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Review

# Real-Time Fluorescence Imaging for Thoracic Duct Identification during Oesophagectomy: A Systematic Review of the Literature

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Postoperative chylothorax is a serious complication after oesophagectomy. Real-time identification of the thoracic duct (TD) could prevent injury or facilitate prompt management when it occurs. Intraoperative TD lymphography with indocyanine green (ICG) is a novel technique that may help prevent chyle leaks following thoracic surgery. A systematic search of PubMed, Embase, MEDLINE, Scopus, and the Cochrane Library for studies published until July 2024 evaluating ICG for TD identification during oesophagectomy was performed. Studies were included in the review if they assessed intraoperative TD identification with ICG to prevent chyle leakage in patients undergoing oesophagectomy. Nine of 265 screened papers were included in the present review, with 3 reporting comparative techniques of TD identification between patients. Only 1 study had a control group without ICG administration. TD was identified in 281 of the 303 patients who received ICG. Chyle leak incidence was 0.66% in the ICG group. The mean observation time of TD after ICG administration was 162 minutes. Most of the included patients received neoadjuvant treatment before surgery. Different application routes of ICG have been reported, with the most prominent one being through the inguinal region under ultrasound guidance. Real-time TD identification with ICG might be a valuable tool for avoiding injury or managing it intraoperatively. To our knowledge, this is the first systematic review on this complex topic. However, as no randomized controlled trials have been published, sufficient evidence is needed to determine whether the aforementioned method can sufficiently reduce the chyle leak rate.

**Keywords:** Fluorescence, Esophagectomy, Minimally invasive surgery, Thoracic duct identification, Indocyanine green

## Introduction

Chylothorax is one of the most serious complications after oesophagectomy, occurring in 2%–12% of patients, although it may be under-reported in the literature [1]. It has also been associated with increased morbidity, prolonged hospital stays, and a mortality rate of up to 30% [2]. Locating and identifying the thoracic duct (TD) during thoracic surgery is an ongoing challenge, as TD injury remains an infrequent but persistent risk. The TD is the largest lymphatic vessel of the human lymphatic system. It transports chyle (a liquid containing lymph and emulsified fats) from most of the body, including the gastrointestinal tract, into the left internal jugular vein. It is primarily located in the thorax and is at risk of injury during the thoracic part of an oesophagectomy. Although the TD has well-known anatomic landmarks, it is frequently not visible in the operative field, especially in obese patients. This makes it difficult to avoid injury and the need for subsequent repair [3].

Fluorescence refers to the ability of certain molecules to absorb light at one wavelength and to emit light at a longer wavelength [4]. Light in the near-infrared (NIR) range (wavelength range, 650–900 nm) has several advantages over visible-range light, including deeper tissue penetration due to less absorption by hemoglobin and water. Near-infrared fluorescence imaging uses fluorescent dyes (fluorophores) that emit invisible NIR light when they are excited by light at a particular wavelength. A fluorescence-enabled camera is required to shine light at that particular wavelength on the fluorophore, capture the light emitted and

finally display it on a screen [5].

Indocyanine green (ICG) is a water-soluble fluorescent molecule. It is an NIR dye for numerous operations that is widely used to measure cardiac output, hepatic function, liver blood flow, and ophthalmic angiography [6]. ICG is safe to use, and only a few adverse events occur at a dosage lower than 0.5 mg/kg. ICG can rapidly bind to plasma protein through intravenous injection, and the peak spectral absorption in the blood is at 800–810 nm. This characteristic facilitates its use as a fluorescent contrast agent, which has been approved by the Food and Drug Administration since 1959 [7,8]. ICG already has various surgical applications, including evaluating anastomotic perfusion, recognizing anatomical structures (such as blood and biliary vessels), and detecting lymphatic drainage for sentinel node biopsy [9-12].

Over the years, multiple attempts have been made to identify the TD intraoperatively or to visualize a possible TD injury in a timely manner. These attempts include preoperative oral or enteral administration of olive oil, fat-containing cream, and methylene blue, as well as conventional lymphangiography/lymphoscintigraphy. To date, these methods have all been challenging intraoperatively, with limited success and increased costs. Yet, only a few studies have been published showing a mechanism to aid in real-time TD identification at the index operation. NIR fluorescence imaging of the TD could potentially provide real-time dynamic imaging during thoracic surgery [10-12].

