



Feasibility of laser speckle contrast imaging (LSCI) in colorectal surgery: a prospective comparison with indocyanine green (ICG) fluorescence angiography

Salvador Morales-Conde^{1,2} · Angela Belvedere^{1,3} · Laura Navarro Morales^{1,2} · Elena Guarnieri¹ · Andrea Balla^{1,2}

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Abstract

Background Adequate bowel perfusion is essential for anastomotic healing in colorectal surgery. Indocyanine green (ICG) fluorescence angiography (FA) is currently considered the gold standard for intraoperative perfusion assessment. Laser speckle contrast imaging (LSCI) is an emerging, dye-free technology that enables real-time evaluation of microvascular blood flow. The aim of this study is to assess the feasibility of LSCI in elective colorectal surgery and to compare its performance with ICG-FA for intraoperative evaluation of bowel perfusion.

Methods A prospective study was conducted including consecutive patients undergoing elective laparoscopic colorectal surgery between September 2025 and March 2026. Bowel perfusion was assessed intraoperatively using both LSCI and ICG-FA. The primary endpoint was feasibility of LSCI, while the secondary endpoint was concordance between these two technologies in determining the bowel section line.

Results Twenty-two patients were included: 7 right hemicolectomies, 11 left hemicolectomies, and 4 anterior rectal resections. LSCI and ICG-FA were successfully performed in all cases (100%). Overall concordance between LSCI and ICG-FA was 86.2%. Concordance was 100% for ileum and 57.1% for transverse colon in right hemicolectomy, 100% in left hemicolectomy and 75% in anterior resection of the rectum. Two postoperative complications were observed, both following anterior resection of the rectum: one patient developed postoperative ileus (Clavien–Dindo I), and one patient developed abdominal pain, fever of unknown origin, and intra-abdominal fluid collection requiring revision surgery, which did not reveal an anastomotic leak (Clavien–Dindo III-b). Mean hospital stay was 6 ± 4 days.

Conclusions LSCI appears to be a feasible tool for intraoperative assessment of bowel perfusion, demonstrating high concordance with ICG-FA. Its dye-free and real-time capabilities make it a promising adjunct to ICG-FA. Larger prospective, multicentre, randomized studies are warranted to further define the clinical impact of LSCI in evaluating bowel vascularization and its potential role in improving surgical outcomes.

Keywords Laser speckle contrast imaging (LSCI) · Indocyanine green (ICG) · Fluorescence angiography (FA) · Intraoperative imaging · Colorectal surgery · Bowel perfusion · Anastomotic leakage (AL)

✉ Andrea Balla
andrea.balla@gmail.com
Salvador Morales-Conde
smoralesc@gmail.com
Angela Belvedere
angela.belvedere@hotmail.it
Laura Navarro Morales
lnavarrom87@gmail.com
Elena Guarnieri
e.guarnieri93@gmail.com

¹ Department of General and Digestive Surgery, University Hospital Virgen Macarena, University of Sevilla, Sevilla, Spain
² Unit of General and Digestive Surgery, Hospital Quirónsalud Sagrado Corazón, Sevilla, Spain
³ Department of General and Digestive Surgery, IRCCS, Sant'Orsola Hospital, Bologna, Italy

Anastomotic leakage (AL) is one of the most severe complications in colorectal surgery, ranging between 3 and 20%, with a negative impact on postoperative morbidity and mortality [1–4].

Several risk factors are related to AL, some of them depending on the patients' characteristics such as age, gender, comorbidities, body mass index (BMI), smoking habits, and others are related to tumour such as the need for neoadjuvant chemoradiotherapy [5–7]. Additionally, other factors are related to surgical technique, including the anastomosis tension and vascular supply [5–7].

Adequate bowel perfusion is essential for proper anastomotic healing [8]. Intraoperative assessment of bowel perfusion may rely on subjective clinical evaluation or on objective methods, including technologies that have been progressively introduced over the years, such as Doppler ultrasound, Doppler flowmetry, and light spectroscopy [9–12]. More recently, indocyanine green (ICG) fluorescence imaging has been increasingly adopted, particularly in minimally invasive surgery, for a variety of intraoperative applications, including anatomical structure identification, lymphatic mapping, and real-time assessment of bowel perfusion [13–20]. As a result, ICG-fluorescence angiography (FA) is now considered the gold standard for intraoperative evaluation of intestinal vascularization during anastomotic creation with improved outcomes in terms of AL compared to conventional assessment methods [21–23].

In parallel with these advancements, fluorescence-guided surgery has opened new perspectives, including the development of novel tracers for tumour-targeted imaging and ureter identification, as well as the use of different light-based technologies to enhance intraoperative visualization of anatomical structures [24]. These innovations have also stimulated the development of alternative, dye-free imaging modalities for tissue perfusion assessment [24].

