World Journal of Surgery and Surgical Research

Research Article
Published: 30 May, 2023

Intraoperative Evaluation of the Gastric Conduit Perfusion with Indocyanine Green Fluorescein Imaging and Correlation with Anastomotic Leakage after Esophagectomy

Mahmoodzadeh H[1], Farahzadi A[1], Omranipour R[1,2], Harirchi I[1], Shirkhoda M[1], Jalayeefar AM[1] and Miri R[1]*

[1]*Department of General Surgery, Tehran University of Medical Sciences, Cancer Institute, Iran*

[2]*Breast Disease Research Center, Tehran University of Medical Sciences, Iran*

Abstract

Aim: Anastomotic Leakage (AL) remains a major cause of postoperative morbidity and mortality in gastrointestinal reconstructive surgery. Insufficient local blood supply is an important risk factor for AL. Indocyanine Green (ICG) fluorescence can visualize gastric blood flow and determine if it is sufficient for anastomosis. We evaluated gastric conduit perfusion and the need to change the anastomotic site based on ICG mapping and compared the postoperative leak rate with a historical control group.

Methods: 2.5 mg of ICG was injected intravenously. Adequate perfusion was defined as clear visualization of fluorescence around the gastric tube at an estimated 15 sec to 60 sec after intravenous administration.

Results: The mean age of patients was 56.44 (SD:10.37) in the ICG group and 56.39 (SD:7.89) in the non-ICG group. The mean operative time was 366.67 min (SD:82.67) and 403.89 min (SD:71.01) in ICG and non-ICG groups, respectively. They were not significantly different. No adverse reactions or allergies to ICG were detected. The Mean extra time for ICG injection was 3 min (SD:3.88). The injection dose of ICG was 2.5 mg. In the ICG group, no patient suffered from anastomotic leakage. Two patients in the non-ICG group developed symptomatic AL after surgery. According to Fisher's exact test, there was no significant association between AL development and ICG use, possibly due to the small sample size. In three cases, the site of anastomosis was changed after ICG perfusion mapping.

Conclusion: We found that intraoperative ICG-FA is a useful adjunct in assessing gastric tube perfusion and reduces the risk of postoperative AL.

Keywords: Anastomotic leakage; Esophageal cancer; Gastric conduit perfusion; Indocyanine green fluorescein imaging

OPEN ACCESS

***Correspondence:**
Athena Farahzadi, Department of General Surgery, Tehran University of Medical Sciences, Cancer Institute, Tehran, Iran,
E-mail: athenafarahzadi@gmail.com

Received Date: *12 May 2023*
Accepted Date: *26 May 2023*
Published Date: *30 May 2023*

Citation:
Mahmoodzadeh H, Farahzadi A, Omranipour R, Harirchi I, Shirkhoda M, Jalayeefar AM, et al. Intraoperative Evaluation of the Gastric Conduit Perfusion with Indocyanine Green Fluorescein Imaging and Correlation with Anastomotic Leakage after Esophagectomy. World J Surg Surgical Res. 2023; 6: 1472.

Introduction

Esophageal carcinoma is the world's eighth leading cause of cancer [1]. Surgery is the cornerstone treatment of esophageal cancer. The stomach remains the preferred organ for restoring gastrointestinal continuity after esophagectomy. Esophagogastric anastomoses are fragile and prone to complications such as leaks, fistulas, bleeding, and strictures. Anastomotic Leakage (AL) remains a major cause of postoperative morbidity and mortality in gastrointestinal reconstructive surgery. After an esophagectomy, leakage incidence ranges from 5% to 20%. Literature reports leak-associated mortality rates from 18% to 40% compared to overall in-hospital mortality of 4% to 6% [2-5].

AL is associated with complications, including mediastinitis, sepsis, acute respiratory distress syndrome, prolonged hospitalization, increased costs of medical treatment, and death. Furthermore, AL has been associated with poorer quality of life, increased cancer recurrence rates, and worsened long-term survival [1,6].