The present study aimed to explore and review the existing literature on the feasibility and effectiveness of near-infrared fluorescence imaging with ICG (ICG-NIR) to identify the TD during oesophagectomy and avoid chyle leakage postoperatively.

# Methods

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines [13].

## Eligibility criteria

Only studies performed in humans and studies written in English were included. Studies were excluded if they did not report TD identification via ICG-NIR, had a primary intervention other than TD identification or intraoperative TD leak assessment, did not identify TD intraoperatively, or did not report results from ICG-NIR TD identification in patients undergoing oesophagectomy. Data duplications were extracted by examining all authors and publications. We also did not include studies that used ICG-NIR to detect TD after the occurrence of post-oesophagectomy chylothorax (as a second operation). Lastly, we excluded case report studies.

## Research strategy

A systematic review of the existing literature was undertaken from inception to July 12, 2024, incorporating PubMed, Embase, MEDLINE, Scopus, and the Cochrane Library review databases. All references from studies included in the review were further evaluated to identify additional literature. No pre-existing protocol for a systematic review on this topic was found. The following MeSH terms were applied: [Oesophagectomy OR esophagectomy] AND [chylothorax] AND/OR [chyle leak] AND [thoracic duct identification] AND [ICG/Indocyanine green] AND [near infrared/NIR] AND [fluorescence imaging]. The eligibility assessment was performed independently in an unblinded standardized manner by 2 reviewers screening the retrieved records' titles and abstracts. Any disagreements between reviewers were resolved by consensus.

## Methodological quality appraisal

The Methodological Index of Non-Randomized Studies (MINORS) was selected to assess the methodological quality and bias assessment of the included studies [14]. This methodological index is a validated quality assessment system for non-randomized surgical intervention trials based on 8 items for non-comparative studies and 12 items for comparative studies.

## Data extraction

From each study, the following data were extracted: enrolment year and country of investigation, study design, number of patients included, age, body mass index (BMI) (if reported), surgical technique (open or minimally invasive and type of oesophagectomy), if TD was visualized with NIR light, the dose and the site of ICG bolus injected, the time of TD visualization after ICG injection, further administration of fatty cream prior to the thoracic part of oesophagectomy, and the incidence of postoperative chylothorax.

# Results

## Study characteristics

The search of the standard medical electronic databases generated 265 studies (Fig. 1). Ninety-six publications were retrieved for full-text review, 42 of which did not meet the inclusion criteria. Nine studies which met the aforementioned criteria were included in this review [15-23].

Table 1 summarizes the demographic data and the characteristics of the included studies. The present review included 321 patients who underwent surgery with intraoperative TD identification. All patients were enrolled between 2017 and 2023 and were all oesophageal or oesophagogastric cancer patients who underwent oesophagectomy. All included studies were prospective and retrospective cohort studies [15-23]. Only 3 studies reported comparative outcomes between patients [17,22,23]; however, because they compared various aspects (different ICG administration techniques and routes, and 1 study reported outcomes on TD identification with and without ICG), no formal meta-analysis was feasible. Most patients received neoadjuvant chemotherapy or chemoradiotherapy according to the type of cancer they had (Table 2).

The risk of bias was evaluated with the MINORS rating score [14]. The overall quality score varied from 8 to 15 (median=11.5) in the non-comparative studies and from 18 to 22 (median=19) in the 3 comparative studies (Supplementary Table 1). All studies had a high score for the following: endpoint appropriate to the aim of the study, follow-up time appropriate to the aim of the study, and loss of follow-up. None of the studies had an appropriate power calculation nor an unbiased assessment of the endpoint. Most of the included studies used different ICG-NIR equipment to assess intraoperative TD injury.