Recently, light-based spectral imaging technologies have been introduced for the assessment of tissue perfusion [25–27]. These modalities can be distinguished according to the wavelength of light employed, including laser speckle contrast imaging (LSCI) (approximately 630–850 nm), hyperspectral imaging (approximately 500–1000 nm), and near-infrared spectroscopy (700–1000 nm) [25–27]. However, despite promising preliminary results, their clinical adoption remains limited, and these techniques are not yet routinely employed in surgical practice [25–27].

LSCI assesses microvascular tissue perfusion by analysing the dynamic interference pattern generated when coherent laser light is scattered by moving red blood cells, provides reliable, real-time, and reproducible information on bowel perfusion, supporting intraoperative decision-making regarding the extent of resection prior to anastomosis in gastrointestinal surgery [26, 27]. However, despite its promising applications, only a limited number of clinical studies have

reported on the use of LSCI for intraoperative assessment of bowel perfusion.

The aim of this study is to assess the feasibility of LSCI in elective colorectal surgery and to compare its performance with ICG-FA for intraoperative evaluation of bowel perfusion.

Materials and methods

This is a prospective study. Institutional review board approval (SICEIA-2025–002336) and informed consent from participants were obtained.

Patients enrolment

From September 2025 to March 2026, all consecutive patients who underwent elective laparoscopic colorectal surgery (including right and left hemicolectomy and anterior resection of the rectum) for benign or malignant diseases with perfusion evaluation by ICG-FA and LSCI in our centre (Unit of General and Digestive Surgery, Hospital Quirónsalud Sagrado Corazón, Sevilla, Spain) were included in the study.

Endpoints

The primary endpoint was to evaluate the feasibility of LSCI to assess the bowel perfusion before the anastomosis creation.

The second endpoint was to compare the concordance between the section line suggested by ICG-FA and LSCI.

Surgical technique and bowel perfusion assessment

All surgical procedures were performed as previously reported [28–30].

The 1788 AIM Camera System (Stryker, Kalamazoo, Michigan, USA) with a 30° forward oblique optic is used [28–30].

ICG powder 25 mg (Verdye, Diagnostic Green, Aschheim-Dornach, Germany) was diluted in 5 cc of sterile water and 3 cc intravenous were employed for fluorescence during surgery (a total of 15 mg per each patient), as previously reported [28–30].

For LSCI, the device used was the ActivSight imaging module (Activ Surgical, Boston, Massachusetts, USA), a Food and Drug Administration (FDA) 510(k)-cleared system for endoscopic fluorescence and near-infrared imaging in minimally invasive surgery [31]. The device enables real-time assessment of tissue perfusion using both LSCI and ICG-FA [31]. The module is positioned between a standard laparoscope and the camera system and integrates an

infrared sensor with conventional red, green, blue (RGB) imaging, allowing the visualization of near-infrared signals [31]. White light and infrared signals are combined to generate a real-time overlay of either the LSCI perfusion colourmap or ICG fluorescence onto the surgical field [31]. LSCI evaluation provides a colourmap based on perfusion: warmer hues (red/orange) indicate higher tissue perfusion, whereas cooler hues (blue) denote lower perfusion [25–27, 31]. These visual patterns were used to guide intraoperative decision-making, with well-perfused areas (warmer colours) considered suitable for transection and anastomosis creation. However, no predefined quantitative thresholds were applied, and perfusion assessment was based on visual interpretation by the operating surgeons.

Before bowel transection (intracorporeally in case of right hemicolectomy and extracorporeally in case of left hemicolectomy and anterior resection of the rectum), the section line was initially defined under white light visualization, followed by perfusion assessment using LSCI and subsequently ICG-FA with the camera positioned approximately 5 cm from the bowel (Figs. 1 and 2). The section line based on ICG-FA was marked at the peak of fluorescence, and the time from ICG injection and fluorescence visualization (TIFV) [30] was recorded. The section line was determined based on the first arrival and peak fluorescence,

as subsequent diffusion of ICG may result in a progressive extension of the fluorescence signal beyond the true perfusion boundary. For this reason, delayed fluorescence was not considered in the assessment.

Perfusion assessment time (in seconds), including LSCI and ICG-FA angiography with TIFV, was recorded from the first section mark under white light to the ICG-FA evaluation mark.

The section lines indicated by the surgeon and by the two technologies were recorded, and the difference between them was measured in centimetres. During right hemicolectomy, the section lines at both the terminal ileum and the transverse colon were recorded.

In cases of discordance among the section lines indicated by the surgeon and the two imaging modalities, the final section line was determined according to a predefined rule. The most proximal well-perfused point was selected in ileum during right hemicolectomy and left colon during left hemicolectomy and anterior resection of the rectum, whereas the most distal well-perfused point was chosen in the transverse colon during right hemicolectomy to ensure adequate perfusion.

A change in the section line was defined as any deviation from the initial section line marked by the surgeon under white light visualization, which was used as the reference.

