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Research Article

Oncologic rationale of ICG use in a general surgery department - Perfusion assessment, sentinel lymph node mapping and liver tumor identification

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Abstract

Introduction*: Over the past decade, fluorescence-guided surgery has seen an incredible surge in technical development and operating-room application, with surgeons trying to bridge the gap between the "seen" and the "unseen" oin an effort to improve surgical accuracy and structure identification. This study reports five years of institutional experience with indocyanine green (ICG) near infrared fluorescence guidance across abdominal and oncologic procedures, summarizing technical principles, clinical applications, and implementation practices.*

Material and Methods: *A prospectively documented cohort of 200 procedures included 50 colorectal perfusion assessments, 78 breast sentinel node mappings and a range of hepatic, gynecologic, and emergency cases. Methods and instrumentation were aligned with contemporary practice: intravenous angiography doses commonly ranged 0.1–0.5 mg/kg (frequently 0.2–0.25 mg/kg for bowel assessment), hepatic tumor imaging used 0.5 mg/kg preoperatively, and lymphatic injections employed submucosal/subserosal or intradermal routes with distilled water solution dilutions as indicated.*

Results: *Findings synthesize institutional outcomes with published syntheses showing lower anastomotic leak rates and improved sentinel node detection when fluorescence guidance is applied, especially in colorectal and gynecologic settings. ICG proved safe with no documented adverse reactions and high sensitivity for detection of subcapsular liver lesions. Operational lessons emphasize standardized dosing, calibrated imaging modes, routine video capture, team training, and transparent reporting principles.*

Conclusion*: Recommendations prioritize harmonized protocols and prospective, preregistered evaluations to enable generalizable assessment of clinical benefit. In conclusion, we believe that introduction of fluorescence-guided techniques with ICG in oncologic surgery can improved surgical accuracy, outcomes and patient benefit, as well as increasing surgeon comfort in complex procedures.*

Introduction

Fluorescence guidance with indocyanine green (ICG) has emerged as a central adjunct in modern oncologic and gastrointestinal surgery, building on the physical property of the dye to emit near infrared light after excitation at wavelengths between 700 and 900 nm. Once injected, ICG binds to plasma proteins and becomes visualizable in the bloodstream with dedicated ICG/near infrared imaging systems that are integrated into standard high definition laparoscopic and robotic platforms and coupled to a xenon cold light source. This configuration permits real time visualization of vascularized structures without altering the conventional operative workflow.(1)

On this technological basis, fluorescence imaging has rapidly expanded from an experimental concept to a widely adopted navigation tool in general surgery.(2) Clinical applications now span multiple organ systems.

In breast cancer and melanoma surgery, ICG has been used for sentinel lymph node biopsy, margin control, assessment of flap perfusion during reconstruction, and evaluation of lymphatic function for lymphedema prophylaxis and treatment.

In liver oncology, ICG serves as an adjunct to standard diagnostics, particularly aiding detection of small, superficial, and metastatic lesions, indetification of primary liver tumors and guiding resection margins.(1,3)

Within gastrointestinal malignancies, peritumoral injection of ICG allows sentinel lymph node detection in low stage gastric, colorectal, and anal cancers, lymph-node mapping and the same optical platform can be used to assess bowel perfusion before resection and after anastomosis creation.(1,3,4) Perfusion assessment has become one of the most intensively investigated indications. Quantitative and qualitative intraoperative fluorescence imaging has been applied to colorectal anastomoses to evaluate blood supply and potentially reduce anastomotic leak, an extremely serious complication in colorectal surgery.(5) Early clinical series using ICG fluorescence angiography reported substantial reductions in the need for anastomotic revision, although these data were derived from relatively small retrospective cohorts.(4) Subsequent systematic reviews and meta analyses in colorectal surgery have largely confirmed a beneficial association between ICG guided perfusion assessment and lower leak rates, with most analyses demonstrating a statistically significant effect.(1) Consensus guidelines from European surgical societies now strongly recommend ICG use for perfusion assessment in colorectal procedures to mitigate anastomotic leak risk.(2)

Evidence from abdominal surgery also points to applications in genitourinary and gynecologic oncology, especially for sentinel lymph node mapping in prostate, endometrial, and cervical cancer.(1,3)

Lymphatic mapping and sentinel lymph node navigation represent another major field of development. In breast, melanoma, and gynecologic malignancies, ICG based mapping has been shown to be safe, time efficient, and at least non inferior to conventional blue dye or technetium based techniques, with favorable detection and bilateral mapping rates.(4,6) For gynecologic cancers, a recent systematic review and consensus statement recommends ICG as tracer of choice in most indications.

