Surgeons Struggle Interpreting Indocyanine Green (ICG) Fluorescence Imaging During Laparoscopic Cholecystectomy

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Introduction

- Visual misperception accounts for up to 97% of surgical errors in laparoscopic cholecystectomy[1]
- Eye-tracking studies show experts demonstrate more efficient gaze patterns (target-focused fixations, shorter fixation durations, faster orientation to relevant anatomy) compared to novices [2–5], though findings in video-based contexts are mixed [6–11]
- ICG enhances visualization of biliary tree[12], but alters the appearance of the surgical scene

Objective:

- **Explore how expertise level and imaging modality (white light vs. ICG fluorescence) influence anatomical identification accuracy and eye-tracking measures during laparoscopic cholecystectomy video viewing**

Methods

- **61 surgeons** (20 experts, 16 intermediates, 25 novices) recruited at SAGES 2025; grouped by years of experience
- **Task:** Viewed video clips (white light & ICG). Videos paused randomly for verbal anatomical identification. Eye movements recorded at 120 Hz (Tobii Pro Fusion) **(Fig. 1)**
- **Measures:** Anatomical identification accuracy (correct, suggestive, and incorrect) and eye-tracking measures
- The suggestive category included those who verbalized uncertainty by proposing one or more possible anatomical structures

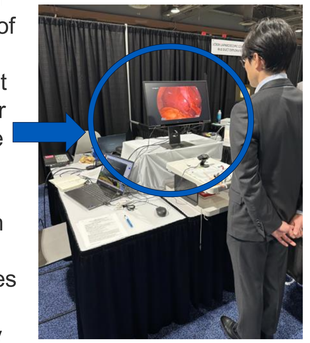


Figure 1: Experimental setup.

Results

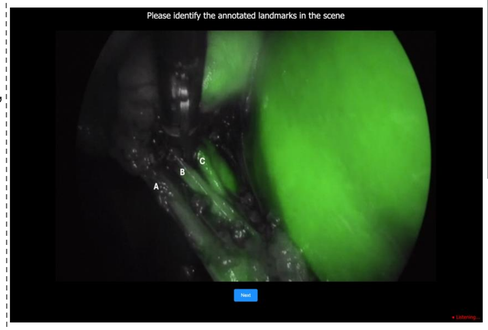


Figure 2: The pause 2 scene under mixed lighting condition asked participants to identify the cystic duct (A) and two cystic arteries (B-C). Identification accuracy was then scored for each structure.

Anatomical Identification Accuracy

- Fisher-Freeman-Halton Exact Tests assessed associations between expertise and identification accuracy
- In the ICG scene **(Fig. 2)**, expertise was significantly associated with correct identification of the cystic artery (p = .018) and cystic duct (p = .046) **(Fig. 5)**
- Experts more often provided *suggestive* (reasoned) responses rather than incorrect identifications
- Novices were more frequently incorrect across conditions
- Response distributions in the white light scene were consistent across groups

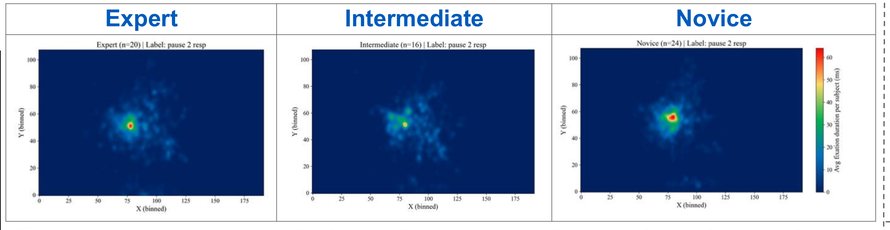
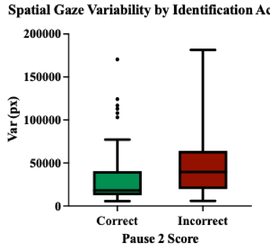


Figure 3: Heatmaps show avg. fixation duration per subject within spatial bins. Warmer colors represent average fixation duration per subject within spatial bins and are normalized by group size.



- A Mann-Whitney U test comparing gaze dispersion between groups approached a significant trend (W = 971, p = 0.053) **(Fig. 4)**
- Correct responders exhibited lower gaze variance (39,346 px; n = 27) than incorrect responders (48,424 px; n = 34), reflecting how broadly surgeons looked across the scene

Figure 4: Plot of spatial gaze variability by identification accuracy.

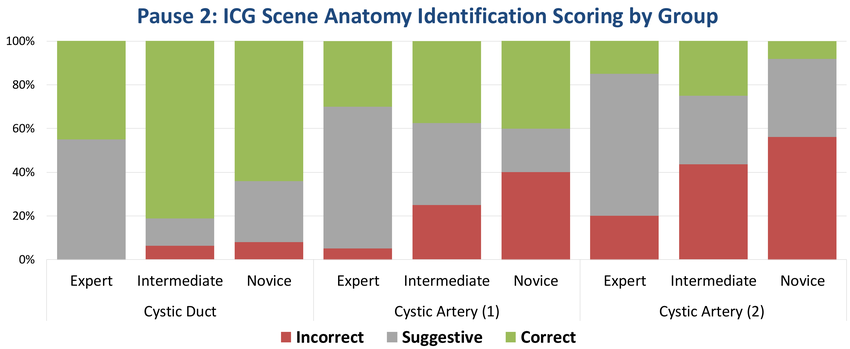


Figure 5. Response type distribution by group in ICG fluorescence.

- Experts' gaze during the response scene was more concentrated to a smaller region as compared novices and intermediates **(Fig. 3)**
- Given that identification accuracy differed across groups, these patterns may suggest a more focused, selective visual attention among the expert group

Conclusion

- **Surgical expertise influenced anatomical identification primarily under perceptually complex conditions,** particularly with ICG fluorescence and abnormal anatomy
- Experts demonstrated more accurate structure identification
- Imaging modality alone did not alter visual behavior; rather, its interaction with task complexity and experience
- Findings highlight the importance of understanding how expertise and imaging technologies impact visual perception and attention to improve surgical safety

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