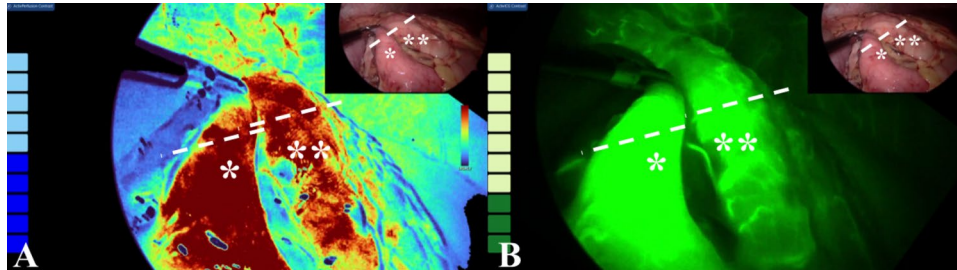


Fig. 1 Right hemicolectomy. **A** Bowel perfusion assessment using laser speckle contrast imaging (LSCI). **B** Corresponding assessment using indocyanine green-fluorescence angiography (ICG-FA).

Dashed white lines indicate the section lines. A single asterisk indicates the ileum, whereas double asterisks indicate the transverse colon

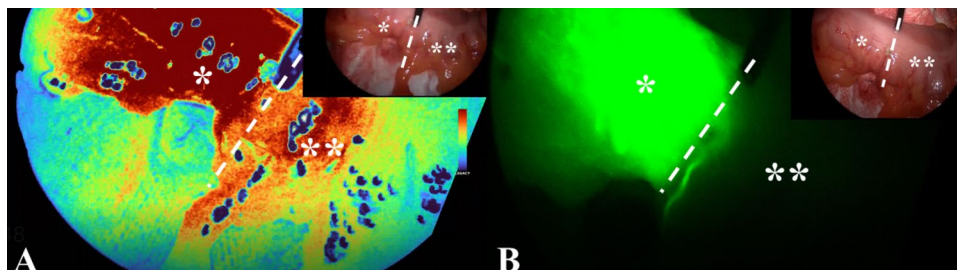


Fig. 2 Left hemicolectomy. **A** Bowel perfusion assessment using laser speckle contrast imaging (LSCI). **B** Corresponding assessment using indocyanine green-fluorescence angiography (ICG-FA).

Dashed white lines indicate the section lines. A single asterisk indicates the proximal colon, whereas double asterisks indicate the rectum

Study design

Gender, age, BMI, comorbidities, previous abdominal surgery, American Society of Anaesthesiologists (ASA) grade, neoadjuvant chemoradiotherapy (n-CRT), indication for surgery, surgical procedure, intraoperative complications, conversion to open surgery, type of anastomosis, protective or ghost ileostomy creation, operative time (minutes), postoperative complications (graded according to the Clavien–Dindo classification [32]), reintervention, length of hospital stay (LOS), mortality, definitive histology and stage according to the American Joint Committee on Cancer (AJCC) classification [33], need for ICG reinjection, TIFV (seconds) [30], concordance between the white light section mark and ICG-FA, mean distance between the white light section mark and ICG-FA, concordance between the white light section mark and LSCI, mean distance between the white light section mark and LSCI, concordance between the ICG-FA and LSCI, mean distance between the ICG-FA and LSCI, change of section line according to perfusion assessment and time required to perform perfusion assessment including ICG-FA and LSCI angiography and TIFV (seconds) were

stored in the Microsoft Excel programme (Microsoft Corporation, Redmond, Washington, USA).

Statistical analysis

Continuous variables are expressed as mean $\pm$ standard deviation (SD), and categorical variables as frequencies and percentages.

Results

Overall, 22 patients were enrolled in this study. Of these patients, 7 underwent right hemicolectomy (31.8%), 11 underwent left hemicolectomy (50%), and 4 underwent anterior resection of the rectum (18.2%). The most common indication for surgery was adenocarcinoma in 19 patients (86%) and benign disease in 3 patients (14%). All patients underwent laparoscopic surgery without intraoperative complications or need for conversion to open surgery. Tables 1 and 2 report patients' demographics and perioperative results, respectively.