## Intraoperative findings regarding TD identification with ICG-NIR

The 9 clinical studies examined in the current review included 321 patients with a mean age of 57.5 years. All included patients had a BMI of less than 23.0 kg/m$^2$ (mean BMI=22.9 kg/m$^2$). Approximately two-thirds of the included patients had oesophageal/gastro-oesophageal squamous cell carcinoma, and almost all the rest were adenocarcinoma patients (Table 2). All included individuals underwent 2- or 3-stage oesophagectomy (either minimally invasive or open) [15-23]. Of these, 303 patients underwent ICG administration, whereas 18 did not receive ICG. Among the patients who received ICG, 22 did not have their TD identified intraoperatively (Table 2). The successful TD identification rate was 92.7% after ICG application. The reported postoperative incidence rate of chyle leak in patients who received ICG was 0.66%. Moreover, the route administration of ICG varied between studies; it was performed in the inguinal region (ICG was injected subcutaneously or in-

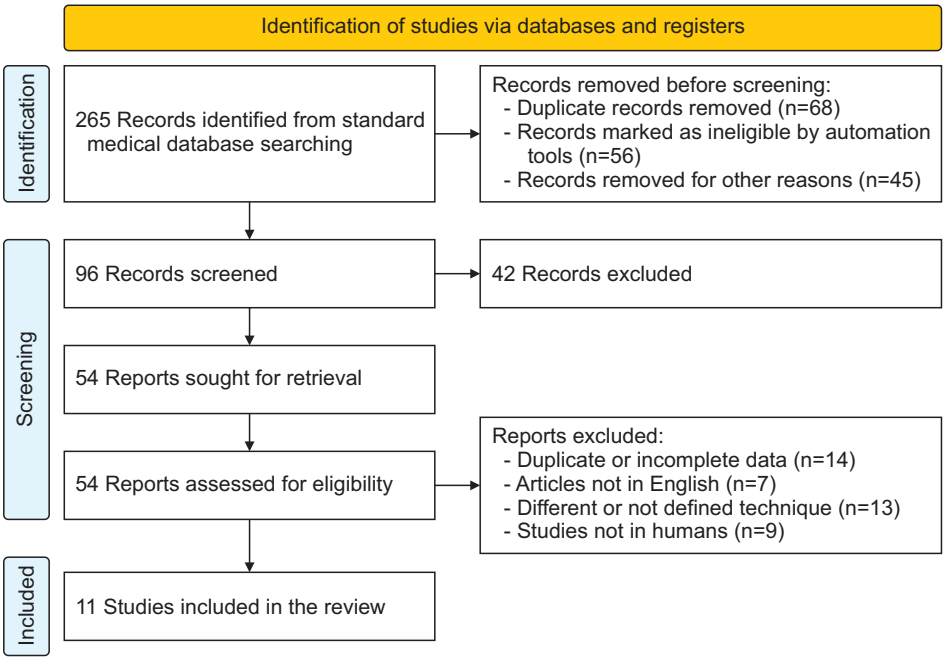


**Fig. 1.** PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flow diagram. From Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71 [13]. https://doi.org/10.1136/bmj.n71

**Table 1.** Characteristics of the included studies

| Year/country | Type of study | No. of participants | Mean age (yr) | Condition/ operation type | Type of cancer | Neoadjuvant chemotherapy |
|---|---|---|---|---|---|---|
| 2020/Italy [16] | Retrospective | 20 | 67.8 | MI Ivor-Lewis (9), MI McKeown (10), MI transhiatal (1) | ADC (8), SCC (12) | 14/16 |
| 2021/Italy [21] | Prospective | 18 | 67.28 | MI Ivor-Lewis (18) | ADC (18), SCC (0) | All patients |
| 2021/UK [22] | Prospective comparison study (NCT03292757) | 20 | 62 | MI Ivor-Lewis (3), open left thoracoabdominal (7), open Ivor-Lewis (10) | NA | All patients |
| 2022/Japan [15] | Retrospective | 16 | 66 | MI Ivor-Lewis (4), MI McKeown (12) | ADC (5), SCC (10), other (1) | 13/41 |
| 2022/India [19] | Prospective | 21 | 54 | MI McKeown (21) | ADC (0), SCC (21) | All patients |
| 2023/China [18] | Prospective, open-label, single-arm clinical study | 41 | 64 | MI Ivor-Lewis (32), MI McKeown (9) | ADC (2), SCC (37), MM (1), NET (1) | 94/99 |
| 2023/India [20] | Prospective | 99 | 55 | MI McKeown (99) | ADC (19), SCC (79), adeno squamous (1) | 14/18 |
| 2024/Iran [17] | Prospective, comparison control study | 36 | 56 | MI McKeown (36) | ADC (10), SCC (26) | Not reported |
| 2024/India [23] | Prospective comparison study | 50 (25 in each group) | 47.4 | MI McKeown (50) | ADC (22), SCC (28) | All patients |
| Total | NA | 321 | 57.5 | MI McKeown (237), MI Ivor-Lewis (66), MI transhiatal (1), open thoracoabdominal or Ivor-Lewis (17) | ADC (84), SCC (213), other (4) | 282 |