In gastric cancer, multiple large multicenter series have used ICG fluorescence lymphography to define lymphatic basins, identifying groups of draining nodes and channels rather than a single node, with high sensitivity compared to radioactive and other probes. Early gastric cancer has been a particular focus, where mapping is being explored to tailor lymphadenectomy according to tumor T stage and patient risk profile. Similar basin oriented concepts have been translated to colorectal surgery to guide extended lymphadenectomy and more precise mesenteric dissection.(6) From a broader methodological perspective, research activity in ICG guided surgery has intensified markedly over the last decade, with more than 500 original trials, systematic reviews, and meta analyses identified in recent overviews.

ICG fluorescence navigation is now regarded as a low cost, widely available, and safe adjunct in general surgery, with high toxic dose thresholds and a very low incidence of allergic reactions, characteristics that have contributed to its rapid adoption in both elective and urgent settings.(2,5)

Recent consensus statements from international societies describe ICG guided cholangiography during laparoscopic cholecystectomy, colorectal perfusion assessment, and detection of superficial liver tumors as well established procedures with strong recommendations for routine clinical use.(2) Within this evolving landscape, departmental experiences with ICG, such as our own, need to be interpreted against a background of rapidly expanding but variably robust evidence and evolving methodological standards for evaluating surgical innovations. Large national registry analyses have documented growing uptake of minimally invasive approaches in emergency general surgery and an association between minimally invasive techniques and lower surgical site infection, shorter hospital stay, and reduced 30-day mortality, findings that may reflect both selection effects and broader shifts in training and practice patterns (8). Such trends suggest that institutional case mix, surgeon experience, and procedural selection should be considered when interpreting departmental ICG outcomes and when designing prospective evaluations.

Background and Rationale

Historical development of fluorescence imaging in surgery

Early concepts of fluorescence guidance in oncologic surgery arose from attempts to improve lymphatic mapping and nodal staging in solid tumors. Radio guided techniques using technetium based tracers were initially introduced for sentinel lymph node biopsy, but their routine use in gastrointestinal surgery remained limited because intraoperative radionuclide injection was technically demanding and required bulky gamma cameras that did not provide real time, sterile field compatible navigation.(6) These constraints created a clear incentive to explore optical dyes that could be visualized with smaller, operative friendly detectors. Indocyanine green subsequently emerged as a particularly attractive fluorophore. ICG is an injectable dye that fluoresces when excited within the near infrared spectrum between 700 and 900 nm, a range compatible with modern laparoscopic and robotic imaging platforms. After intravenous or locoregional administration, ICG binds to plasma proteins and can be visualized intraoperatively with dedicated near infrared systems that are coupled to full high definition cameras and xenon cold light sources.(1) These technical properties facilitated seamless integration of fluorescence into standard minimally invasive workflows and set the stage for broader surgical adoption. One of the earliest and most influential clinical uses of fluorescence imaging was sentinel lymph node biopsy in breast cancer and melanoma. In these fields, sentinel node biopsy has been validated as standard of care, and the introduction of ICG near infrared imaging provided a radiation free alternative to blue dye and technetium tracers.(3,6) Extensive evaluation in endometrial and cervical cancer demonstrated that ICG based mapping is safe, time efficient, and reliable, with non inferior detection and false positive rates and improved bilateral mapping compared with conventional tracers, leading to recommendations that ICG be used as tracer of choice for most gynecologic malignancies. Parallel developments occurred in gastrointestinal oncology, where ICG fluorescence lymphography enabled real time visualization of lymphatic channels and nodes after submucosal, subserosal, or intradermal injection. ICG disperses in lymph, binds to lipoproteins, and is drained along lymphatic pathways, allowing surgeons to locate functional lymphatic vessels, identify chyle leaks, and map sentinel nodes.(6)

As fluorescence technologies matured, applications extended from lymphatic mapping to perfusion assessment and tumor localization. In colorectal surgery, ICG fluorescence angiography has been used to evaluate anastomotic perfusion, with multiple studies reporting safe and effective intraoperative assessment and reductions in anastomotic leak. Quantitative approaches, including fluorescence time curves and derived parameters such as peak time, half time, and slope, were developed to provide more objective thresholds for predicting leak or necrosis. Similar principles have been applied across esophageal, gastric, bariatric, and

