Surgery 172 (2022) S38–S45

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Use of fluorescence imaging and indocyanine green during colorectal surgery: Results of an intercontinental Delphi survey

Steven Wexner, MD, PhD (Hon)[a,*], Mahmoud Abu-Gazala, MD[b], Luigi Boni, MD[c], Kenneth Buxey, MBBS, (Hons)[d], Ronan Cahill, MD[e], Thomas Carus, MD, PhD[f], Sami Chadi, MD, MS[g], Manish Chand, MBBS, BSc, FRCS, MBA, PhD[h], Chris Cunningham, MD, FRCSEd[i], Sameh Hany Emile, MD[j], Abe Fingerhut, MD, FACS(h)[k], Chi Chung Foo, MBBS, MS[l], Roel Hompes, MD, PhD[m], Argyrios Ioannidis, MD, PhD[n], Deborah S. Keller, MS, MD[o], Joep Knol, MD, PhD[p], Antonio Lacy, MD[p], F. Borja de Lacy, MD, PhD[q], Gabriel Liberale, MD, PhD[r], Joseph Martz, MD[s], Ido Mizrahi, MD[t], Isacco Montroni, MD, PhD[u], Neil Mortensen, MD, FRCS[v], Janice F. Rafferty, MD[w], Aaron S. Rickles, MD[x], Frederic Ris, MD, PD[y], Bashar Safar, MD[z], Danny Sherwinter, MD[aa], Pierpaolo Sileri, MD, PhD[bb], Michael Stamos, MD[cc], Paul Starker, MD[dd], Jacqueline Van den Bos, MD, PhD[ee], Jun Watanabe, MD, PhD[ff], Joshua H. Wolf, MD[gg], Shlomo Yellinek, MD[hh], Oded Zmora, MD[ii], Kevin P. White, MD, PhD[jj], Fernando Dip, MD[kk], Raul J. Rosenthal, MD[a]

[a] Ellen Leifer Shulman and Steven Shulman Digestive Disease Center, Cleveland Clinic Florida, Weston, FL
[b] Hadassah-Hebrew University Medical Center, Jerusalem, Israel
[c] Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico di Milano, University of Milan, Italy
[d] Sandringham Hospital, Alfred Health, Melbourne, Australia
[e] UCD Centre of Precision Surgery, University College Dublin, Dublin, Ireland
[f] Niels-Stensen-Kliniken, Elisabeth-Hospital, Thuine, Germany
[g] University of Toronto, Toronto, Ontario, Canada
[h] University College London, London, UK
[i] Oxford University Hospitals NHS Trust, Oxford, UK
[j] Mansoura University Hospital, Mansoura, Egypt
[k] Medical University of Graz, Graz, Austria
[l] University of Hong Kong, Hong Kong, China
[m] Amsterdam University Medical Centers, Location AMC, Amsterdam, The Netherlands
[n] Athens Medical Center, Athens, Greece
[o] University of California at Davis Medical Center, Sacramento, CA
[p] Department of Abdominal Surgery, ZOL Hospital, Genk, Belgium
[q] Hospital Clinic of Barcelona, Barcelona, Spain
[r] Institut Jules Bordet, Université Libre de Bruxelles (ULB), Brussels, Belgium
[s] Northwell Health, New York, NY
[t] Hebrew University of Jerusalem, Jerusalem, Israel
[u] Ospedale per gli Infermi, Faenza, Italy
[v] Oxford University Hospitals Oxford, UK
[w] The Christ Hospital, Cincinnati, OH
[x] Rochester Colon and Rectal Surgeons, Rochester, NY
[y] Geneva University Hospitals and Medical School, Geneva, Switzerland
[z] Johns Hopkins University, Baltimore, MD
[aa] Maimonides Medical Center, Brooklyn, NY

This article is published as part of a supplement supported by the International Society for Fluorescence Guided Surgery (ISFGS) with funding from Arthrex, Diagnostic Green, Intuitive, Medtronic, Olympus, Karl Storz Endoscopy, Stryker, and Richard Wolf.

* Reprint request: Steven D. Wexner, MD, PhD (Hon), Department of Colorectal Surgery, Cleveland Clinic Florida, 2950 Cleveland Clinic Blvd, Weston, FL 33331.

E-mail address: wexners@ccf.org (S. Wexner);

Twitter: @SWexner

https://doi.org/10.1016/j.surg.2022.04.016

[bb] Università Vita Salute, San Raffaele, Milan, Italy
[cc] UC Irvine, Irvine, CA
[dd] Overlook Medical Center, Summit, NJ
[ee] Maastricht University Medical Center, Maastricht, The Netherlands
[ff] Yokohama City University Medical Center, Yokohama, Japan
[gg] Sinai Hospital of Baltimore, LifeBridge Health, Baltimore, MD
[hh] Shaare Zedek Medical Center, Jerusalem, Israel
[ii] Shamir Medical Center, Tel Aviv, Israel
[jj] ScienceRight Research Consulting, London, Ontario, Canada
[kk] Hospital de Clínicas José de San Martín, Buenos Aires, Argentina

