

Narrative Review on the Use of Indocyanine Green Fluorescence in Surgical Oncology

Danilo COCO^a, Silvana LEANZA^a

^aDepartment of General, Robotic and Oncologic Surgery,
Giglio Foundation Hospital Cefalu', Palermo, Italy



ABSTRACT

Indocyanine green (ICG) has emerged as a transformative tool for intraoperative imaging in the field of oncology, significantly improving the identification and localization of tumors, lymphatic structures and metastatic lesions. This narrative review aims to synthesize findings from a comprehensive range of studies that evaluate the efficacy, applications and limitations of ICG fluorescence-guided surgery across various surgical specialties, including colorectal, gynecologic and hepatobiliary oncology.

We meticulously analyzed studies published from 2010 to the present, highlighting the technical aspects of ICG administration and imaging techniques as well as the quantitative metrics of success, such as detection rates and negative surgical margins. The review identifies a trend toward increasing use of ICG due to its ability to provide real-time feedback during surgery, thus facilitating more precise and minimally invasive procedures.

Moreover, this review explores recent advancements in ICG applications, including multimodal imaging techniques that combine fluorescence with other imaging modalities, such as near-infrared imaging and preoperative imaging studies. These innovations hold promise for further enhancing surgical precision, improving patient outcomes and optimizing intraoperative decision-making. Limitations associated with ICG use, such as variability in fluorescence intensity among different tumor types and the challenge of quantifying the optimal dosage, are also discussed. In conclusion, this narrative review underscores the critical role of ICG fluorescence in modern surgical oncology and provides insights into future research directions aimed at refining its use and expanding its applicability. Potential avenues for investigation include standardized protocols for ICG administration, investigation of patient selection criteria and comprehensive evaluations of long-term outcomes associated with ICG-guided surgical procedures.

Keywords: indocyanine green (ICG), fluorescence-guided surgery, oncology, colorectal surgery, hepatobiliary surgery, gynecologic surgery.

Address for correspondence:

Danilo Coco, MD

Department of General, Robotic and Oncologic Surgery, Giglio Foundation Hospital Cefalu', Palermo, Italy

Email: webcostruction@msn.com

Article received on the 6th of November 2024 and accepted for publication on the 16th of December 2024

INTRODUCTION

Indocyanine green (ICG) is a fluorescent dye that absorbs near-infrared light, making it ideal for real-time imaging in a variety of surgical procedures. Its primary role in surgery is to visualize blood vessels and tissues, which in turn aids surgeons in distinguishing healthy tissues from pathological ones. The utilization of ICG has notably increased in oncology, where accurate delineation of tumor margins and detection of metastases are critical for successful surgical outcomes. By providing enhanced visualization, ICG empowers surgeons to make more informed decisions during operations, potentially improving the prognosis of patients.

Recently, advances in fluorescence imaging technology have broadened the applications of ICG in surgical fields, leading to a transformation in traditional surgical techniques. For instance, integrating ICG into minimally invasive procedures, such as laparoscopic and robotic surgeries, allows for greater precision while also minimizing recovery times and associated complications for patients. The versatility of ICG across various surgical contexts, including colorectal, gynecologic and hepatobiliary surgeries, underscores its significant potential as a tool for enhancing surgical care.

This narrative review aims to synthesize the existing literature on the role of ICG in fluorescence-guided surgery (FGS) and highlight key findings, clinical applications, challenges and future research directions regarding the impact of ICG on surgical outcomes across multiple disciplines in oncology. □

METHODS

To gather relevant studies focused on ICG in surgical oncology, a structured literature search was performed using PubMed, Scopus and other recognized medical databases. The search targeted publications from 2014 to 2024, with a focus on studies that utilized ICG in surgical interventions. A Boolean search strategy was employed, incorporating specific keywords such as "Indocyanine green", "fluorescence-guided surgery", "neoplasms", "colorectal cancer" and "peritoneal metastases" as well as related terms to refine our search.