MI, minimally invasive; ADC, adenocarcinoma; SCC, squamous cell carcinoma; NA, not available; MM, malignant melanoma; NET, Neuroendocrine Tumor.

tranodally under ultrasound guidance) in 9 studies [14-23], in the foot dorsum in 1 study [23], in the small bowel mesentery [22], and lastly, 1 study described unsuccessfully administrating ICG via the enteral route, through the existing feeding jejunostomy [22]. According to the included studies, the ICG injection route for potentially successful TD identification appeared to be the inguinal region, as 248 patients received ICG through the inguinal nodes with a success rate of 96%. Table 2 summarizes all characteristics and results of the evaluated papers. The mean observation time of the TD after ICG administration was 162 minutes (range, 20 minutes to 20 hours). In most studies, only a few cases necessitated intraoperative prophylactic ligation of the TD (n=50) (Table 2). Overall, 2 studies that administered ICG to identify TD reported, in total, 2 cases of postoperative chylothorax (0.66%) [15,22]. In the 18 patients who did not receive ICG, only 1 case of postoperative chylothorax was reported [17]. Two studies reported further fat administration to optimize TD identification (18 patients) [17]. All reported chylothorax cases were successfully treated conservatively. There were no acute or long-term complications of ICG administration in any of the included studies. Overall, this appears to be a safe and feasible technique to perform. The mean additional time required for ICG injection was approximately 12.3 minutes in the reported studies. Furthermore, none of the included studies reported more than 15 minutes for IGC administration.

## Surgical technique

Surgical strategies to recognize and prevent injury to the TD intraoperatively with ICG administration varied among the included studies [15-23]. The most frequently described technique supports injecting 0.2–0.5 mg/kg of ICG into the subcutaneous tissue in the inguinal region bilaterally under ultrasound guidance immediately before repositioning the patient for the thoracic stage of oesophagectomy or exactly after completing the abdominal stage. Most studies preferred the inguinal lymph node region, as the lymph nodes are superficial, consistently present, easily accessible, relatively larger in size, and easy to visualize under ultrasound [15-20]. Alternatively, ICG could be administered in the small bowel mesentery during the abdominal phase [22] or the foot's first web space just before thoracoscopy or thoracotomy [23].

According to the included studies, the time required to

**Table 2.** Results of the included studies

| Study | ICG dose | Area of injection | Time to evaluate from ICG injection | TD identification success | Chylothorax incidence | Prophylactic TD ligation/ dissection |
|---|---|---|---|---|---|---|
| [16] | 0.5 mg/kg | Bilateral superficial inguinal lymph nodes | 52.7 min | All patients | None | 3/20 |
| [21] | 0.5 mg/kg | Bilateral superficial inguinal lymph nodes | 20 hr | All patients | None | All patients |
| [22] | - ICG cream (group 1): 50 mL of double cream mixed with 2.5 mL of reconstituted ICG (10 mL in 25 mg of ICG)<br>- Small bowel mesentery (group 2): 1.5–2 mL of reconstituted ICG (as above) | Group 1: administered via feeding jejunostomy<br>Group 2: injected into the small bowel mesenteric root | 150 min | 15/20 (all patients in group 1 and 2 patients in group 2) | 1/20 | NA |
| [15] | 0.2–0.5 mg/kg | Bilateral superficial inguinal lymph nodes | 119 min | 15/16 | 1/16 | 5/16 |
| [19] | 2 mL of 1 mg/mL solution of ICG | Bilateral superficial inguinal lymph nodes | 35 min | All patients | None | 3/21 |
| [18] | 4 mL of reconstituted ICG | Right inguinal lymph nodes | 30 min | 38/41 | None | 3/41 |
| [20] | 25 mg powder reconstituted in 10 mL of water—1 mL solution contains 2.5 mg of dye | Bilateral superficial inguinal lymph nodes | 60 min | 93/99 | None | 16/99 |
| [17] | 1 mg | Bilateral superficial inguinal lymph nodes | 81.39 min | All patients | 1/36 (non-ICG group) | 2 (1 in each group) |
| [23] | 1 mL of ICG dye in both groups | Group 1: bilateral inguinal nodes<br>Group 2: bilateral foot first web space | Group 1: 20 min<br>Group 2: 45 min | All patients in group 1 and 18/25 in group 2 | None | None |
| Total | NA | Bilateral inguinal lymph nodes: 235<br>Right inguinal lymph nodes: 41<br>- Bilateral first web space of the foot: 25<br>- Into the small bowel mesenteric root: 17<br>- Via the feeding jejunostomy: 3 | Range: 20 min to 20 hr | 281/303 patients (92.7%) who received ICG | - Chyle leak incidence with ICG 2/303 (0.66%)<br>- 3/321 (0.9%) in all groups | 50 |