The common risk factors for AL are surgical technique, site of anastomosis, the tension on the anastomosis, surgeons experience, active smoking, corticosteroid therapy, and comorbidities. Another important risk factor for AL is the inadequate local blood supply. The gastric tube is at high risk for AL due to its anatomical conditions with arterial perfusion exclusively *via* the right gastroepiploic artery and the possibility of venous congestion. Furthermore, changing the stomach to the gastric conduit by stapling makes it more susceptible to blood insufficiency [7,8]. Therefore, intraoperative assessment of gastrointestinal perfusion remains a challenge in surgery. Subjective parameters for assessing perfusion are bleeding from surgical margins, supply vessel pulsation, and tissue color. In addition, some techniques like laser Doppler flowmeters have been investigated, but could not be established [6]. Clinical judgment is not reliable in determining anastomotic perfusion. Hence, there is an urgent need for objective, validated, and reproducible methods to assess tissue perfusion at the anastomosis site. Indocyanine Green Angiography (ICGA) is Near-Infrared Fluorescence (NIRF) perfusion imaging. It is a safe, straightforward, and reproducible method for graft perfusion analysis [2,4,5].

Recent studies have revealed that ICG fluorescence can visualize gastric mucosal blood flow in patients undergoing esophagectomy [5,9-12]. However, a correlation between the blood flow observed by ICG fluorescence and Esophagogastric anastomotic leakage has not been demonstrated.

This study evaluated gastric conduit perfusion after esophagectomy with Indocyanine Green. We compared the postoperative leak rate with a historical group that underwent the same procedure without a fluorescence guide. The need for a change of anastomosis site based on perfusion assessment of gastric conduit with ICG was investigated, too.

Material and Methods

In this study, we evaluated adequate perfusion of the gastric conduit and the need for changing the location of anastomosis if perfusion was insufficient by using NIR fluorescence-angiography. We compared the anastomotic leakage rate with a historical control group who underwent minimally invasive esophagectomy without this novel technique.

1 ml (2.5 mg) of ICG was injected intravenously to visualize the perfusion of the stomach. Adequate perfusion was defined as direct and clear visualization of fluorescence around the gastric tube at an estimated 15 sec to 60 sec after intravenous administration.

All patients with esophageal cancer who was a candidate for minimal invasive Mc Kwon esophagectomy with gastric pull-up between September 2020 and June 2022 enrolled in the study with the following inclusion criteria:

Patients aged 18 or over; American Society of Anesthesiologists (ASA) class I, II, or III; elective surgery; and written acceptance to be included in the study.

Patients with an allergy to iodine, a history of asthma, who cannot undergo transthoracic esophagectomy, pregnant women, and patients unable to understand the consensus were excluded. FDA approved the clinical use of ICG in 1959. Our Ethical Committee approved the use of NIR fluorescence imaging with ICG. All participants signed a written informed consent form.

Gastric conduit formation

A gastric conduit with a 4 cm width was created by stapling the lesser curvature of the stomach. The right gastric artery, right gastroepiploic artery, and branches of the left gastroepiploic arteries were saved. The vascular supply to the gastric conduit was provided through an arcade of peripheral vessels. The omentum was divided about 1 cm from the gastric vascular arcade and freed from the transverse colon.

Evaluation of gastric perfusion with ICG fluorescein imaging

A 2.5 mg (1 ml) bolus of ICG dye was injected after forming the gastric conduit. Vascular networks were evaluated within the gastric wall about 15 s to 60 s after ICG administration using a near-infrared imaging system (the STRYKER 1588AIM camera system). We switched from standard mode to NIR mode using the camera button. The data was recorded as a movie file (Video 1). Real-time visualization of the tissue perfusion enabled the operating surgeon to assess adequate perfusion of the anastomosis site. The vascular territories with sufficient and low perfusion areas were identified based on ICG fluorescein imaging. We defined rapid (sufficient) perfusion sites as safe areas for anastomosis, and low (insufficient) perfusion sites as unsafe. In the latter cases, the place of anastomosis was changed within the rapid perfusion area. Cervical esophagogastric end-to-side anastomoses were performed using a circular stapler *via* a posterior mediastinal route. Cases not evaluated by ICG fluorescence imaging were included in the non-ICG group.