Table 1 Patients' demographics

	Entire series <i>N</i> = 22	Right hemicolectomy <i>n</i> = 7	Left hemicolectomy <i>n</i> = 11	Anterior resection of the rectum <i>n</i> = 4
Sex ratio (men/women), <i>n</i> (%)	9 (41): 13 (59)	3 (43): 4 (57)	3 (27.3): 8 (72.7)	3 (75): 1 (25)
Mean age $\pm$ standard deviation, years	65.4 $\pm$ 10.8	66 $\pm$ 11	64 $\pm$ 11.9	66.7 $\pm$ 11.4
Mean body mass index $\pm$ standard deviation, Kg/m ²	26.5 $\pm$ 5.3	26 $\pm$ 4.3	26.5 $\pm$ 6.7	27 $\pm$ 2.9
Comorbidities, <i>n</i> (%)				
Hypertension	8 (36)	3 (42.9)	3 (27.3)	2 (50)
Diabetes mellitus	3 (14)	2 (28.6)	1 (9.1)	–
Ischaemic heart disease	1 (4.5)	–	–	1 (25)
Cardiac arrhythmia	2 (9)	1 (14.3)	1 (9.1)	–
Obstructive sleep apnoea	1 (4.5)	–	1 (9.1)	–
Cerebral stroke	1 (4.5)	–	1 (9.1)	–
Smoke habits	3 (14)	1 (14.3)	1 (9.1)	1 (25)
Previous abdominal surgery, <i>n</i> (%)				
Laparoscopic hysterectomy	1 (4.5)	1 (14.3)	–	–
Open distal pancreatectomy	–	–	1 (9.1)	–
Caesarean section	–	–	1 (9.1)	–
American Society of Anaesthesiologists grade, <i>n</i> (%)				
I	2 (9)	–	1 (9.1)	1 (25)
II	11 (50)	4 (57.1)	5 (45.5)	2 (50)
III	9 (41)	3 (42.9)	5 (45.5)	1 (25)
Neoadjuvant therapy, <i>n</i> (%)				
Chemotherapy	1 (4.5)	–	–	1 (25)
Indication to surgery, <i>n</i> (%)				
Adenocarcinoma	19 (86)	5 (71)	10 (90)	4 (100)
Benign disease	3 (14)	2 (29)	1 (10)	–

Table 2 Perioperative results

	Entire series <i>N</i> = 22	Right hemicolectomy <i>n</i> = 7	Left hemicolectomy <i>n</i> = 11	Anterior resection of the rectum <i>n</i> = 4
Intraoperative complications, <i>n</i> (%)	–	–	–	–
Conversion to open surgery, <i>n</i> (%)	–	–	–	–
Type of mechanical anastomosis, <i>n</i> (%)				
Side-to-end	15 (68)	–	11 (100)	4 (100)
Side-to-side	7 (32)	7 (100)	–	–
Ghost ileostomy creation, <i>n</i> (%)	3 (14)	–	–	3 (75)
Mean operative time $\pm$ standard deviation, minutes	92 $\pm$ 46	61 $\pm$ 14	92 $\pm$ 50	124 $\pm$ 38
Postoperative complications <i>n</i> , (% according to Clavien–Dindo classification) grade				
Paralytic ileus	1 (4.5)	–	–	1 (25, I)
Fever of unknown origin	1 (4.5)	–	–	1 (25, III-b)
Anastomotic leakage	–	–	–	–
Reintervention, <i>n</i> (%)	1 (4.5)	–	–	1 (25)
Mean hospital stay $\pm$ standard deviation, days	6 $\pm$ 4	5 $\pm$ 1	4.6 $\pm$ 1.3	12.5 $\pm$ 8
Mortality, <i>n</i> (%)	–	–	–	–
Definitive histology, <i>n</i> (%)				
Adenocarcinoma	19 (86)	5 (71)	10 (90)	4 (100)
Adenoma	3 (14)	2 (29)	1 (10)	–
Stage, <i>n</i> (% out of 19 patients)				
I	6 (32)	3 (60)	1 (10)	2 (50)
II	6 (32)	–	5 (50)	–
III	6 (32)	2 (40)	3 (30)	2 (50)
IV	1 (4)	–	1 (10)	–

Both LSCI and ICG-FA were performed in all patients. LSCI and ICG-FA successfully assessed the bowel perfusion before the creation of the anastomosis in all cases (100%).

Overall, concordance rate between the white light section mark and ICG-FA was 93% (27 out of 29 perfusion evaluations), 79.3% between the white light section mark and LSCI (23 out of 29 perfusion evaluations), and 86.2% between the ICG-FA and LSCI (25 out of 29 perfusion evaluations). The mean time required for perfusion assessment, including both ICG-FA and LSCI, was 156.8 $\pm$ 13.8 s (02:36 min), and overall mean operative time of the entire procedure was 92 $\pm$ 46 min (Table 3).

Overall, the intracorporeal evaluation of bowel perfusion during right hemicolectomy had a concordance rate was 78.6% (11 out of 14 section lines) between LSCI and ICG-FA, while extracorporeal evaluation during left hemicolectomy and anterior resection of the rectum had a concordance rate of was 93.3% (14 out of 15 section lines) between LSCI and ICG-FA.

During right hemicolectomy concordance rate between white light, LSCI and ICG-FA for the ileum evaluation were 100% (7 out of 7). For the transverse colon evaluation, concordance rate between white light and ICG-FA was 100% (7 out of 7), and the concordance rate between LSCI and white

light, as well as between LSCI and ICG-FA, was identical at 57.1% (4 out of 7). The three discordant cases show a mean distance between white light and ICG-FA with LSCI of 1.7 $\pm$ 0.6 cm. Mean TIFV was 24.5 $\pm$ 7.5 s, and mean time required for perfusion assessment was 159.3 $\pm$ 15.9 s (02:39 min), and overall mean operative time of the entire procedure was 61 $\pm$ 14 min. Postoperative complications did not occur, and mean LOS was 5 $\pm$ 1 (Tables 2 and 3).