ICG, indocyanine green; TD, thoracic duct; NA, not available.

administer the ICG is usually no more than 15 minutes. After placing the thoracic trocars or performing thoracotomy, most authors recommended dissection of the peri-oesophageal tissues before switching the camera to NIR mode. When this step is achieved, the camera could be switched from standard mode to NIR mode using the camera button for TD visualization and checking for potential injury intraoperatively when visualization of the TD is expected to be optimal. The operating room light is turned off during TD imaging. Studies reported that the TD was visualized approximately 1 hour after the small bowel mesentery ICG injection and 2 hours after the inguinal lymph node ICG injection. Only 1 of the included studies reported administering ICG the night before the oesophagectomy [21]. Confirmation of the anatomy and the ability to switch camera images from standard light to NIR mode made the dissection safe and feasible in all included studies. Moreover, in cases where the TD needed dissection for oncological radicality, the ICG and NIR fluorescence assisted in ligating the 2 stumps and checking for the absence of any leakage.

Few of the included studies also performed preoperative

fat meal administration through jejunostomy or nasogastric tube, which has been shown to improve TD visibility and reduce iatrogenic duct damage [15,22]. Of course, more cases are needed to determine whether this step is beneficial or whether it can be omitted. Lastly, it is recommended that further studies determine with certainty whether the site of injection and the concentration used could be standardized.

### Comparison of ICG administration versus no ICG

In 1 study, ICG was compared with no ICG administration [17]. More specifically, 18 patients received ICG, and 18 patients underwent oesophagectomy without ICG. Each group had a 5.5% rate of TD ligation. In the ICG group, TD injury was detected intraoperatively, and ligation was performed at the injury site. In all ICG patients, the entire thoracic course of TD was visualized clearly after a mean time of 81.39 minutes from ICG injection to visualization. No patient in the ICG group experienced chylothorax. One patient in the non-ICG group developed postoperative chylothorax that was managed conservatively.

### Comparison of different ICG administration areas and routes

The 2 studies that compared different ICG administration methods described different approaches. In the first study [23], patients were divided into the inguinal node and foot-first web space ICG instillation groups. Under ultrasound guidance, the former group had 1 mL of ICG dye instilled into the bilateral inguinal nodes. In contrast, the other group received 1 mL of ICG dye injected at the bilateral foot first web space and then underwent surgery. The TD was visualized in 72% of cases of the first web space instillation group, whereas 100% was visualized in the inguinal node instillation group. None of the patients had chyle leak or an acute complication from ICG. The researchers also did not describe any necessitated prophylactic TD ligation. In the second study [22], ICG was administered via 2 different routes: the first group received ICG mixed with double cream administered enterally via a feeding jejunostomy, and the second group had a sub-peritoneal injection of ICG into the small bowel mesentery during the abdominal phase of surgery. The primary outcome of the study was TD identification. However, early in the study (in the first 3 patients), the enteral route failed to fluoresce the TD and was abandoned. The TD was identified under fluorescence after a mesenteric injection in the rest of the included patients. In 6 of the 17 participants receiving ICG via a mesenteric injection, an intraoperative TD injury was identified by fluorescence imaging only, and the TD was ligated. None of the patients experienced a postoperative chyle leak. The study concluded that ICG administration via mesenteric injection could successfully highlight the TD during oesophagectomy and may be a potential technology to prevent chyle leaks following surgery.