Definition of postoperative complications

AL was regarded as a dehiscence of Esophagogastric anastomosis that was clinically symptomatic (abscess, mediastinitis, externalized drainage of digestive fluid). AL was assessed by a water-soluble, contrast medium (Gastrografin) in suspected cases. Superficial pus expressed from the abdominal, thoracic, or drains incision sites, requiring surgical debridement and antibiotic treatment, was defined as surgical site infection. Respiratory complications included a bronchial circulatory disturbance, ventilation disorders, atelectasis, pneumonia, respiratory failure, and acute respiratory distress syndrome.

Statistical analysis

The demographic parameters of the patients were recorded using descriptive statistics.

Measured data are depicted as mean ± standard deviation. The independent sample t-test, chi-square test, and Fisher exact test were used to compare groups and to determine the difference between the two groups. Statistical analysis was completed using SPSS® version 22, with $p<0.05$ indicating a statistically significant difference.

Results

Demographic parameters

Thirty-six (36) patients participated in this study. Minimal invasive McKeown esophagectomy with ICG was performed in 18 patients. The same procedure without ICG was done in another 18 patients. Patients and tumor specifications are summarized in Table 1. There were no significant differences in age, sex, smoking, ASA, comorbidities, neoadjuvant chemotherapy, or tumor location between the two groups. Squamous cell carcinoma was the most common pathological type in both groups. There were six patients with esophageal adenocarcinoma (33.3%) in the ICG group and four

Table 1: Demographic parameters and tumor characteristics of the patients.

	ICG-group (n=18)	Non ICG-group (n=18)	P-value
Age (years)	56.44	56.39	0.986
Sex			0.505
Female	10	8	
Male	8	10	
BMI	23.38	23.33	0.949
History of smoking			0.658
Yes	2	4	
NO	16	14	
ASA			1
I	4	4	
II	11	11	
III	3	3	
Comorbidities			
Hypertension	5	3	0.691
Diabetes mellitus	1	2	0.22
Cardiovascular disease	3	4	1
Cerebrovascular disease	1	0	1
Neoadjuvant chemo radiotherapy	18	18	0.402
Histological type			0.457
Squamous cell carcinoma	12	14	
Adenocarcinoma	6	4	
Others			
Tumor location			0.7
Upper	0	0	
Middle	4	5	
Lower	14	13	
Operation time (min)*	366.67 (sd:82.67)	403.89 (sd:71.01)	0.34
Anastomotic leakage	0	2	0.486
Change of anastomotic site	3	0	0.229
Vagus sparing procedure	14	0	
Postoperative hospital stay (d)*	10.77	12.44	0.339
Death	0	2, related to COVID-19 infection	

(22.2%) in the non-ICG group. The mean BMI of patients in the ICG group was 23.38 (SD:3.17), and in the non-ICG group was 23.33 (SD:1.18).

The median postoperative hospital stay was 10.77 (SD:6.03) and 12.44 (SD:4.10) days in ICG and non-ICG groups, respectively. It was not significantly different.

The mean age of patients was 56.44 (SD:10.37) in the ICG group and 56.39 (SD:7.89) in the non-ICG group. The mean operative time was 366.67 min (SD:82.67) and 403.89 min (SD:71.01) in ICG and non-ICG groups, respectively. They were not significantly different.

There were no adverse reactions or allergies to ICG. The Mean extra time for ICG injection was 3 min (SD:3.88). This time included intravenous injection, turning off the lights in the operating room with the NIR imager, and recording video or taking appropriate photographs. The injection dose of ICG was 2.5 mg. No patient required a repeated dose. In the ICG group, no patient suffered from anastomotic leakage. Two patients in the non-ICG group developed symptomatic AL after surgery. One of them was managed conservatively, and the other had undergone surgery. According to Fisher's exact test, there was no significant association between AL development and ICG use, possibly due to the small sample size. In three cases, the site of anastomosis was changed after ICG perfusion mapping.