hepatic procedures to characterize tissue vascularization.(5) Comprehensive overviews of abdominal surgery document how these individual innovations coalesced into a broad field of ICG guided surgery. Systematic reviews and meta analyses across breast, liver, gastrointestinal, genitourinary, and gynecologic oncology have catalogued roles for ICG in tumor identification, sentinel node biopsy, perfusion assessment, and reconstruction, with particular strength of evidence for anastomotic leak prevention and lymphatic mapping in colorectal and gynecologic indications.(1,3) Critical appraisal using the AMSTAR 2 instrument, however, has revealed frequent methodological shortcomings, including incomplete reporting of excluded studies and inadequate evaluation of publication bias, underscoring the need for more rigorous study designs.(1,7) Large reviews of perioperative interventions likewise report substantial heterogeneity and low certainty ratings when studies are assessed with GRADE, which may suggest that inconsistent outcome definitions and reporting standards have limited the ability to draw firm conclusions across trials (9). These observations imply that fully definitive recommendations for imaging protocol standardization and quantitative thresholds for ICG will likely require adequately powered randomized studies with prespecified endpoints and clearer reporting so that findings can be compared across centers and technologies.

Consensus statements from international societies such as EAES and ISFGS now regard fluorescence guidance as a mature adjunct rather than an experimental technique. These documents highlight ICG guided cholangiography during laparoscopic cholecystectomy, colorectal perfusion assessment, and detection of superficial liver tumors as well established procedures that should be routinely available.(1,2) At the same time, recent narrative and systematic reviews in general and colorectal surgery emphasize that, despite promising results across many applications, standardization of imaging protocols, quantitative analysis methods, and high quality randomized studies remain necessary to consolidate indications and optimize patient benefit.

Indocyanine green as a surgical adjunct

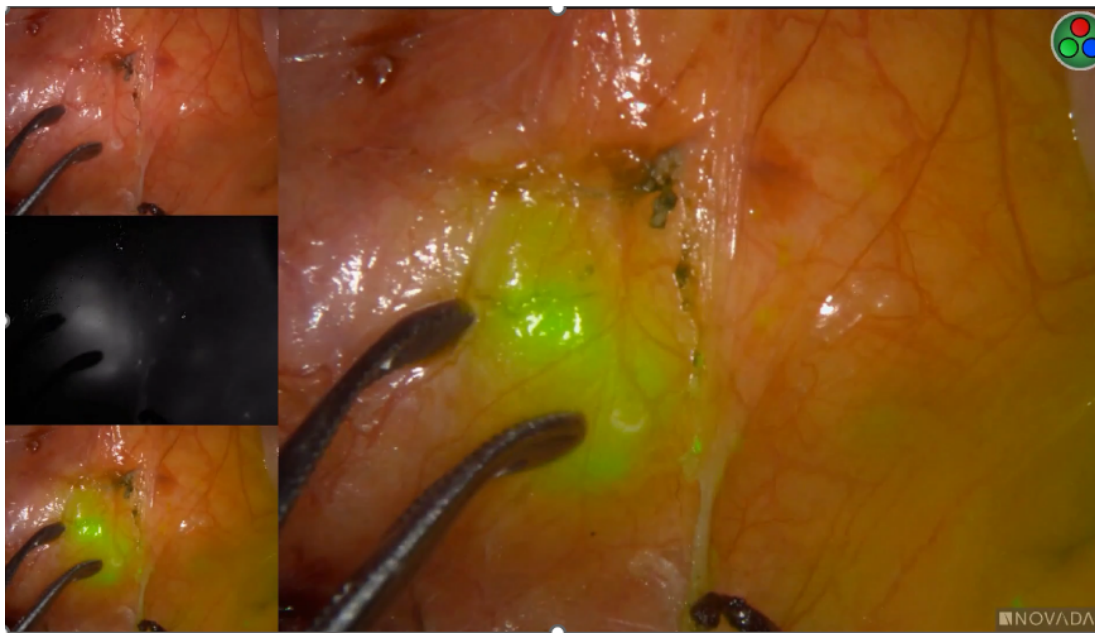
In day to day oncologic practice, we draw on ICG primarily as an intraoperative navigation aid that exploits near infrared fluorescence to extend what we can see beyond the limits of white light. ICG behaves as an injectable fluorochrome: after excitation with light in the near infrared spectrum between 700 and 900 nm, absorbed energy promotes electrons to a higher shell, and their return to the ground state is accompanied by emission of photons that can be detected as a distinct fluorescent signal. Once administered intravenously or locoregionally, the dye binds to plasma proteins and becomes visible within the bloodstream using ICG/near infrared imaging technology that is coupled to full high definition laparoscopic and robotic camera systems

and a xenon cold light source, without requiring any change in the standard operative setup.(1) These physical and technical properties underpin the versatility of ICG across multiple domains of abdominal oncology, from perfusion assessment to lymphatic mapping and tumor localization.(1,3) Perfusion assessment is the indication in which ICG has had the most immediate impact on my colorectal practice. Intraoperative fluorescence angiography allows qualitative and quantitative evaluation of blood supply at the level of bowel segments and anastomoses using the same laparoscopic platform, and several clinical series have associated its use with safe and effective appraisal of colorectal anastomotic perfusion and a reduction in anastomotic leaks. Consensus recommendations from international societies now classify ICG guided perfusion assessment in colorectal surgery as a well established procedure, endorsed with a strong grade of recommendation to help reduce anastomotic leak.(1,2)