During left hemicolectomy, the concordance rate between white light and ICG-FA, as well as between white light and LSCI, was identical at 82% (9 out of 11), and concordance rate between ICG-FA and LSCI was 100% (11 out of 11). The two discordant cases show a mean difference in section line of 6 $\pm$ 5.6 cm. Mean TIFV was 23.3 $\pm$ 6.6 s and mean time required for perfusion assessment was 155.5 $\pm$ 14.9 s (02:35 min), and overall mean operative time of the entire procedure was 92 $\pm$ 50 min. Postoperative complications did not occur, and mean LOS was 4.6 $\pm$ 1.3 (Tables 2 and 3).

In the group of anterior resections of the rectum, all patients underwent total mesorectal excision (TME), and in three of them (75%) a ghost ileostomy was performed in order to avoid protective ileostomy. Concordance rate between white light and ICG-FA was 100% (4 out of 4), and the concordance rate between white light and LSCI

Table 3 Perfusion assessment

	Total stumps assessed <i>N</i> =29	Right hemi- colectomy ileum <i>n</i> =7	Right hemi- colectomy colon <i>n</i> =7	Left hemi- colectomy <i>n</i> =11	Anterior resection of the rectum <i>n</i> =4
ICG reinjection, <i>n</i> (%)	—	—	—	—	—
Mean time TIFV $\pm$ SD, seconds	23.4 $\pm$ 6.3	24.5 $\pm$ 7.5		23.3 $\pm$ 6.6	22 $\pm$ 5
Concordance between the white light section mark and ICG-FA, <i>n</i> (%)	27 (93)	7 (100)	7 (100)	9 (82)	4 (100)
Mean distance between the white light section mark and ICG-FA $\pm$ SD, centimetres	6 $\pm$ 5.6	—	—	6 $\pm$ 5.6	—
Concordance between the white light section mark and LSCI, <i>n</i> (%)	23 (79.3)	7 (100)	4 (57.1)	9 (82)	3 (75)
Mean distance between the white light section mark and LSCI $\pm$ SD, centimetres	4 $\pm$ 3.6	—	1.7 $\pm$ 0.6	6 $\pm$ 5.6	7
Concordance between the ICG-FA and LSCI, <i>n</i> (%)	25 (86.2)	7 (100)	4 (57.1)	11 (100)	3 (75)
Mean distance between ICG-FA and LSCI $\pm$ SD, centimetres	3 $\pm$ 2.7	—	1.7 $\pm$ 0.6	—	7
Change of line section according to perfusion assessment, <i>n</i> (%)	3 (10.3)	—	—	2 (18)	1 (25)
Mean time for perfusion assessment including ICG-FA, LSCI, and TIFV $\pm$ SD, seconds	156.8 $\pm$ 13.8	159.3 $\pm$ 15.9		155.5 $\pm$ 14.9	156.3 $\pm$ 7.5

SD standard deviation, *TIFV* time from indocyanine green injection and fluorescence visualization, *ICG* indocyanine green, *FA* fluorescence angiography, *LSCI* laser speckle contrast imaging

and between ICG-FA and LSCI was identical at 75% (3 out of 4). A 7 cm discrepancy was observed between the LSCI assessment and both ICG-FA and white light assessments; the section line was ultimately based on LSCI, as it identified the most proximal margin. Mean TIFV was 22 ± 5 s and mean time required for perfusion assessment was 156.3 ± 7.5 s (02:36 min), and overall mean operative time of the entire procedure was 124 ± 38 min. Two post-operative complications were observed, both following anterior resection of the rectum: one patient developed postoperative ileus (Clavien–Dindo I), which was successfully managed with conservative measures and bowel rest, and one patient developed abdominal pain, fever of unknown origin, and intra-abdominal fluid collection diagnosed by computed tomography (CT) scan, requiring surgical reintervention (Clavien–Dindo III-b). In this last case, Transanal Minimally Invasive Surgery (TAMIS) for anastomotic evaluation confirmed an intact anastomosis, and subsequent re-laparoscopy with intraperitoneal lavage did not reveal any intra-abdominal collection or anastomotic leakage. As a result, no ALs occurred in this series. Mean LOS was 12.5 ± 8 (Tables 2 and 3).

A detailed analysis of the concordance between white light assessment, LSCI and ICG-FA across the different procedures, as well as the resulting impact on the section line, is summarized in Fig. 3.