Inclusion and exclusion criteria

Inclusion criteria mandated that studies be peer-reviewed articles published in English, focusing specifically on the use of ICG within surgical settings. To ensure a comprehensive evaluation, the review encompassed a wide array of study designs, including randomized controlled trials, observational studies, cohort studies and case reports. The selected studies needed to provide clear data on the effectiveness of ICG-enhanced surgical techniques and report clinical outcomes, including rates of tumor detection, positive surgical margins and complications.

Exclusion criteria comprised studies that were non-peer-reviewed, published in languages other than English, or focused on animal models. Investigations that did not specifically address the implementation of ICG fluorescence in surgical contexts were also omitted from the review.

Data extraction and categorization

Identified studies were systematically reviewed and categorized according to their surgical applications, which included colorectal surgery, gynecologic surgery, hepatobiliary surgery and other pertinent oncological interventions. Information was meticulously extracted regarding procedural effectiveness, intraoperative imaging outcomes, patient safety and postoperative results.

Statistical analysis

Key findings were quantitatively and qualitatively analyzed. Meta-analytical techniques were applied where appropriate to synthesize data, particularly in studies with comparable outcomes. Heterogeneity among studies was assessed using the I^2 statistic and the potential for publication bias was evaluated through the Egger test. The overall strength of the collective evidence was analyzed, with a focus on the implications for clinical practice and future research directions.

Adherence to PRISMA-P guidelines

This narrative review was conducted in accordance with PRISMA-P guidelines, which provides a structured framework for reporting systematic reviews and meta-analyses. A PRISMA flowchart was included to visually represent the study selection process, detailing the number of records identified, screened, assessed for eligibility and included in the review (Figure 1). This step-by-step

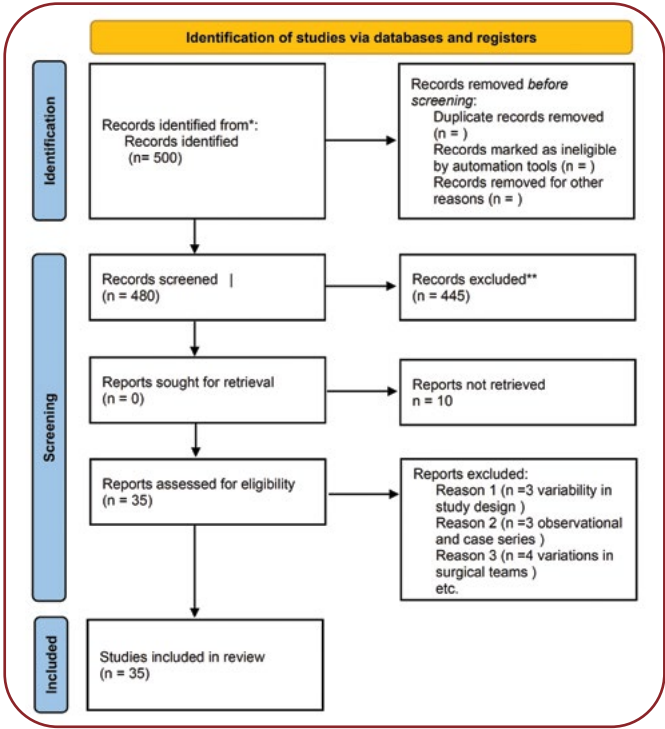


FIGURE 1. PRISMA flow diagram of the selection process
Records identified (n = 500): total number of records identified through database searches.
Records screened (n = 480): the number of records after duplicates removed.
Records excluded (n = 445): records excluded for not meeting eligibility criteria based on title/abstract.
Full-text articles assessed for eligibility (n = 35): the number of articles reviewed in full text.
Studies excluded (n = 10): specific reasons for exclusions at this stage can be added (*e.g.*, not involving ICG, non-humans).
Studies included in the review (n = 35): number of studies included for analysis.