Indications in Oncologic Abdominal Surgery

Colorectal cancer surgery

In our colorectal practice, fluorescence guidance has become most relevant for assessing anastomotic perfusion, given the central role of anastomotic leak as a life threatening complication. Intraoperative ICG fluorescence angiography is used qualitatively to examine blood flow in colonic segments and colorectal anastomoses, with several studies reporting that this approach can safely and effectively appraise perfusion and reduce leak rates in colorectal surgery.(5,6) Some series have associated prolonged time intervals between intravenous ICG administration and visualization at the rectal stump with subsequent development of anastomotic leak, highlighting the potential of intraoperative fluorescence times as risk markers. Beyond global perfusion, several groups have investigated serosal and mucosal oxygenation alongside ICG imaging. Experimental work comparing mucosal and serosal perfusion in ischemic colon segments has demonstrated predominant mucosal ischemia, indicating that serosal evaluation alone may underestimate the true extent of ischemia and that careful interpretation of fluorescence findings at the bowel surface is required. Clinical studies summarized in recent reviews indicate that multiple colorectal series have used ICG fluorescence intraoperatively to judge anastomotic perfusion and that these applications are associated with lower leak rates and improved outcomes.



Perfusion analysis has also been connected to functional outcomes. One study evaluating intestinal perfusion at the transection site with ICG fluorescence found that insufficient perfusion requiring more proximal relocation of the transection was linked to higher postoperative fecal volumes, suggesting a possible relationship between vascular status and subsequent diarrhea. Such observations complement my clinical impression that optimizing perfusion may influence not only leak risk but also postoperative bowel function, although robust causal evidence remains limited.

From a wider abdominal oncology perspective, ICG lymphography has been used to delineate lymphatic routes and sentinel node basins around colorectal tumors – Figure 1, including obturator and inguinal regions, with proposals that extended fluorescence guided lymphadenectomy might reduce local nodal recurrence and refine mesenteric dissection around main vascular trunks in right colectomy and flexure cancers.(6,14)

Hepatic tumor surgery

In liver oncology, intraoperative fluorescence has become a critical adjunct for detecting primary and metastatic lesions that might otherwise escape conventional inspection, palpation, and ultrasound. Systematic evaluation in hepatopancreatobiliary surgery shows that preoperative intravenous ICG administration followed by near infrared imaging during resection permits identification of approximately 80 % of all tumors present in the liver when the surface is inspected directly in a cohort of 1090 patients, with reported ranges

between 43 % and 100 %. Sensitivity increases markedly for subcapsular disease, reaching up to 98 % for lesions located within 8 mm of the liver surface (3,14).

For colorectal liver metastases, a comparative cohort showed that ICG fluorescence during resection led to identification of additional metastases in 25 % of patients, compared with 13 % in a control group without fluorescence imaging. Tumors seen exclusively by fluorescence were significantly smaller than those found by inspection, palpation, or intraoperative ultrasound, with mean diameters of 3.2 ± 1.8 mm versus 7.4 ± 2.6 mm. These data align closely with our own impression in laparoscopic liver surgery, where ICG often exposes tiny subcapsular deposits that are not apparent on preoperative imaging – Figure 2 (3,14) Technical aspects of ICG dosing and timing have been fairly consistent across published series, although an optimal regimen has not been definitively established. Most authors administer an intravenous dose of 0.5 mg/kg within two weeks before surgery, using the same quantity as for the ICG retention test. If the retention test was performed earlier than two weeks before resection, some groups recommend an additional fixed dose of 2.5 mg on the day before surgery. Despite these pragmatic protocols, several reports emphasize that ICG removal from noncancerous tissue may be insufficient in patients with impaired liver function, which can generate false positive nodules. In cirrhotic livers, positive predictive values as low as 5.4 % have been reported, in contrast to noncirrhotic livers where values approach 100 %. These observations have influenced how we interpret fluorescence patterns in patients with advanced fibrosis, where we rely heavily on correlation with ultrasound and preoperative imaging.