Discussion

AL and graft necrosis are possible complications occurring in 5% to 20% after esophagectomy with gastric reconstruction and are associated with high mortality [3,13]. Among the risk factors affecting anastomosis integrity, poor perfusion is a surgically improvable factor.

It has been reported that 20% of the fundus perfusion is relied on the blood supply within the gastric wall, while the rest of the gastric conduit blood supply is derived from the right gastroepiploic artery. The blood supply to the surgical anastomosis is primarily through the local microvascular network within the ventricular fundus. The blood supply to the anastomosis is often measured subjectively by relatively weak parameters, such as palpable pulsation in the gastric tube and active bleeding from the resection edge. These parameters do not have predictive accuracy, and this makes an assessment of the boundaries between well-perfused and under-perfused regions difficult [2,14].

Fluorescent imaging with ICG is an emerging technology that assists the surgeon with intraoperative decision-making. It can assess perfusion, thus delineating the ideal site for anastomosis and evaluating the vitality of final anastomosis [15,16].

A special telescope detects the fluorescence that is transmitted to a standard monitor that allows visualization of the anatomical structures in which the dye is present (e.g., biliary tract, vessels, lymph nodes, etc.). It is a low-cost technique that can show the vascularization of the stomach in real time [17].

ICG has an absorption maximum of around 760 nm to 780 nm and is known to bind readily to plasma proteins which leads to its confinement to the vascular compartment, its low toxicity, and its rapid and exclusive biliary excretion. Adverse events have been reported in fewer than 1 of 40,000 patients and most often include hypersensitivity reactions. Its excellent safety record contributed to its rapid approval by the Food and Drug Administration for clinical use in 1956.

Zehetner et al. assessed and quantified graft perfusion in EC patients using laser-assisted angiography. AL occurred in 16.7% of patients and was significantly less probable when the anastomosis was placed in an area with sufficient perfusion [12,18]. Rino et al. and Nakashima et al. investigated blood flow by ICG fluorescence imaging around the anastomosis with good results like Kitagawa et al. study [19-21] Masaki Ohi et al. objectively assessed tissue perfusion using ICG fluorescein imaging and showed that ICG fluorescein imaging was associated with a decreased risk of AL after EC surgery [22].

In Koyanagi et al. study, no anastomotic leakage occurred in ICG defined sufficient perfusion group. These findings strongly recommend that sufficient blood perfusion of the gastric conduit wall is vital for tissue healing at the anastomosis site [5].

Karampinis et al. divided the gastric tube perfusion into a well-perfused "optizone" and a poorly perfused area. In most patients (33/35), anastomosis was placed in the "optizone." AL occurred in only one patient in the optizone group. They reported a significantly lower AL rate in the ICG-FI group (3% *vs.* 18.2%) compared to a retrospective control group [23].

Kumagai et al. suggested a 90-second rule: All anastomoses were performed in the area that was enhanced within 90 sec after initial amplification at the distal end of the gastric tube. The tip was excised in 50% (35/70), and in 18 of those 35 cases, there was a change in the anastomotic site. The anastomosis was not performed at a site with enhancement after more than 90 sec. Anastomotic leakage occurred in one of 70 patients (1.4%) at an anastomotic site that was enhanced after 77 sec [24].

Noma et al. compared the postoperative outcomes of 285 patients before and after using an ICG protocol. The gastric conduit and area of potential anastomosis were imaged after the injection of 12.5 mg of ICG. If perfusion was visible after 20 sec, an anastomosis was performed on the area, and if the anastomosis area was perfused within 30 sec, further mobilization was performed before anastomosis formation. If no perfusion was seen in the anastomosis area after 30 sec, the line was "charged" by adding a microvascular anastomosis. The study found that AL rates in patients in the ICG protocol were statistically lower than before protocol introduction (8.8% *vs.* 22%, P=0.03) [25].