ARTICLE INFO

Article history:
Accepted 10 April 2022

ABSTRACT

Background: Fluorescence imaging with indocyanine green is increasingly being used in colorectal surgery to assess anastomotic perfusion, and to detect sentinel lymph nodes.
Methods: In this 2-round, online, Delphi survey, 35 international experts were asked to vote on 69 statements pertaining to patient preparation and contraindications to fluorescence imaging during colorectal surgery, indications, technical aspects, potential advantages/disadvantages, and effectiveness versus limitations, and training and research. Methodological steps were adopted during survey design to minimize risk of bias.
Results: More than 70% consensus was reached on 60 of 69 statements, including moderate-strong consensus regarding fluorescence imaging's value assessing anastomotic perfusion and leak risk, but not on its value mapping sentinel nodes. Similarly, although consensus was reached regarding most technical aspects of its use assessing anastomoses, little consensus was achieved for lymph-node assessments. Evaluating anastomoses, experts agreed that the optimum total indocyanine green dose and timing are 5 to 10 mg and 30 to 60 seconds pre-evaluation, indocyanine green should be dosed milligram/kilogram, lines should be flushed with saline, and indocyanine green can be readministered if bright perfusion is not achieved, although how long surgeons should wait remains unknown. The only consensus achieved for lymph-node assessments was that 2 to 4 injection points are needed. Ninety-six percent and 100% consensus were reached that fluorescence imaging will increase in practice and research over the next decade, respectively.
Conclusion: Although further research remains necessary, fluorescence imaging appears to have value assessing anastomotic perfusion, but its value for lymph-node mapping remains questionable.

Introduction

Approximately 600,000 colorectal surgeries are performed annually in the United States to treat various colorectal disorders, most commonly malignancy, inflammatory bowel disease, and diverticulitis.[1] Unfortunately, perioperative complications are common, occurring in 25% of patients or more, depending on the indication for surgery and patient's preexisting level of health.[2–5] Among these complications, anastomotic leaks (AL) are the most common potentially catastrophic complications, significantly increasing patient morbidity and mortality, prolonging hospital stays, and resulting in reduced long-term quality of life and further complications.[6]

In recent years, intraoperative fluorescence imaging (FI) has gained increasing acceptance across a broad range of surgical scenarios to increase the visualization of anatomical structures and, thereby, reduce complications. The effectiveness of FI has been documented in published randomized clinical trials (RCTs) for both total thyroidectomy and laparoscopic cholecystectomy.[7,8] Numerous meta-analyses demonstrating its effectiveness have also been published, including one assessing its role in patients undergoing minimally invasive cholecystectomy. This latter study demonstrated that using FI with indocyanine green (ICG) reduced the rates for bile duct injury and conversion to open surgery to one-fourth and one-seventeenth as high as in controls, respectively.[9]

In colorectal surgery, FI has largely been used to prevent, detect, and manage AL[10–13] and identify sentinel lymph nodes (SLN) in patients with colorectal cancer.[14–17] However, some variability continues to exist in numerous technical aspects of how FI is used and performed, not just during colorectal surgery, but across all surgical fields that its use has been introduced. Such variation exists in many facets, including indications and contraindications, issues of patient education and consent, the dose and timing of ICG administration, and whether dosing can be repeated (and, if so, how and when).

To address these challenges, in February 2019, members of the Advisory Board of the International Society for Fluorescence-Guided Surgery (ISFGS) met at a consensus conference in Frankfurt, Germany, where they made the decision to orchestrate, over 2 to 3 years, a series of surveys to identify the areas of consensus and nonconsensus on intraoperative FI among the world's experts across multiple surgical fields. To accomplish this, a modified-Delphi survey approach would be employed to permit anonymous voting and, thereby, reduce voter bias potentially caused by peer pressure.[18] The present article describes the results of our survey among surgeons using FI during colorectal surgery, specifically for the detection and management of AL and identification of SLN during colorectal cancer surgery.

Methods

Expert recruitment and data collection

A Delphi survey was completed over the spring and summer of 2020, adhering to published guidelines[19] and coordinated by an international, MD-PhD level expert in survey design (K.P.W.). The Delphi technique has achieved appreciable popularity and credence to achieve consensus and identify areas of nonconsensus among experts across a wide variety of health- and nonhealth-related fields.[19]

After the consensus conference in Frankfurt,[18] e-mails were sent to all ISFGS Advisory Board members requesting that anyone who felt willing to oversee a survey within their particular area of expertise volunteer to do so, and that everyone provide a list of questions and issues they considered important pertaining to using

FI during procedures within their surgical field. These questions were screened and used to generate a series of Delphi surveys intended for distribution among experts within each specific surgical field. For the colorectal Delphi survey, the final statement items were selected by S.D.W., edited for clarity and format by K.P.W., then sent back to S.D.W. and 2 other experts in FI (F.D. and R.J.R.) for further review. After several iterations, the final survey consisted of 5 questions on the nature of each expert's surgical practice, followed by 69 statements that participating experts were asked to vote upon. The survey was divided into 5 modules: Module 1: Patient preparation and contraindications ($n = 11$ statements); Module 2: Indications for and general statements regarding FI during colorectal surgery ($n = 21$); Module 3: Technical aspects of FI ($n = 16$); Module 4: Potential advantages/disadvantages and effectiveness versus limitations of FI ($n = 13$); and Module 5: Training and research ($n = 8$). Among these 69 statements, 49 had the binary response option agree/disagree and 20 statements had multiple response options, like routinely/selectively/never.

During survey design, several approaches were adopted to reduce the risk that the survey instrument itself might influence responses through either the wording or order of its statements/response options (acquiescence bias). This included balancing statements that might be perceived as favorable to FI with approximately an equal number of unfavorably worded items, incorporating numerous nonjudgmental statements, and varying the order of response options, sometimes listing the most FI-agreeable option first, sometimes last, and sometimes in the middle.