Fluorescence characteristics appear to reflect underlying tumor biology. Studies in HCC describe differentiation dependent patterns, with well differentiated tumors retaining ICG because of impaired excretion via multidrug resistance associated protein 2, resulting in homogeneous intratumoral fluorescence – Figure 2. Poorly differentiated and metastatic lesions may fail to take up or excrete the dye, instead producing a rim pattern or halo sign due to accumulation in surrounding hepatocytes. More broadly, research in liver cancer concludes that ICG is a useful adjunct to standard diagnostics, particularly for small, superficial, and metastatic lesions, and that fluorescence imaging may inform pathological assessment and tumor differentiation grading, although specificity for lesion type remains limited.(3,14)

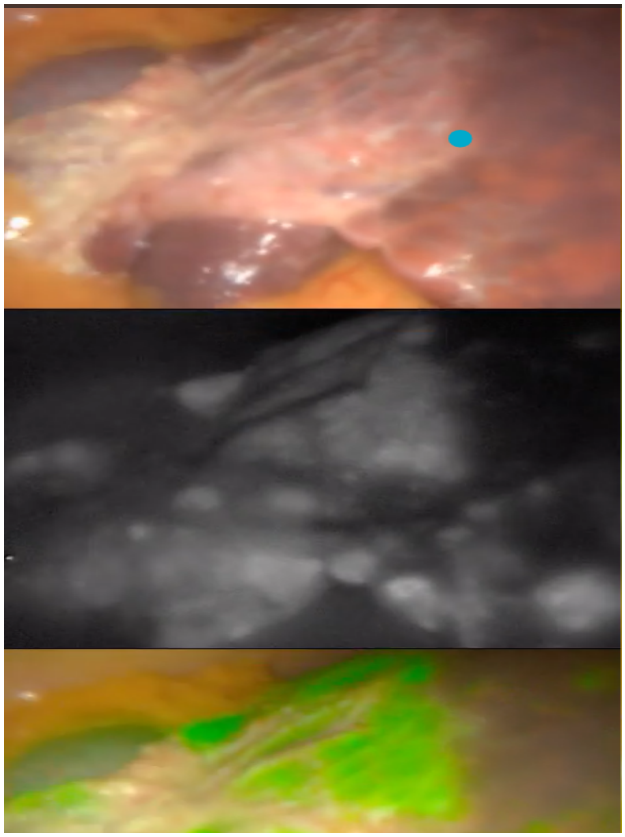


Figure 2. Multicentric HCC visible in NIR spectrum after ICG admimistration

Application on ICG in Our General Surgery Department

In our department, indocyanine green is used along the same major indication lines that have been described for abdominal and oncologic surgery, namely perfusion assessment, lymphatic mapping, and tumor identification, and our local experience is best interpreted against these established domains.(1,3,5) Over a five year period, we have integrated ICG into 200 oncologic procedures, reflecting its status as a widely available, low cost, and intraoperatively compatible fluorochrome that can be administered intravenously or locoregionally without altering the standard laparoscopic or open setup. This integration has been facilitated by imaging platforms that couple near infrared detection to full high definition cameras and xenon cold light sources, as described for minimally invasive applications in abdominal surgery.(1,2)

Colorectal cancer operations constitute a major segment of our cohort. Consistent with the central role of perfusion assessment in colorectal surgery, we have used ICG fluorescence angiography in 66 patients to evaluate blood supply to colonic segments, colorectal anastomoses, or colonic stumps. Published series in colorectal surgery report that intraoperative fluorescence imaging can safely and effectively assess

anastomotic perfusion and is associated with lower anastomotic leak rates, findings that have driven our decision to implement routine perfusion checks in technically demanding resections.(1,5,6) In these patients, we adhere closely to protocols described in abdominal surgery reviews, administering ICG as an intravenous bolus at doses within the commonly recommended range and observing time based fluorescence parameters in addition to the qualitative signal, in line with work that identifies time to enhancement and related metrics as informative for predicting ischemia.(5,6) This focus on leakage prevention mirrors meta analytic data in which most colorectal analyses demonstrate a statistically significant benefit of ICG guided perfusion assessment, particularly in low rectal resections.(1) While with standard colonic resections the estimated leak-rate improvent is only moderate, we have found that low rectal resection with very-low anastomoses seem to benefit the most from fluorescence guidance – with a significant improvent in ischemia and leak rate in our cohort (10-12 % in an area where leak rate can reach up to 40%).