Nerup et al. quantified gastric conduit perfusion by using a previously published algorithm. As a result, quantification of ICG (q-ICG) revealed different locations for the best anastomotic position compared to white light assessment and ICG-FI without quantification. A delayed fluorescent enhancement at the tip after injection (>98 s) was related to anastomotic spillage [17].

In a systematic review by Van Daele et al., the leak rate was 9.9% in the ICG group and 20.5% in the non-ICG group (p<0.001). Within the ICG-guided esophagogastric anastomosis group, 592 showed good ICG perfusion but still, lead to an anastomotic leakage rate of 6.3%. Ninety-three patients had low perfusion at the tip of the stomach, with different modifications resulting in adequate tip perfusion and a leak rate of 6.5%, comparable to the AL rate of the well-perfused cohort and significantly lower than the 47.8% leak rate in the poorly perfused group (P<0.001) [26].

Casas et al. analyzed 32 studies with 3,171 patients undergoing minimally invasive thoracoabdominal esophagectomy. An ICG-FI was done in 381 patients. In contrast to the previously published data, the authors revealed equal AL rates in both groups [27].

Slooter et al. in their meta-analysis illustrated the use of ICG for perfusion evaluation of the gastric conduit before anastomosis is safe and leads to a decrease in anastomotic leakage and graft necrosis (OR: 0.30, 95% CI: 0.14-0.63). The pooled results reveal that fluorescence angiography has an added value, as the change in management occurs in 25%, and anastomosis leakage is less with fluorescein angiography than without. However, anastomotic leakage still occurs in the group of patients undergoing treatment modification (14%). This relatively high rate of leakage can be explained by anastomotic tension and selection bias in a group of patients with relatively poor vascularization at baseline. The creation of an anastomosis in the perfused area might come at the cost of an anastomosis under tension. Additional resection of the poorly perfused gastric conduit may put the anastomosis onto more tension, although perfusion is better at the chosen location. They have the same outcomes as Ladak et al. published on fluorescence angiography to evaluate the perfusion of the gastric conduit [28,29].

Zhi-Nuan Hong et al. reported that the application of ICG fluorescence effectively reduces the incidence of AL and lessens the postoperative hospital stay for patients undergoing cervical anastomosis although it was not effective for patients having intrathoracic anastomosis [30].

Groot et al. investigate the effect of ICG-FA during robotic minimally invasive esophagectomy with an intrathoracic anastomosis. The quantification of ICG-FA showed that the gastric conduit reaches its maximum intensity in a base-to-tip direction. Perfusion of the entire gastric conduit was worse for patients with anastomotic leakage, although was not statistically different [31].

This study enrolled 36 esophageal cancer patients who underwent minimally invasive esophagectomy. Gastric duct perfusion was evaluated in 18 patients with ICG-FA. The need to change the anastomotic site during surgery and postoperative leakage of the anastomotic site was recorded and compared with a historical control group who underwent the same procedure without ICG injection. The originally selected site of gastric conduit for anastomosis was changed in three patients (16.6%) based on ICG-FA findings. None of the patients in the ICG group developed AL compared with two patients (11.11%) in the non-ICG group. We found that intraoperative ICG-FA helped to identify which patients were at high risk for anastomotic leakage, and anastomosis could be at another site with adequate perfusion.

The disadvantages of our study are the small number of enrolled patients and the non-randomization of the study population.

Conclusion

Intraoperative ICG-FA is useful as an adjunct to the assessment of gastric tube perfusion. Perfusion plays a critical role in anastomotic integrity, but leak development is multifactorial, so ICG-FA should be used in conjunction with patient and procedure component optimization to minimize leak rates. Prospective, randomized studies are necessary to validate the interpretation, efficacy, and usage of ICG-FA in minimally invasive esophagectomy.

Video link:

https://youtu.be/pDhR5QKKAIc

References

1. Ohi M, Toiyama Y, Mohri Y, Saigusa S, Ichikawa T, Shimura T, et al. Prevalence of anastomotic leak and the impact of indocyanine green fluorescein imaging for evaluating blood flow in the gastric conduit following esophageal cancer surgery. Esophagus. 2017;14(4):351-9.