PRISMA-P checklist for a systematic review on ICG in surgical oncology	
1. Title	
Identify the report as a systematic review protocol:	
"Systematic review protocol: Use of indocyanine green fluorescence in surgical oncology"	
2. Abstract	
Provide a structured abstract:	
Objective, background, methods, expected results and conclusion.	
3. Introduction	
Rationale: explain the reasons for the review.	
Objectives: state the specific objectives or hypotheses of the review.	
4. Methods	
Eligibility criteria: describe criteria for including and excluding studies.	
Information sources: list all databases and other sources of information.	
Search strategy: provide a detailed search strategy.	
Selection process: describe the process for selecting studies (<i>e.g.</i> , screening, eligibility assessment).	
Data extraction: detail the method for extracting data from included studies.	
Risk of bias assessment: explain how the risk of bias will be assessed in individual studies.	
Data synthesis: specify methods for synthesizing data and any planned statistical analyses.	
Meta-analysis: indicate if a meta-analysis is planned, and if so, describe the methods.	
Subgroup analyses: specify any planned subgroup analyses.	
Sensitivity analysis: describe any planned sensitivity analyses.	
5. Results	
Study selection: describe the number of studies that met the inclusion criteria.	
Study characteristics: describe the characteristics of included studies.	
Synthesis of results: present the results including any adverse effects.	
6. Discussion	
Summary of evidence: provide a summary of the main findings.	
Limitations: discuss potential limitations of the evidence.	
Implications for practice: discuss implications for clinical practice and future research.	
7. Funding	
Provide details about the sources of funding and any potential conflicts of interest.	

TABLE 1. PRISMA-P checklist for a systematic review on indocyanine green fluorescence (ICG) in surgical oncology

methodology ensured transparency and reproducibility in the review process (Table 1).

Synthesis of findings

Key findings were systematically extracted from the literature concerning the effectiveness of ICG in surgical procedures, interactions with other imaging modalities and intraoperative implementation of fluorescence imaging techniques. Furthermore, the review explored overall patient outcomes, highlighting improvements in surgical precision, reductions in operative time and decreases in the rates of complications.

The present review also addressed complications, limitations and challenges associated with the usage of ICG technology in surgery, including variability in fluorescence intensity among different tumors, optimal dosage considerations and logistical challenges in operating room settings.

Overall, this systematic examination aims to present a nuanced understanding of ICG's role in surgical oncology, paving the way for future innovations and enhanced patient care protocols. ▣

RESULTS

Colorectal surgery

1. Application of indocyanine green fluorescence

A pivotal study conducted by Liberale *et al* demonstrated that ICG fluorescence-guided surgery significantly enhanced the detection of hepatic and lymphatic metastases in patients diagnosed with colorectal cancer. The study was particularly noteworthy as it highlighted the capability of ICG to reveal metastatic sites that were previously undetectable through standard imaging techniques. By facilitating the identification of these elusive metastatic locations, surgeons were able to perform more comprehensive resections. The findings indicated that such thoroughness enhance surgical outcomes, correlating with reduced recurrence rates and longer postoperative survival times (1). This is critically important in colorectal surgery, where the presence of metastases can dramatically influence the treatment plan and overall prognosis. By integrating ICG into surgical practice, clinicians are better equipped to achieve a more complete tumor resection, which is a key determinant of long-term patient survival.

2. Assessment of intestinal blood flow

The research conducted by Watanabe *et al* explored the profound utility of ICG in the assessment of blood flow near the rectosigmoid junction, a pivotal region during colorectal surgeries. The study emphasizes that the real-time visualization provided by ICG angiography is instrumental in preventing ischemic complications, which can arise from inadequate blood supply to the intestinal tissues. Surgeons were able to utilize ICG to visualize arterial perfusion and assess tissue viability, leading to informed intraoperative decisions regarding resections and anastomoses. This ability to visualize blood flow real-time translates into a marked decrease in post-operative complications, such as anastomotic leaks and bowel ischemia, ultimately improving patient healing and recovery outcomes (2). The real-time feedback cycle allowed by ICG not only enhances the safety of the surgical procedure but also significantly contributes to enhancing the overall quality of care delivered to patients undergoing complex colorectal surgeries.