Discussion

This prospective study demonstrates the feasibility of LSCI for the intraoperative assessment of bowel perfusion in colorectal surgery. Our findings show a high concordance rate between LSCI and ICG-FA (overall 86.2%), supporting the potential role of this technology as a reliable tool for real-time intraoperative bowel perfusion evaluation. However, when analysed according to the type of procedure, concordance was 100% for ileum and 57.1% for transverse colon in right hemicolectomy, 100% in left hemicolectomy and 75% in anterior resection of the rectum. The lower concordance observed during intracorporeal perfusion assessment (78.6%) in comparison to the extracorporeal assessment (93.3%) may be related to technical factors, such as the presence of adjacent bowel loops, increased volumes of overlying adipose tissue, and bowel movement, which may interfere with optical signal acquisition and lead to underestimation of perfusion [26]. These limitations are not present in extracorporeal bowel evaluation [26].

In this study, right hemicolectomy, left hemicolectomy, and anterior resection of the rectum were included to comprehensively assess the feasibility of LSCI across different types of colorectal procedures. This design allowed

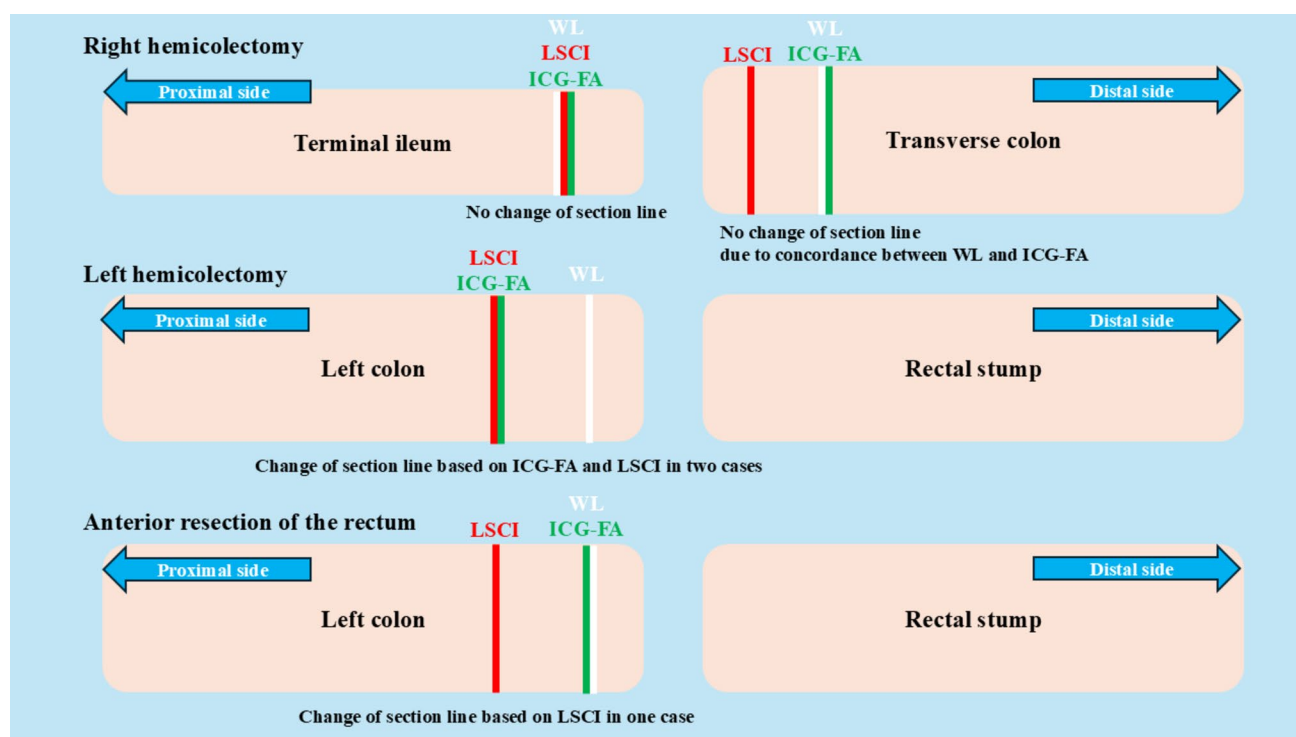


Fig. 3 Summary of perfusion assessment and concordance between white light (WL) evaluation, indocyanine green-fluorescence angiography (ICG-FA), and laser speckle contrast imaging (LSCI) across different colorectal procedures. No changes in the section line were observed during right hemicolectomy. At the ileal level, all methods were concordant. At the transverse colon level, no changes were required, as ICG-FA was concordant with WL assessment and both

were more distal compared to LSCI. In left hemicolectomy, two changes in the section line were required, as both ICG-FA and LSCI indicated a more proximal well-perfused area compared to the initial WL marking. In anterior resection of the rectum, one change in the section line was observed, as LSCI indicated a more proximal well-perfused area compared to initial WL marking and ICG-FA

evaluation of LSCI in both intracorporeal and extracorporeal settings, as typically performed in right-sided and left-sided/rectal resections, respectively.

LSCI was compared with ICG-FA to provide a direct and objective comparison with the current reference standard for intraoperative assessment of bowel perfusion, while ensuring that patients received the standard of care without being exposed to an increased risk of AL. By analysing differences in the section line determined by each technology, we were able to assess the level of concordance between LSCI and ICG-FA and, consequently, to evaluate the reliability of LSCI as a perfusion assessment tool.