2. Thakur B, Li A, Devkota M, Chaudhary M, Regmi Y. Fluoroscence angiography for assessment of gastric conduit: Initial experience from a tertiary care center. Nepal J Cancer. 2019;3(1):13-8.

3. Pavone G, Tartaglia N, Pacilli M, Maddalena F, Petruzzelli F, Ambrosi A. Leak after sleeve gastrectomy with positive intraoperative indocyanine green test: Avoidable scenario? Int J Surg Case Rep. 2022;95:107168.

4. Van Daele E, Van Nieuwenhove Y, Ceelen W, Vanhove C, Braeckman BP, Hoorens A, et al. Assessment of graft perfusion and oxygenation for improved outcome in esophageal cancer surgery: Protocol for a single-center prospective observational study. Medicine (Baltimore). 2018;97(38):e12073.

5. Koyanagi K, Ozawa S, Oguma J, Kazuno A, Yamazaki Y, Ninomiya Y, et al. Blood flow speed of the gastric conduit assessed by indocyanine green fluorescence: New predictive evaluation of anastomotic leakage after esophagectomy. Medicine (Baltimore). 2016;95:e4386.

6. Fabbi M, Hagens ERC, van Berge Henegouwen MI, Gisbertz SS. Anastomotic leakage after esophagectomy for esophageal cancer: Definitions, diagnostics, and treatment. Dis Esophagus. 2021;34(1):doaa039.

7. Schroder W, Stippel D, Beckurts KT, Lacher M, Gutschow C, Holscher AH. Intraoperative changes of mucosal pCO2 during gastric tube formation. Langenbecks Arch Surg. 2001;386(5):324-7.

8. Schilling MK, Redaelli C, Maurer C, Friess H, Buchler MW. Gastric microcirculatory changes during gastric tube formation: assessment with laser Doppler flowmetry. J Surg Res. 1996;62(1):125-9.

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(4):259-66.

10. Balla A, Corallino D, Quaresima S, Palmieri L, Meoli F, Cordova Herencia I, et al. Indocyanine green fluorescence angiography during laparoscopic bariatric surgery: A pilot study. Front Surg. 2022;9:906133.

11. Thammineedi SR, Saksena AR, Nusrath S, Iyer RR, Shukla S, Patnaik SC, et al. Fluorescence-guided cancer surgery-A new paradigm. J Surg Oncol. 2021;123(8):1679-98.

12. Alander JT, Kaartinen I, Laakso A, Pätilä T, Spillmann T, Tuchin VV, et al. A review of indocyanine green fluorescent imaging in surgery. Int J Biomed Imaging. 2012;2012:940585.

13. von Kroge P, Russ D, Wagner J, Grotelüschen R, Reeh M, Izbicki JR, et al. Quantification of gastric tube perfusion following esophagectomy using fluorescence imaging with indocyanine green. Langenbecks Arch Surg. 2022;407(7):2693-701.

14. Karliczek A, Harlaar NJ, Zeebregts CJ, Wiggers T, Baas PC, van Dam GM. Surgeons lack predictive accuracy for anastomotic leakage in gastrointestinal surgery. Int J Colorectal Dis. (2009) 24:569-76.

15. Campbell C, Reames MK, Robinson M, Symanowski J, Salo JC. Conduit vascular evaluation is associated with reduction in anastomotic leak after esophagectomy. J Gastrointest Surg. 2015;19:806-12.

16. Prasetya H, Jansen SM, Marquering HA, van Leeuwen TG, Gisbertz SS, de Bruin DM, et al. Estimation of microvascular perfusion after esophagectomy: A quantitative model of dynamic fluorescence imaging. Med Biol Eng Comput. 2019;57:1889-990.

17. Nerup N, Svendsen MBS, Svendsen LB, Achiam MP. Feasibility and usability of real-time intraoperative quantitative fluorescent-guided perfusion assessment during resection of gastroesophageal junction cancer. Langenbecks Arch Surg. 2020;405(2):215-22.