3. Colorectal cancer metastasis identification

In a study by Nakamura *et al*, the effectiveness of intraoperative near-infrared fluorescence systems was highlighted in detecting needle tract implantation and peritoneal seeding after radio-frequency ablation in patients with recurrent hepatocellular carcinoma. Although the primary focus is on hepatocellular carcinoma, the implications of this study deeply resonate within the field of colorectal cancer treatment, particularly in identifying metastatic spread. This research underscores the utility of ICG in monitoring potential intraoperative complications and bolstering surgical safety in colorectal contexts. Accurate identification of metastatic disease is crucial for determining the success of surgical interventions. By employing ICG, surgeons can gain a clearer picture of the extent of cancer spread, which is instrumental in guiding subsequent therapeutic strategies, whether they involve additional surgical interventions, chemotherapy, or targeted therapies (3). The integration of ICG into the surgical workflow not only aids in the meticulous identification of tumors but also instills greater confidence in surgical teams, thereby enhancing the overall approach to managing colorectal cancer.

Gynecologic surgery

1. Endometriosis detection

In a pivotal study, Siegenthaler *et al* critically examined the effectiveness of laparoscopy combined with near-infrared optics using ICG to identify endometriosis lesions, a condition that has been often posing diagnostic and therapeutic challenges. Their findings reveal that the fluorescence emitted by ICG significantly enhance the visualization of endometriosis lesions, which are typically difficult to detect with conventional techniques. This enhanced visibility leads to improved surgical precision, enabling surgeons to more accurately target and excise affected tissue during laparoscopic procedures. Moreover, the study suggests that the use of ICG may contribute to a reduction in recurrence rates of endometriosis postoperatively, as more complete lesions can be managed during surgery. The implications of this research are profound, indicating that the integration of ICG in laparoscopic endometriosis management can lead to enhanced patient outcomes, including decreased incidence of chronic pain and other complications associated with untreated lesions (4).

2. Nerve-sparing surgery in endometriosis

Kanno *et al* provided compelling evidence supporting the role of ICG in facilitating nerve-sparing surgeries for deep endometriosis, which can often compromise critical neurovascular structures. Their study demonstrate that the fluorescence visualized via ICG allows surgeons to effectively identify and preserve these crucial structures during surgical excision. The ability to differentiate between endometrial tissue and surrounding nerves under fluorescent light is instrumental in achieving optimal surgical outcomes, particularly in preserving urinary and sexual function postoperatively. By minimizing trauma to neurovascular tissues, ICG not only enhances the overall safety of the procedure but also significantly reduces patient morbidity, improving the quality of life for those undergoing treatment for deep endometriosis. This research highlights ICG's potential as a valuable tool in enhancing the precision of complex gynecologic surgeries, affirming its role in advancing minimally invasive techniques while safeguarding critical anatomical features (5).

3. Evaluation of anastomotic perfusion

A groundbreaking randomized controlled trial conducted by Leitao *et al* evaluated the applica-

tion of near-infrared technology with ICG to assess anastomotic perfusion during rectosigmoid resections in ovarian cancer patients. The study reinforces the clinical relevance of utilizing ICG for the real-time visualization of blood flow at anastomotic sites, which is critical in ensuring the viability of surgical connections. By enabling surgeons to monitor perfusion patterns intraoperatively, the use of ICG significantly aids in identifying poorly perfused segments that could be susceptible to ischemia, thereby reducing the risk of anastomotic complications such as leaks or strictures. The findings of this trial not only emphasize the importance of optimizing anastomotic techniques in gynecologic oncology but also showcase the broader potential of ICG in enhancing surgical outcomes. The integration of real-time perfusion assessment represents a significant advancement in surgical practice, aligning with the goals of improving patient safety and recovery (6).

