COMPUTER VISION ENHANCED NEAR-INFRARED FLUORESCENCE CHOLANGIOGRAPHY: TOWARDS CLEARER INTRAOPERATIVE IMAGING FOR PRECISION IN LAPAROSCOPIC CHOLECYSTECTOMY

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Objective of the Technology

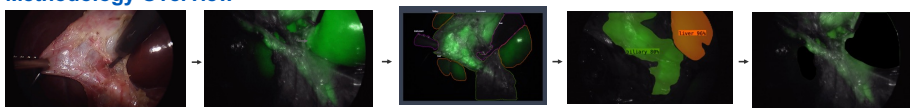
Despite the advantage of displaying enhanced extrahepatic biliary duct (EHBD) signals over white light imaging, the use and interpretation of indocyanine green (ICG)-based near-infrared fluorescence (NIRF) imaging remain highly subjective, variable, and suboptimal due to the background ICG noise in the liver.

We hypothesize that improving the signal-to-background ratio (SBR) during NIRF cholangiography by use of a computer vision algorithm trained to suppress the hepatic parenchymal signals will facilitate visualization of the critical structures in the hepatocystic triangle, thus improving surgeon visual perception and ultimately increasing safety.

Description of the Technology and Method of its Use or Application

- A multi-institution laparoscopic cholecystectomy (LC) video database was curated from 2019 to 2024 (n = 853, IRB: #HSC-MS-22-0910, UB: #20-003) (Figure 1a).
- Video sequences with NIRF use were identified, resulting in 331 unique clips which were sampled at 2 frames per second (Figure 1b). Roboflow was used for manual instance segmentation labeling of three classes: EHBD, liver, and instruments (Figure 1c). These human-labeled images were augmented using rotation, shear, blur, noise, saturation, and brightness variation resulting in a dataset with 2,321 labeled images.
- A computer vision instance segmentation model was then trained with YOLOv11 using the COCOs-seg checkpoint (Figure 1d, 1e).
- To test the visual impact of our computer vision model, we analyzed the SBR (as defined by signal intensity divided by background intensity) using ImageJ via quantification of the color intensity of the EHBD (signal) and liver (background) before and after our computer vision model was applied on n =100 unique images.

Methodology Overview



a. Laparoscopic Cholecystectomy Video Database

b. NIRF Cholangiography clips

c. Human – Annotated Video Frame

d. Computer Vision Model Output

e. Our model output, with optimized Signal-to-Background ratio

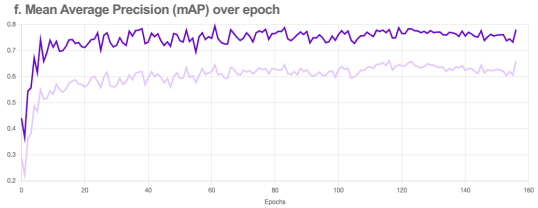
Results

Computer Vision Model Performance

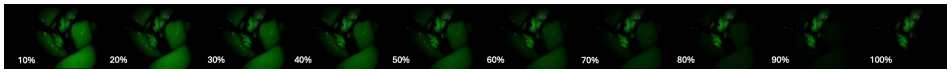
- After training for 156 epochs, model performance was assessed.
- Performance evaluation showed reliable object detection and classification, with high precision indicating few false positives and balanced recall reflecting comprehensive identification across classes (mean Average Precision [mAP]: 78.0%, Precision: 80.7%, Recall: 73.3%) (Figure 1f).
- Loss parameters were optimized to 0.63 for box loss, 0.62 for class loss, and 1.182 for object loss, underscoring the model's effective convergence across key segmentation tasks (Figure 1g).

Demonstrating Variable Control of SBR

- Variable control of the SBR is accomplished using alpha channel manipulation of the background mask during model inference, which can be adjusted for surgeon preference (Figure 1j).

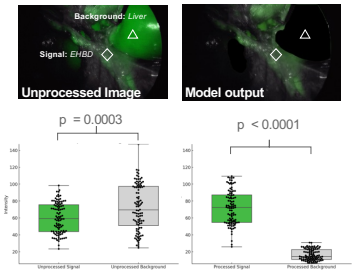






Assessing Signal-To-Background Ratio Improvement

- Unprocessed images demonstrated a mean SBR of 0.83 +/- 0.67, suggesting limited intensity difference between signal and background.
- Processing these images using our computer vision model significantly improved the mean SBR to 4.46 +/- 3.06, (t=-6.35, p<0.0001) (Figure 1h, 1i).



h. Signal-to-background, unprocessed images

i. Signal-to-background, model output

Conclusions & Future Directions

- We demonstrate the development of a computer vision model aimed specifically at improving SBR during NIRF cholangiography in LC.
- We will next deploy this technology in simulated settings to optimize visual overlay parameters and test visual perception improvements in clinical settings under IRB.
- We plan to scale this concept to other surgical domains where NIRF is used and envision the potential to leverage image fusion and multispectral paired labeling techniques to train future models that may enable the visual advantages of NIRF without the need for a pharmacological agent.