Experts were selected using the following eligibility criteria: (1) co-authorship of at least 1 published clinical study examining FI use during colorectal surgery; or (2) ≥10 years in surgical practice and 5 years using FI during colorectal surgery. They also had to (3) be acknowledged as an international expert by the ISFGS Advisory Board, (4) be fluent in written English, (5) express willingness to participate, and (6) express willingness to review and provide comments on the manuscript's penultimate draft before submission for publication. Potential experts were identified by word of mouth and by reviewing all currently published studies on FI for colorectal surgery to identify corresponding authors. This ultimately resulted in a list of 52 international experts spanning 5 continents. Once the list of willing experts was generated, an e-mail was sent to everyone on the list, asking them to participate in the survey and providing a link to the online survey application SurveyMonkey with follow-up e-mails sent to all nonrespondents once weekly for 3 weeks, followed by an e-mail or telephone call from S.D.W. to anyone who had not yet responded. Round 1 was considered complete within 1 week of the above-noted telephone calls, and all Round 1 data analyzed to identify the degree of consensus reached with each of the 69 statements. Based upon published guidelines,[19] only statements for which adequate consensus was not reached were included in the Round 2 survey, to which all 52 experts were again sent an e-mail and link, adhering to the same e-mail, telephone, and data collection termination protocol used for Round 1. In accordance with published Delphi-survey guidelines, along with the statements for which no Round 1 consensus was achieved, Round 2 participants also were informed of the percentage of participants who had selected each response option in Round 1.[19]

Data analysis

Percentage consensus, defined as agreement between responders, rather than agreement with any given statement, was calculated as the number of voters selecting the most commonly selected response, divided by the total number of experts voting on that particular statement, with ≥70% consensus considered adequate consensus. Percentage participation also was calculated for each statement, with ≥80% participation considered necessary for consensus/nonconsensus to be considered valid. For quality control, all data were analyzed using both Survey Monkey's intrinsic data-analysis tool and Windows Excel version 16.0.

Table I
Practice characteristics of the sample

Practice characteristics	No. of experts	%
Region of practice		
Asia-Pacific	3	8.6
Europe	16	45.7
Middle East	5	14.3
North America	11	31.4
Nature of practice		
Primarily university based	27	77.1
Some university affiliation	5	14.3
Nonacademic	3	8.6
Yr performing colorectal surgery		
<10	10	28.6
10–20	13	37.1
>20	12	34.3
Yr performing fluorescence-guided colorectal surgery		
<5	14	40.0
5–10	13	37.1
>10	8	22.9

Results

Sample characteristics

Thirty-five (67.3%) of the 52 experts asked to complete the survey participated. Table I summarizes the practice characteristics of these 35 experts.

Consensus results

Twenty-four of the 69 statements included in this survey were favorably worded to FI, 20 unfavorably, and 25 neither favorably nor unfavorably (Table II). At least 70% consensus was reached on 60 statements: 48 in the first round, and 12 in the second. The overall consensus after 2 rounds was 82.1%, ranging from a high mean consensus of 85.9% for Module 5 (training and research) to low means of 79.1 and 79.2% for Modules 1 (patient preparation and contraindications) and 3 (technical aspects), respectively. Complete (100%) consensus was reached on just 6 statements.

Among the statements on patient preparation and contraindications (Table III), there was a strong consensus (>90%) for only 3 statements: on the rarity of allergic reactions to ICG, patients should be asked about potential allergies, and patients should be asked to provide informed written consent regarding the use of ICG. Consensus ranged from 71% to 79% for all the remaining statements where consensus was achieved, with 1 statement failing to do so; votes were roughly evenly split between those who agreed (42%) and disagreed (58%) with iodine or shellfish allergy being an absolute contraindication to ICG use.

Considerably more statements achieved ≥80% degree of consensus in the module on FI indications and general statements (Table IV), with 9 of 21 achieving >90% consensus, and 5 80% to 89% consensus. Two among the 4 statements for which under 70% consensus was achieved in Round 1 achieved consensus, while 2 failed to in Round 2. Indecision remained as to whether or not evaluating stump perfusion and whether or not assessing right-sided anastomoses should be routinely or selectively performed; however, only 1 of the 33 experts who participated in Round 2

Table II
Overall summary of results

Statements	No. of experts	%
Total no. of statements	69	100
Consensus reached	60	87.0
No consensus reached	9	13.0
Consensus reached in first round	48	69.6
Consensus reached in second round	12	17.4
100% consensus reached	6	8.7
90%–99% consensus reached	20	29.0
80%–89% consensus reached	11	15.9
70%–79% consensus reached	23	33.3
Statements agreed with (total)	31	44.9
Statements disagreed with (total)	18	26.1
Statements agreed with (consensus)	31	44.9
Statements disagreed with (consensus)	15	21.7
Statements worded favorably to fluorescence imaging or ICG	24	34.8
Statements worded unfavorably to fluorescence imaging or ICG	20	29.0
Nonjudgmental statements	25	36.2
Average consensus: Patient preparation and contraindications	79.1%	
Average consensus: General statements and indications	83.8%	
Average consensus: Technical aspects	79.2%	
Average consensus: Advantages/disadvantages and effectiveness/limitations	83.3%	
Average consensus: Training and future research	85.9%	
Average consensus: Overall	82.1%	
Minimum-maximum consensus	52-100%	
Min. When consensus reached	71%	

ICG, indocyanine green.

voted that either of these 2 steps should never be performed. Agreement with the statement was achieved for all seven statements asking experts to agree or disagree with FI being used to assess anastomoses. Conversely, 75% of respondents disagreed that FI was necessary for SLN mapping; 71% disagreed that SNL mapping with FI influenced resection more than half the time; and only 71% agreed that using FI increased the yield of retrieved lymph nodes.