Hepatobiliary surgery

1. Detection of peritoneal recurrence

In a significant study by Hayashi *et al*, the authors delved into the limitations of ICG fluorescence in detecting peritoneal recurrence, particularly following hepatectomy for hepatocellular carcinoma. While ICG has shown promise in various surgical contexts, the study reveals that its sensitivity in identifying peritoneal metastasis is suboptimal, which poses a challenge in ensuring comprehensive surgical management. The researchers emphasized the necessity for optimized strategies to enhance the efficacy of ICG in this particular surgical setting. Suggestions included exploring adjunctive agents that may complement ICG's fluorescence properties or modifying existing imaging protocols to improve visualization and sensitivity (7). The findings underscore the importance of continued innovation in fluorescence imaging, encouraging the development of multi-modal approaches that could potentially improve diagnostic accuracy and surgical outcomes in patients with advanced hepatobiliary cancers.

2. Fluorescence imaging for hepatic metastasis

In another pivotal work, Bijlstra *et al* illustrated the application of ICG in fluorescence-guided metastasectomy for hepatic metastases, providing a valuable contribution to the field of oncological surgery. Their research demonstrates that the inte-

gration of ICG significantly enhances surgical practices by offering real-time feedback during the resection of metastatic lesions. The ability to visualize hepatic tumors more clearly during the surgical procedure has been shown to improve surgical precision, thereby facilitating more effective removal of malignancies while sparing surrounding healthy tissue. This targeted approach not only minimizes intraoperative complications but also significantly reduces postoperative morbidity, ensuring better recovery trajectories for patients (8). Furthermore, this study highlights the potential for ICG to be implemented as a standard component of surgical protocols for hepatic metastasis, thereby transforming the conventional approach to managing these complex cases.

3. Robotic surgery with ICG

The groundbreaking work presented by Spinoglio *et al* showcased the successful applications of ICG in robotic right colectomy with complete mesocolic excision, emphasizing its instrumental role in enhancing outcomes during intricate surgical procedures. Their study illustrates how the incorporation of ICG into robotic surgery aids in accurate tumor localization and critical anatomical identification, addressing one of the persistent challenges in managing colorectal malignancies. The enhanced visualization afforded by ICG allows surgeons to navigate complex anatomical structures with greater confidence and precision, thereby facilitating safer and more effective resections (9). Moreover, the use of robotic platforms, combined with ICG fluorescence, opens avenues for minimally invasive surgical techniques, potentially leading to decreased postoperative pain, shorter recovery times and improved overall patient satisfaction. This integration of technology underscores a promising trend in surgical oncology, where innovative tools are increasingly employed in tandem to enhance clinical outcomes for patients with hepatobiliary cancers.

Other applications

1. Sentinel lymph node mapping

In a pioneering study, Buda *et al* introduced an innovative approach for sentinel lymph node mapping utilizing the near-infrared fluorescent S1 HD Pinpoint System in conjunction with ICG. Their research emphasized the versatility of ICG in a variety of surgical settings beyond traditional oncology, revealing its potential as a reliable tool

for facilitating lymphatic mapping. The study demonstrates that ICG could effectively delineate sentinel lymph nodes, providing surgeons with real-time visual feedback that improves the accuracy of lymphatic staging in various cancers. By successfully navigating lymphatic drainage patterns, this technique not only enhances intraoperative decision-making but also has significant implications for reducing the incidence of postoperative complications associated with sentinel node biopsy. The findings contribute to the expanding body of evidence which supports the adoption of fluorescence-guided techniques in improving the precision of surgical interventions and patient outcomes (10).

2. Assessment of intestinal viability

The research conducted by Diana *et al* explored the profound implications of using an enhanced-reality fluorescence system to assess intestinal viability during laparoscopic procedures. This innovative study effectively deployed ICG to visualize tissue perfusion, a critical factor in preventing ischemic complications that can occur during gastrointestinal surgeries. By allowing surgeons to evaluate blood flow in real-time, ICG enhances surgical safety by assisting in making informed decisions regarding resection margins and anastomotic approaches. The ability to monitor tissue viability intraoperatively leads to a higher degree of surgical safety, ultimately reducing the risks of postoperative complications such as bowel necrosis or leakage. This advancement in laparoscopic surgery highlights the potential for improved patient outcomes through the integration of cutting-edge imaging technologies that focus on the preservation of functional organ tissue (11).