Overall, the inguinal region appears to be the most successful area for ICG application. Eight of the included studies, with a total of 271 patients, reported a success rate of 92.7% for TD identification from ICG application through the inguinal region under ultrasound guidance.

## Discussion

ICG already has various surgical applications, including evaluating anastomotic perfusion, recognizing anatomical structures (such as blood vessels, biliary vessels, and lymphatic vessels), and detecting lymphatic drainage for sentinel node biopsy [24]. ICG for intraoperative TD lymphography is a novel technique that can be successfully used to prevent chyle leaks following thoracic surgery and oesophagectomy. It is generally considered a safe and well-tolerated technique [25]. The special cameras used in ICG-NIR can be incorporated in both laparoscopic, open, and robotic surgery, which makes it straightforward to adapt ICG assessment to existing surgical procedures [26].

The present study is a large cohort review of pooled data suggesting that ICG administration decreases chylothorax rates as it facilitates easy, expeditious, and safe real-time TD identification during thoracic surgery. A study with a pooled population of more than 300 patients showed a chyle leak rate of 0.66% after using ICG, substantially lower than the reported incidence of 2%–12% [1-3]. Furthermore, the TD identification success rate with ICG administration was 92.7%, suggesting that real-time NIR imaging could be effective and beneficial in intraoperative TD lymphography and prevention of post-oesophagectomy chyle leak. It appears to be a safe and effective technique for TD identification to both prevent and identify iatrogenic TD injury, and there are no reported acute or long-term complications in the existing literature.

Preventing postoperative chylothorax is of utmost importance during oesophagectomy. Although its prevalence is considered low, its existence is correlated with high morbidity and mortality rates. High volumes of fluid can be lost from a TD injury, resulting in long durations of in-

dwelling chest drains, hypovolemia and malnutrition from the loss of fat-soluble vitamins, proteins, loss of emulsified fat, chylomicrons and electrolytes. The risk of sepsis secondary to lymphopenia from the depletion of T-cells and death following TD injury is also increased [27], with the mortality rate reported as high as 75%. When a large-volume leakage occurs, operative intervention is required to localize the leak and ligate the TD. Such reoperation in the early postoperative setting can be extremely challenging, partly due to variations in TD anatomy and its accessory channels [28]. Moreover, identifying the site of TD chyle leak during reoperative procedures can be difficult. Several methods, such as magnetic resonance-thoracic ductography and lymphoscintigraphy, using Tc99-filtered sulfur colloid combined with single-photon emission computed tomography have been described; however, none of these methods provides dynamic real-time imaging in operation theatre. ICG is a highly promising method for real-time identification of the TD during oesophagectomy. In those patients, the ICG-NIR technique may be highly efficient for intraoperative assessment of a missed TD injury, providing an excellent clinical tool for the identification of a chylous leakage site with very high levels of sensitivity and specificity. Therefore, an easy-to-perform and quick preventative method that facilitates real-time TD identification at the index thoracic operation would be of great importance. However, no randomized controlled trials have been performed yet, and the existing studies generally provide low-grade evidence.

Previous studies have already proven the efficacy of ICG in identifying the TD in animal models. Ashitate et al. [29] reported that ICG-NIR fluorescence imaging could provide real-time visualization of TD anatomy in pigs. Moreover, Steffey and Mayhew [30] successfully performed TD ligation in 15 dogs by identifying the TD using intraoperative ICG-NIR lymphography through popliteal lymph nodal ICG injections. Lastly, Kamijo et al. [31] compared computed tomography lymphography and ICG-NIR fluorescent thoracoscopy to successfully identify the TD in cats.