Sentinel lymph node mapping represents the other major pillar of our experience. Over the same five year interval, we have performed ICG guided sentinel node procedures in 62 breast cancer patients. In this setting, we adopted ICG as an alternative to technetium and blue dye because sentinel node biopsy with optical tracers has been validated as standard of care in breast oncology, and near infrared imaging has been described as safe, time efficient, and at least non inferior to conventional tracers with low false negative rates.(3,4) Our protocol for periareolar injection with subsequent near infrared detection underlines the advantages that have been reported for ICG in sentinel node biopsy, with a complete detection rate.(3)

Beyond breast surgery, we have extended sentinel node mapping with ICG to gynecologic malignancies, particularly early-stage endometrial and cervical cancer, following evidence that fluorescence mapping in these tumors is reliable, improves bilateral detection, and has led to recommendations that ICG be considered tracer of choice.(3,6) These gynecologic cases (7) form part of the remaining ICG indications in our 200 patient cohort and align our practice with consensus statements that emphasize lymphatic mapping as a well supported domain for ICG guidance.(1,6)

The final group in our series includes hepatobiliary and pancreatic procedures, where we have used ICG for liver tumor identification, delineation of ischemic demarcation lines during liver resection, and adjunctive nodal mapping. Reviews of liver cancer surgery describe ICG as a good adjunct to standard diagnostics, particularly for small, superficial, and metastatic lesions, and highlight its potential to aid pathologic assessment and suggest tumor differentiation patterns, which has encouraged us to adopt preoperative dosing regimens similar to those used in large hepatocellular carcinoma and colorectal liver metastasis cohorts.(3,14) Intraoperative fluorescence has helped us define resection planes based on ischemic demarcation, in keeping

with reports that fluorescence can outline perfused versus non perfused parenchyma during liver surgery and other organ resections.(4,6)

A smaller subset of patients (5) in our cohort underwent ICG assisted lymphatic mapping for colorectal cancers, following submucosal injection protocols akin to those described for lymphatic basin identification and extended mesocolic excision planning.(6,14) Across these diverse procedures, our departmental usage pattern therefore reflects the organ specific applications and indications summarized in recent meta reviews and consensus guidelines, while providing a structured base for the outcome analyses presented in subsequent sections.

Technical Considerations - Administration protocols

In daily practice we have to make explicit choices regarding dose, timing, dilution, and route of indocyanine green administration, because these variables directly influence image quality and interpretability. For fluorescence angiography in abdominal and colorectal surgery, recommended intravenous doses range from 0.1 to 0.5 mg/kg, with 0.2 to 0.25 mg/kg reported as the most commonly used regimen for intraoperative bowel viability assessment and emergency indications.(6,12) Package information still proposes a standard adult dose of 5 mg diluted in 1 mL, not exceeding a total of 2 mg/kg, yet published series describe substantial heterogeneity, with single doses between 0.25 mg and 15 mg or weight based regimens around 0.2 mg/kg. In our own colorectal perfusion protocols, which underpin the 66 anastomotic assessments described in our departmental series, we have aligned dosing with these ranges to remain within well documented safety margins while obtaining sufficiently bright signals for time based perfusion analysis.(5,12)

Timing of injection relative to imaging is equally critical. For emergency bowel evaluation, intravenous ICG is typically administered one to two minutes before imaging, with peak fluorescence in well perfused tissue often observed between 30 and 60 s and a useful imaging window lasting several minutes. During laparoscopic resections, we generally inject once the bowel is positioned in its final configuration and watch for this characteristic rise in signal before deciding on the transection line, mirroring the time frames described for strangulated hernias and intestinal ischemia in emergency settings.(12) For upper gastrointestinal reconstructions, Cassinotti and colleagues report a pragmatic 90 s rule, constructing anastomoses only in gastric conduit segments that enhance within 90 s after injection, and early quantitative work has begun to differentiate simultaneous versus delayed flow based on time intensity curves.(6)

Dilution and solvent choice deserve explicit attention. Guidance from emergency and lymphatic applications recommends reconstituting ICG with sterile water for injection to achieve the desired concentration, with subsequent use as is or after syringe rinsing with isotonic saline.(6,12) Some reports caution that saline based solutions may promote precipitation of the dye, although others tolerate saline dilution for systemic angiography, underscoring the importance of adhering to locally validated preparation protocols.(6,12) In our department, for intravenous boluses we follow the emergency surgery recommendations of 10 to 25 mg total dose in adults, adjusted to 0.2 to 0.5 mg/kg, and for lymphatic mapping we also use sterile water based dilutions prepared at concentrations between 0.1 and 5 mg/mL, depending on the specific indication.(6,12,14)