3. Detection of peritoneal endometriosis

In a notable case report, Levey illustrated how fluorescence imaging with ICG significantly aided in the identification of peritoneal endometriosis. Historically, diagnosing endometriosis can be a challenge due to its often subtle presentation and the limitations of conventional imaging techniques. This case underscores ICG's potential to enhance detection capabilities during gynecologic surgeries, thus improving surgical outcomes and the overall quality of life for patients suffering from this condition. By providing enhanced visualization of pathological lesions, ICG facilitates more accurate excision of endometrial implants

and adhesions. This approach showcases how ICG can be utilized beyond oncological applications, contributing positively to the field of women's health and further demonstrating the versatility of fluorescence imaging in various surgical contexts (12).

4. Robotic single-site endometriosis resection

Research conducted by Guan *et al* delved into the application of ICG in robotic single-site endometriosis resection, leveraging Firefly technology to enhance surgical outcomes. Their findings revealed the efficacy of ICG in improving surgical detection rates, which is particularly crucial in minimally invasive procedures where visualization can be limited. By providing real-time fluorescence guidance, ICG supports critical decision-making by allowing surgeons to identify and excise endometrial tissue with precision while minimizing damage to surrounding structures. This application exemplifies the beneficial intersection of robotic surgical techniques and advanced imaging modalities, underscoring the potential for ICG to enhance the quality of surgical care in the complex management of endometriosis. As the field of minimally invasive surgery continues to evolve, the integration of technologies such as ICG promises to further improve surgical efficiency and patient satisfaction (13). □

DISCUSSION

The integration of ICG into surgical oncology signifies a substantial advancement in intra-operative imaging techniques, representing a transformative approach to surgical guidance. The insights derived from the reviewed studies unequivocally highlight that ICG markedly enhances visualization in both colorectal and gynecologic surgeries (1, 4). This improvement in visualization has far-reaching consequences, including facilitating surgeons' ability to identify and delineate tumors, evaluate surrounding tissues, and recognize critical vascular structures. The real-time feedback enabled by ICG provides important assessments of blood flow and tissue viability, which contribute significantly to enhanced surgical outcomes and improved patient safety (2, 5).

Additionally, the combination of ICG technology with robotic and minimally invasive surgical techniques exemplifies its remarkable versatility

and critical importance across a wide spectrum of surgical contexts. Studies documented that robotic applications of ICG have shown superior efficacy in performing complex surgical procedures, suggesting a broader potential for the adoption of ICG within robotic surgical platforms (9). For instance, Spinoglio *et al* (2019) demonstrated the successful use of ICG in robotic right colectomy, leading to improved precision in tumor localization and enhanced visualization of anatomical structures (9). Such advancements highlight how ICG can augment standard surgical approaches, yielding better outcomes for patients.

Nevertheless, despite these promising findings, several challenges and limitations persist, particularly regarding optimal implementation strategies for ICG in complex surgical situations, such as those frequently encountered in hepatobiliary surgeries (3, 7). Standardization of ICG protocols is essential for maximizing its potential benefits; variations in administration timing, dosage strategies, and imaging techniques can significantly impact the effectiveness of ICG-guided procedures (6). Moreover, specialized training in fluorescence-guided surgical techniques is crucial for surgical teams to harness the full capabilities of this technology (8). Without such training, there may be variations in the quality of outcomes linked to the operator's experience and technical proficiency.

Ongoing research should aim to refine methodologies for applying ICG in clinical practice and focus on conducting large-scale, multicenter studies to establish standardized protocols and further validate existing findings. Such efforts are vital to mitigate the variability and inconsistency in current research, thereby enabling a clearer framework for the practical application of ICG in diverse surgical scenarios. Furthermore, enhancing education and training programs for medical professionals will foster the wider adoption of ICG fluorescence technology across different surgical specialties, ultimately leading to improved patient care and outcomes (10). Investigating the long-term implications of ICG use, such as its effect on cancer recurrence rates and overall survival, will also be essential in reinforcing the value of this technology in surgical oncology.

