

# Prospective Evaluation of Precision Multimodal Gallbladder Surgery Navigation: Virtual Reality, Near-infrared Fluorescence, and X-ray-based Intraoperative Cholangiography.

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### Abstract

**OBJECTIVE:** We aimed to prospectively evaluate NIR-C, VR-AR, and x-ray intraoperative cholangiography (IOC) during robotic cholecystectomy.

**BACKGROUND:** Near-infrared cholangiography (NIR-C) provides real-time, radiation-free biliary anatomy enhancement. Three-dimensional virtual reality (VR) biliary anatomy models can be obtained via software manipulation of magnetic resonance cholangiopancreatography, enabling preoperative VR exploration, and intraoperative augmented reality (AR) navigation.

**METHODS:** Fifty-eight patients were scheduled for cholecystectomy for gallbladder lithiasis. VR surgical planning was performed on virtual models. At anesthesia induction, indocyanine green was injected intravenously. AR navigation was obtained by overlaying the virtual model onto real-time images. Before and after Calot triangle dissection, NIR-C was obtained by turning the camera to NIR mode. Finally, an IOC was performed. The 3 modality performances were evaluated and image quality was assessed with a Likert-scale questionnaire.

**RESULTS:** The three-dimensional VR planning enabled the identification of 12 anatomical variants in 8 patients, of which only 7 were correctly reported by the radiologists ( $P = 0.037$ ). A dangerous variant identified at VR induced a "fundus first" approach. The cystic-common bile duct junction was visualized before Calot triangle dissection at VR in 100% of cases, at NIR-C in 98.15%, and in 96.15% at IOC. Mean time to obtain relevant images was shorter with NIR-C versus AR ( $P = 0.008$ ) and versus IOC ( $P = 0.00000003$ ). Image quality scores were lower with NIR-C versus AR ( $P = 0.018$ ) and versus IOC ( $P < 0.0001$ ).

**CONCLUSIONS:** This high-tech protocol illustrates the multimodal imaging of biliary anatomy towards precision cholecystectomy. Those visualization techniques could complement to reduce the likelihood of biliary injuries ([NCT01881399](#)).

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