18. Ishige F, Nabeya Y, Hoshino I, Takayama W, Chiba S, Arimitsu H, et al. Quantitative assessment of the blood perfusion of the gastric conduit by indocyanine green imaging. J Surg Res. 2019;234:303-10.

19. Rino Y, Yukawa N, Sato T, Yamamoto N, Tamagawa H, Hasegawa S, et al. Visualization of blood supply route to the reconstructed stomach by indocyanine green fluorescence imaging during esophagectomy. BMC Med Imaging. 2014;14:18.

20. Nakashima Y, Saeki H, Yukaya T, Tsutsumi S, Nakanishi R, Sugiyama M, et al. Blood flow assessment with indocyanine green fluorescence angiography for pedicled omental flap on cervical esophagogastric anastomosis after esophagectomy. J Am Coll Surg. 2016;222(5):e67-9.

21. Kitagawa H, Namikawa T, Iwabu J, Fujisawa K, Uemura S, Tsuda S, et al. Assessment of the blood supply using the indocyanine green fluorescence method and postoperative endoscopic evaluation of anastomosis of the gastric tube during esophagectomy. Surg Endosc. 2018;32(4):1749-54.

22. Ohi M, Toiyama Y, Mohri Y, Saigusa S, Ichikawa T, Shimura T, et al. Prevalence of anastomotic leak and the impact of indocyanine green fluorescein imaging for evaluating blood flow in the gastric conduit following esophageal cancer surgery. Esophagus. 2017;14(4):351-9.

23. Karampinis I, Ronellenfitsch U, Mertens C, Gerken A, Hetjens S, Post S, et al. Indocyanine green tissue angiography affects anastomotic leakage after esophagectomy. A retrospective, case-control study. Int J Surg. 2017;48:210-14.

24. Kumagai Y, Hatano S, Sobajima J, Ishiguro T, Fukuchi M, Ishibashi KI, et al. Indocyanine green fluorescence angiography of the reconstructed gastric tube during esophagectomy: Efficacy of the 90-second rule. Dis Esophagus. 2018;31(12).

25. Noma K, Shirakawa Y, Kanaya N, Okada T, Maeda N, Ninomiya T, et al. Visualized evaluation of blood flow to the gastric conduit and complications in esophageal reconstruction. J Am Coll Surg. 2018;226(3):241-51.

26. Van Daele E, Van Nieuwenhove Y, Ceelen W, Vanhove C, Braeckman BP, Hoorens A, et al. Near-infrared fluorescence guided esophageal reconstructive surgery: A systematic review. World J Gastrointest Oncol. 2019;11(3):250-63.

27. Casas MA, Angeramo CA, Bras Harriott C, Dreifuss NH, Schlottmann F. Indocyanine Green (ICG) fluorescence imaging for prevention of anastomotic leak in totally minimally invasive Ivor Lewis esophagectomy: A systematic review and meta-analysis. Dis Esophagus. 2022;35(4):doab056.

28. Slooter MD, Eshuis WJ, Cuesta MA, Gisbertz SS, van Berge Henegouwen MI. Fluorescent imaging using indocyanine green during esophagectomy to prevent surgical morbidity: A systematic review and meta-analysis. J Thorac Dis. 2019;11(Suppl 5):S755-S765.

29. Ladak F, Dang JT, Switzer N, Mocanu V, Tian C, Birch D, et al. Indocyanine green for the prevention of anastomotic leaks following esophagectomy: A meta-analysis. Surg Endosc. 2019;33(2):384-94.

30. Hong ZN, Huang L, Zhang W, Kang M. Indocyanine green fluorescence using in conduit reconstruction for patients with esophageal cancer to improve short-term clinical outcome: A meta-analysis. Front Oncol. 2022;12:847510.

31. de Groot EM, Kuiper GM, van der Veen A, Fourie L, Goense L, van der Horst S, et al. Indocyanine green fluorescence in robot-assisted minimally invasive esophagectomy with intrathoracic anastomosis: A prospective study. Updates Surg. 2023;75(2):409-18.