In conclusion, the integration of ICG into surgical oncology presents a remarkable opportunity to elevate surgical practice through enhanced visibility and real-time feedback during procedures.

Addressing the current challenges associated with its implementation will be critical in further unlocking the potential of ICG as a routine component of surgical care. By continuing to refine techniques and develop consistent protocols, the surgical community can leverage ICG to enhance the precision and safety of oncological surgeries, ultimately improving patient outcomes.

Study limitations and potential biases

Despite the considerable advancements and promising results associated with the integration of ICG into surgical oncology, this review is not without its limitations. One significant limitation stems from the variability in study designs, methodologies and endpoints across the included studies. The heterogeneity of patient populations, surgical techniques and clinical scenarios makes it difficult to draw generalized conclusions. For instance, the different protocols for administering ICG, including variations in dosage and timing relative to surgical intervention, raise questions about the consistency and comparability of outcomes (1).

Moreover, many studies included in this review were observational or case series, which inherently limits the strength of the evidence. While randomized controlled trials (RCTs) provide more robust data, the number of such studies specifically examining ICG in surgical oncology remains relatively scarce. This scarcity can lead to an over-reliance on preliminary findings that may not be generalizable across broader populations or different surgical contexts. The potential for publication bias should also be acknowledged, as studies with positive outcomes are more likely to be published than those demonstrating minimal or negative effects, skewing the overall perceived effectiveness of ICG in surgical oncology (2).

Another limitation is the variation in the training and experience of surgical teams using ICG technology. The efficacy of ICG fluorescence can be significantly influenced by the proficiency of the operators and their familiarity with fluorescence imaging techniques. Consequently, the outcomes reported in studies may not accurately reflect the potential of ICG technology for all surgical teams or in less experienced settings. Therefore, the results could be biased towards institutions or teams with higher levels of expertise and experience.

Furthermore, the studies reviewed did not comprehensively address the long-term implications and outcomes of ICG use in surgical oncology. While intraoperative benefits such as improved visualization and reduced rates of complications are noteworthy, there is a need for further research that follows patients postoperatively to assess longer-term outcomes, such as recurrence rates, overall survival and quality of life considerations (3). Without such data, it is challenging to ascertain the true impact of ICG on comprehensive patient management and prognosis.

The variability in definitions related to endpoints also warrants consideration. For example, some studies may have measured blood flow or tissue viability using different criteria, which could lead to discrepancies when evaluating overall effectiveness across multiple research efforts. Such inconsistencies may yield results that are difficult to compare or synthesize, contributing further to the limitations of the current body of literature.

Lastly, the potential impact of confounding factors should not be overlooked. Variables such as tumor biology, the stage of cancer at the time of surgery, the presence of comorbidities, and varying surgical approaches can significantly influence outcomes. These factors can introduce bias if not adequately controlled or reported in the studies, leaving room for misinterpretation of the results related to ICG's effectiveness (4).

In conclusion, while the integration of ICG into surgical oncology exhibits substantial potential and innovation, it is essential to recognize the limitations and biases present in the current research landscape. Future studies should aim to implement more rigorous designs, such as multi-center randomized controlled trials that can provide comprehensive data on the effectiveness and safety of ICG across diverse surgical settings. In doing so, researchers will be better equipped to formulate standardized guidelines for ICG use in surgical oncology, ultimately paving the way for its wider adoption and improved patient outcomes. ■

CONCLUSION

The utilization of indocyanine green fluorescence-guided surgery presents substantial potential for enhancing surgical outcomes across various oncological fields. The evidence consolidated from the studies reviewed underscores the

capability of ICG to improve surgical precision and reduce complications, which, in turn, may positively impact patient prognosis. Sustained research efforts are essential for defining optimal protocols and expanding the applications of ICG in clinical settings. The future of surgical oncology appears primed for increased integration of

fluorescence imaging technologies, which holds the promise to revolutionize the approaches taken in complex surgical cases. ▣

Conflicts of interest: none declared.