There was consensus with most statements regarding technical aspects of FI use (Table V), including 100%, 79%, and 78% consensus that the timing of ICG administration, and both the concentration and dose of ICG are very important, respectively. However, there was strong consensus that the optimum dose of ICG for lymphatic area identification remains unknown and that research remains needed to establish the optimum ICG dose, concentration, and timing of administration for assessing anastomosis perfusion. Nonetheless, for evaluating anastomotic perfusion, our experts agreed on the optimum total ICG dose (5–10 mg) and timing of administration (30–60 seconds before evaluation); that ICG should be dosed on a milligram/kilogram basis, rather than as an absolute dose; that intravenous lines need to be flushed with saline, rather than serum, before such assessments; and that the ICG dose can be repeated if bright perfusion is not achieved. No consensus was reached on how long surgeons should wait before administering a second dose, with 58% selecting 3 to 5 minutes, but almost a third of experts claiming that more than a 10-minute wait was necessary between the first and second ICG dose.

Regarding the mechanics of lymphatic area evaluations, there was consensus that 2 to 4 injection points were needed. However, no consensus was reached on the plane into which the ICG should be injected (submucosal or subserosal) or on the optimum total ICG dose.

In terms of FI disadvantages and limitations (Table VI), our experts agreed that equipment availability was a limitation of intraoperative FI for colorectal surgery, but disagreed that inadequate fluorescence requiring repeat dosing, operating time, identifying suitable candidates, inadequate empirical evidence, and background fluorescence were limitations; no consensus was reached on whether regulatory issues were a limitation, though two-thirds said "no." With respect to the impact of FI on intraoperative patient risks, consensus was reached that FI decreased overall risk and the risk of AL, but exerted no impact on the risk of hemorrhage or the time required to complete surgery. Strong consensus was reached (91%) that FI has the potential to significantly change colorectal surgery practice; but no consensus was reached over whether FI was required for all or just some colorectal procedures.

Absolute agreement (100% consensus) was expressed supporting FI as a useful teaching tool for surgical residents, with 79% of participants agreeing that nonsurgical residents should also learn about ICG (Table VII). However, no consensus was reached on the

Table III
Module 1: Patient preparation and contraindications

Statement	Response	No. of rounds	Consensus, %
Consensus reached			
Allergic reactions to ICG are extremely rare.	Agree	1	100
All patients should be asked if they are allergic to iodine, shellfish, or ICG before having ICG administered.	Agree	1	96
Prior to undergoing fluorescence imaging with ICG, patients should provide written informed consent specific to its use.	Disagree	2	91
Inability to provide informed written consent is an absolute contraindication to using fluorescent angiography with ICG.	Disagree	1	79
Pregnancy is a relative contraindication to fluorescence imaging with ICG.	Agree	2	76
Known or suspected allergy to iodine or shellfish is a relative contraindication to fluorescence imaging with ICG.	Agree	1	75
Pregnancy is an absolute contraindication to fluorescence imaging with ICG.	Disagree	1	75
Prior to undergoing fluorescence imaging with ICG, patients should be provided with written information specifically addressing its use.	Disagree	2	75
Inability to provide informed written consent is a relative contraindication to using fluorescent angiography with ICG.	Disagree	1	75
Prior to undergoing fluorescence imaging with ICG, patients should be informed that its use is still experimental.	Disagree	1	71
No consensus reached			
Known or suspected allergy to iodine or shellfish is an absolute contraindication to fluorescence imaging with ICG.	Disagree	2	58

Response rate exceeded 90% for all statements
ICG, indocyanine green.

Table IV
Module 2: Indications for and general statements regarding FI during colorectal surgery

Statement	Response	No. of rounds	Consensus, %
Consensus reached			
When assessing a right-sided anastomosis, indecision regarding adequate or optimal anastomosis perfusion is an indication for FA.	Agree	1	100
Confirming adequate perfusion of the anastomosis is a reason for FA during colorectal surgery.	Agree	1	100
When assessing a left-sided anastomosis, assessing perfusion is an indication for FA.	Agree	1	96
Potentially decreasing the risk of anastomotic leakage is a reason for FA during colorectal surgery.	Agree	1	96
When assessing a right-sided anastomosis, significant atherosclerosis and mesenteric occlusion are indications for FA.	Agree	1	92
Suspected inadequate anastomosis perfusion is an indication for postanastomosis PSO (intraluminal trans-anal endoscopy) with a FA anal assessment.	Agree	1	92
Quantification of anastomotic bowel perfusion during colorectal surgery is desirable.	Agree	1	92
FA can be used to identify ureters during pelvic dissection.	Agree	1	92
When assessing a left-sided anastomosis, ischemic colitis is an indication for FA.	Agree	1	91
Potentially decreasing the risk of a stoma is a reason for FA during colorectal surgery.	Agree	1	88
When assessing a left-sided anastomosis, internal mesenteric artery ligation is an indication for FA.	Agree	1	87
FA can be used to identify pelvic nerves during pelvic dissection.	Disagree	1	83
FA significantly impacts the way that colorectal surgery is performed.	Agree	1	83
Avoiding retroperitoneal dissections is a reason for FA during colorectal surgery, especially in obese patients.	Disagree	2	82
For assessing a left-sided anastomosis, FA should be performed (routinely, selectively, never).	Routinely	1	79
If used with a left-sided anastomosis, postanastomosis PSO (intraluminal trans-anal endoscopy) with FA should be undertaken (routinely, selectively, never).	Selectively	2	76
Intraoperative lymph mapping is necessary during right-sided colectomy.	Disagree	1	75
Fluorescent lymph node mapping can increase the number of lymph nodes retrieved during colorectal surgery.	Agree	1	71
>50% of the time, fluorescent lymph node mapping influences surgical resection.	Disagree	1	71
No consensus reached			
Surgeons should evaluate rectal stump perfusion (routinely, selectively, never).	Routinely	2	64
For assessing a right-sided anastomosis, fluorescent angiography should be performed (routinely, selectively, never).	Selectively	2	52