Route and site of administration vary by objective. For fluorescence angiography, all authors cited in emergency protocols employ intravenous injection, preferably through a central or large peripheral vein to secure rapid distribution.(12) In contrast, lymphatic mapping in gastrointestinal tumors relies on submucosal, subserosal, or intradermal injection around the lesion, with doses of approximately 0.2 to 0.3 mg/kg diluted in saline or 20 % albumin and volumes of 2 to 4 mL at concentrations between 0.1 and 5 mg/mL.(6,14) For colon cancer, prospective work has shown optimal visualization of lymphatic drainage ten minutes after subserosal injection of 4 mL of a 0.5 mg/mL solution, and intraoperative lymph flow mapping has led to modification of the planned extent of mesocolic excision when observed drainage patterns diverged from preoperative expectations.(14) In hepatic and hepatopancreatobiliary surgery, most series performing tumor detection or lymphatic mapping administer 0.5 mg/kg intravenously within two weeks before resection or inject 0.5 mL of a 5 mg/mL solution into Calots triangle to visualize regional and para aortic nodes.(3,14) Safety considerations are inherent to any protocol. Emergency surgery guidance reports an extremely low rate of adverse reactions to ICG injection, around 0.003 % at doses exceeding 0.5 mg/kg, and notes that the small iodine content in the formulation permits use even in patients with mild iodine allergy where standard iodinated contrast is contraindicated.(12)

Across gastrointestinal oncology, systematic overviews emphasize wide variability in dose, timing, and route but still converge on 0.5 mg/kg as a pragmatic standard for preoperative liver tumor imaging and on 0.1 to 0.25 mg/kg for intraoperative angiography.(1,14) Against this background, my aim in our 200 patient departmental cohort has been to document dosing, dilution, and administration characteristics prospectively so that future syntheses can interpret our outcomes in light of contemporary PRISMA and AMSTAR 2 based quality frameworks.

Future Perspectives

Protocol harmonization is, in our view, the most pressing prerequisite for translating indocyanine green guidance from a promising adjunct into a reproducible standard of care in abdominal oncology. Across perfusion assessment and lymphatic mapping, published series employ highly variable doses, dilutions, timing schedules, and imaging workflows, which complicates interpretation and direct comparison of outcomes.(5,6,14) This variability contrasts with our own departmental practice, where we have prospectively aligned dosing for colorectal perfusion, lymphatic mapping, and hepatic tumor imaging with commonly reported ranges and documented administration details for all 200 ICG guided oncologic procedures to facilitate future synthesis.(1,5,14).

Subsequent work stressed that fluorescence images should be acquired with ICG specific modes at a fixed camera distance of approximately 4 to 5 cm, and that imaging equipment calibration and software validation are prerequisites for meaningful comparison of perfusion thresholds, yet these technical conditions are rarely reported systematically.(5,12) Lymphatic mapping protocols show comparable heterogeneity. Cassinotti et al. describe submucosal, subserosal, and intradermal injection routes, dilution of ICG in saline or 20 % albumin, and weight based doses around 0.2 to 0.3 mg/kg, but acknowledge that there is no standardized technique and that timing and route differ across early gastric and colorectal cancer series.(6,6) For colon cancer, prospective work identified optimal visualization of lymphatic drainage ten minutes after subserosal injection of 4 mL of a 0.5 mg/mL solution, which then allowed intraoperative modification of the mesocolic excision according to observed drainage, yet this schedule is not universally adopted.(14)

In our own lymphatic mapping cases, including 78 breast sentinel procedures and selected gynecologic and gastrointestinal indications, we have chosen sterile water based dilutions and timing windows anchored to these published experiences, and we record injection site, volume, and interval before imaging in a standardized fashion.(3,6,14) Administration strategies for perfusion imaging likewise require convergence. Emergency and upper gastrointestinal reports recommend intravenous boluses of 0.1 to 0.2 mg/kg, diluted in sterile water or saline, with assessment during the first 60 to 90 s after injection; some authors additionally propose a 90 s rule, performing anastomoses only in segments that enhance within this interval.(6,6,12) Simion and co authors summarize that most colorectal studies use ICG both qualitatively and quantitatively and that multiple series have demonstrated safe and effective perfusion evaluation with leak reduction, but they also emphasize that surgeons have yet to adopt the technique routinely, partly because of absent high level evidence and concerns about cost without clearly standardized benefit.(5)

Large international surveys indicate that minimally invasive techniques remain underused in emergency practice and that surgeons who routinely perform laparoscopy in elective settings, and those with greater experience, are likelier to adopt novel intraoperative methods; this pattern may partly explain why ICG guidance has not been embraced uniformly across centers (25). These patterns mirror observations in the broader minimally invasive and robotic surgery literature, where reviewers note higher equipment costs, variable evidence for long-term benefit, and heterogenous training as recurring obstacles to routine uptake of new intraoperative methods (26).

