First Thirty-Four Consecutive Patients Using De Novo Laparoscopy-Compatible Real-time Imaging Device Combining Laser Speckle Contrast Imaging and Near-infrared Fluorescence in Colorectal and Bariatric Surgery, and Laparoscopic Cholecystectomy

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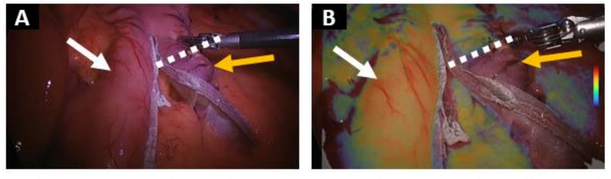
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OBJECTIVE:

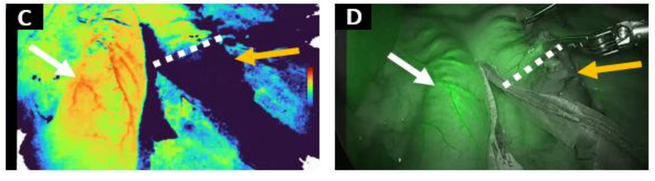
- Laser speckle contrast imaging (LSCI) uses coherent laser light to detect and display perfusion and blood flow in several open clinical applications but its feasibility in laparoscopic visceral surgery has not been reported.
- We report the first clinical usability, utility, and safety trial of this intraoperative visualization technology capable of LSCI and indocyanine green (ICG) near-infrared fluorescence (NIRF) to detect and display tissue perfusion/blood flow laparoscopically in real-time, on-demand, without using a fluorophore/dye while simultaneously visualizing ICG.

DESCRIPTION:

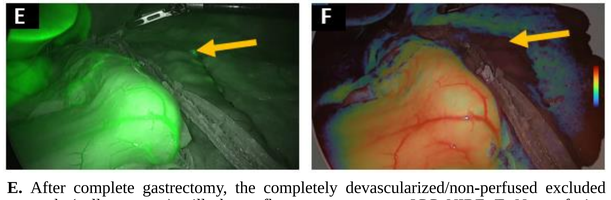
- ActivSight™, an FDA-cleared device, consists of an imaging module (an adapter positioned between standard white light camera head and laparoscope), a light engine, and a light guide.
- ActivSight detects tissue perfusion using LSCI – no external fluorophore – and displays it to the surgeon as a heatmap. In addition, ActivSight visualizes ICG using NIRF.
- Safety was measured by adverse event occurrence to patient, surgeon, or technology, and usability by the human factor testing on a Likert scale (1-5), per FDA guidelines. Utility was measured by comparing ICG with ActivSight-Perfusion modes (without fluorophore) for perfusion.
- To determine accuracy of ICG and LSCI perfusion display, a post-hoc survey using intraoperative images of sleeve gastrectomy was performed to determine the boundary between perfused and non-perfused tissue in white light, ICG, and LSCI images, respectively.



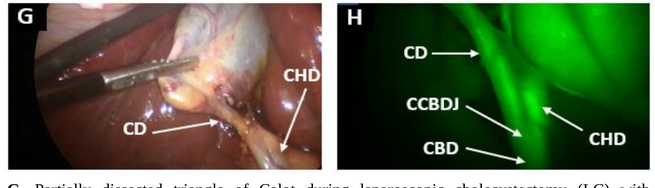
A. Sleeve gastrectomy showing the gastric remnant (white arrow) and partially resected stomach (yellow arrow). Partially resected stomach is well perfused proximally but non-perfused distally. Dotted white line is the boundary between perfused and non-perfused segments. **B.** Perfusion to stomach assessed using ActivSight Perfusion-Overlay Mode which displays perfusion signals in addition to the white light image without a fluorophore. Warmer colors represent areas of higher perfusion, cooler colors represent areas of lower perfusion.



C. ActivSight Perfusion-Contrast Mode displays perfusion of the stomach without the white light image. **D.** Perfusion of the gastric remnant and partially excluded stomach assessed using ActivSight ICG-Gray Scale Mode which demonstrates the same boundary between perfused and non-perfused portion of the stomach as was demonstrated using the two ActivSight Perfusion Modes.



E. After complete gastrectomy, the completely devascularized/non-perfused excluded stomach (yellow arrow) still shows fluorescent areas on ICG NIRF. **F.** No perfusion signal is noted over the non-perfused, resected stomach on assessment using ActivSight Perfusion-Overlay Mode (yellow arrow).



G. Partially dissected triangle of Calot during laparoscopic cholecystectomy (LC) with assessment of the extrahepatic bile ducts under white light. **H.** Assessment of the cystic duct, cystic-common bile duct junction (CCBDJ), common bile duct (CBD) and common hepatic duct (CHD) under ICG NIRF during LC.

Patient demographics/outcomes	Colorectal n (%)	Bariatric n (%)	Cholecystectomy n (%)
Number	RCo: 5 (50) LCo/LAR: 5 (50)	GBP: 9 (60) SG: 6 (40)	9 (100)
Age (years; mean ± SD)	68.4 ± 9.85	44 ± 11.25	58.74 ± 14.30
Sex (male:female)	1:4	1:6.5	1:8
BMI (mean ± SD)	27.99 ± 3.98	41.71 ± 7.37	34.14 ± 4.86
Indication for surgery	Neoplasms: 9 (90) Crohn's disease: 1 (10)	Obesity: 13 (86.7) GERD*: 2 (13.3)	Sx chole: 4 (44.4) Bil Dys: 2 (22.2), CC: 2 (22.2) Choledocholithiasis: 1 (11.1)
Procedure time (mins; mean ± SD)	216 ± 64	179 ± 69	62 ± 26
28-day post-op complication rate‡	0 (0)	0 (0)	0 (0)

*RCo Right Colectomy, LCo Left Colectomy, LAR Low Anterior Resection, GBP Gastric Bypass, SG Sleeve Gastrectomy, *GERD Gastroesophageal Reflux Disease only, Sx Chole Symptomatic Cholelithiasis, Bil Dys Biliary Dyskinesia, CC Chronic cholecystitis, BMI Body Mass Index, SD Standard deviation, LOS length of stay*

RESULTS:

- 34 consecutive patients undergoing elective colorectal and bariatric, and LC surgeries were enrolled (**Table 1**) NCT#04633512; IRB#20-0967.
- Human factor evaluation (n=11 surgeons) demonstrated: display quality of 4.10 ± 1.03; ease of setup 4.18 ± 1.00; form-factor 3.94 ± 1.05; and weight 3.97 ± 1.13. No adverse events in patients, surgeons, or systems (**Table 1**).
- First-to-detect LSCI latency in luminal organs was 150ms whereas time from first ICG injection to detection using NIRF was significantly longer (mean=34.3 seconds, p<0.0001).
- Perfusion boundaries (**Fig. 1A-D**) on post-hoc survey of surgeons (n=10) was concordant between intraoperative identified boundaries (ground truth) and LSCI images (p=0.329), and significantly discordant with ICG images detected within two minutes of first ICG injection (p=0.043). After multiple ICG injections, residual ICG was detected in the interstitium of non-perfused tissue (**Fig. 1E**). This false-positive display was absent when using LSCI (**Fig. 1F**).

CONCLUSION:

- We demonstrate that the first laparoscopy-compatible form-factor combining LSCI and ICG NIRF, ActivSight, provides accurate, repeatable, on-demand (no perceptible latency), real-time visualization of tissue perfusion/blood flow without a fluorophore.
- Perfusion detection and display using LSCI was found to be more accurate than ICG. Hepatically cleared ICG in extrahepatic structures was consistently detectable.