Response rate exceeded 90% for all statements.
FA, fluorescent angiography; *PSO*, proctosigmoidoscopy.

Table V
Module 3: Technical aspects of fluorescence imaging during colorectal surgery

Statement	Response	No. of rounds	Consensus, %
Consensus reached			
For fluorescence angiography with ICG, the timing of ICG administration is very important.	Agree	1	100
When assessing bowel perfusion, the line needs to be flushed.	Agree	1	96
The optimum dose of ICG to administer for lymphatic area identification during colorectal surgery is not yet known.	Agree	1	96
When flushing the line, it should be flushed with (saline, serum).	Saline	1	92
Research is necessary to determine the optimum dose and concentration of ICG and timing of ICG administration before assessing anastomosis perfusion.	Agree	1	88
The optimum dose of ICG to administer to assess bowel perfusion has not yet been determined.	Agree	2	85
The optimum number of ICG injection points to administer for lymphatic area evaluation is (0–1, 2–4, >4).	2–4 points	1	83
For fluorescence angiography with ICG, the concentration of ICG administered is very important.	Agree	2	79
For fluorescence angiography with ICG, the dose of ICG administered is very important.	Agree	1	78
The optimum dose of ICG to administer for fluorescent perfusion assessment during colorectal surgery is (<5, 5–10, >10 mg).	5–10 mg	2	78
If bright perfusion is not achieved, the dose of ICG should be repeated.	Agree	1	75
The dose of ICG to administer for fluorescent perfusion assessment during colectomy should be determined (mg/kg, absolute dose).	mg/kg	2	73
The optimum timing for ICG administration before assessing anastomosis perfusion is generally… (<30, 30–60, >60 s)	30–60 s	1	71
No consensus reached			
For lymphatic area identification during colorectal surgery, the plane into which ICG should be injected is (submucosal, sub-serosal, other, unknown).	Submucosal	2	61
When repeating the dose of ICG to assess anastomosis perfusion, the second dose should be given after waiting (1–2, 3–5, 6–10, >10 min).	3–5 min	2	58
The optimum absolute dose of ICG to administer for lymphatic area identification during colorectal surgery is (<5, 5–10, >10 mg).	5–10 mg	2	56

Response rate exceeded 90% for all statements.
ICG, indocyanine green.

timepoint at which physician trainees should initially be exposed to this technology: medical school or residency. Consensus also was reached that using FI during colorectal surgery is not overly difficult, with 79% believing that ≤10 cases are necessary to overcome the required learning curve. Absolute (100%) to near absolute (96%) agreement was achieved that FI use will increase during the next decade, both in surgical practice and in research, respectively. Consistent with the consensus reached in Module 3 that further research is necessary to establish the optimum dose, concentration, and the timing of ICG administration, 96% of our experts agreed

Table VI
Module 4: Potential advantages, disadvantages, effectiveness, and limitations of FA during colorectal surgery

Statement	Response	No. of rounds	Consensus, %
Consensus reached			
Inadequate fluorescence and the need for repeat dosing is a major limitation of FA during colorectal surgery.	Disagree	2	97
During colorectal surgery, relative to white light alone, FA (increases, decreases, has no impact on) the risk of major hemorrhage.	Has no impact	1	92
Increased operating time is a significant limitation of using FI during colorectal surgery.	Disagree	1	92
Equipment unavailability is a major barrier to using FI during colorectal surgery.	Agree	1	92
Identifying suitable surgical candidates who might benefit from fluorescence imaging is a major barrier to its use during colorectal surgery.	Disagree	1	92
FA has the potential to significantly change colorectal surgery practice.	Agree	1	91
During colorectal surgery, relative to white light alone, FA (increases, decreases, has no impact on) overall risks.	Decreases	1	83
During colorectal surgery, relative to white light alone FA (increases, decreases, has no impact on) the risk of anastomotic leak.	Decreases	1	83
Inadequate empirical evidence supporting efficacy is a major barrier to performing FI during colorectal surgery.	Disagree	2	82
During colorectal surgery, relative to white light alone, FA (increases, decreases, has no impact on) the overall time required.	Has no impact	2	79
Background fluorescence is a significant disadvantage of using FI during colorectal surgery.	Disagree	1	71
Consensus not reached			
Regulatory issues are a major barrier to using FI during colorectal surgery.	Disagree	2	67
FA is necessary for all colorectal surgery.	Disagree	2	64

Response rate exceeded 90% for all statements.
FI, fluorescence imaging; *FA*, fluorescent angiography.