Such analyses also indicate that centres with established laparoscopic or robotic programmes and structured training pathways are more likely to incorporate innovations like fluorescence imaging, which suggests that protocol harmonization must be paired with pragmatic resource and training planning. The timing and prioritization of emergency source control have been shown to be both variably defined and critically important, with three practical urgency tiers, emergent, urgent, and delayed, proposed for intra-abdominal interventions; such stratification appears to limit the routine use of adjunctive technologies in unstable patients and may therefore constrain how fluorescence guidance is implemented in urgent settings (27). For that reason, protocol harmonization should explicitly consider how dosing, imaging windows, and documentation are adjusted across these urgency levels so that ICG guidance can be applied sensibly in both elective and emergency scenarios.

Thus, beyond technical calibration and dose harmonization, efforts to standardize ICG protocols should also address training, routine incorporation into elective workflows, and local availability so that perioperative teams become familiar enough to use fluorescence reliably in higher-risk or urgent cases. International expert panels have argued that training should target the entire operative team and include standardized simulation, assessment tools, and minimal caseload requirements to reach and maintain proficiency. This emphasis on team-wide, curriculum-based education appears directly relevant to ICG adoption, since centres with structured training and regular elective use are more likely to deploy fluorescence reliably in urgent cases (28) The recent WSES review similarly recommends a laparoscopy-first approach for stable emergency abdominal patients, notes uneven adoption related to variable training and resource access, and remarks that ICG imaging has been increasingly incorporated into laparoscopic platforms as a useful adjunct (29). Such observations may suggest that harmonizing protocols will require pairing clear technical standards with pragmatic training benchmarks and resource planning so that fluorescence becomes a routine option even in time-pressured settings.

Given these reservations, our departmental protocol for colorectal resections specifies weight based doses within the 0.2 to 0.25 mg/kg range, central or large bore peripheral administration, and a fixed observation window captured on video for every injection, so that perfusion decisions can be audited against future, more robust cut offs.(5,12) At the level of evidence synthesis, formal guidance such as PRISMA highlights the importance of explicitly reporting synthesis methods, heterogeneity exploration, and sensitivity analyses, including exact summary estimates, confidence intervals, and measures such as I^2 and τ^2.(7,7) Pantelis et al. applied AMSTAR 2 to 75 meta analyses of ICG in abdominal surgery and found frequent deficiencies, especially incomplete lists of excluded studies and limited investigation of publication bias, yet still documented that 86.3 % of colorectal meta analyses showed a significant benefit of ICG for anastomotic leak prevention and that all colorectal sentinel node meta analyses found a positive effect.(1) For our 200 patient experience, I therefore plan any forthcoming systematic evaluations to conform strictly to these PRISMA and AMSTAR 2 items, including transparent protocol registration, prespecified subgroup and sensitivity analyses, and rigorous reporting of heterogeneity.(1,7) Consensus documents already move in this direction by defining organ specific indication clusters such as fluorescence cholangiography, colorectal perfusion assessment, gastric and esophageal anastomoses, and lymphatic mapping in gastric and colorectal surgery, and by affirming that ICG use is safe, cost effective, and no longer experimental.(1,6)

In our unit, I see protocol standardization as the bridge between these high level endorsements and day to day practice: aligning doses, injection techniques, imaging settings, and data capture across colorectal, breast, gynecologic, and hepatic procedures will not only improve internal consistency, but also allow our results to be meaningfully integrated into future multi center syntheses that meet contemporary methodological standards.

Conclusion

Indocyanine green fluorescence has emerged as a versatile intraoperative tool across oncologic abdominal surgery, with recurrent clinical advantages in vascular assessment, lymphatic mapping, and tumor localization. Its capacity to provide real time visualization of perfusion dynamics and lymphatic drainage has altered intraoperative decision making in colorectal, hepatobiliary, breast, and gynecologic procedures, and has shown particular benefit in reducing anastomotic complications and improving sentinel node detection rates.

Clinical series and aggregated analyses indicate that time based fluorescence metrics, for example time to peak intensity, half time, and slope, offer more informative discrimination of tissue viability than static intensity measures. In colorectal resections these dynamic parameters have guided adjustments of transection lines and informed selective use of protective stomas. In liver surgery, preoperative systemic administration enables detection of small, superficial lesions and can reveal additional metastases on the liver surface or specimen cut planes, though interpretation must account for altered hepatic clearance in advanced fibrosis. Locoregional administration of ICG reliably maps lymphatic basins in gastric and selected colorectal contexts, supporting less extensive nodal dissection in appropriately selected early tumors.

From my perspective as both surgeon and researcher, ICG fluorescence has evolved from an experimental adjunct to an integral component of complex oncologic operations, aligning with recent consensus statements that no longer consider near infrared imaging experimental but rather a mature navigation technology that should be routinely available whenever feasible.

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