Financial support: none declared.

REFERENCES

1. **Liberales G, Bourgeois P, Larsimont D, et al.** Indocyanine green fluorescence-guided surgery after IV injection in metastatic colorectal cancer: A systematic review. *Eur J Surg Oncol* 2017;43:1656-1667. doi: 10.1016/j.ejso.2017.04.015.
2. **Watanabe J, Ota M, Suwa Y, et al.** Evaluation of the intestinal blood flow near the rectosigmoid junction using the indocyanine green fluorescence method in colorectal cancer surgery. *Int J Colorectal Dis* 2015;30:329-335. doi: 10.1007/s00384-015-2129-6.
3. **Nakamura M, Hayami S, Ueno M, et al.** Detection of needle tract implantation and peritoneal seeding after radiofrequency ablation using intraoperative near-infrared fluorescence system for recurrent hepatocellular carcinoma: a case report. *Surg Case Rep* 2018;4:76. doi: 10.1186/s40792-018-0485-5.
4. **Siegenthaler F, Knabben L, Mohr S, et al.** Visualization of endometriosis with laparoscopy and near-infrared optics with indocyanine green. *Acta Obstet Gynecol Scand* 2020;99:591-597. doi: 10.1111/aogs.13803.
5. **Kanno K, Aiko K, Yanai S, et al.** Clinical use of indocyanine green during nerve-sparing surgery for deep endometriosis. *Fertil Steril* 2021;116:269-271. doi: 10.1016/j.fertnstert.2021.03.014.
6. **Leitao MM Jr, Iasonos A, Tomberlin M, et al.** ARIA II: a randomized controlled trial of near-infrared Angiography during Rectosigmoid resection and Anastomosis in women with ovarian cancer. *Int J Gynecol Cancer* 2024;34:1098-1101. doi: 10.1136/ijgc-2024-005395.
7. **Hayashi H, Shimizu A, Motoyama H, et al.** Usefulness and limitation of indocyanine green fluorescence for detection of peritoneal recurrence after hepatectomy for hepatocellular carcinoma: a case report. *BMC Surg* 2021;21:107. doi: 10.1186/s12893-021-01111-8.
8. **Bijlstra OD, Achterberg FB, Tummers QRJG, et al.** Near-infrared fluorescence-guided metastasectomy for hepatic gastrointestinal stromal tumor metastases using indocyanine green: A case report. *Int J Surg Case Rep* 2021;78:250-253. doi: 10.1016/j.ijscr.2020.12.058.
9. **Spinoglio G, Petz W, Borin S, et al.** Robotic right colectomy with complete mesocolic excision and indocyanine green guidance. *Minerva Chir* 2019;74:165-169. doi: 10.23736/S0026-4733.18.07831-8.
10. **Buda A, Passoni P, Reato C, Di Martino G.** Laparoscopic Minimally Invasive Approach to Sentinel Lymph Node Mapping of the Ovary Using the Near-infrared Fluorescent S1 HD Pinpoint System with Indocyanine Green Dye. *J Minim Invasive Gynecol* 2018;25:336-337. doi: 10.1016/j.jmig.2017.07.018.
11. **Diana M, Noll E, Diemunsch P, et al.** Enhanced-reality video fluorescence: a real-time assessment of intestinal viability. *Ann Surg* 2014;259:700-707. doi: 10.1097/SLA.0b013e31828d4ab3.
12. **Levey KA.** Use of fluorescence imaging technology to identify peritoneal endometriosis: a case report of new technology. *Surg Laparosc Endosc Percutan Tech* 2014;24:e63-5. doi: 10.1097/SLE.0b013e31828fa28d.
13. **Guan X, Nguyen MT, Walsh TM, Kelly B.** Robotic Single-Site Endometriosis Resection Using Firefly Technology. *J Minim Invasive Gynecol* 2016;23:10-11. doi: 10.1016/j.jmig.2015.08.001.