Table VII
Module 5: Training and research on fluoroscopic imaging during colorectal surgery

Statement	Response	No. of rounds	Consensus, %
Consensus reached			
FI is useful for training surgical residents about colorectal surgery.	Agree	1	100
Over the next decade, the use of FI in surgical practice is likely to (increase, decrease).	Increase	1	100
Over the next decade, the use of FI in research is likely to (increase, decrease).	Increase	1	96
To help answer some of the technical questions related to the use of FI during colorectal surgery, an international registry would be helpful.	Agree	1	96
Not just surgery residents, but residents in other, nonsurgical fields should learn about FI.	Agree	1	79
The number of cases of FA during colorectal surgery that need to be completed to overcome the learning curve is approximately (1–10, 11–25, >25) cases.	1–10 cases	1	79
A randomized clinical trial to determine the role of fluorescence imaging in the assessment of anastomosis perfusion is needed.	Agree	1	71
Consensus not reached			
Exposure to physician trainees should begin during (medical school, residency).	Residency	2	67

Response rate exceeded 90% for all statements.
FI, fluorescence imaging; *FA*, fluorescent angiography.

that an international registry would be helpful for such purposes, while 71% agreed that an RCT remains necessary.

Discussion

In all 4 published meta-analyses on FI which assessed anastomotic perfusion during colorectal surgery, statistically significant reductions in AL rates were identified among patients undergoing colorectal cancer surgery under FI.[10–13] These 4 reviews all contained studies where large reductions in leak rates, often 3- to 5-fold, failed to be statistically significant in each instance because of inadequate statistical power, thereby documenting the limitations inherent in relying on the results of individual studies alone. Since the publication of those meta-analyses, 2 additional case-control studies, both involving hundreds of patients, identified not only statistically significant reductions in the rate of ALs, but a statistically significant impact of fluorescent angiography results on resection margins[20,21]; in this way, FI impacted the surgical plan.

How FI with ICG is believed to reduce the risk of bowel anastomosis leakage is primarily linked to its ability to evaluate the adequacy of tissue perfusion and, thereby, determine a given tissue region's postoperative viability.[11] Prior meta-analyses have established FI with ICG as a useful and accurate tool for assessing tissue perfusion in other clinical settings, like plastic, vascular, and organ-transplant surgery, for such purposes as predicting tissue flap viability and wound healing, and ensuring adequate graft micro-perfusion.[22–25]

Contrary to its extensively documented efficacy assessing anastomoses, 4 published meta-analysis on FI use during colorectal surgery to identify SLN all failed to identify adequate evidence supporting its effectiveness.[14–17] Such results contrast against other meta-analyses in the literature that have examined the use of FI for SLN detection in other forms of malignancy, such as breast cancer,[26–29] melanoma,[26] head and neck cancer,[28] uterine and endometrial cancer,[30–34] and gastric cancer.[14,35–38] In such settings, sensitivity generally exceeds 90%, even when FI is used alone; and combining FI with some other technique, such as radio-scintigraphy, typically enhances SLN detection. Furthermore, in every one of the above-mentioned meta-analyses in which ICG was compared with methylene blue for SLN detection in breast, skin, and gynecological cancer, clear superiority of ICG was observed,[26,28,30,32,33] likely related to its superior tissue penetration.[14] The reasons proposed for the inferior results observed with colorectal versus these other cancers include the location of colonic sentinel lymph nodes in the fatty mesocolon and limited penetration even of fluorescent dyes into fat[14]; the risk that dye is inadvertently injected into the muscle rather than subucosal layer where the main lymphatic network is located[15]; tremendous variations in the dose, timing, number, and tissue location of ICG injections[14–16]; other technical issues; and the heterogeneity of colorectal tumors.

Regarding the technical aspects of FI during anastomosis assessments, our experts agreed that, though further research is needed for verification, the optimal ICG dose and timing are 5 to 10 mg and 30 to 60 seconds before the evaluation, respectively. They also agreed that ICG should be dosed in milligrams per kilogram, intravenous lines must be flushed with saline, and the ICG dose can be repeated if bright perfusion is not achieved. Conversely, regarding the mechanics of lymphatic area evaluations, the only consensus achieved was that 2 to 4 injection points generally are needed.

It also is notable that, among those who regularly use FI during colorectal surgery, although consensus was reached that it should be routinely performed to assess left-sided anastomoses, no consensus was reached for anastomoses on the right. Moreover, almost two-thirds of those participants who voted (64%) believed that FI is not necessary for all colorectal surgery.

Also highly notable is the strong call for further research, including RCTs, and for a registry to assist with establishing guidelines regarding the use and orchestration of FI during colorectal surgery. Clearly, although our expert panel was strongly supportive of using FI to assess the adequacy of perfusion of colorectal anastomoses and was confident in most technical aspects of its use for this purpose, most also felt that further research is necessary to confirm their beliefs and further optimize such use.

Our study has the limitations of any opinion study as it is based on the experts' experiences, including the inevitable bias favoring a given approach among experts already choosing to use it. In attempt to obviate this potential bias, we enlisted the participation of a diverse, international panel of highly qualified and highly experienced experts and attempted to minimize any influence the survey itself might have on responses by balancing the statements favoring and not favoring FI, and altering the order of favorable versus nonfavorable response options.

In conclusion, although further research remains necessary, FI appears to have value assessing anastomosis perfusion during colorectal surgery. However, its value for lymph node mapping in colorectal cancer patients is yet to be determined.

Funding/Support

Diagnostic Green; Intuitive; Medtronic; Olympus; Karl Storz; Stryker: Each provided unrestricted grants for the International Society for Fluorescence Guided Surgery (ISFGS) Advisory Board meeting, Frankfurt, Germany, September 8, 2019, during which the Delphi consensus was discussed. Diagnostic Green also funded accommodations and meals. Diagnostic Green, Medtronic, Karl Storz, Stryker, Arthrex, and Richard Wolf provided additional financial support to ISFGS for this publication.

