FA. No additional injections were required to achieve adequate vascular fluorescence. Fluorescence imaging was performed with NIFI technology (SPY Imaging, Novadaq, Bonita Springs, FL) built in to the robotic platform optical system (Firefly Fluorescence Imaging Scope, Intuitive Surgical, Sunnyvale, CA). The time from injection to detectable fluorescence within the short gastric and right gastroepiploic vasculature was recorded. All patients were monitored for adverse events potentially related to the use of ICG, in accordance with Common Terminology Criteria for Adverse Events Version 3.0.

RESULTS

From February 2012 to May 2013, 30 of 42 patients undergoing RAMIE were assessed by ICG injection and NIFI-FA. Eleven patients were excluded because the necessary robotic imaging system was not available, and 1 was excluded because of a documented allergy to the contrast dye. Patient demographics and results are summarized in Table 1.

The median time from injection to visualization of fluorescence was 37.5 seconds (range, 20–105 seconds). Fluorescence was achieved and NIFI-FA was considered to be accurate in all cases (30/30 [100%]). There were no ICG-related adverse events. Two patients (7%) had grade II or greater anastomotic leaks, and 3 (11%) had grade II or greater anastomotic strictures.

DISCUSSION

The published experience with NIFI-FA for esophageal resection is limited and largely reflects attempts to visualize vasculature and perfusion of the esophageal replacement conduit. Pacheco et al. describe the use of NIFI-FA in 11 patients undergoing open transhiatal esophagectomy with cervical anastomosis [7]: Ten patients had good perfusion identified by NIFI-FA, however two developed anastomotic leaks, including one with poor perfusion identified by NIFI-FA that was not identified by gross clinical examination of the conduit alone. Murawa et al. performed NIFI-FA in 15 patients undergoing transhiatal esophagectomy just before gastric translocation and performance of the neck anastomosis[8]. NIFI-FA identified suspected vascular insufficiency in 4 patients, although there was one anastomotic leak in a patient despite visualization of adequate perfusion with NIFI-FA. Shimada et al. describe the use of ICG and NIFI-FA to assess conduit perfusion in 40 patients undergoing cervical or thoracic open esophagectomy with neck anastomosis.[9] Vascular perfusion was visualized in all conduit organs, including stomach, colon, and free jejunal grafts. Three patients in whom microcirculation could not be visualized had anastomotic leaks; however, this was not a specific finding, as 15 of 18 patients with unvisualized microcirculation did not develop anastomotic leaks.

In the current study, our purpose was to evaluate NIFI-FA for the identification and assessment of the gastric vascular anatomy before and during stomach mobilization in patients undergoing RAMIE. Technically, the NIFI-FA platform proved simple to use, with simple instrumentation allowing the operator to toggle between fluorescence and normal light imaging. In the macrocirculation, fluorescence can be expected to last 1 to 2 minutes. The safety profile of ICG is well-established, and multiple injections can be given if needed. Over time, ICG accumulates primarily in the liver, where it is metabolized.

Subjectively, NIFI-FA was a helpful adjunct to safe mobilization of the stomach, mainly through confirmatory visualization of the vasculature (Video 1). In particular, the terminus of the gastroepiploic arcade was identified with increased confidence before starting the formal greater curve dissection. In some cases, NIFI-FA was able to identify otherwise unrecognized small communicating arteries between the terminus of the gastroepiploic arcade and the first short gastric artery, as well as between the short gastric arteries (Figure

1). Although the true clinical significance of this finding is speculative, it is possible that preservation of these arcades improves blood supply over a greater length of the transplanted organ.

Overall, this technology allowed for clear visualization of the vascular structures, although this was reduced in obese patients. Adipose tissue overlying the vessels remains a significant limitation to visualization, and we found that fluorescence was not able to overcome this to a significant degree. Improved visualization appears to be largely attributable to the enhanced contrast between the green fluorescence and the dark/black background, versus the less distinct contrast between natural arterial and venous coloration and fat of the omentum. This application of NIFI-FA has the potential benefits of increased confidence identifying the gastric vasculature and improved safety by better avoiding intraoperative injury and misadventures that can compromise conduit perfusion; however, it would be greatly augmented by improvements to the technology that allow for increased depth of vascular visualization in obese patients. With its current limitations in depth of visual penetration, the potential increased benefit for experienced surgeons is less clear, compared with that for inexperienced surgeons or trainees.

While the limitations of this nonrandomized, uncontrolled experience with small patient numbers and subjective “soft” end points are significant, the simple and straightforward design is adequate to establish proof of concept and safety. These limitations are in line with the study design as a prospective, observational series to describe a novel use for NIFI-FA. The impact of this technological application on clinical outcomes such as anastomotic leak and intraoperative vascular injury is beyond the scope of this study and remains unknown—large, randomized, controlled studies would be required to address these issues. Also, cost issues regarding the use of this technology should be considered. Although the cost of ICG is nominal (approximately $70 per vial), the additional cost of the fluorescence imaging systems, available also for standard laparoscopic and open surgical approaches, can be significant.