Apart from animal models, other recent studies have described the identification of the TD during various operations, including lateral neck lymph node dissection. The pioneering study in this field was conducted by Chakedis et al. [32]. The authors described the successful identification of the TD in 5 of 6 patients (83.3%) who underwent lateral modified radical neck dissection for thyroid cancer and melanoma [32]. In their study, 1–2 mL of ICG was injected into the patient's left foot, and subsequently, the TD was identified by using a handheld NIR probe. No injuries of the TD were identified, and there were no chylous fistulas on follow-up. Another recent study performed by Yang et al. [33] described the utility of the ICG in 4 patients diagnosed with postoperative chylothorax after pulmonary resection and mediastinal nodal dissection. ICG dye at a dosage of 0.2 mg/kg was injected subcutaneously into the bilateral inguinal region approximately 30 minutes before surgery to detect the site of the leak. The authors reported successful identification and ligation of the TD with NIR thoracoscopy and real-time fluorescence lymphography, resulting in chylothorax resolution. Furthermore, few case reports in the literature have described the successful use of ICG for TD identification and ligation in patients who had postoperative chylothorax after oesophagectomy [34-37]. All concluded that the potential use of ICG to help identify chyle leak at the time of reoperative surgery would be highly efficient. Lastly, 2 interesting case reports on patients without oesophageal cancer reported outcomes of successful TD visualization with ICG assistance in patients who had idiopathic chylothorax without any known previous thoracic intervention [38,39].

We acknowledge that identifying the TD can be challenging in patients who undergo salvage oesophagectomy and/or had neoadjuvant chemoradiotherapy, due to existing fibrosis. Especially in those cases, ICG-NIR may be helpful, as it could assist in performing safer dissection in these scenarios. Furthermore, according to the findings from the present review, the key to successful imaging of the TD could be a proper image-confirmed intranodal inguinal ICG injection, as this appeared to be the most successful route for ICG administration. The results of this study indicate that fluorescence guidance could facilitate safe, rapid, and comfortable thoracic dissection, giving constant feedback to the surgeon without the need for additional instruments or interruptions in the surgical field. Additionally, in cases requiring resection of the TD for oncological radicality, fluorescence imaging aids in easy ligation of the stumps and real-time checking for any chyle leakage. Prophylactic ligation of the TD during oesophagectomy is not a routine procedure. However, it has been performed in order to reduce the incidence of postoperative chylothorax. Recent meta-analyses have not managed to come to an agreement on whether prophylactic TD ligation would be beneficial [40-44]. Taking this into consideration, ICG-NIR could help preserve the TD when only tributaries need to be resected and ligated close to the main TD for oncological reasons.

Overall, we recommend standard incorporation of ICG

in patients undergoing oesophagectomy for TD visualization and prevention of iatrogenic injury. Due to existing fibrosis, IGC visualization of TD appears significantly beneficial in preventing iatrogenic TD injuries, especially in those undergoing salvage oesophagectomy and/or having received neoadjuvant chemoradiotherapy. This simple technique may help reduce postoperative chylothorax complications and simplify patients' postoperative recovery. However, additional studies involving larger patient populations are needed to strengthen the external validity of the results and provide further insights into which subgroups of patients could benefit most from prophylactic ICG use in oesophagectomy.

This review has some limitations. In particular, it is a rather medium-sized study of pooled data, including 321 patients, and lacked randomization or effective comparison. However, to our knowledge, it is the most recent and up-to-date review of the existing literature, suggesting that ICG administration decreases chylothorax rates. It includes all the high-quality studies published to date. Larger randomized controlled trials are required to validate these results and add further value in improving perioperative and oncological outcomes in thoracic surgery.

## Conclusion

Real-time TD lymphography with ICG-NIR is a novel technique that can successfully identify chyle leaks during thoracic surgery and oesophagectomy. Based on the existing evidence, routine TD identification with ICG fluorescence may prevent chylothorax and improve perioperative outcomes in patients undergoing oesophagectomy. However, larger, high-quality, randomized controlled studies would be beneficial in justifying the true value of ICG in TD identification on a longer basis and in reducing the post-oesophagectomy chyle leak rate.

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### Author contributions

Data curation: DP. Formal analysis: MB. Methodology: DP. Project administration: DP. Visualization: MB. Writing–original draft: DP. Writing–review & editing: MB. Final approval of the manuscript: all authors.

### Conflict of interest

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### Supplementary materials

Supplementary materials can be found via https://doi.org/10.5090/jcs.24.091. **Supplementary Table 1**. Risk of bias in the included studies (MINORS rating score).

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