Conflict of interest/Disclosure

Luigi Boni: consultant, Karl Storz and Arthrex; Ronan Cahill: speaker fees Olympus, Ethicon, Stryker, Diagnostic Green; consultancy: Stryker, Distalmotion; research funding: Intuitive Surgery, Medtronic, Irish Government with IBM Research and Deciphex, EU Horizon 2020. Sami Chadi: consulting and Speaker for Stryker Endoscopy; Manish Chand: consultancy: Arthrex, Activ Surgical, Karl Storz; Isaaco Montroni: Olympus SE Europe and FRESENIUS Kabi (Ger): faculty at international courses; Janice Rafferty: Stryker (consultant, speaker), Ethicon (consultant); Ris: consultant: Stryker and Arthrex; invited lecturer: MSD, J & J, Hollister; Raul Rosenthal: Consulting fees from Medtronics, Arthrex, Diagnostic Green and Ethicon. Advisory Board Member Axon Imaging Technologies. Stock Holder: Hechtech / Medicad Simulation, Germany; Danny Sherwinter: ownership interest Brainchild Surgical Devices LLC; Jun Watanabe: grants from Medtronic, AMCO, and TERUMO; payment for lectures from Medtronic, Johnson and Johnson, and Lilly (not relevant to this work); Joshua Wolf: consultant: Aroa Biosurgery; Oded Zmora: adviser, speaker, study steering committee: Takeda; speaker: Novadac/Stryker; Steven Wexner: consulting fees from Stryker, Medtronic, Intuitive, and Olympus and Royalties for intellectual property license from Intuitive and from Karl Storz; No other authors report any financial disclosures.

Acknowledgements

Luigi Boni, Danny Sherwinter, Fernando Dip, Raul Rosenthal, Kevin White, and Steven Wexner are members of the ISFGS Advisory Board. None of the industry sponsors were actively involved in any process of the Delphi consensus or drafting, review, or revision of the manuscript. All companies are sponsors/Corporate Council members of the ISFGS.

References

1. SAGES. Colon resection surgery patient information from SAGES March 1, 2015; 2015. Available from: https://www.sages.org/publications/patient-information/patient-information-for-laparoscopic-colon-resection-from-sages/#:~:text=About%20Conventional%20Colon%20Surgery%E2%80%A6,a%20number%20of%20colon%20diseases. Accessed March 11, 2021.
2. Fry DE, Nedza SM, Pine M, et al. Risk-adjusted regional outcomes in elective medicare colorectal surgery. *Am J Surg*. 2018;215:430–433.
3. Gamboa AC, Lee RM, Turgeon MK, et al. Impact of postoperative complications on oncologic outcomes after rectal cancer surgery: an analysis of the US Rectal Cancer Consortium. *Ann Surg Oncol*. 2021;28:1712–1721.
4. Gignoux B, Gosgnach M, Lanz T, et al. Short-term outcomes of ambulatory colectomy for 157 consecutive patients. *Ann Surg*. 2019;270:317–321.
5. Napolitano MA, Skancke M, Walters J, et al. Outcomes and trends in colorectal surgery in US veterans: a 10-year experience at a tertiary Veterans Affairs medical center. *J Laparoendosc Adv Surg Tech A*. 2020;30:378–382.
6. Armstrong G, Croft J, Corrigan N, et al. IntAct: intraoperative fluorescence angiography to prevent anastomotic leak in rectal cancer surgery: a randomized controlled trial. *Colorectal Dis*. 2018;20:O226–O234.
7. Dip F, Falco J, Verna S, et al. Randomized controlled trial comparing white light with near-infrared autofluorescence for parathyroid gland identification during total thyroidectomy. *J Am Coll Surg*. 2019;228:744–751.
8. Dip F, LoMenzo E, Sarotto L, et al. Randomized trial of near-infrared incisionless fluorescent cholangiography. *Ann Surg*. 2019;270:8.
9. Dip F, LoMenzo E, White KP, et al. Does near-infrared fluorescent cholangiography with indocyanine green reduce bile duct injuries and conversions to open surgery during laparoscopic or robotic cholecystectomy? - A meta-analysis. *Surgery*. 2021;169:859–867.
10. Blanco-Colino R, Espin-Basany E. Intraoperative use of ICG fluorescence imaging to reduce the risk of anastomotic leakage in colorectal surgery: a systematic review and meta-analysis. *Tech Coloproctol*. 2018;22:15–23.
11. Mizrahi I, Wexner SD. Clinical role of fluorescence imaging in colorectal surgery: a review. *Expert Rev Med Devices*. 2017;14:75–82.
12. Rausa E, Zappa MA, Kelly ME, et al. A standardized use of intraoperative anastomotic testing in colorectal surgery in the new millennium: is technology taking over? A systematic review and network meta-analysis. *Tech Coloproctol*. 2019;23:625–631.
13. Shen R, Zhang Y, Wang T. Indocyanine green fluorescence angiography and the incidence of anastomotic leak after colorectal resection for colorectal cancer: a meta-analysis. *Dis Colon Rectum*. 2018;61:1228–1234.
14. Ankersmit M, Bonjer HJ, Hannink G, et al. Near-infrared fluorescence imaging for sentinel lymph node identification in colon cancer: a prospective single-center study and systematic review with meta-analysis. *Tech Coloproctol*. 2019;23:1113–1126.
15. Emile SH, Elfeki H, Shalaby M, et al. Sensitivity and specificity of indocyanine green near-infrared fluorescence imaging in detection of metastatic lymph nodes in colorectal cancer: systematic review and meta-analysis. *J Surg Oncol*. 2017;116:730–740.