In summary, NIFI-FA may be a useful adjunct during MIE gastric mobilization. When used as an aid to identify the gastric vascular supply with greater confidence, NIFI-FA may help prevent intraoperative misadventures and unintended injury, especially early in the learning curve for these operations. Potential additional future applications of this technology may include evaluation of conduit perfusion, identification and evaluation of lymph nodes, and assessment of tumor margins. Further experience and formal study is necessary to better establish the potential role of NIFI-FA in these minimally invasive procedures.

References

1. Biere SS, van Berge Henegouwen MI, Maas KW, Bonavina L, Rosman C, Garcia JR, et al. Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet. 2012; 379:1887–1892. [PubMed: 22552194]
2. Luketich JD, Pennathur A, Awais O, Levy RM, Keeley S, Shende M, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg. 2012; 256:95–103. [PubMed: 22668811]

3. Lazzarino AI, Nagpal K, Bottle A, Faiz O, Moorthy K, Aylin P. Open versus minimally invasive esophagectomy: trends of utilization and associated outcomes in England. Ann Surg. 2010; 252:292–298. [PubMed: 20622666]

4. Tsai WS, Levy RM, Luketich JD. Technique of minimally invasive Ivor Lewis esophagectomy. Operative Tech Thorac Cardiovasc Surg. 2009; 14:176–192.

5. Sarkaria IS, Rizk NP, Finley DJ, Bains MS, Adusumilli PS, Huang J, et al. Combined thoracoscopic and laparoscopic robotic-assisted minimally invasive esophagectomy using a four-arm platform: experience, technique and cautions during early procedure development. Eur J Cardiothorac Surg. 2013; 43:e107–115. [PubMed: 23371971]

6. de la Fuente SG, Weber J, Hoffe SE, Shridhar R, Karl R, Meredith KL. Initial experience from a large referral center with robotic-assisted Ivor Lewis esophagogastrectomy for oncologic purposes. Surg Endosc. 2013; 27:3339–3347. [PubMed: 23549761]

7. Pacheco PE, Hill SM, Henriques SM, Paulsen JK, Anderson RC. The novel use of intraoperative laser-induced fluorescence of indocyanine green tissue angiography for evaluation of the gastric conduit in esophageal reconstructive surgery. Am J Surg. 2013; 205:349–352. discussion 352–343. [PubMed: 23414958]

8. Murawa D, Hunerbein M, Spychala A, Nowaczyk P, Polom K, Murawa P. Indocyanine green angiography for evaluation of gastric conduit perfusion during esophagectomy--first experience. Acta Chir Belg. 2012; 112:275–280. [PubMed: 23008991]

9. Shimada Y, Okumura T, Nagata T, Sawada S, Matsui K, Hori R, et al. Usefulness of blood supply visualization by indocyanine green fluorescence for reconstruction during esophagectomy. Esophagus. 2011; 8:259–266. [PubMed: 22557942]

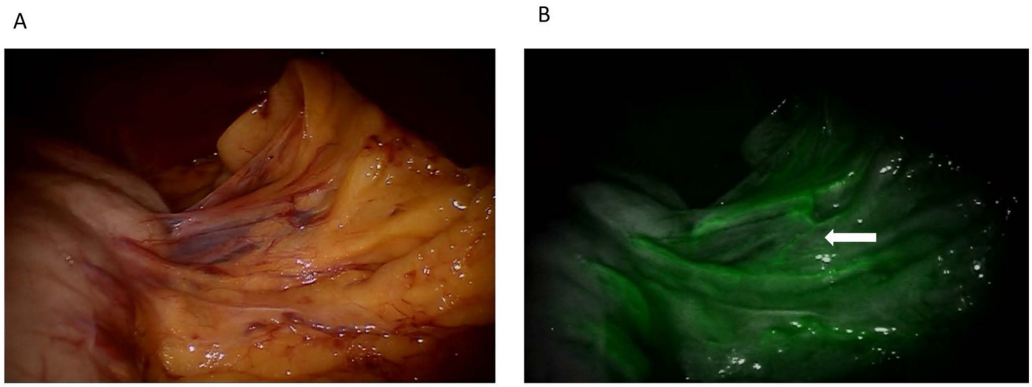

Figure 1.
Short gastric arteries visualized without NIFI-FA (A.) and with NIFI-FA (B.). In this patient, NIFI-FA clearly identifies a perforating artery between short gastric arteries (white arrow).

Table 1

Patient demographic characteristics and results

Characteristic	Total
Age, years, median (range)	59 (37–76)
Male	22 (73)
Body mass index, median (range)	28.8 (18.0–47.8)
Adenocarcinoma	24 (80)
Induction chemoradiation	24 (80)
Operative approach	
Ivor Lewis	25 (83)
McKeown (3-hole)	5 (17)
Anastomotic leak	2 (7)
Anastomotic stricture	3 (11)

Data are no. (%) unless otherwise noted.