It should be noted that no standardized threshold defining an acceptable level of concordance between imaging modalities currently exists. Therefore, these findings should be interpreted in the context of an exploratory feasibility study, and the clinical relevance of discordant findings remains to be determined. Furthermore, concordance between imaging modalities does not necessarily reflect accuracy or clinical validity. Discrepancies between LSCI and ICG-FA should therefore be interpreted with caution, as it remains unclear whether they reflect limitations of either modality or both. In

our series, concordance varied according to anatomical location, with lower agreement observed in clinically relevant segments such as the right colon and rectum. In particular, the spatial discrepancies observed in some cases (up to 7 cm in rectal resections) may have important implications for surgical decision-making, as they could influence the choice of transection line. The clinical significance of these differences remains uncertain and warrants further investigation.

Despite these considerations, in the present study, each patient served as their own control, minimizing the impact of patient-related and intraoperative factors that could influence bowel perfusion. This approach reduces potential confounding factors and allows a more accurate and unbiased comparison between the two imaging modalities.

In the literature, only a limited number of clinical studies have reported on the use of LSCI in colorectal surgery, all demonstrating the feasibility of this technology for intraoperative bowel perfusion evaluation [26, 27, 31, 34–38] (Table 4).

The majority of the available studies on LSCI in colorectal surgery have predominantly focussed on left-sided resections or anterior rectal surgery [27, 31, 34–36]. Only a

Table 4 Series about the clinical use of laser speckle contrast imaging (LSCI) reported in the literature

Authors	Study design	N of patients: LSCI/white light	Surgery performed	Difference in section line based on LSCI, <i>n</i> (%)	Bowel section based on LSCI	Anastomotic leak, <i>i</i> (%)
Paramasivam et al. [26]	Prospective	20/-	Right hemicolectomy	10 (50) ^a	No	2 (10)/-
Yu et al. [27]	Propensity score match analysis	60/60 ^b	Anterior resection of the rectum	5 (10)	Yes	2 (3.3)
Skinner et al. [31]	Retrospective match analysis	23 in comparison to ICG-FA	Left-sided resection*	4 (17.4)	n.s	n.s
Kojima et al. [34]	Retrospective match analysis	27/27	Left-sided resection*	0	Yes	0 / 5 (18.5)
Kaneko et al. [35]	Retrospective match analysis	36/87	Left-sided resection*	15 (41.6)	Yes	3 (8.3)/13 (14.9)
Yu et al. [36]	Retrospective match analysis	105/176	Anterior resection of the rectum	6 (5.7)	Yes	2 (1.9)/15 (8.5)
Heeman et al. [37]	Prospective	64/-	Right and left-sided resection*	11 (17) ^a	No	2 (3.1)/-
Present series	Prospective	22/-In comparison to ICG-FA	Right and left-sided resection*	Right hemicolectomy, ileum:- Right hemicolectomy, colon:- Left hemicolectomy: 2 (18) Rectum resection: 1 (25)	Yes	0/-

LSCI laser speckle contrast imaging, ICG-FA indocyanine green-fluorescence angiography, *n.s.* not specified

*Including left hemicolectomy, sigmoidectomy, high anterior resection, low anterior resection, or ultra-low anterior resection

^aLSCI impact was evaluated postoperatively

^bEach patient served as their own control, undergoing both LSCI and white light assessment of bowel perfusion

limited number of studies, including those by Paramasivam et al. and Heeman et al., have evaluated the use of LSCI in right-sided resections, while most of the current evidence remains restricted to left colon and rectal procedures [26, 37]. This reflects an early phase in the clinical adoption of this technology. Given the relevance of perfusion assessment across the entire spectrum of colorectal surgery, LSCI should ideally be evaluated and applied in both right- and left-sided resections. In this context, our study contributes by providing data across all types of colorectal procedures, including right hemicolectomy, which remains underrepresented in the literature (Table 4).

Among the available studies, only a limited number have assessed the impact of LSCI on intraoperative decision-making, particularly regarding changes in the bowel transection line [27, 34–36]. These studies have used LSCI to guide resection, demonstrating that this technology may be useful for intraoperative surgical decision-making [27, 34–36]. In our study, however, we deliberately chose to base the final decision on ICG-FA findings, as LSCI is not yet a standardized or widely validated technique. This approach ensured patient safety and adherence to the current standard of care.

Although preliminary data suggest that LSCI-guided assessment may be associated with lower AL rates compared to conventional white light evaluation, this comparison has been reported in few studies to date [34–36]. Consequently, these findings should be interpreted with caution due to the heterogeneity of study designs and the limited level of evidence [34–36] (Table 4).