16. Liberale G, Bohlok A, Bormans A, et al. Indocyanine green fluorescence imaging for sentinel lymph node detection in colorectal cancer: a systematic review. *Eur J Surg Oncol*. 2018;44:1301–1306.
17. Villegas-Tovar E, Jimenez-Lillo J, Jimenez-Valerio V, et al. Performance of indocyanine green for sentinel lymph node mapping and lymph node metastasis in colorectal cancer: a diagnostic test accuracy meta-analysis. *Surg Endosc*. 2020;34:1035–1047.
18. Dip F, Boni L, Bouvet M, et al. Consensus conference statement on the general use of near-infrared fluorescence imaging and indocyanine green guided surgery: results of a modified Delphi study. *Ann Surgery*. 2022;275:685–691.
19. Keeney S, Hasson F, H M. *The Delphi Technique in Nursing and Health Research*. Chichester. UK: Wiley-Blackwell, 2011.
20. Hasegawa H, Tsukada Y, Wakabayashi M, et al. Impact of intraoperative indocyanine green fluorescence angiography on anastomotic leakage after laparoscopic sphincter-sparing surgery for malignant rectal tumors. *Int J Colorectal Dis*. 2020;35:471–480.
21. Watanabe J, Ishibe A, Suwa Y, et al. Indocyanine green fluorescence imaging to reduce the risk of anastomotic leakage in laparoscopic low anterior resection for rectal cancer: a propensity score-matched cohort study. *Surg Endosc*. 2020;34:202–208.
22. Jeon FHK, Varghese J, Griffin M, et al. Systematic review of methodologies used to assess mastectomy flap viability. *BJS Open*. 2018;2:175–184.
23. Liu EH, Zhu SL, Hu J, et al. Intraoperative SPY reduces postmastectomy skin flap complications: a systematic review and meta-analysis. *Plast Reconstr Surg Glob Open*. 2019;7:e2060.
24. Rother U, Amann K, Adler W, et al. Quantitative assessment of microperfusion by indocyanine green angiography in kidney transplantation resembles chronic morphological changes in kidney specimens. *Microcirculation*. 2019;26:e12529.
25. Rother U, Lang W. Noninvasive measurements of tissue perfusion in critical limb ischemia. *Gefasschirurgie*. 2018;23(suppl 1):8–12.
26. Niebling MG, Pleijhuis RG, Bastiaannet E, et al. A systematic review and meta-analyses of sentinel lymph node identification in breast cancer and melanoma, a plea for tracer mapping. *Eur J Surg Oncol*. 2016;42: 466–473.
27. Sugie T, Ikeda T, Kawaguchi A, et al. Sentinel lymph node biopsy using indocyanine green fluorescence in early-stage breast cancer: a meta-analysis. *Int J Clin Oncol*. 2017;22:11–17.
28. Zeng HC, Hu JL, Bai JW, et al. Detection of sentinel lymph nodes with near-infrared imaging in malignancies. *Mol Imaging Biol*. 2019;21: 219–227.
29. Zhang X, Li Y, Zhou Y, et al. Diagnostic performance of indocyanine green-guided sentinel lymph node biopsy in breast cancer: a meta-analysis. *PLoS One*. 2016;11:e0155597.
30. Ulain Q, Han L, Wu Q, et al. Indocyanine green can stand alone in detecting sentinel lymph nodes in cervical cancer. *J Int Med Res*. 2018;46:4885–4897.
31. Wu Y, Jing J, Wang J, et al. Robotic-assisted sentinel lymph node mapping with indocyanine green in pelvic malignancies: a systematic review and meta-analysis. *Front Oncol*. 2019;9:585.
32. Bodurtha Smith AJ, Fader AN, Tanner EJ. Sentinel lymph node assessment in endometrial cancer: a systematic review and meta-analysis. *Am J Obstet Gynecol*. 2017;216:459–476.e10.
33. Lin H, Ding Z, Kota VG, et al. Sentinel lymph node mapping in endometrial cancer: a systematic review and meta-analysis. *Oncotarget*. 2017;8: 46601–46610.
34. Sullivan SA, Rossi EC. Sentinel lymph node biopsy in endometrial cancer: a new standard of care? *Curr Treat Options Oncol*. 2017;18:62.
35. He M, Jiang Z, Wang C, et al. Diagnostic value of near-infrared or fluorescent indocyanine green guided sentinel lymph node mapping in gastric cancer: a systematic review and meta-analysis. *J Surg Oncol*. 2018;118:1243–1256.
36. Huang L, Wei T, Chen J, et al. Feasibility and diagnostic performance of dual-tracer-guided sentinel lymph node biopsy in cT1-2N0M0 gastric cancer: a systematic review and meta-analysis of diagnostic studies. *World J Surg Oncol*. 2017;15:103.
37. Skubleny D, Dang JT, Skulsky S, et al. Diagnostic evaluation of sentinel lymph node biopsy using indocyanine green and infrared or fluorescent imaging in gastric cancer: a systematic review and meta-analysis. *Surg Endosc*. 2018;32: 2620–2631.
38. Takeuchi H, Kitagawa Y. Sentinel node navigation surgery in patients with early gastric cancer. *Dig Surg*. 2013;30:104–111.