LSCI presents several potential advantages compared to ICG-FA [26, 27, 31, 34–38]. It is a dye-free technology that does not require intravenous dye injection, thereby avoiding potential risks associated with contrast agents [26, 27, 31, 34–38]. In addition, LSCI allows continuous, real-time perfusion assessment and can be repeated multiple times without limitations [26, 27, 31, 34–38]. Furthermore, unlike ICG-FA, LSCI is not influenced by time-dependent diffusion phenomena, which in fluorescence imaging may result in a progressive spread of the signal and a potential misinterpretation of the true perfusion boundary [26, 27, 31, 34–38]. However, this technology also has important drawbacks such as it is highly sensitive to motion artifacts, it has a limited depth of tissue penetration, typically assessing only superficial perfusion (approximately 1–2 mm), and the fact that

integration of the LSCI device into standard laparoscopic instrumentation increases the weight of the laparoscopic system and reduces manoeuvrability [26, 27, 31, 34–38]. In addition, in robotic surgery, the use of LSCI requires an additional auxiliary camera, which could limit its widespread adoption [31, 38] (Table 4).

Only one study by Skinner et al. has directly compared LSCI with ICG-FA in colorectal surgery [31]. In that study, conducted exclusively in left-sided resections, a discordance rate between the two modalities was observed, similar to that reported in our series (17% versus 13.8% among all the procedures) [31]. However, no data are available on such comparison in right-sided procedures, further highlighting the novelty of our findings and the need for additional studies in this setting (Table 4).

Finally, in the study by Paramasivam et al. and Heeman et al. [26, 37], the impact of LSCI on surgical decision-making was evaluated postoperatively, based on retrospective video analysis rather than real-time intraoperative use [26, 37]. This limits the interpretability of their findings, as it does not fully reflect the actual intraoperative decision-making process. Overall, the current literature on LSCI in colorectal surgery remains highly heterogeneous in terms of study design, patient population, surgical procedures, and endpoints, making direct comparisons challenging and underscoring the need for standardized methodologies in future research.

The main limitations of the present study include the small sample size, which represents a major limitation inherent to its feasibility design and may significantly limit the generalizability of the findings. Its single-centre design, with procedures performed by experienced surgeon, may also introduce selection and operator bias. A potential learning curve effect associated with the use and interpretation of LSCI cannot be excluded, and LSCI assessment may also be influenced by device-specific characteristics and operator-dependent interpretation. Furthermore, the study was not powered to evaluate clinical outcomes such as AL, as its primary aim was to assess feasibility and concordance between imaging modalities. Moreover, no formal inferential statistical analysis was performed due to the limited sample size, particularly when considering subgroup analyses according to the type of surgical procedure, which further reduces the robustness of comparative findings and precludes more advanced agreement analyses.

In addition, the heterogeneity of the included procedures (right hemicolectomy, left hemicolectomy, and anterior resection of the rectum) may have influenced the perfusion assessment and the concordance rates observed between LSCI and ICG-FA. Furthermore, technical factors such as bowel manipulation, the presence of adjacent structures, and variability in adipose tissue distribution may have affected the quality of LSCI signal acquisition, particularly in right-sided resections.

The lack of quantitative perfusion thresholds and the reliance on visual interpretation may introduce observer bias and represent additional limitations of both imaging modalities, highlighting the need for further standardization and validation, highlighting the need for further standardization, including the development of quantitative perfusion metrics and objective thresholds to improve reproducibility and reduce interobserver variability. Finally, cost considerations and resource availability may influence the adoption of LSCI in clinical practice and were not evaluated in this study.

Despite these limitations, this study also presents several strengths. To our knowledge, this is one of the few clinical studies comparing LSCI with ICG-FA in colorectal surgery, and among the very limited number reporting data on right-sided resections. This aspect is particularly relevant, as right hemicolectomy presents specific technical and anatomical challenges that may influence perfusion assessment. In fact, if LSCI is to be considered as a potential alternative to ICG-FA, its performance in right-sided procedures should be carefully evaluated. Our findings highlight the need for further investigation of LSCI in this setting, and future studies should specifically address its reliability and limitations in right colon surgery. Moreover, the prospective design of the study and the within-patient comparison, with each patient serving as their own control, represent additional strengths, minimizing confounding factors and allowing a more accurate comparison between the two imaging modalities. Finally, the inclusion of different types of colorectal resections increases the clinical applicability of our findings and provides a comprehensive evaluation of LSCI across various surgical scenarios.

In conclusion, LSCI appears to be a feasible tool for the intraoperative assessment of bowel perfusion in colorectal surgery, showing a high level of agreement with ICG-FA. These findings should be considered preliminary, given the limited sample size and feasibility design of the study. Its dye-free and real-time capabilities make it a promising adjunct to ICG-FA. Larger prospective, multicentre, randomized studies are warranted to further define the clinical impact of LSCI in evaluating bowel vascularization and its potential role in improving surgical outcomes.

Declarations

Disclosures Salvador Morales-Conde, Angela Belvedere, Laura Navarro Morales, Elena Guarnieri, and Andrea Balla have no conflicts of interest or financial ties to disclose.

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